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1 Introduction

The way we produce and manage energy may be the critical issue of our time. Economic development and almost every aspect of our lives depend on energy use; however, the use of fossil fuels for energy production is altering the climate of our planet in ways that may produce great harm. Most climate scientists believe that the greenhouse gas emissions created by the burning of fossil fuels must be reduced dramatically in order to avoid the prospect of rising seas and other drastic consequences of climate change. Fortunately, these reductions can be made utilizing cost effective technologies that exist today or are very close to readiness for deployment. However, clean energy technologies are not yet being adopted intensively enough to make a significant difference in greenhouse gas emissions. In contrast to the history of new ventures that changed the world by commercializing technologies such as electric power, telephones, automobiles, and computer technology, new ventures have been unsuccessful commercializing clean energy technologies that appear to be ripe for wide adoption. This dissertation will explore the reasons behind these failures, and what can be done to improve the chances that clean energy technologies introduced by new ventures will be widely adopted.

The initial problem considered for this research was to determine the optimal technologies to support the use of distributed generation (DG). That problem was then expanded to include the support of demand side management (DSM) and energy efficiency technologies. As additional information was gathered, however, it was determined that there were a wide variety of attractive DG and DSM solutions being promoted by new ventures that were inexplicably not being adopted, and as a result, many of these firms were struggling or failing. The focus of the research then turned to the question of why these economically efficient clean energy technologies were not being adopted, and why these new ventures were failing. Based on data from over a hundred interviews, a system dynamics simulation model was created to develop a better understanding of the factors that determined whether these ventures would succeed or fail and whether their products would become widely adopted.

This introduction will first define and lay out the benefits of clean energy technologies and discuss why more widespread adoption of these technologies would benefit both the users of the technology and society. Next, the reasons for focusing on new ventures are addressed. Finally, the objectives of the research are presented, followed by an outline of the remainder of the dissertation.

1.1 Definition and Benefits of Clean Energy Technology

For the purpose of this dissertation, clean energy technology is defined as any technology that reduces harmful emissions that result from the production and use of energy. Webster defines technology as "the practical application of knowledge especially in a particular area." Harmful emissions principally include greenhouse gases (CO2, methane, etc.), Sox, and NOx. Energy is defined as "capacity of a physical system to do work" or "usable power (e.g. as heat or electricity)". In practical terms, energy is principally delivered as electricity or fuels (fossil fuels, biomass, etc.) for heating, cooling, and transportation. 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; efficient energy storage; green building technologies; biofuels; and ancillary products and services that reduce emissions associated with power generation, transmission and distribution.

1.1.1 Why Focus on Clean Energy Technology

Clean energy technology is critical because of its potential to offset anthropogenic climate change. Other than drastically reducing the standard of living in the developed world and thwarting the aspirations of developing regions, the widespread adoption of technology that reduces greenhouse gas emissions is the only currently feasible solution to address this crisis. A discussion of climate change and its causes is outside the scope of this dissertation, but for reference, see the IPCC reports and Stern Review (IPCC, 2007; IPCC et al., 2001; Stern, 2006). In brief, greenhouse gas emissions (primarily CO_2) from the burning of fossil fuel (primarily for transportation and electricity generation) are causing a greenhouse effect in the earth's atmosphere, which is causing the planet to warm at an accelerating rate. Potential harms include the loss of species; changes in weather patterns that will negatively affect food production and disease transmission; disruption of the water cycle; and rising seas that may flood cities located on coastlines. Recent research indicates that these trends correlate directly with the production of greenhouse gas emissions, and that they are accelerating.

The only feasible way to minimize global warming and its consequences is to drastically reduce total greenhouse gas emissions. (Note that reducing the rate of increase in emissions, or even halting the increase of emissions altogether would not be sufficient). Because the growth of industrial economies have relied on the burning of fossil fuels, reducing worldwide emissions from these fuels is a tremendous challenge that will require disruptive technology and radical new ways of generating and using energy.

1.1.2 Classes of Clean Energy Technology

Two significant classes of clean energy technologies are distributed generation (DG) and demand-side management (DSM):

Distributed Generation (DG): For the purpose of this dissertation, DG is the efficient generation of power (usually electricity and sometimes heat or cooling) at the site of the user. This is also sometimes known as *embedded generation*, and is distinguished from centralized and distribution-level generation, which is generated at a power plant and transmitted over the electric grid to the user. It is also distinguished from backup generation; energy produced at the user site but meant to run only when the grid fails and which often increase emissions. Distributed generation may be renewable (e.g. wind or solar power), conventional engines producing combined heat and power (CHP), or a wide variety of older (e.g. diesel engines) or newer (e.g. microturbines, fuel cells) technologies that may be economically run continuously and that produce significantly fewer emissions per unit of power generated than technologies associated with a central-grid system.

Demand-Side Management (DSM): For the purpose of this dissertation, DSM is the management of power usage (most often electricity) that maximizes efficiency, minimizes cost, and uses as little energy as possible while achieving the same or better level of production and comfort for members of the organization or community served. It encompasses energy efficiency measures, as well as load shifting or shaping (shifting power use to periods of lower demand and cost). DSM is distinguished from Demand Response (DR), which is the ability to respond to a request to reduce the usage of power on a short-term basis.

1.1.3 Benefits of Clean Energy Technology

Economically efficient use of clean energy as exemplified by DG and DSM technologies provide numerous benefits to end users and to society. Some of these benefits are summarized below:

DG (with cogeneration) can generate power more efficiently and more economically: Distributed generation based on cogeneration technologies (CHP) yields much higher efficiencies than even the most advanced central stations, with over 80 percent of the energy from fuel being used for productive purpose (Miller, Rogol, & Martin, 2004). Central plant efficiency usually ranges from 35 to 50 percent, and approximately 10 percent of electricity generated at central plants is lost to heat during transmission and distribution over long distances. Greater efficiency--less fuel burned to generate the same amount of useful energy-- lowers costs as well as reduces greenhouse gas and other harmful emissions.

DG reduces overall system costs and price volatility: Placing smaller, more efficient generators closer to end users reduces the need to construct large power plants, thus obviating some transmission and distribution costs. When additional generation capacity is required, it is quicker, easier, less costly, and less risky to add capacity through distributed generation facilities sited close to the sources of load than to build new central generation plants. The much smaller capital outlay over time ("right-sizing") required for local distributed generation systems reduces risk. Price volatility (when market prices are present) will be reduced because users have more precise control over onsite generation assets.

DSM is economically beneficial for both end users and utilities: It has been estimated that users typically use at least 10 percent (and often up to 30 percent) more electricity than necessary to meet their power demands (Borbely-Bartis, 2003). Given that U.S. businesses and consumers spent ~$300 billion on electricity in 2006 (Energy Information Administration, 2007), it's possible that between $30 and $90 billion could have been saved by using energy efficiency measures to meet power demands more efficiently. For example, one business that implemented programs to reduce energy consumption, Owens Corning, achieved $32 million in annual energy cost savings while increasing production by 18 percent. Garforth (2003) cites many other examples of similar savings.

Reducing consumption demand will also save many utilities from having to make costly new investments in generation capacity. By using electricity more intelligently, consumers will not only save electricity, but will reduce peak load demands, which can result in significantly higher cost savings (operations and investment). For supply-constrained remote (village) systems, it is essential to manage the demand as well as the supply of power.

***The use of DSM and DG can create opportunities for the use of generation technologies that produce no harmful emissions*:** As described above, using DSM technologies to reduce consumption of electricity by 10 to 30 percent will reduce generation of electricity, and consequently reduce emissions. Additionally, because the final few percent of generation required by peak loads is often the least efficient, these technologies could contribute to emissions reductions significant larger than 10 to 30 percent. Sensitivity to local conditions and the opportunity to produce power at small scales combine to create greater flexibility in the use of energy sources, including renewable sources, which produce no harmful emissions at all and ease dependence on fossil fuel sources.

DSM and DG systems increase security and reliability: A hybrid distributed system including multiple sources and kinds of generation, some sited close to end users, would be significantly less vulnerable to natural or man made disasters. Such a system could also be much more reliable than a system of central plants with extensive and sometimes overloaded transmission and distribution networks. Insofar as they are part of the hybrid system, overloaded grid-based elements will be less strained by a more balanced load. For some large businesses, the cost of a single outage can be in the millions of dollars. Increasing reliability will reduce the probability and frequency of system outages, and therefore reduce the attendant costs.

DSM and DG systems can reduce generation requirements: By using DSM to lower the peaks of load curves, the minimum generation capacity required to assure reliable supply will be reduced. Furthermore, given stochastic sources of generation, such as wind, shifting loads from peak to off-peak times will increase the real-time value of generation during off-peak periods and reduce the need for storage. Also, greater reliability will reduce system costs by eliminating the need for redundant systems.

1.1.4 Why This Problem Requires Engineering Systems Analysis

Daniel Hastings defines Engineering Systems as technologically enabled networks and meta-systems which transform, transport, exchange and regulate mass, energy and information (D. Hastings, 2004). By almost any definition, the systems that produce, transport, and utilize energy are among the largest and most significant engineering systems in the world. Analysis of these systems requires a systems level approach, meaning that the many components and stakeholders of the systems and the relationships between them must be taken into account. Systems dynamics is a powerful methodology for performing such analysis, as will be discussed in Chapter 2. Though this dissertation focuses on only one aspect related to these systems, mainly how the adoption of clean technologies promoted by new ventures may be increased, the analysis must and does take into account the structure of the current system, the relationships between the users, providers and regulators of energy, and exogenous parameters such as the price of fuels and state of the economy. Also, though it has not been the case in the past, sustainability (which is achieved, in part, by reducing or preventing harmful emissions) will need to be an organizing design principle for energy-related engineering systems in the future (Cutcher-Gershenfeld et al., 2004). The policy and strategy implications of this dissertation should promote the inclusion of a large proportion of clean energy technologies in these systems.

1.2 Problem Statement

Though high energy prices, deregulation, security concerns, and the availability of new technologies have fostered adoption of clean energy technologies on a limited basis, they are not as widely adopted as would optimally benefit users and society. Economic analysis alone does not explain why adoption has been muted.

1.2.1 State of Adoption of Clean Energy Technology

There appears to be a large disconnect between the acknowledged value of DG and DSM and the adoption of these technologies. According to the Congressional Budget Office, DG "is an important, although small, component of the nation's electricity supply (Congressional Budget Office, 2003). The Energy Information Administration (EIA) estimates that in 2000, only 0.5 percent of total U.S. electricity generation was from "non-utility generation for [customers] own use." And according to NYSERDA, in NY state, which has programs in place to encourage DG, existing market penetration of CHP (the most economical form of DG) is small except for large industrial applications (Hedman, Darrow, & Bourgeois, 2002). According to a DSM program assessment report prepared in 2000, nearly all the DSM programs studied had lower participation levels than originally envisioned (Albert et al., 2000).

1.3 Why Focus on New Ventures

Though the vast majority of energy production and use (including the use of clean energy technologies) is currently managed by large firms, if new technology is to be widely adopted, it is more likely to be driven by new ventures. This has been the case for many significant disruptive technologies that initially had no or limited adoption and progressed to widespread adoption. In fact, James Utterback, citing previous research by other researchers as well as his own collaborative projects, found no case where a disruptive innovation that expanded established markets and that was not based on existing core competencies of an industry came from within the industry in question (J. M. Utterback, 1996). Examples include:

Gas light to electricity: In the 1870s, gas lamps were the primary source and preferred technology for residential, commercial, and public lighting in the United States. Though hundreds of firms supported the gas-based system, a new venture fundamentally changed the lighting industry. In 1878, Thomas Edison formed the Edison Electric Lighting Company to commercialize electric lighting. Within 25 years, electric lighting had replaced gas lighting as the preferred technology in U.S. cities (J. M. Utterback, 1996).

Automobiles: At the beginning of the 20^{th} century, horse-drawn vehicles were the dominant modes of road transportation. In 1900, a former Edison engineer formed the Henry Ford Company. As Ford's innovations sparked innovations on the part of many other new ventures, automobiles became the dominant mode of road transportation within two decades (Kimes, 2005).

Computers and Computer Software: One of the most important and largest industries in the world today is dominated by companies that began as new ventures commercializing new computer-based technology. The story of companies such as Intel, Microsoft, and Google are well known. Intel was founded in 1968 by two scientists who left an established company (Fairchild Semiconductor) and did not hire their fourth employee or announce their first product until 1969. However, their technology was rapidly adopted, and they went public in 1971, became a Fortune 500 company by 1978, and became the number one semiconductor manufacturer by 1991 (Intel, 2006). Microsoft was founded in 1975 by two college dropouts, went public in 1986, and was selling the most widely used computer operating system and was one of the largest companies in the world by 1993 (Tsang, 2000). Google was founded in 1998 by two Ph.D. students, went public in 2004, and today is not only the number one web search company but is one of the world's largest companies.

Each of these major innovations arose in the presence of substantial established industries and companies supporting competing technologies. In each case, new ventures drove the commercialization of the new technologies, eventually supplanting major existing industries and their attendant engineering systems. Given this history, if clean energy technologies are to replace or significantly supplement existing energy technologies, new ventures rather than established companies will drive the process.

Because clean energy technology can provide significant value, one would expect that some of the thousands of these firms that have attempted to produce them over the last few decades would have become extremely successful by now, and a reasonable percentage would have been moderately successful. This has not been the case.

The most successful new clean energy ventures are still miniscule compared to traditional energy companies and utilities, and most new clean energy ventures have not been successful at all. In a sample of approximately 1,000 clean energy companies that sought funding from early stage investors between 1997 and 2006, not a single company achieved widespread adoption of their products or technology. Many of these companies failed to become profitable at all.

1.4 Research Objectives

Based on these observations four questions are posed that guide this research:

1. Assuming that clean energy technologies are economically and environmentally beneficial in many cases, why are they rarely adopted?

2. What are the institutional/regulatory/economic/technical factors bearing on the introduction of a clean technology and how do these constitute a dynamic system?

3. What factors determine whether companies commercializing clean energy technologies will succeed or fail in bringing them to market?

4. What strategies and policies will increase the odds of success of these companies and the widespread adoption of clean energy technology?

Extensive investigation has revealed no prior investigation of these questions based on a systems view linking technology and commercial attributes to economic, policy, and institutional factors in a dynamic framework. Furthermore, little work has been done to better understand the factors that determine whether new ventures commercializing clean energy technologies will succeed. Most importantly, the development and analysis of an empirically based model will suggest specific strategies and policies to increase the odds of success of these ventures.

1.5 Dissertation Outline

This chapter has addressed the objectives of the dissertation, the type of data to be analyzed, the methodology selected, and the research questions to be addressed. Subsequent chapters will fill out these introductory comments in greater detail.

Chapter Two reviews the literature related to the adoption of clean energy technologies, the analysis of such adoption, and success factors for new technology ventures. In particular, we will look at engineering and economic analysis that has been performed for DG, DSM, and clean energy technologies in general that demonstrate their value to customers and to society. We will also review the literature that details the challenges inherent in the adoption and diffusion of innovation. We will review literature that discusses the most important factors in the success or failure of new technology ventures, and review the data on early stage investments in these ventures. Finally, we will examine how system dynamics has been used to analyze and develop better understanding of similar problems.

Chapter Three draws on an extensive set of interviews to reveal the attitudes and incentives of the wide range of stakeholders involved in a decision to adopt a new clean energy technology, and to lay out the regulatory, market, institutional, behavioral and technical factors in the adoption of clean energy technologies.

Chapter Four presents three case studies of clean energy technology ventures and the challenges they face. The first case is a company that is profitable but has not yet achieved widespread adoption that sells technology to manage the use of energy for commercial real estate. The second is a company working to become profitable that is selling a product and service that improves the operation of power plants at very low cost. The third is a company that no longer exists, which attempted to provide CHP systems to produce low-cost heat and power for commercial real estate. Each of the case studies demonstrates some of the factors essential to the success or failure of such a venture.

Chapter Five describes the system dynamics simulation model developed from this research, including its structure and equations. This chapter describes the boundaries, parameters, and relationships between the parameters of the model.

Chapter Six presents the results of running the model with default parameters for a prototypical clean energy technology venture. The results of sensitivity analysis on the parameters will be presented, and analysis of the simulation will be used to determine what factors have the greatest impact on the success or failure of the venture.

Chapter Seven presents a summary of the research and builds upon the prior analysis to provide specific strategy and policy suggestions to increase the odds of success of clean energy technology ventures. Analysis of the model is used to examine the effect of the strategy and policy prescriptions. Further, the contributions of this study are presented, and opportunities for further research are discussed.

2 Literature Review

A fundamental premise of this study is that clean energy technologies are beneficial, are not as widely adopted as would be optimal, and that increasing the diffusion of these technologies is warranted. We assume that the success of new ventures is an important factor in the diffusion of these technologies and that factors that contribute to the success of these ventures (such as the availability of capital from private investors) are critical. This chapter will review the support in the literature for these assumptions. The first section is a brief review of studies of the benefits and barriers to the adoption of clean energy technologies, and specifically to distributed generation and demand side management. The second section is a review of the extensive literature on the diffusion of technology and innovations most relevant to this study. Third, we review the literature on what factors are most important to the success of new ventures, and review data on and studies of the financing of new ventures. Given that the focus of this work is to improve the odds of success of new ventures with the purpose of increasing the adoption of new technologies, these last two sections will provide the most relevant grounding for this work. Finally, we will briefly discuss system dynamics--the modeling methodology applied in this research to help us learn how to enable new clean energy technology ventures to be more successful.

2.1 Clean Energy Technology

As stated in Chapter 1, for the purpose of this dissertation, “clean energy technology” is defined as any technology that reduces harmful emissions resulting from the production and use of energy. Two classes of technology comprise a significant percentage of clean energy technologies available today: distributed generation (DG) which includes renewable forms of energy generation (such as solar, geothermal, and distributed wind) and various forms of energy efficiency improvements under the heading of demand side management (DSM). This section will present evidence for the benefits of those technologies and the barriers they face.

2.1.1 Distributed Generation

A considerable body of work (e.g. Lovins (2002); Honton (2000)) has established the economic and other values of DG. In a detailed 400-page report, Lovins (2002) identifies 207 distinct economic benefits of "making electrical resources the right size." The main findings of this investigation are:

- "The most valuable distributed benefits typically flow from financial economics—the lower risk of smaller modules with shorter lead times, portability, and low or no fuel-price volatility. These benefits often raise value by most of an order of magnitude (factor of ten) for renewables, and by about 3–5-fold for nonrenewables.
- Electrical-engineering benefits—lower grid costs and losses, better fault management, reactive support, etc.—usually provide another ~2–3-fold value gain, but more if the distribution grid is congested or if premium power quality or reliability are required.
- Many miscellaneous benefits may together increase value by another ~2-fold—more where waste heat can be reused.
- Externalities, though hard to quantify, may be politically decisive, and some are monetized.
- Capturing distributed benefits requires astute business strategy and reformed public policy."

Case studies have been performed to demonstrate those benefits, such as Firestone, Creighton, Bailey, Marnay, & Stadler (2003), Bailey, Ouaglal, Bartholomew, Marnay, & Bourassa (2002), and Siddiqui et al.(2003). Furthermore, many studies have been done on the prospects and market potential for DG, both nationally (Congressional Budget Office, 2003; Daniels & Greenberg, 2002), and regionally (Hedman et al., 2002), and have consistently found that DG technologies have not yet come close to reaching their market potential.

The literature lays out various barriers DG faces (National Renewable Energy Laboratory, 2000); (California Energy Commission, 2000). These barriers include volatile fuel and electricity prices, entrenched and politically powerful competition, and regulatory issues such as interconnection, standby charge and siting regulations (Lovins, 2002).

2.1.2 Demand Side Management and Energy Efficiency

DSM initiatives have been supported through consumer marketing, education (including technical assistance), subsidies, and regulatory standards (U.S. Department of Energy, 1997; Wirl & Orasch, 1998). The purpose of these programs is to stimulate energy efficiency through incentives and regulations. The technologies involved have included higher efficiency appliance motors and lighting, programmable thermostats, insulation, etc. Consumers and businesses have been encouraged to purchase and properly use these technologies.

Some researchers have disputed the extent of the benefits provided by utility-sponsored DSM programs (P. L. Joskow, Marron, Donald B, 1992); (Loughran & Kulick, 2004). In fact, utilities have conflicting incentives to support DSM programs. Though they have been required to offer these programs and have been compensated for successful implementation, in many cases maximizing the energy efficiency of their customers lowers their profits. Therefore, though they have incentives to appear "green" they often have a financial incentive *not* to increase customers' energy efficiency. Nevertheless, an array of reports and studies has shown considerable benefits from the energy efficiency technologies promoted by these programs. Weizsacker, Lovins, and Lovins (1997) report that efficiency efforts of California utilities saved nearly $2 billion more than they cost, and saved the amount of energy predicted for far less than the cost of producing the same energy. Parfomak and Lave (1996), in an econometric study of results of conservation efforts by 39 utilities found that 99.4% of reported conservation impacts were statistically observable in system level sales. And the National Association of Regulatory Utility Commissioners (2001) found that utility sponsored DSM programs saved about 29,000 megawatts at a cost of only $0.03 per kilowatt-hour saved in the early 1990s. Whether or not provided through a utility-sponsored program, energy efficiency is widely considered beneficial to its users (CoolCompanies, 2005; Garforth, 2003). These benefits include:

- Reducing energy costs for the firms that adopt energy efficiency measures;
- Reducing system-wide energy costs by decreasing peak loads on central generation and transmission systems;
- Lowering dependence on the supply of fossil fuels;
- Improving indoor comfort and air quality through the use of energy efficient insulation and heating and cooling systems;
- Increased production at lower cost resulting from the use of more efficient industrial equipment.

While confirming the benefits of DSM, the literature also indicates the various barriers DSM faces (Albert et al., 2000; Machold, 1994). Similar to DG, volatile fuel and electricity prices make it difficult to determine the return on investment for energy efficiency. Insufficient marketing and lack of understanding by end users also limits the adoption of these technologies.

2.1.3 Real Time Pricing and Demand Response

Much of the work listed above notes the importance of real time pricing in order to encourage DG and DSM (e.g. (Congressional Budget Office, 2003)). To understand the pricing of electricity in competitive markets, the seminal work is Schweppe, Caramanis, and Tabors (1989). A recent study by the Center for the Study of Energy Markets (CSEM) analyzes the benefits of "dynamic pricing" coupled with demand response (Borenstein, Jaske, & Rosenfeld, 2002). Several studies have been based on experience with real time pricing and demand response program trials (Neenan et al., 2003; Williamson, 2002). And another recent study (Matsukawa, 2004) shows that access to information about energy use contributed to adoption of energy conservation measures among residential users.

2.2 Adoption and Diffusion of Innovations

The literature on the diffusion of innovations is extensive and encompasses a number of different perspectives, theoretical formulations, and empirical results. This section will present a summary of economic models of technology diffusion including epidemic, rank, order, stock, and threshold models principally based on (F. M. Bass, 1969; Blackman, 1999; Granovetter, 1978 ; Mansfield, 1961; Stoneman, 2002); review four influential and widely cited works on how and why innovations are adopted and widely diffused (Christensen, 2000; Moore, 1991; Rogers, 2003; J. M. Utterback, 1996); and present some of the empirical results of diffusion research.

2.2.1 Economic Theories of Technology Diffusion

As discussed in Blackman (1999) and based on the work of Stoneman (2002), economic theories of technology diffusion can be categorized into epidemic models (which includes the Bass model), as well as rank, order, and stock models. Also, Granovetter (1978) developed models of collective behavior which could be applied towards the diffusion of innovations where the key concept is that of a threshold.

2.2.1.1 Epidemic Models

Epidemic models (Mansfield, 1961) are the most influential theoretical models of diffusion. These models are based on the idea that diffusion and adoption of new technologies, products, or ideas often spread in a similar manner to an epidemic. They start off slowly, but as more people are infected or firms adopt the product, they infect or introduce the innovation to their friends and neighbors, who in turn pass it on to their contacts, leading to exponential growth. Eventually, however, a large enough percentage of the susceptible population has already contracted the disease or adopted the innovation to slow down the rate of new infections or adoptions as it asymptotically approaches the maximum adoption level. This creates a classic S-shaped curve (Figure 2-1).

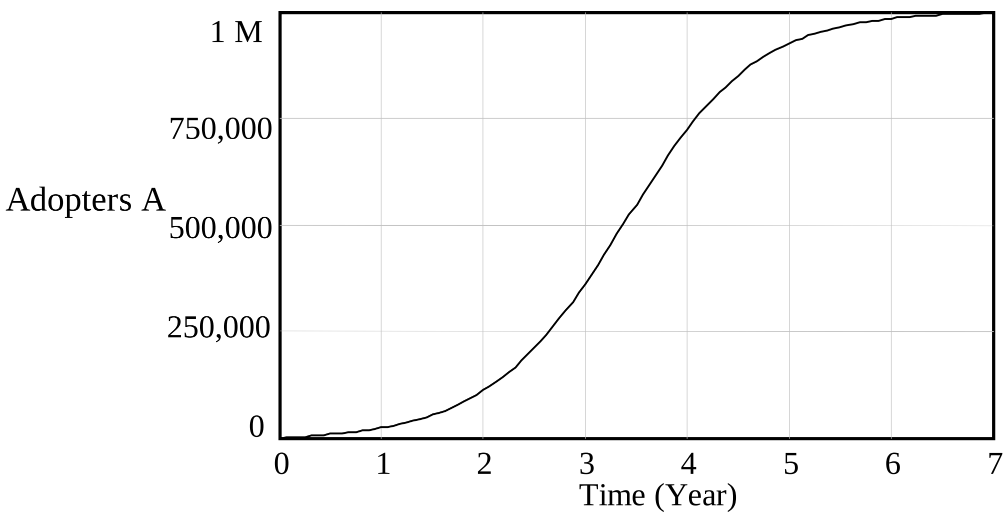

Figure 2-1: Prototypical Adoption Curve

Bass (1969) developed a well-known model for new product growth by adding the effect of marketing to a logistic epidemic model (Figure 2-2). In this model, marketing and advertising create an initial adoption rate that establishes and increases the stock of adopters. As the number of adopters increases, adoption stimulated by word of mouth increases (the infection), creating a positive feedback loop and exponential growth. However, as that growth drains the number of potential adopters the negative feedback loops of market saturation gain strength and the rate of adoption slows as the remainder of the population become adopters. The equations are:

(1) Adoption Rate = Adoption from Advertising + Adoption from Word of Mouth

(2) Adoption from Advertising = Advertising Effectiveness a * Potential Adopters P

(3) Adoption from Word of Mouth = Contact Rate c * Adoption Fraction i * Potential Adopters P * Adopters A/Total Population N

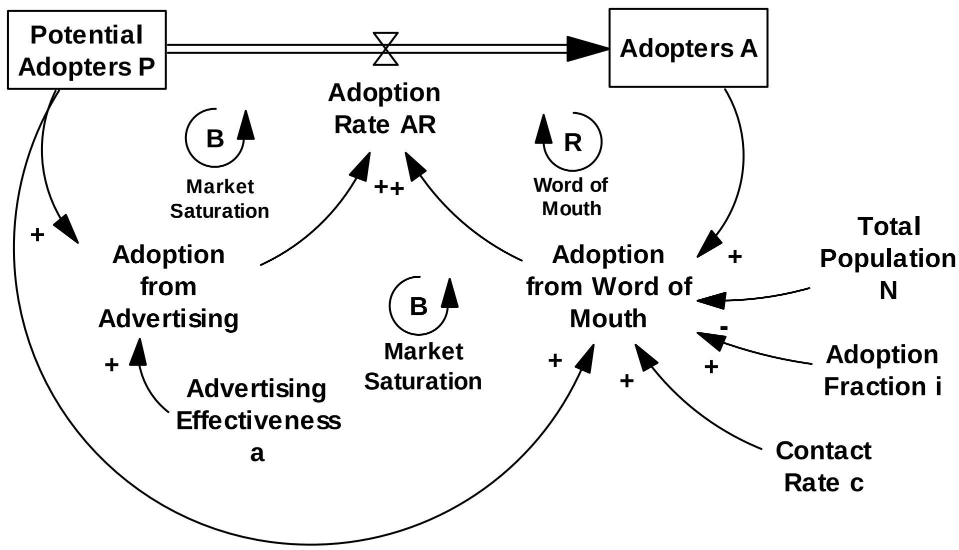

Figure 2-2: Bass Diffusion Model (diagram from (Sterman, 2000))

Empirically, the Bass diffusion model describes the adoption curve of a large number of new products and innovations quite well. In response to the criticism that the model does not include decision variables such as price, Bass and his colleagues generalized it to include decision variables (F. Bass, Krishnan, & Jain, 1994). They have also demonstrated why the standard Bass model without decision variables works as well as it does empirically and how the generalized model can be used for product planning purposes. Also see Mahajan, Muller, & Wind (2000).

2.2.1.2 Rank, Order, Stock and Threshold Models

Epidemic models have been criticized for not adequately reflecting reality. It is said to be more probable that a firm would adopt an innovation based on its own characteristics and profit maximizing behaviors than simply based on advertising and social contact. Rank models are based on the idea that these differences among firms explain diffusion patterns. Blackman (1999) identifies seven variables critical to adoption decisions:

- *Capital vintage.* Firms with less productive and older capital will find it more profitable to adopt.
- *Firm size.* Larger firms that can take advantage of economies of scale, spread risks, and access credit can more easily adopt new technologies than smaller firms can.
- *Beliefs about the return on the new technology.* Firms with more optimistic expectations about the economic benefits to them of the innovation are more likely to adopt.
- *Search costs.* Firms that can more easily find and learn about new innovations (perhaps due to their geographical location or the attributes of their personnel) are more likely to adopt.
- *Input prices.* It may cost some firms less to adopt, making them more likely to do so.
- *Factor productivity.* Firms that can more productively utilize the innovation (perhaps due to better labor productivity) are more likely to adopt.
- *Regulatory costs.* Firms that have less exposure or susceptibility to regulatory costs associated with the innovation are more likely to adopt.

Rank models assume that firms can be "ranked" based on one or more of these variables and that the higher ranked firms will adopt first. For example, Salter (1960) found capital vintage to be a differentiating factor in adoption, Davies (1979) found firm size to be a factor in adoption, Jensen (1983) found beliefs about return on the new technology to be important, Kislev and Shchori-Bachrach (1973) found factor productivity to be a differentiating factor, and Millman and Prince (1989) found variation in firms' exposure to regulatory costs to help determine which firms would adopt a new technology first. These models assume that the more firms that have high rankings across these variables, the more quickly the innovation will be adopted (cf. epidemic models, in which the rate of information transfer controls the rate of adoption).

Order models are based on the idea that firms that adopt innovations earlier will obtain higher returns from the innovation (e.g., early-adopter wind farm developers will secure premium wind-generation sites, and get the most out of the technology). These models assume that over time the net return on the innovation increases enough to overcome these effects and allow for wide adoption (e.g. wind turbine prices will fall far enough to enable lesser sites to be developed profitably). For further examples, see Fundenberg and Tirole (1985) and Ireland and Stoneman (1986).

Stock models assume that the value of an innovation decreases as the stock of firms who have adopted increases (e.g. as more firms adopt an innovation that enables them to respond to real time prices of electricity, the differential in prices will decrease, lowering the value of responding). The net return on adoption declines as the total stock of firms that have adopted increases. For examples, see Reinganum (1981) and Quirmbach (1986).

Threshold models are based on the theory that a critical parameter must exceed a threshold in order for a decision (such as to adopt an innovation) to be made (Jacobsen, 2000). For example, Granovetter (1978) proposes threshold models where potential adopters act based on the concentration and distribution of present adopters, and only when the number or proportion of others have made the decision to adopt exceed a threshold do the net benefits of adoption exceed the net costs.

2.2.1.3 Summary of Economic Theories of Technology Diffusion and Relationship to Clean Energy Technologies

Epidemic, rank, order, and stock models explain different aspects of technology diffusion. The models take into account information and learning; the characteristics of the technology innovation being adopted; and the characteristics of the firms making the adoption decisions. Each of those factors plays a role in diffusion, and depending on the nature of the innovation and the industry (or sectors) and the geographical region or country where the technology is being adopted, one or two of those factors may explain most of the adoption behavior. These models provide insights into how these factors affect the strength and timing of the diffusion.

Based on a review of the literature on economic theories of technology diffusion, Blackman (1999) presents several policy prescriptions to increase the adoption of clean energy technologies to address climate change:

- Subsidies for activities that improve information flow about clean energy technologies, such as demonstration projects, testing and certification of new technologies, consultancy services, and science parks;
- More stringent regulation of polluting activities;
- Reductions in energy subsidies;
- Improvements in the financial intermediation for clean energy projects; and
- Investments in human capital and infrastructure in the energy sector.

2.2.2 Influential Works on Technology Diffusion

2.2.2.1 Diffusion of Innovations

Diffusion of Innovations (Rogers, 2003), first published in 1962 and revised five times since, is a classic and comprehensive work on how (and why) innovations are adopted. Rogers defines *diffusion* as "the process by which an innovation is communicated through certain channels over time among the members of a social system." He defines an *innovation* as "an idea, practice, or object perceived as new by an individual or other unit of adoption." He asserts that "the characteristics of an innovation, as perceived by the members of a social system, determine its rate of adoption." Rogers provides an extensive history of diffusion research, and discusses several major criticisms. For this study, the two most relevant of these are the pro-innovation bias and the individual-blame bias.

The *pro-innovation bias* is the implication of most diffusion research that an innovation should be diffused to and adopted by all members of a social system, that it should be diffused rapidly, and that the innovation should be neither re-invented nor rejected. Rogers states that

> even in the case of an overwhelmingly advantageous innovation, potential adopters may perceive it very differently than change agents or researchers. Simply to regard the adoption of the innovation as *rational* (defined as use of the most effective means to reach a given end) … is to fail to understand that individual innovation-decisions are idiosyncratic. They are based on an *individual's* perceptions of the innovation.

This is an extremely important point with respect to the adoption of clean energy technologies. Though rational analysis (as above) may demonstrate the benefits of adoption, the perception of the decision maker may be very different. Given his or her frame of reference, the rational decision may be to not adopt.

Rogers defines the *individual-blame bias* as "the tendency to hold an individual responsible for his or her problems, rather than the system of which the individual is a part." This tendency is also known as fundamental attribution error (Ross, 1977). This is an important idea. Neither clean energy technology developers nor customers can be held fully responsible for the failure of these technologies to be adopted. It is a system-wide problem, and requires a system-wide solution.

Rogers' describes five stages in the *innovation-decision proces*s:

***Knowledge**,* when the individual is exposed to the innovation's existence and gains an understanding of how it functions;

Persuasion, when the individual forms a favorable or unfavorable attitude toward the innovation;

***Decision**,* when the individual engages in activities that lead to a choice to adopt or reject the innovation;

***Implementation**,* when the individual puts an innovation into use; and

Confirmation, when the individual seeks reinforcement for an innovation decision already made but may reverse the decision if exposed to conflicting messages about it.

Finally, as a central thesis of his work, Rogers describes five attributes of innovation and their rate of adoption. Four of these attributes positively related to adoption: relative advantage, compatibility, trialability, and observability as perceived by potential adopters. Increased complexity, however, is negatively related.

According to Rogers, relative advantage is the "degree to which an innovation is perceived as better than the idea it supersedes." For the purpose of this dissertation, we are going to focus on clean energy technologies that have a demonstrable relative advantage in terms of a better feature set than the competition. However, the perception of this relative advantage on the part of the adopter is an open question.

Compatibility is the “degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.” Clearly identifying an innovation and comparing it to previous ideas are very valuable in making an innovation seem compatible with a customer’s needs. It is important that those pushing adoption understand indigenous knowledge systems in which an individual’s understanding of the new technology is couched.

The other two positive attributes are trialability, “the degree to which an innovation may be experimented with on a limited basis,” and observability “the degree to which the results of an innovation are visible to others.” Possession of these four qualities enhances the likelihood that an innovation will be adopted.

Complexity, the “degree to which an innovation is perceived as relatively difficult to understand and to use,” is likely to inhibit adoption If members of a social system, such as a firm, find a new technology intimidating and complex, they will be less likely to adopt it.

Rogers identifies five categories of adopters, based on the degree of their innovativeness, defined as “the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system.” These categories are: innovators, early adopters, early majority, late majority, and laggards. He finds that the earlier adopters tend to be more venturesome, have greater rationality and intelligence, have more empathy and are more social and interconnected. They are characterized by having a greater ability to cope with uncertainty and risk, and to have generally higher socioeconomic status than do later adopters.

Rogers finds that social networks and opinion leaders are critical in the diffusion of innovations. While innovators may be eager to adopt an idea, regardless of network influences, a member of the late majority group may be much more resistant. Peer network influences are likely to be much more influential in such a firm’s decision to adopt a new technology.

2.2.2.2 Mastering the Dynamics of Innovation

In the introduction to *Mastering the Dynamics of Innovation* (1996) James Utterback restates Robert Solow’s premise that “technological change, broadly considered, contributes as strongly to economic growth and wealth creation as do the traditional factors of production: labor and capital.” Utterback provides numerous examples of how technological innovation results in the creation of new firms and new industries as well as the decline or demise of established ones.

Utterback develops a general model of innovation dynamics for assembled products in an industry. The model consists of three phases, which he terms fluid, transitional, and specific. In the fluid phase, the initial product innovation hits the market (the first typewriter appears in a store, or Edison demonstrates the light bulb). Numerous entrepreneurial firms spring up to refine the idea and bring it to market in different ways (different keyboards appear for typewriters or body designs for automobiles). Eventually, a dominant design emerges which is sufficient for the market to accept en masse.

This marks the transitional phase, which is characterized by a decrease in the rate of product innovation, the exit of many of the initial competitors and an increase of process innovation by the remaining firms to lower the cost of large-scale manufacturing and distribution (the QWERTY keyboard is standardized and steel auto bodies are stamped out in factories).

Eventually, the industry enters the specific phase characterized by highly defined products and relatively few large firms competing on the bases of price, efficiency, and incremental improvements. In the course of time and invention, an "outsider' firm may develop a radical innovation and start the cycle all over again with a different set of players (e.g. the replacement of electric typewriters with word-processing computers).

This last point is important if not central. Citing previous research by other researchers as well as his own collaborative projects, Utterback finds no case in which a disruptive innovation that expanded established markets and that was not based on existing core competencies of an industry came from within the industry in question. In other words, there is no evidence that an established firm has ever successfully diffused a disruptive innovation. Utterback provides multiple explanations for why this is the case, such as the tradeoffs between efficiently producing the current product to meet the needs of existing customers vs. investing in a radical innovation that might not pay off. Also see Henderson & Clark (1990).

2.2.2.3 The Innovator's Dilemma

In *The Innovator's Dilemma* (2000), Clayton Christensen reinforces Utterback's conclusion by explaining how the very attributes that lead to success for large firms prevent them from successfully developing and marketing disruptive innovations. He asserts that the strategies and forces that enable an industry to most effectively meet the needs of and profit from existing majority markets prevent them from developing and marketing innovations that will create the majority markets of the future. Christensen believes that new ventures have a powerful advantage in building markets for technologies when it does not make sense for established leaders to do so. In order for existing firms to succeed in the face of disruptive technologies that change an industry, they must create or spin off new ventures themselves. Christensen provides "distributed power generation" as an example of disruptive technology to electric utilities.

2.2.2.4 Crossing the Chasm

Geoffrey Moore, in *Crossing the Chasm* (Moore, 1991) addresses the challenges associated with marketing and selling technology products to majority adopters. He advances the thesis that there is a gap (chasm) between early adopters and the early majority adopters. Because early majority adopters are pragmatists rather than visionaries, they are less willing to take risks on unproven technologies (or technologies that their peers are not using). Although demand for increased efficiency (and reduced emissions in the case of energy technologies) may push them toward the front of the adoption life cycle, regulatory and budgetary constraints, as well as their own prudence, keep them cautious.

Late majority adopters, whom Moore calls "conservatives," are even more risk averse. This is the type of adopter that many clean energy technology companies must approach as their initial customers (e.g. utilities). Conservatives tend to distrust discontinuous innovation, and believe in tradition more than progress, incremental gains rather than massive changes. Their real goal is to avoid a foolish move. Moore observes that "numerous studies have shown that in the high-tech buying process, word-of-mouth is the number one source of information buyer's reference." Majority adopters prefer to wait until a technology is an "industry standard" before adopting it. Of course, a new technology cannot become an industry standard without being adopted by these users. How can technology firms and their would-be customers overcome this paradox?

Moore's prescription is to implement a niche market strategy. For a new technology to become the market leader, the initial market must be focused and small. He uses a "D-day" analogy:

1. *Target the point of attack*: Identify target customers who may have a "compelling" reason to adopt an innovation;

2. *Assemble an invasion force:* Construct a "whole product" and the partners and allies needed to make it a reality;

3. *Define the battle*: Create the competitive criteria and position the product, in that context, as the easiest to adopt;

4. *Launch the invasion:* Select a distribution channel and set pricing to provide motivational leverage.

Moore states that though it is very difficult for a new technology to break into a mainstream market, once it has it is relatively easy (and lucrative) to stay. This is especially true for clean energy technologies. As will be detailed in subsequent chapters, it is much harder, takes much longer, and is much more expensive to achieve wide scale adoption of energy technology. However, if wide scale adoption is achieved, the technology will become a standard for a long time.

2.2.3 Empirical Diffusion Research

An extensive amount of empirical diffusion research has been performed. Hastings (1976) found that the availability of complementary assets accelerates adoption of technology. Davies (1979) studied 22 process innovations in the U.K. and concluded that more complex and costly innovations take longer to diffuse than simple and inexpensive ones, and that older capital stocks lead to higher rates of adoption of new technologies. Stoneman (2002) found that R&D and better human capital lead to higher rates of adoption. See also (V Mahajan, Muller, & Bass, 1990; Vijay Mahajan et al., 2000; Maier, 1998; Parker, 1994) for a sampling of the literature on diffusion models applied to the sales of new products. Chandrasekaran and Tellis (2006) provide a review of new product diffusion models and their findings. Sood and Tellis (2005), using data on 14 technologies from four markets, found that technological evolution follows a step function rather than a single S-curve, with steep improvements in performance following long periods of no improvement. Hauser, Tellis, and Griffin (2006) provide a review of the literature on innovation across five research fields, including consumer response to innovation, market entry strategies, and prescriptive techniques for product development processes.

With respect to energy technologies, Joskow and Rose (P. L. Joskow & Rose, 1990) found that larger firms are more likely to adopt technologies earlier than smaller firms, perhaps due to their greater ability to invest initial capital. Also, they observed that investor-owned utilities tend to adopt innovations earlier than publicly owned utilities, and exhibit more involvement in R&D. Joskow also argues (2000) that new entrants to the electricity market will not succeed unless they offer markedly different services from the incumbents. In a study of energy efficiency improvements, Jaffe and Stavins (Jaffe & Stavins, 1995) found that regulatory pressure accelerates the adoption of clean energy technologies.

2.3 Success Factors for New Ventures

Surprisingly few comprehensive studies have focused on the factors that are most important to the success of new technology ventures. To date, the author has been unable to find any comprehensive studies focusing on the factors most important to the success of a new clean energy technology venture.

Michael Porter (1980; 1985) discusses strategies that lead to success for firms in general in his seminal works on competitive strategy. Relevant advice for new ventures includes pursuing niche markets that are not served by larger competitors with products that have high value but narrow scope. This is similar to Moore's advice (Moore, 1991). Porter also makes the point that for new and rapidly growing industries, the costs of entry are lower. A later empirical study of entry barriers (Robinson & Mcdougall, 2001) supported the assertion that the effect of entry barriers on venture performance is less restrictive at the early stages of an industry life cycle. While these observations may not apply to the energy industry as a whole, those segments related to clean energy technology are new, rapidly growing, and seemingly ripe for new entrants. Of course, Porter's theory of the "five forces" (plus, perhaps, a sixth force that would include government influence) and his theories regarding sustainable competitive advantage apply to new ventures as well as existing ones.

Roberts (1991) published one of the most significant works on new technology ventures to date. Having collected detailed information through interviews and questionnaires and from public records, he studied several hundred early stage high technology companies. He defined success for these firms based on their sales history, growth, and profitability. He found the following characteristics tended to be most significantly correlated to success:

- Multiple founders;
- Founders with appropriate personal characteristics, such as a high need for achievement and only moderate need for personal power;
- Starting with a leading-edge, advanced, and attractive technology, with a high degree of technology transfer from its prior source or incubator organization;
- Product orientation from the beginning (as opposed to personal services);
- Relatively large investment of initial capital, especially for firms that are subject to strong regulatory controls;
- Extensive sales experience among the founders;
- Marketing orientation of the firm from the outset, including attentiveness towards customers desires and awareness of competitors' behavior and strengthening of the marketing orientation as the firm evolves;
- Managerial orientation of the firm from the outset, including prior supervisory or business experience on the part of the founders, an effort to balance technical, sales, manufacturing, and administrative functions, and sensitivity to the company's cost structure; and
- Strategic focus of the firm on its core technology and markets.

In a more recent study, Eesley and Roberts (2007) found that prior startup experience among founders with master's degrees, even if limited to a single instance, correlates significantly with higher performance of new ventures. Wong, Cheung, and Venuvinod (Wong, Cheung, & Venuvinod, 2005) studied incubated high technology ventures in Hong Kong, and found that entrepreneurial personality, motivation for starting the venture, managerial skills, and approach towards innovation significantly influenced their potential for success.

Several researchers have looked at various factors that contribute to success or failure of new ventures that are primarily not technology-based. Lussier (Lussier, 1995) developed a model to evaluate the "nonfinancial" factors that best predict the success of young firms. He found that business planning, the use of professional advisors, education level of the founders, and the ability to attract and retain high quality employees were the most significant predictors of success. His review of others studies showed that capital, record keeping and financial control, industry and management experience, business planning, and the use of professional advisors were good predictors of success or failure. Brûderl, Preisendorfer, and Ziegler (Bruderl, Preisendorfer, & Ziegler, 1992) combined human capital theory with ideas from organizational ecology to test which factors most contributed to success based on a survey of 1,840 businesses founded in Germany. They found that education, general work experience, industry-specific experience, start-up size (number of employees, capital invested, etc.) and access to larger markets showed the strongest effects. Note that these studies of primarily non-technology businesses emphasize basic education and general experience of the founders, while Roberts' study of technology ventures focuses more on the personal characteristics and focus of the management team. This difference is likely due to the fact that in order to found a technology venture a base level of education and experience is required (though Roberts found that a doctoral level education was, in fact, negatively correlated with success).

Utterback, Meyer, Tuff, & Richardson (1992) studied technology ventures inside a large aluminum company. They found that successful ones demonstrated lasting commitment and persistence above all else and that speeding concepts to market can be a mistake. However, in a system dynamics study of software startups, Hilmola, Helob, and Ojalac (2003) found that reducing product development lead time is one of the most important factors that determine the success of the ventures .

Joglekar and Levesque (2006) studied startups with staged venture financing in which research and development (R&D) and marketing were significant fractions of overall expense (primarily technology ventures) to determine how best to allocate resources between those functions. They determined that allocations of resources to R&D and marketing should account for the anticipated productivity of those functions, and that it may be best to cap both R&D and marketing expenses in certain situations. They also determined that it is best to minimize the number of venture funding rounds (i.e. it is better to obtain a single large investment than multiple smaller ones). They found it often suboptimal for a firm to focus on profit maximization to the exclusion of other strategies that would increase the value of the venture (e.g. investment in growth).

Gans and Stern (2003) develop a synthetic framework to determine commercialization strategies for technology ventures based on the "commercialization environment--the microeconomic and strategic conditions facing a firm that is translating an 'idea' into a value proposition for customers." They determine that the prime drivers of a successful startup commercialization strategy is the degree to which competitors who may be familiar with the technology are nevertheless unable to develop and market it themselves, and the degree to which incumbent firms have assets that contribute to the value of adopting the new technology. They assert that when the technology is non-appropriable (e.g. through intellectual property protection) and important complementary assets are held by incumbent firms, the new venture is well positioned to cooperate with the incumbents rather than compete. Conversely, when their intellectual property protection is weak and assets required by incumbent firms are not required, it is optimal for the new venture to compete and create their own market by exploiting the "blind spots" of incumbents. This has implications for new clean energy ventures that may or may not depend on the assets of utilities and other incumbents. For example, a venture with patented technology to improve the efficiency of electric transmission grids may be well positioned to cooperate with the grid owners and operators. However, a venture that is selling a combined heat and power system that does not have strong intellectual property protection and can be used for "off grid" operation may wish to find markets where current operators are not active.

2.4 Venture and Angel Investing

One of the most critical factors identified for the success of new technology ventures, particularly energy technology ventures, is the availability and amount of financing. The principal source of financing for most technology ventures is private equity investors, including those who invest their own capital (often known as “angel” investors), and professional investors who raise funds to invest in new ventures (venture capital investors).

2.4.1 New Venture Investment Data

An excellent source for data on venture investing in startup and early stage companies is the Pricewaterhouse Coopers *MoneyTree Report*, which is a collaboration between PricewaterhouseCoopers and the National Venture Capital Association based upon data from Thomson Financial (Pricewaterhouse Coopers, 2006). The *MoneyTree Report* has tracked professional venture capital investments by stage of company, geographical region, industry, and several other categories every three months since 1995.

The M*oneyTree Report* defines a seed or start-up stage company as being in “the initial stage” of development. Such a company would have a concept or product under development, but probably not yet fully operational. The firm has usually been in existence less than 18 months. The report characterizes an early stage (more advanced than a start-up) company as having “a product or service in testing or pilot production. In some cases, the product may be commercially available.” The early stage company may or may not be generating revenues and usually has been in business less than three years.

A similarly excellent source for data on angel investing is the Center for Venture Research (CVR) at the University of New Hampshire (The Center for Venture Research, 2006). The CVR tracks angel investments across the United States. Its data show that most seed stage investments are made by angels, in terms of both number of investments and in total dollars invested. However, the mean investment by an angel is significantly smaller than the mean seed stage venture investment. See Figure 2-3 for a comparison of mean venture early stage and seed investments 1995 through 2006 (Pricewaterhouse Coopers, 2006) and of mean investments by angels in 2000 and 2003 through 2006 (Center for Venture Research, 2006).

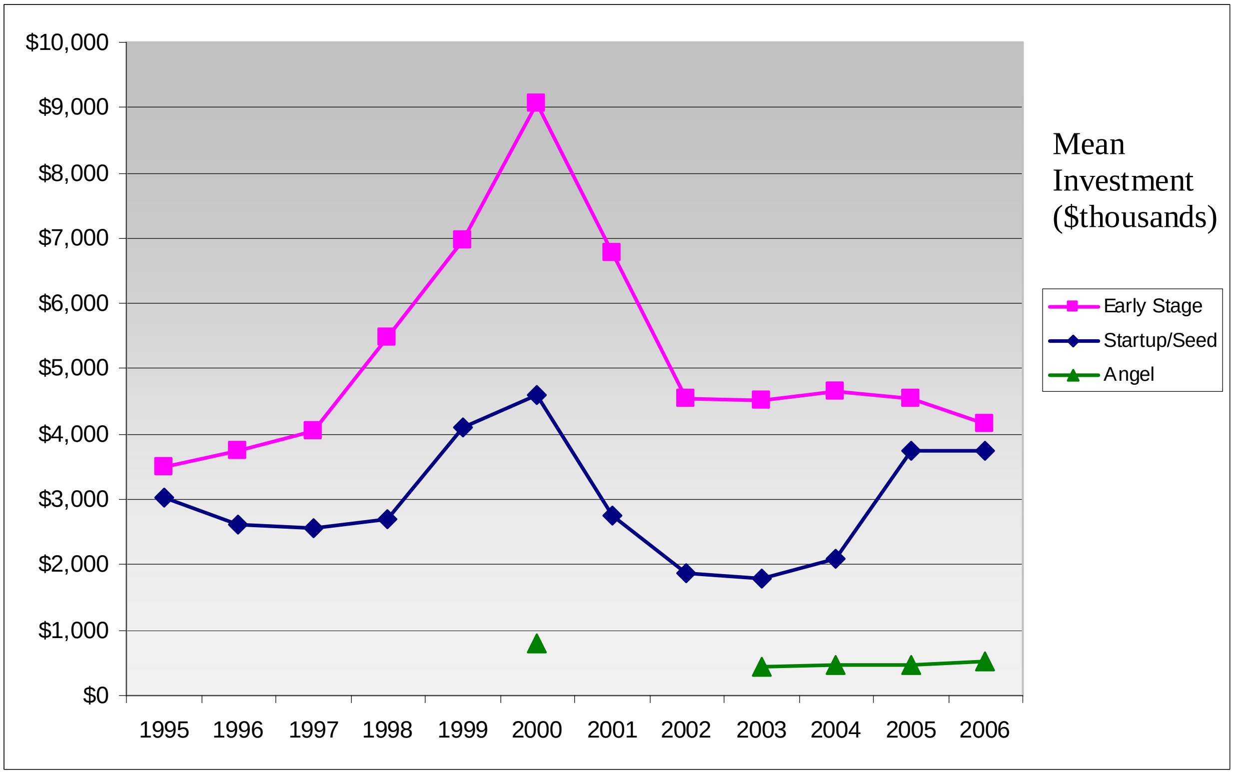

Figure 2-3: Mean VC and Angel Investments

2.4.2 Funding Gaps

A report prepared for the Economic Assessment Office of the National Institute of Standards and Technology (Branscomb & Auerswald, 2002) found that "most funding for technology development in the phase between invention and innovation comes from individual private-equity 'angel' investors, corporations, and the federal government--not venture capitalists." This is consistent with the CVR data (Center for Venture Research, 2006) showing that the majority of early stage investments come from angel investors. The NIST report also found that capital markets for early stage technology ventures are not efficient, and that conditions for success of innovations are concentrated in a few geographical regions (e.g. Boston metro area, Silicon Valley) and industrial sectors.

Figure 2-4, from this report, shows that angel investors fill a funding gap between federal funding for basic research and proof of concepts and venture funding for product development. An early stage company with a market-ready innovation that it has not yet successfully introduced to the market may face this gap, and both the NIST report and CVR assert that the current level of angel investing alone is not adequate to fully fill it.

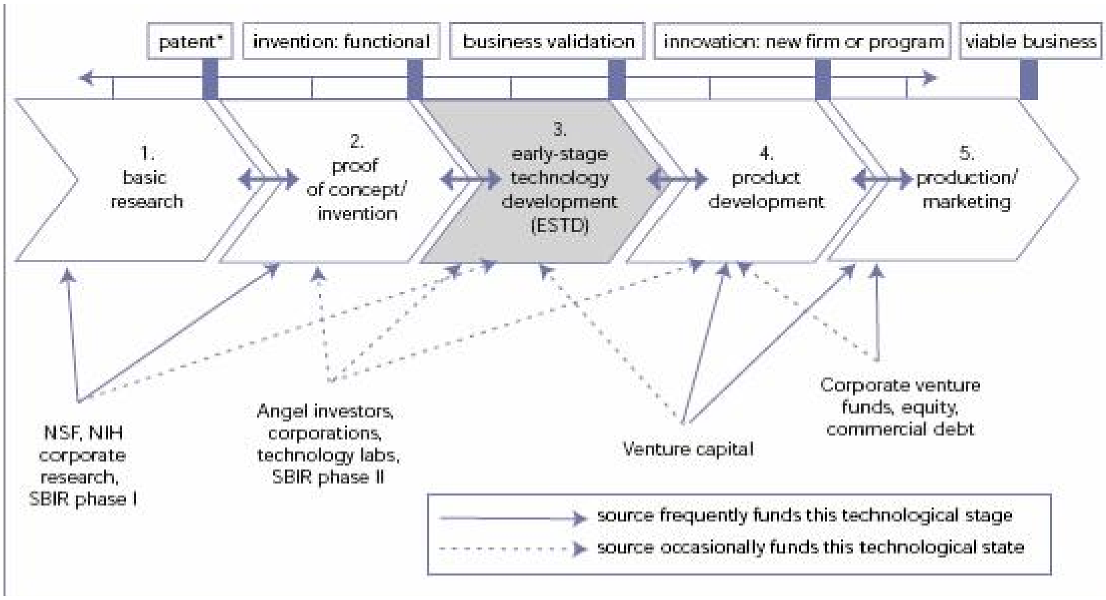

Figure 2-4: Funding Stages and Gaps

2.5 System Dynamics

The modeling methodology that has been used for this research is system dynamics. The best explanation and examples of the use of system dynamics is Sterman's *Business Dynamics* (Sterman, 2000). System dynamics is a powerful methodology for studying and understanding complex "real world" systems (such as a business or industry). What distinguishes system dynamics from other system modeling methodologies is the use of feedback loops, accumulation of flows into stocks, and time delays. These attributes combine to create models with nonlinear and often non-intuitive behavior, which often can provide useful insight into the behavior of the real world system being modeled.

However, as Sterman cautions, "all models are wrong" (Sterman, 2002). The best constructed model is still a simplification and abstraction of reality, and its best use lies in how well we learn from it (by improving our own mental models), and not in its replication of the behavior of a real world system. The details supporting the assumptions and construction of the model used in this research are outlined in Chapter 5.

2.5.1 System Dynamics Modeling of Electricity Markets

System dynamics has been used extensively and effectively to study the electrical power industry and markets and aid in resource planning. Ford (1997) lists 33 publications on the application of system dynamics to electric power, which range from models of national energy systems to the impact of new technologies to the behavior of individual companies. Lyneis has modeled both technology diffusion (Lyneis, 1993) and competition in the electric utility industry (Lyneis, 1997). Also see Bunn and Larsen's *System Modelling for Energy Policy* (1997).

2.5.2 System Dynamics Modeling of Diffusion of Innovation

System dynamics models have been used effectively to analyze the adoption of a wide variety of innovations. In one example, Homer (1977) developed a system dynamics simulation model to analyze the emergence of new medical technologies which took into account the development and manufacturing efforts of the manufacturers as well as the selection and use of the technologies by the physicians who adopted them.

Vij, Vrat, and Sushil (1991) modeled the diffusion of energy technologies using a probit approach. Rather than base the adoption rate on word of mouth from adopters, the adoption rate is based on the potential adopters' perception of the rate of return of adopting the new technology. The rate of return of the new energy technology is based on energy prices and the perceived risk of adopting the new technology as well as on its cost and financial benefits.

Maier (1998) used system dynamics to investigate the process of innovation diffusion by extending traditional new product diffusion models to include competition and the process of substitution among successive product generations.

2.6 Conclusion and Rationale for this Research

Of the bodies of literature most relevant to this study, the literature on diffusion of innovations is considerably more extensive than that on the factors that lead to success of new ventures. Yet given the assertion that only new ventures can successfully commercialize disruptive innovations (e.g. see Christensen (2000) and Utterback (1996)), if we are interested in encouraging the adoption of disruptive innovations, than we should be interested in encouraging the success of new ventures who attempt to commercialize them. Clean energy technology is a disruptive innovation in that it supplies energy using none of or much less of the predominant source of energy in the world today (fossil fuels), and reduces the need of the massive infrastructure built to transmit energy and electricity great distances. And given the benefits of these clean energy disruptive innovations, we should be interested in finding out how to encourage the success of new clean energy technology ventures. Yet little work has been done in this area. This research attempts to fill that gap.

3 Stakeholders and Factors in the Adoption of Clean Energy Technology

This chapter draws on an extensive set of interviews to reveal the attitudes and incentives of the wide range of stakeholders involved in decisions to adopt new clean energy technologies. Each stakeholder may play more than one role in the negotiation of product adoption (or rejection). The diverse factors that may impinge upon such a decision are also considered. This chapter disaggregates the roles, incentives, and disincentives that influence a decision to adopt a new clean energy technology. The next chapter fleshes out the process by presenting the complex interaction of the stakeholders in three real cases of the experiences of new ventures in the clean energy technology market.

3.1 Interviews

Over the course of four and a half years, over 100 interviews were conducted with clean energy entrepreneurs and a variety of stakeholders related to clean energy ventures. The stakeholders, described in detail in Section 3.2, 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. The consent form for the interviews is attached as Appendix A and the questions for those interviews are attached as Appendix B.

3.2 Stakeholders in the Adoption of Clean Energy Technologies

Because the goal of this research to is to better understand and thus overcome current barriers to the adoption of clean energy technologies, it is critical to know who the primary stakeholders are and how they relate to a clean energy technology venture and to each other.

To be adopted, a clean energy technology must be of significant value to all stakeholders along both its customer chain and supply chain. Those along the customer chain include the adoption decision maker, as well as direct and indirect users. Stakeholders in the supply chain include the developer of the technology, resellers and distributors, and partners who provide complementary systems and services. The needs and interests of other significant industry players such as electricity distribution companies (DISCOs), energy service companies (ESCOs), system operators (ISOs and RTOs), regulatory bodies (state and federal), and public policy makers and their constituents must also be taken into account. Without the explicit or implicit support from a preponderance of these players, the adoption of the technology will be impeded. This section fills in the outline of the stakeholders in the adoption of a clean energy technology (Table 3-1 column 1), their interests and needs in relation to and independent of the new technology (column 2), and the roles each stakeholder can play in affecting the adoption of a new technology (column 3).

Stakeholders	**Relevant Interests and Needs**	**Role in Technology Adoption**
Clean Energy Technology Developer	• Maximize adoption of the technology • Meet and exceed customer needs • Overcome barriers to the adoption of the technology	• Developer • Marketer • Enabler • Proponent
Facility Managers	• Ease of use (save time and resources) • Minimize risks to facility • Reduce complaints from occupants • Reliable power • Minimize expense	• Adoption decision Maker • Direct User • Indirect User
CFOs or Financial Managers	• Minimize expense • Generate good return on investment • Minimize risk to business	• Adoption decision Maker • Indirect User

Facility Users and Occupants	• Maximize comfort • Maximize ability to do work • Reliable power	• Indirect User • Proponent • Opponent
Utilities (distribution companies)	• Maximize revenue (or minimize loss of revenue) from distribution service • Minimize risk to distribution network • Reduce complexity, and personnel time required per customer	• Barrier • Enabler
Large scale generation owners	• Maximize revenue (or minimize loss of revenue) from generation	• Opponent
ISOs, RTOs	• Maximize and maintain system-reliability • Minimize system costs enhance price stability	• Barrier • Enabler
ESCOs	• Maximize revenue from services and distribution of products • Expand business offerings and services • Enhance reputation	• Enabler • Marketer • Proponent • Opponent
DG Equipment Manufacturers:	• Maximize revenue from equipment sales • Enhance reputation and visibility	• Enabler • Marketer • Proponent
Competing and complementary technology-providers:	• Maximize revenue (or minimize loss of revenue) from technology sales • Maximize network effects (through adoption of complementary technology) • Minimize direct competition	• Proponent • Enabler • Opponent • Barrier
Government, Policy Makers	• Maximize overall welfare of producers and consumers • Maximize system reliability • Minimize system costs • Minimize environmental damage • Improve system security	• Enabler • Barrier
General Public	• Minimize retail power costs • Improve system reliability and security • Minimize environmental damage	• Proponent • Opponent

Table 3-1: Stakeholders, Roles, and Interests.

3.2.1 Stakeholders and their Interests

The first two columns of Table 3-1 list 12 classes of stakeholders and the interests that motivate them.

Clean Energy Technology Developer – The New Venture: The clean energy technology developer is primarily concerned with developing a technology that meets and exceeds the needs of the adopters, and maximizing the adoption of the technology and thereby maximizing its revenues and viability as a commercial venture. To do so, the developer has to understand the needs and requirements of each of the other significant stakeholders (especially potential customers), and be able to overcome objections and barriers that exist today and will arise in the future.

Facility Managers: Most likely, the facility manager of a given organization is a central player in deciding whether that organization will install a clean energy technology. Facility Managers want a technology that is easy to use and conforms to expectations of how to manage their facilities. It is important to them to minimize any possible physical or financial risks to their organizations, and they may be skeptical of a technology until it is proven to be completely reliable in their eyes. However, a Facility Manager who is currently experiencing problems with the reliability and/or expense of power, and is under pressure to find a solution, will be motivated to try a new solution. If the organization has already adopted or decided to adopt a prior clean energy technology, a Facility Manager is more likely to be willing to adopt another. Word of mouth from colleagues who have experience with a similar technology is also likely to play an important role. In the final analysis, direct users such as facility managers will have to "trust" the technology before fully adopting it.

CFOs or Financial Managers: Organizations that do not have a suitable facility manager or for which the CFO or Financial Manager of a division make the energy decisions are likely to evaluate clean energy technologies on a more purely economic basis. The question will be what the return on investment and financial risks will be. Unless it can be proven that adoption of a new technology will provide significant economic benefits to their organization (i.e. by saving money on power expenses and improving the reliability of power) without incurring significant risks, they may block its adoption.

Facility Users and Occupants: It is important to consider the comfort and needs of the people who occupy any facility that uses a new energy technology. They may become the system's strongest advocates or detractors depending on how it affects their work and comfort. They also may play a role in the decision whether to adopt the system in the first place. If an energy technology is successful in increasing the reliability of power at a facility as well as the responsiveness of systems such as HVAC and lighting to the needs of occupants, then the users may become proponents of the system and facilitate its adoption through word of mouth. However, if they perceive that the new technology interferes with their comfort or ability to do their work, they are likely to become vocal opponents of the technology.

Utilities (distribution companies): Utilities currently have enormous influence over the deployment of clean energy technologies. They may also influence whether organizations deploy these technologies. Utilities and distribution companies will be concerned about loss of revenue resulting from the use of DG and DSM. They will also be concerned about risks to the distribution network resulting from the use of DG. As a result, they have in the past and may in the future impose strict interconnection requirements and significant standby charges that would reduce the incentive for any organization to adopt DG.

It is therefore important that the system-wide benefits of any new clean energy technology be conveyed to the utilities. For example, the adoption of DG may reduce their need to make expensive upgrades to the distribution network, and may result in more satisfied customers. However, if distribution companies continue to impose barriers to protect their revenue, other means, such as through changes in regulation, may have to be found to overcome these barriers

Large-scale generation owners: Large-scale generation owners (such as the owners of coal-fired plants) are not likely to favor the promotion of DG based clean energy technologies. In a deregulated environment, they are likely to view successful DG operators and manufacturers as competitors, and are likely to oppose the adoption of DG and any complementary clean energy technologies. This opposition must be heeded during the development of regulations that may affect the adoption of DG. See below for more on the impact of regulations. However, if the clean energy technology provide benefits to the generation owners or enable them to conform to new regulations, the generation owners may become adopters of the clean energy technology. However, it must be kept in mind that these are likely to be extremely conservative adopters.

ISOs and RTOs: The Independent System Operator (ISO) or Regional Transmission Organization (RTO) is responsible for the reliable operation of the bulk power generation and transmission system. Therefore, they are likely to support any technology that they think will increase the reliability and stability of the transmission system, and to oppose any technology, which they perceive will introduce undue risks.

No single clean energy technology is likely to affect the bulk power transmission system unless and until it is widely adopted. However, if the possibility of its wide adoption becomes apparent, the ISO or RTO for a region may become a powerful ally or opponent of the system depending on its managers' perception of potential system-wide effects. For this reason, the system should be designed to have positive system wide-effects that can be effectively communicated to the ISO or RTO.

ESCOs: Energy service companies (ESCOs) are often the implementers and installers of clean energy technologies within other organizations. This puts them in a position to advocate for technologies they approve. They are also likely to be interested in expanding their product offerings. If a new technology can benefit their customers, and marketing it would enhance their reputations as well as revenues, they could directly market and resell the system.

However, ESCO personnel would first have to be trained in the usage and installation of the new technology and to represent the product well. Poorly trained representatives could impede the adoption of a new energy technology even more than well-trained representatives could encourage its adoption.

DG Equipment Manufacturers: Current DG manufacturers will have an incentive to advocate for new clean energy technologies that use their products. However, they first must be made aware of the existence and the benefits of these technologies. They also must be convinced that the technologies enhance the value and usage of their particular systems.

Competing and Complementary Clean Energy Technology Providers: At first blush, it seems that competing ventures would strongly oppose the use of another clean energy technology. However, if the functionality of their system and the new technology does not completely overlap (which is likely to be the case), perhaps ways to partner can be found. For example, multiple energy management systems can be used to check the validity and enhance the reliability of each other's data. Furthermore, competing and complementary ventures are likely to be on the same side of the fence with respect regulatory and legislative battles.

The success or failure of similar products and technologies may affect the adoption of other new technologies. If similar systems are wildly successful, interest in new clean energy technologies will likely increase. However, if customers have strongly negative experiences with similar systems, they may be unwilling to consider a new energy technology.

Government, Policy Makers: The government and policy makers are unlikely to be directly affected by a new clean energy technology unless and until it becomes very widely adopted (or their own facility adopts it). However, regulations and legislation can have significant impacts on the adoption of clean energy technologies. The impact of regulation will be covered below.

General Public: Because the initial market for new clean energy technologies is likely to be large commercial and industrial facilities, the general public may not be affected by them initially unless they are occupants of a facility that adopts the technology. However, the influence of the general public on government representatives may have an effect on the adoption of these technologies, particularly with respect to addressing climate change. Once widely adopted, the technologies may have system-wide effects that could increase reliability of power and lower prices for all consumers, in addition to providing environmental benefits.

3.2.2 Interaction among Stakeholders: Roles in the Introduction of New Technologies

Naturally, the activities and concerns of these stakeholders interact in various ways as their roles in the future of a new technology play out. For example, enablers and barriers to a significant degree, and proponents and opponents to a lesser degree, will affect the decisions of potential customers. Competing technology providers may be opponents in one situation (selling to the same customer) but allies in another (lobbying regulatory bodies). An indirect user of the system in one situation (such as the occupant of a facility) may become a proponent or enabler in another situation (such as at a legislative hearing).

Though some of these interactions may not be foreseeable, all potential interactions should be taken into account to understand the factors in the adoption of new clean energy technologies. In each specific case, some stakeholders and the roles they play will be more significant than others will, but each will influence how extensively the technology will be adopted. As indicated in column 3 of Figure 1, the nine roles a stakeholder may play are:

Developer: This is the new venture working to develop and provide the clean energy technology.

Marketer: This is a person or organization that markets and sells the clean energy technology. This could be the new venture itself, a reseller, partner, or distributor.

Adoption Decision Maker: This is the most directly critical role. It is the individual or group at a given facility having the authority to adopt the clean energy technology for use at that facility. Though this person or group may consult with other stakeholders, the technology will not be adopted without the approval of this decision maker.

Direct User: This is also a critical role. This is the individual or group at a facility that is the prime user or adopter of the clean energy technology. The Direct User is likely to be the facility manager who will configure the system and interact with the interface to the system on the most frequent basis. Very often, Direct Users will also make or assist in making the adoption decision. They are also likely to play the most significant role in whether the technology receives positive or negative word of mouth.

Indirect User: This is an individual or group at a facility affected by the use of the clean energy technology, but not the direct user. For example, the occupants of a facility that uses a clean energy technology to manage energy use will be affected by changes in heating or cooling set points or in quality of power, though they may not configure or interface with the system directly. These users may also play a role in the adoption decision, and whether the technology receives positive or negative word of mouth.

Enabler: This is an organization with the authority or ability to enable or support the adoption of the technology. For example, the government could play the role of enabler by adopting legislation providing incentives for facilities to adopt the technology.

Barrier: This is an organization with the authority or ability to create or strengthen barriers to the adoption of a technology. For example, a utility distribution company can play the role of a

Barrier in the adoption of DG by making it time-consuming and expensive for a facility to connect DG to the grid.

Proponent: This is an individual or organization that expresses support for the adoption of the technology. Though a Proponent may not be in position to adopt the technology itself, it may influence the decision makers, users, and enablers to support the technology.

Opponent: This is an individual or organization that expresses opposition to the adoption of the technology. Though they may not be in position to erect barriers to the adoption of the technology themselves, they may influence the decision makers, users, and enablers to oppose the technology.

It is important to keep in mind the roles played by stakeholders, as their converging and conflicting interests determine the role they will play in promoting wider distribution of clean energy technologies developed by new ventures.

3.3 Factors in the Adoption of Clean Energy Technologies

To overcome the barriers to the adoption of clean energy technologies, it is critical to understand what the barriers to adoption of clean energy technologies are today, as well as what barriers new ventures may face when they attempt to commercialize these technologies. The many barriers that have slowed the adoption of clean energy technologies include regulatory, economic, institutional and behavioral, and technical reasons. The most prominent barriers to date have been regulatory and market-based in nature (Congressional Budget Office, 2003; Hedman et al., 2002).

3.3.1 Regulatory Factors

External forces resulting from regulation may have significant impacts upon the adoption of clean energy technologies. These may include real time pricing regulations, regulations which dictate the forms of power which are to be preferred (such as a carbon tax, or regulations that encourage energy efficiency), and subsidies (such as existing subsidies for fossil fuels). This section is a description of the regulatory factors and strategies that the technology provider may use to mitigate risks and encourage opportunities. The regulatory factors include:

Carbon Taxes or Cap and Trade Regulations: Many policy makers have discussed recognizing the cost of the externalities of carbon emissions (e.g. the danger of climate change) by imposing taxes or tradable caps on the emission of carbon. These regulations, if enacted, would likely increase the price of fossil-fuel based power, and encourage the adoption of clean energy technologies, which, by definition, reduce carbon emissions. These kinds of policies and their effects are discussed in Chapter 6.

Energy Efficiency Regulations: Regulators could also recognize the externalities of power production or react to power shortages by enacting regulations that encourage or even mandate the efficient use of energy or the adoption of specific classes of energy-saving technologies. These regulations would also encourage the adoption of energy technologies that optimize the efficient use of energy. The effects of policies that encourage adoption are also discussed in Chapter 6.

Subsidies: Existing legislation and regulations provide subsidies for the development of fossil fuel resources (such as oil, gas, and coal). If such regulations are enhanced, fossil fuel based power production could become more economical, and clean energy technologies will become comparatively less beneficial. On the other hand, legislation that provides encouragement through subsidies for clean energy technologies could have a very beneficial impact on adoption. These policies and their effects are discussed in Chapter 6.

Real Time Pricing: Distributed and intelligent clean energy technologies that react to changing conditions are more warranted when pricing information is changing in real time. However, real time pricing for electricity does not exist in most US markets. This does not mean that these types of technologies will be unusable, but it will reduce the perceived benefit of these systems. Many national level organizations have been touting the benefits of real time pricing for some time:

"Lack of price responsive demand is a major impediment to the competitiveness of electricity markets." (FERC 2000)

"[To] improve the reliability of electric supply, some or all electric customers will have to be exposed to market prices." (NERC 2000)

If and when real time pricing is adopted in a given market, it will increase the benefits and adoption of clean energy technologies such as DG, DSM, and intelligent energy management systems. In the meantime, clean energy technologies that depend on real time pricing will have to be sold on the basis of their other benefits or in other markets (perhaps internationally) that have adopted real time pricing.

Utility Interconnection Regulations and Requirements: Utilities are permitted to prevent customers from connecting small generators to the grid unless they meet a complex set of requirements to ensure the safety and reliability of the grid. Though there is a strong rationale behind this policy (the protection of the grid), utilities often force customers who wish to install DG to incur unwarranted costs (National Renewable Energy Laboratory, 2000).

Utility Surcharges for Stranded Costs and Standby Service: Regulations in most states allow utilities to levy surcharges on customers who install and operate DG in order to cover the cost of prior investments the utilities have made (stranded costs) and the cost to enable the provision of standby service to the customer. However, many DG customers believe that they should not be responsible for stranded costs, and that the surcharges for these costs are excessive (Congressional Budget Office, 1998). In any case, the existence of these charges impedes the adoption of DG.

Environmental Concerns (e.g. Siting Restrictions and Air Permitting Issues): Most municipalities in the US (including states, counties, and cities) regulate the installation and operation of electricity generating equipment for environmental, safety, and zoning purposes. California alone has extensive regulations (California Energy Commission, 2000). Unfortunately, these regulations are not consistent nationally, and make it difficult for the manufacturers and users of DG equipment to know whether they comply.

3.3.2 Economic Factors: The Market

External market forces will have significant impacts upon the adoption of clean energy technologies. These forces may include the price of power from various sources; knowledge and degree of certainty regarding the economic benefits; and the existence, price and quality of competing technologies. These factors include:

Price of Power: One of the key selling points of clean energy technologies is that they enable the adopting organization to save money on power costs. If power costs increase or decrease significantly, this may enable or disable the market potential for the product. For example, if a shortage in fossil fuels caused electricity prices to raise dramatically, many organizations would be more willing to adopt clean energy technologies that would reduce the impact of those increased costs. However, if power prices were to decrease dramatically, the motivation to try new technology would be decreased correspondingly.

It must be kept in mind that some forms of DG use natural gas as fuel, and therefore an increase in the price of natural gas may decrease the adoption of DG. However, this may have a beneficial impact on other forms of DG (such as wind power) and may have a beneficial impact on the adoption of DSM systems and other clean energy technologies.

Prices for Power Sold to Utilities: DG is most cost effective when excess power generated can be sold (or credited) at retail electricity rates. However, most states have no standardized rules that allow all DG operators to do this. Though many states have net metering regulations[1] that enable customers to run their meters backwards when they supply power, these regulations are often restricted to small, renewable sources of generation. Even when a generator at a customer site is able to produce power at a cost below the marginal wholesale cost of electricity from the grid, it may not be permitted to do so.

Uncertainty Surrounding Economic Benefits: When an organization is deciding whether to install or implement a new energy technology, generally the cost of the installation will be known, and will be incurred up front. However, the amount of benefit or savings the system(s) will provide will often be unknown. An organization may not know how much electricity they will save by implementing DSM or even how much electricity they will generate with a DG system. Even if they did, they may not be able to calculate the savings, since they will be dependent upon the future cost of electricity from grid and of the fuel for the DG system (often natural gas). Also, without long term contracts to purchase the power from renewable power generation, developers of these projects will be uncertain as to their value over time. This may

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[11] See www.awea.org/policy/netmeter.html for a summary of states net metering programs as of May 2001.

make the developers of renewable energy or decision makers adopting DG or DSM hesitant to go ahead with the investment and creditors hesitant to finance it.

New Technology or Markets: Clean energy technologies may be designed to work within the current system of power generation and transmission technology and markets. If radical new energy technology is developed or the natures of the markets are significantly changed, the adoption of the clean energy technologies will be affected.

3.3.3 Managing Regulatory Impacts

As seen above, regulations could have significant positive or negative effects upon the adoption of new energy technologies. There is strong interest to make progress on regulatory barriers to clean energy technologies. Interconnection standards have come into being (such as IEEE 1547) and federal and state regulatory bodies are aware of these regulatory issues and are actively working to resolve them.

However, regulations that favor entrenched interests can be notoriously hard to change. Furthermore, these regulations, and efforts to update them vary across 50 states. Without progress on the regulatory side, technological solutions may be insufficient to drive the adoption of clean energy technologies. Though the forces that shape these regulations cannot be fully controlled, nongovernmental activities in the civic and private sector can influence the regulatory process, mitigate the risks of uncertainty, and encourage opportunities:

Participation in the political process: Focused, knowledgeable, and motivated participants in the political process tend to have greater influence. By assuring that policy makers are informed of the benefits and costs of different types of regulations, it may be possible to have a positive impact.

Industry groups: Though knowledge alone is powerful, legislators are more likely to listen to a large and organized coalition than to an individual or small group. The more that clean energy technology providers and advocates band together, the greater influence on legislation they may have.

Visibility of benefits of the technology: If clean energy technologies are deployed and used successfully, and policy makers become aware of this success, they are more likely to support regulations that encourage its use.

Good relationships with the organizations that implement regulations: Once regulations are enacted, whether positive or negative, the nature of their implementation is likely to have a more significant impact than the actual text of the regulation. Positive relationships with those who have the authority to implement regulations are important.

3.3.4 Institutional and Behavioral Factors

Forces within institutions and the way people behave when evaluating new technology are significant factors in any decision to adopt a technology. These factors include:

Lack of incentives for decision makers – agency problems: Sometimes decision makers do not have an incentive to make an investment in order to save on energy costs. For example, the architects and engineers who are designing and building a particular site may wish to avoid any initial investments that would increase the cost of a project, even if they would ultimately provide significant energy savings to the occupants. Similarly, the owner of a building for which the tenants pay their own energy costs may have no incentive to make an investment to decrease those costs. Or the users of power at an institution may not be responsible for paying for the use of that power.

Advantages for delay: If similar clean energy technologies are not already commonly installed within an industry or region, decision makers will perceive more risk associated with putting in new technology, compared to “doing what everyone else is doing.” Even when aware of the benefits of these technologies, they may choose to delay installation due to an expectation that price and functionality will improve over time.

Unwillingness to invest the time necessary to learn and use a new energy technology: Even if a new energy technology is sold on a “share of savings” basis with no upfront financial investment required, some upfront investment of time will be required. Users who are occupied with other problems may not be willing to make this investment of time. Organizations face many challenges today, and are often resource-constrained. Therefore, even when the economic benefit of installing a new technology is clear, an organization may not have personnel with the time and qualifications to manage the project and ensure that it operates in such a way to incur its full economic benefit. To complicate matters further, the installations of energy systems are often quite complex.

Chicken and egg problem with experience: Potential adopters of new technology are often hesitant to accept it until they have directly observed its benefits and have personal experience with the systems. However, they may not be able to gain such experience until they have adopted the technology.

3.3.5 Technology Factors

Finally, the nature of the technologies themselves undoubtedly plays a role in whether they are adopted or not. These factors include:

Lack of progress on clean energy technologies: Though it is enticing to assume that technology in any given area will steadily advance, there is never a guarantee of this. For example, the promise of inexpensive fuel cells and microturbines may never materialize, while the price of renewable generation technologies may remain uneconomical for some time. And efficiency gains may stop being made. And without progress on the ‘hardware’ side, energy management software will have greatly reduced benefit.

Unexpected consequences: Even if new promising technology is developed, it may not work under “real world conditions” the same way it works in the lab.

3.3.6 Summary of Factors

Figure 3-1 shows the interaction of many of the factors affecting the cost and value of implementing and utilizing clean energy technology. Some factors are clearly more important for particular technologies than others. (For example, siting regulations are important for DG but not DSM.) Other factors would affect almost any clean energy technology (e.g. carbon taxes). Some factors have more of an indirect effect (e.g., the political power of utilities allows them to influence regulations that have a direct effect on the adoption of clean energy technologies).

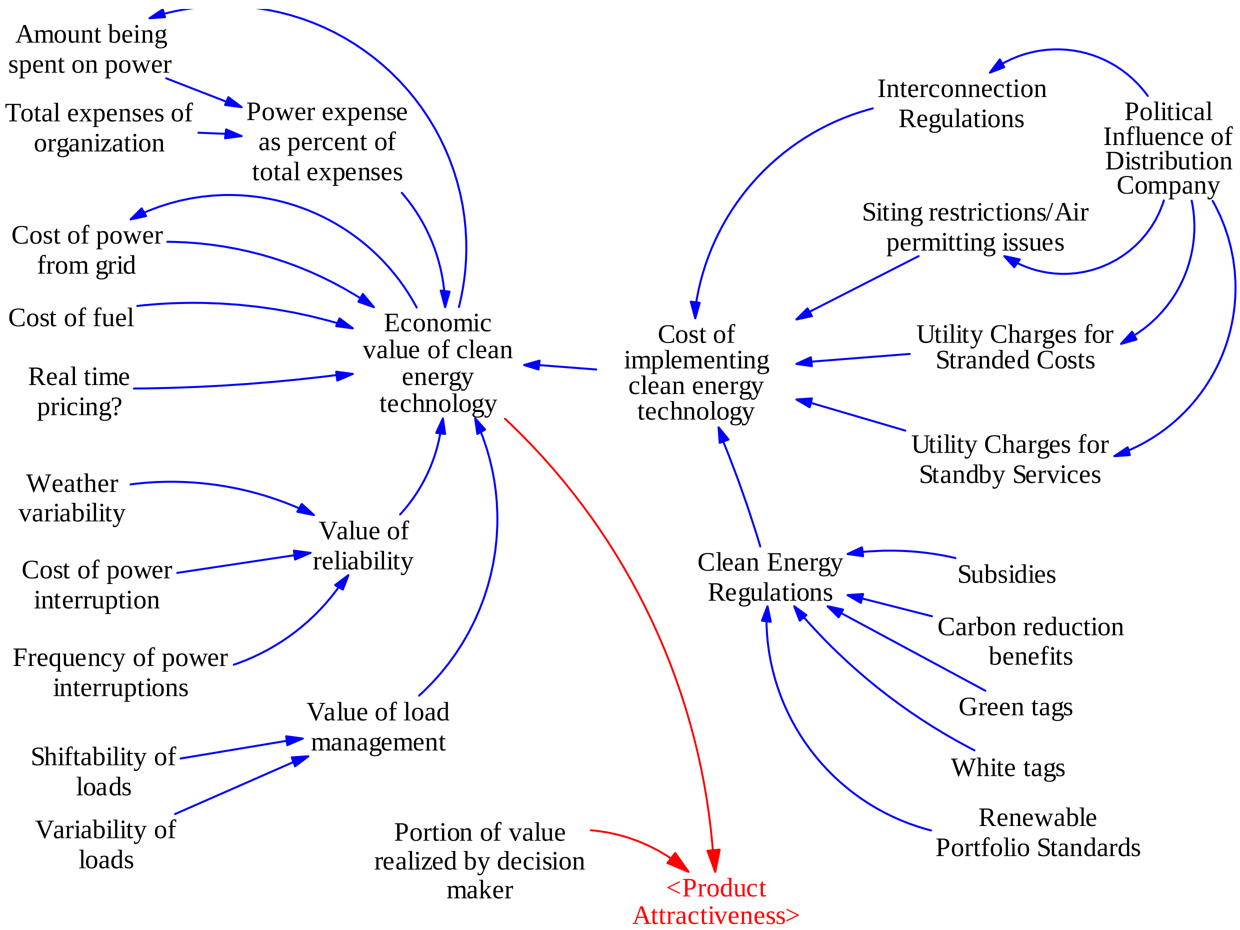

Figure 3-1: Factors Effecting Value of Clean Energy Technology

3.4 Feedbacks that Support Established Energy Technologies

Though a clean energy technology may be economically advantageous, many positive feedbacks support established energy technologies and the companies that provide them. Figure 3-2 depicts many of these loops.

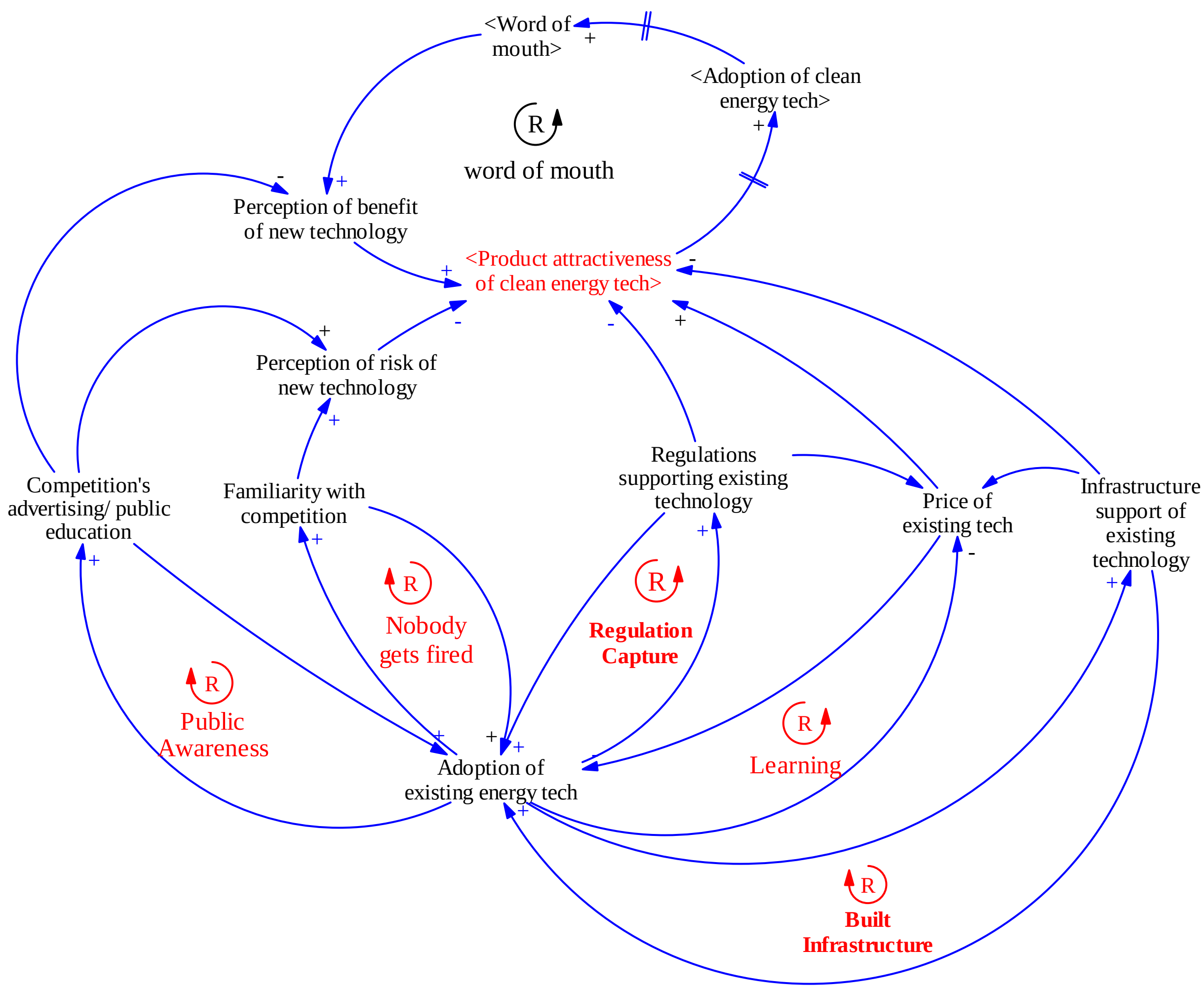

Figure 3-2: Loops Effecting the Adoption of Clean Energy Technology

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. Furthermore, any new energy technology will be perceived as risky (it has not been 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 once its supporting infrastructure built marginal costs are lower. 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.

3.5 Conclusion

In this chapter we have disaggregated the complex web of stakeholders, roles, and factors that can promote or inhibit the adoption of a clean energy technology. Clearly, there is serious regulatory, market, institutional, behavioral, and technological challenges. This is why new clean energy technologies must provide significant benefits over existing technologies in order to be widely adopted and these benefits must be clearly and strongly communicated.

Some of the interviews on which the information in this chapter is based also contribute to the in-depth case analyses in Chapter 4. These detailed studies demonstrate three instances in which stakeholders interacted to affect the adoption of a new technology and the fate of the new venture that developed the product.

Chapter 5 will describe a model with a direct sales-oriented perspective towards the adoption of clean energy technologies (i.e. not only do attributes of the technologies and products have to make them attractive to end users, but the technologies and products must be directly sold through considerable sales and marketing effort).

Chapter 6 and 7 will then analyze the results of running the model and provide a discussion of the effect that management strategies and government policies may have to increase the adoption of clean energy technologies and overcome the barriers and challenges that were described in this chapter.

4 Case Studies

This chapter presents case studies of three clean energy technology ventures. Over a dozen ventures were evaluated in depth for this research, and these three were selected as a representative sample. They are SoftTech Systems, whose products manage energy consumption for buildings and who are profitable but have not yet achieved widespread adoption; Dharma Power, who provide wireless technology and services to monitor power plant equipment and who are working to achieve profitability; and Bluestone Power, whose plan was to assemble, install, own and operate on-site combined-heat-and-power generation (CHP) systems, but was not able to achieve significant revenue, and whose assets have been sold.[2]

These companies differ in some significant ways, but also have some factors in common. Each appeared to have great prospects—high quality and economically advantageous products, excellent management, and sophisticated analyses of the market. Each failed to meet its goals. The history of each company and the reasons for the difficulties they faced were distilled from interviews with the CEOs. In retrospect, the CEOs understood many of the reasons that their companies did not perform up to expectations. Each offers some lessons that should make it easier for other start-up firms in the clean energy technology market to succeed.

The attributes of these firms and many other like them and the commonalities observed in their capital requirements, business models, sales cycles and labor requirements contributed significantly to the structuring of the system dynamics models developed in this study. And many of the "lessons learned" will be echoed in Chapters 6 and 7 in the discussion of the strategies new ventures should employ and the policies that would assist them.

[2] The names of the companies have been changed for discussion in this analysis.

4.1 SoftTech Systems

SoftTech (not the real name) was launched in late 2000, with four founders who had experience in the energy and building industries, and in software development. Their original purpose was to develop a company to optimize energy usage across all spectrums (transmission, distribution; and generation). Their initial products were designed to monitor energy consumption for buildings, aggregate the data and intelligently control and optimize equipment settings. By mid-2001 they had developed a beta product that helped to manage energy use in buildings and tests of this product resulted in reported savings of over 20% of the energy used at the government facilities where it was installed. SoftTech had its commercial launch in the first quarter of 2002.

SoftTech was funded by venture capitalists and was provided with enough capital for the company to afford a significant workforce and the time to develop a quality product as well as to develop the market. Their business model is a "share of savings" model in which customers are charged relatively little up front, but SoftTech is then paid a percentage of the customer's energy savings over time. This model has appeared to work for SoftTech, as they were able to attract large institutions to be their customers, and more than double their revenue every year to achieve profitability.

SoftTech's CEO believes that several factors were critical to the success they have had. In the first place, the venture was well-financed from the outset. With these resources, they were able to hire and retain well-qualified personnel who were creative and persistent in developing the company's products and finding a market for them. The principals further positioned the firm by developing excellent public relations through winning awards, speaking at conferences, serving on industry committees, etc.

External conditions were also favorable for SoftTech's launch. Increases in energy demand were putting pressure on supply. This creates great incentives for energy efficiency. Customers seeking greater efficiency are familiar with high tech solutions that intelligently collect and use data. They are very hospitable to a high tech answer to an energy question.

Building on customers' confidence in technology, SoftTech provides an interface to their system that enables customers to see how it works and interact with it. Customers can easily see the quantifiable benefits of SoftTech's system. The firm's product provides a demonstrable return on the customer's investment that differentiates SoftTech from competitors.

However, with all these successes and advantages, SoftTech has not been as successful as the founders and investors originally envisioned. Adoption of its products and services has not been widespread and has been much slower than the founders hoped. The CEO suggests a number of factors that have hindered their success.

Utilities and ISOs (Independent System Operators) do not provide markets for energy efficiency products and services. They are principally concerned with generation and are slow to change. Deregulation, which held the promise of creating new markets, has not progressed significantly over the last decade.

Customers and industries are conservative and slow to adopt new energy technologies. According to the CEO, "on the commercial and industrial load size of the business, nobody gets fired for not saving money, but they do get fired for failing when trying to adopt new technologies and processes." The risk of potentially losing their job if the technology doesn't work strongly discourages employees of potential commercial customers from adopting new technologies when the only benefit they see is to save their employer money on energy use. Furthermore, potential customers may not even be aware that options exist to lower their energy usage and costs.

It is not just corporate culture that may discourage managers from seeking innovative technology for energy conservation. Laws and regulations support generation over efficiency and fossil fuels over other forms of energy or energy savings.

Another issue was that efforts to raise more capital were very difficult and time-consuming. Even though SoftTech was initially well-financed, management miscalculated the length of the sales cycle. SoftTech's management team was surprised at how slow and low adoption of their products and services have been.

The lessons learned, and the advice the CEO would impart to other entrepreneurs in this business include:

- understanding the lessons from "Crossing the Chasm" (see Chapter 2);

- minimizing the cost of the technology by having it do the least amount necessary to accomplish its purpose and by developing additional innovations only as customers demand them;
- emphasizing more strongly to potential customers regarding the benefits, including cost benefits, of reducing energy usage;
- understanding the importance and impact of regulations and lawmaking;
- understanding the market and how to add value to customers;
- focusing on larger customers;
- understanding the importance of “holding their hands”; and
- recognizing how much time it takes to make a sale.

Though many of these points may appear to be obvious, Softech’s experienced CEO did not fully appreciate or take these into account until he learned them through the experience of running this venture.

SoftTech’s CEO believes that widespread adoption of “energy management” technology will be achieved when 80% of enterprises have adopted it to cover over 80% of leasable square footage. He believes this will take at least ten years, but that it is bound to happen.

4.2 Dharma Power

Dharma Power (not the real name) was founded in early 2003 to use wireless technology to monitor equipment in power plants and thereby increase their reliability and efficiency. The company's product is a clean energy technology because it reduces emissions by first reducing outages and then by increasing the efficiency of equipment in power plants. Dharma's founders had good connections with owners and operators of power plants, and the company's product and service reduces their maintenance costs by an order of magnitude.

When the company was founded, there was no competing product or service at a comparable price point, and the company had a strong competitive advantage through the special expertise of one of the cofounders. Furthermore, Dharma was able to establish a relationship with the electric power industry's research consortium. This relationship established the credibility and underscored the value of Dharma's products.

The company's first customer and trial site was a nuclear power plant. This was considered a very positive sign for the prospects of the company, as nuclear power plants are considered one of the most difficult types of customers with which to establish trials. Furthermore, Dharma's products performed well during the trial and the customer was very satisfied. As a result, the founders were able to attract several million dollars of investment capital within two years and build a strong management and engineering team.

Unfortunately, the nuclear power plant market turned out to be unattractive for Dharma. First, there are relatively few nuclear power facilities. Also, while Dharma's product worked well in the trial, the cost savings it produced was not significant compared to the budgets of these plants. These plants are very conservative, reluctant and slow to try new technologies. Furthermore, the companies running nuclear power plants could afford to create their own suite of the services comparable to those offered by Dharma. It is possible that Dharma might have done better to seek its first market among a greater population of companies in greater need of the value of its services.

Dharma's CEO identified several other reasons why the company did not achieve the sales he anticipated. These can be bundled into problems understanding the market, particularly the sales cycle, and the wrong mix of personnel.

First, the market: Dharma initially targeted a single vertical market, which has, in the CEO's words, the "longest sales cycle in world." And after having entered the nuclear power plant market, management was unclear which markets to address next. Even in the new markets, the sales cycle was much longer than anticipated—six to 12 months rather than the projected three months. Regulations hindered the ability of power plants to quickly adopt new technologies. And Dharma underestimated the level of inertia and impact of annual budget cycles on their potential customers. Furthermore, unaware of the impact of these factors, Dharma's management did not raise enough money to fund operations through long sales cycles.

Second, the personnel mix included too many technical employees and too few skilled sales personnel. Dharma started off dominated by technical people, with only one person with significant sales experience. The company was more focused on getting the technology to work better and on supporting beta customers than on selling the product. Dharma's management team was uncertain how best to sell their products and services, who would be good at selling, to what level of management they should be selling, and how to price their product. Another oversight was a failure to create and secure non-appropriable intellectual property (e.g. patents) in the course of developing Dharma's technology. The building of such a resource might have attracted additional investors.

According to the CEO, Dharma's prospect chain looks like that depicted in Figure 4-1. The figure depicts each of the steps a potential customer must go through before becoming an adopter of their product, with the time range and average amount of time spent in each stage.

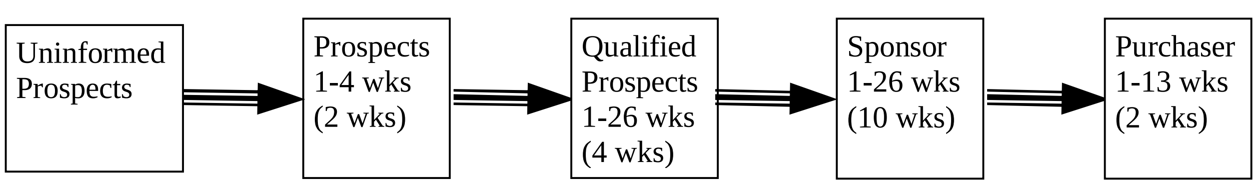

Figure 4-1: Dharma's Prospect Chain

Dharma's CEO believes the following factors are most important in determining whether they will make a sale:

- Meeting a need of the customer's and whether they're solving the customer's problem
- Having high quality sales people and continuously selling to the customer
- Quality of the product they're selling
- Pricing
- Brand recognition
- Having the trust of the customer and having demonstrated expertise in the customer's business
- Recommendation from the customer's peers (references and word of mouth)
- Delivering the product on a timely basis with high quality service during the sales and deployment process
- Conforming to the customer's budget process and cycle

Dharma has maintained a competitive advantage with respect to both price and features for its product and service offerings and Dharma's management believes they should be able to achieve wide adoption. Having learned the lessons from their early experiences and having developed a better understanding of their market, coupled with positive feedback and good word of mouth from their customers, Dharma's management has high hopes for the future...

4.3 Bluestone Power

Bluestone Power (not the real name) was launched in 2003 after the principals participated in an elite business school's business plan competition. As articulated in their plan, their goal was to "assemble, install, own and operate standardized, modular, on-site combined-heat-and-power generation (CHP) systems designed specifically to supply commercial and institutional facilities in the New England and Middle Atlantic states with reliable, economic, environmentally friendly electricity and thermal energy." As discussed in Sections 1.1.3 and 2.1.1, distributed generation and CHP have many economic benefits.

Figure 4-2 shows a schematic of Bluestone's system, which was designed to use 80% of the energy from natural gas, which is over twice the efficiency of grid based electricity. The business model was to finance, install, and operate CHP units primarily at suburban office buildings. Each CHP unit would deliver approximately 40% of a facility's electricity and thermal energy. The facility owner would pay Bluestone standard retail prices for the power and thermal energy. Bluestone would make a significant profit since its costs would be less than wholesale due to the economies of CHP and to economy of scale. The building owner would benefit from having the greater reliability of on site power in addition to a connection to the grid and because Bluestone would pass on part of its profits to them. Everyone would win (except, perhaps the local utility and owners of central generation).

Bluestone's founders were confident in the competitive advantages of their product. The CHP system could be mass-produced, lowering the hardware and installation costs. They had a relationship with a natural gas procurement and logistics company to provide the fuel at a wholesale cost. Bluestone had a first-mover advantage in entering a large, growing, and underserved market. In addition, their management team had experience in the critical elements of energy, manufacturing, information technology, finance, real estate, and risk management.

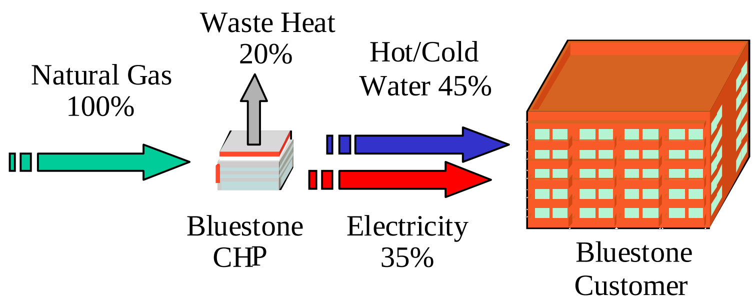

Figure 4-2: Bluestone CHP Diagram

Over time, Bluestone gained other advantages as well. They developed a relationship with an energy project financing company that had the resources and expertise to finance its projects. Their most significant competitor went out of business due to some strategic blunders, making available experienced personnel Bluestone could hire and projects that it could take over. The managers were able to enter negotiations with some large commercial property owners. Bluestone projected that it would have over $14 Million in revenues and a net income of over $850,000 within two years. See Figure 4-3.

Pro Forma Income Statement	2004	2005	2006
Revenues	$ 235,909	$3,892,493	$14,390,428
COGS			
Maintenance & Support	$ 19,096	$ 315,084	$ 1,164,856
Insurance & Risk Management	$ 8,000	$ 132,000	$ 488,000
Fuel	$ 114,372	$1,887,133	$ 6,976,673
Gross Profit	$ 94,441	$1,558,276	$ 5,760,899
Operating Expenses			
G&A	$ 238,456	$ 807,021	$ 1,150,812
Sales Expenses	$ 59,188	$ 351,955	$ 1,192,480
EBITDA	$ (203,203)	$ 399,300	$ 3,417,607
Depreciation Expense	$ 67,519	$ 677,715	$ 2,418,644
Interest Income	$ 59,938	$ 231,085	$ 504,951
Interest Expense	$ 202,407	$1,093,103	$ 3,071,260
Earnings Before Taxes	$ (345,671)	$ (462,718)	$ 851,299
Taxes	$ -	$ -	$ -
Net Income	$ (345,671)	$ (462,718)	$ 851,299

Figure 4-3: Bluestone Financial Projections

However, after four years in business, Bluestone was not able to complete a single project and had no significant revenues. What happened?

According to the founder and CEO, Bluestone faltered for several reasons. One major cause was the already low price of retail energy; saving a portion of these expenses was not compelling to the firm's potential customers. Furthermore, energy costs overall are a small portion of the costs of most large real estate organizations. Lowering these costs is not perceived to provide a significant competitive advantage. Therefore, there is no compelling reason to adopt a new technology to do so.

As with Dharma and SoftTech, issues that stretched out the time required to complete a sale proved significant. Regulations and policies that support utilities and the centralized grid, such as standby tariffs and interconnection requirements and charges increased the time required and raised the cost of doing projects, lowering the economic benefits. The sales cycle was too long for Bluestone to manage.

According to the CEO their sales cycle looked like that depicted in Figure 4-4. The time ranges provided are estimates based on their initial experience. However, he admits that even the high sides of the time ranges proved to be optimistic. After two years of working on some deals, terms still had not been negotiated.

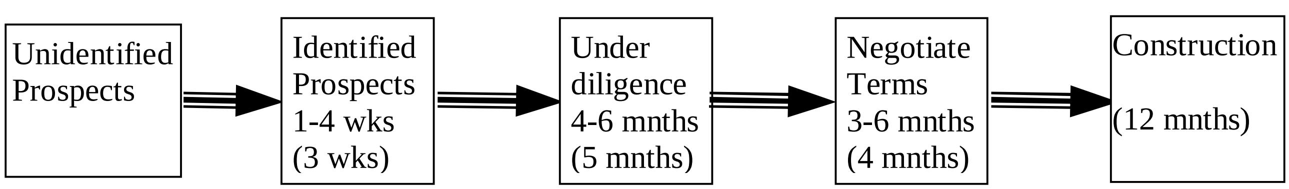

Figure 4-4: Bluestone's Prospect Chain

Bluestone's management was surprised by "how long it takes," by the "commercial complexity" of deals, and by the fact that making a sale was dependent more on having a strong and motivated advocate for the deal within the customer's organization than by the financial advantages of the deal itself. The founder says that if he were starting the business today, he would change "most everything." He would have found more seasoned managers with experience in the industry to join the Bluestone team. The founders would have raised more initial capital to sustain them through the long sales cycles. They would have been more strategic in finding their market and would have chosen a more workable business model (namely, creating two entities, one to develop the projects and another to own the CHP assets).

Bluestone's CEO still believes that CHP is a good business, and that a 25% adoption rate for economically advantageous projects is achievable (meaning that 150MW could be adopted in the NY downstate region alone). However, he believes that for this to happen, the regulatory environment has to be changed to support rather than impede the adoption of CHP.

Rather than the regulatory disincentives of interconnection charges and standby rates, commercial facility owners should be given incentives to adopt CHP. Rather than subsidizing fossil fuel production, governments should charge for the externalities of fossil fuel production through either a cap-and-trade program or carbon taxes. He also notes that it would be advantageous for interest rates to remain low to ease the financing of CHP projects.

This CEO offers the following advice for any entrepreneur getting into the business. Most importantly, he emphasizes, "Do your homework." It is important to identify the major risk characterizing one's specific business. Above all, recognize that "you don't know you don't know." Among the factors determining business success is choosing the right combination of markets. Dharma's principals learned this also in their first move into nuclear power plants. Also, find the right personnel mix: once the markets are identified, pick people who know how to sell to and serve those companies. An important strategy of good sales people is to find a champion within any potential customer organization. This CEO also advises that a new firm should raise sufficient working capital to sustain the business through much longer sales cycles than expected.

At the end of 2006, Bluestone's assets were sold to a better capitalized venture focusing on a wide variety of distributed generation and CHP projects and solutions. Bluestone's founder believes that the lessons he learned through the Bluestone experience will serve him well as an executive in the new enterprise.

4.4 Conclusion

These three energy technology companies each had some problems unique to its product, objectives, and potential customer base. However, some common problems can be observed.

First, none of the three anticipated how long the sales cycles would be. Even a very well capitalized and profitable company like SoftTech found itself surprised at how time consuming it was to make sales. For this reason, the CEOs advise that a firm should be aware of the need for sufficient funds to carry it through the first rounds of slow cycles. Second, the objective value of a product is not enough to sell it. These experiences point to the fact that a start-up firm must carefully calculate the influences of corporate culture, economic factors, and regulatory environments to determine whether their product will be truly desirable. Third, the CEOs counsel that sales ability is at least as important as technical competence once a firm enters the marketplace. Given a limited amount of funds for salaries, a firm should hire skilled, experienced sales staff and save the development of more product features until customers signal that they need them.

5 Description of Simulation Model

This chapter presents a description of the new clean energy technology venture simulation model. It first provides a clarification of the problem the model addresses and the model boundaries. Then an overview of the model is provided which is divided into three components: the firm, the market, and competition. Six sectors of the model will then be described in more detail: cash flow, labor (including vacancies, hiring, and layoffs), product development, the market and prospect chain (including sales and marketing effort and word of mouth), customer support, and pricing. Since the focus of the model is the new venture, most of these sectors apply primarily to the firm being modeled. The only exceptions are the product development sector, which incorporates the product development of competition, and pricing, which incorporates the costs and pricing of the competition. The structure, parameters, and assumptions built into the model are supported by the literature discussed in Chapter 2 and by the interviews, the case studies, and the personal experience of the author working with clean energy technology ventures. The full documentation for the model, including all equations, is presented in Appendix C.

Though a substantial portion of the model is based on standard system dynamics structures which model the product development, labor, and market of firms, some aspects are uniquely and specially adapted to modeling *new clean energy technology* ventures. To emphasize attributes and strategies related to *new* ventures, the model focuses on the cash position of the firm (working capital), and decisions about hiring and firing are made based on the current level of working capital. To focus on qualities specific to *technology* ventures, a significant portion of the model is devoted to the product development process (R&D), including a provision for non-appropriable features (i.e. technologies that have intellectual property protection). To focus the model towards *clean energy* ventures, the market sector and prospect chain structure and parameters of the model are based on the results of interviews with clean energy companies and are specifically tuned to the market for clean energy products and services. Further, the effects of clean energy policies are built into the model, and these are described in Chapter 6.

5.1 Clarification of Problem Statement and Model Boundaries

The first step in the development of a system dynamics model is to clarify the problem statement and define the model boundaries (Hines, 2004; Sterman, 2000). Over the course of this research and definition of the model, a number of aspects of the research came into focus and defined the model boundaries:

Subject: The subject of the model is a prototypical clean energy technology venture, where clean energy is defined as per Chapter 1. The venture is assumed to be an early stage company with a product that has advanced features that are attractive to and economically beneficial to its intended customer base, but has not yet been able to generate significant sales or adoptions.

Market: The customer base for the venture is assumed to be industrial or medium to large commercial enterprises, which can economically make use of the clean energy technology. The aspect of the power system and markets which will be addressed will be primarily the end users and facilities, while taking into account the interface to the distribution and transmission networks.

Geographical Focus: The intended geographical focus of the model and research is the United States. The model is restricted to the U.S. since regulation and the nature of markets vary from country to country and all the interviewees were based in the U.S. The model boundary is not smaller than the U.S. since even small companies selling clean energy technologies often have national markets, and the capital market is also national in scope.

Time Horizon: The time horizon of the model is a start time of anytime between 1995 and the present, and duration of twenty years. This is the case since the vast majority of the relevant experience of the interviewees occurred between 1995 and now, and the majority of changes in the energy industry due to deregulation occurred before 1995. Due to the long timeframes of adoption of energy technologies, the duration of the model needed to be as long as possible, but describing the fortunes of a technology company beyond twenty years would enter into the realm of pure speculation, as technologies and markets are likely to change significantly over that time period.

Regulatory Environment and Macro-economic Variables: The regulatory environment and the effect of macro economic variables, such as the price of fossil fuels are adjustable, but exogenous to the model. The goal here is to determine how the venture will perform given a particular economic and regulatory context. The effects of policies that adjust the prices of fossil fuels and of clean energy product development are examined in Chapter 6.

5.2 Model Overview

The purpose of the simulation model presented here is to better understand the parameters and strategies that shape the early stage success or failure of a clean energy technology venture. 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 1 is an overview of the model highlighting three sectors: the firm, the market and the competition.

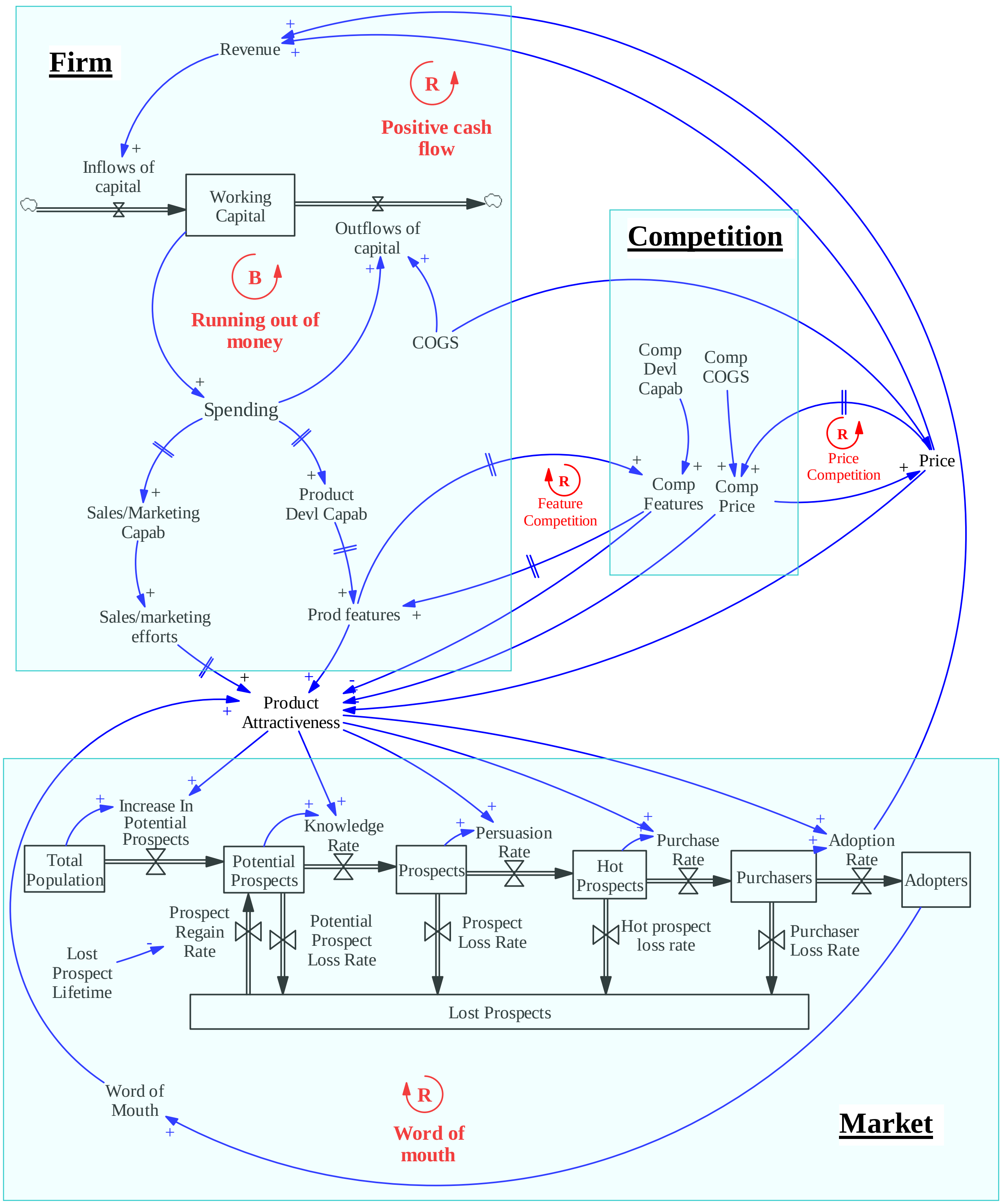

Figure 5-1: High Level Overview of Model

5.2.1 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 to pay for COGS (the cost of goods sold) 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 incorporate 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 Chapter 6.

5.2.2 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 described in Chapter 2. 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.

The model also takes into account how the stock of potential prospects is replenished from the total population ("market growth"). Also, in addition to the influence of advertising and word of mouth, the 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.

5.2.3 The Competition

The competition sector of this model includes only a couple of 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.

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.

The next sections detail six sectors of the overall model: cash flow, labor (including vacancies, hiring, and layoffs), product development, the market and prospect chain (including sales and marketing effort and word of mouth), customer support, and pricing.

5.3 Cash Flow

The cash flow sector of the model is based on aspects of the financial accounting module in Oliva, Sterman, & Giese (2003).

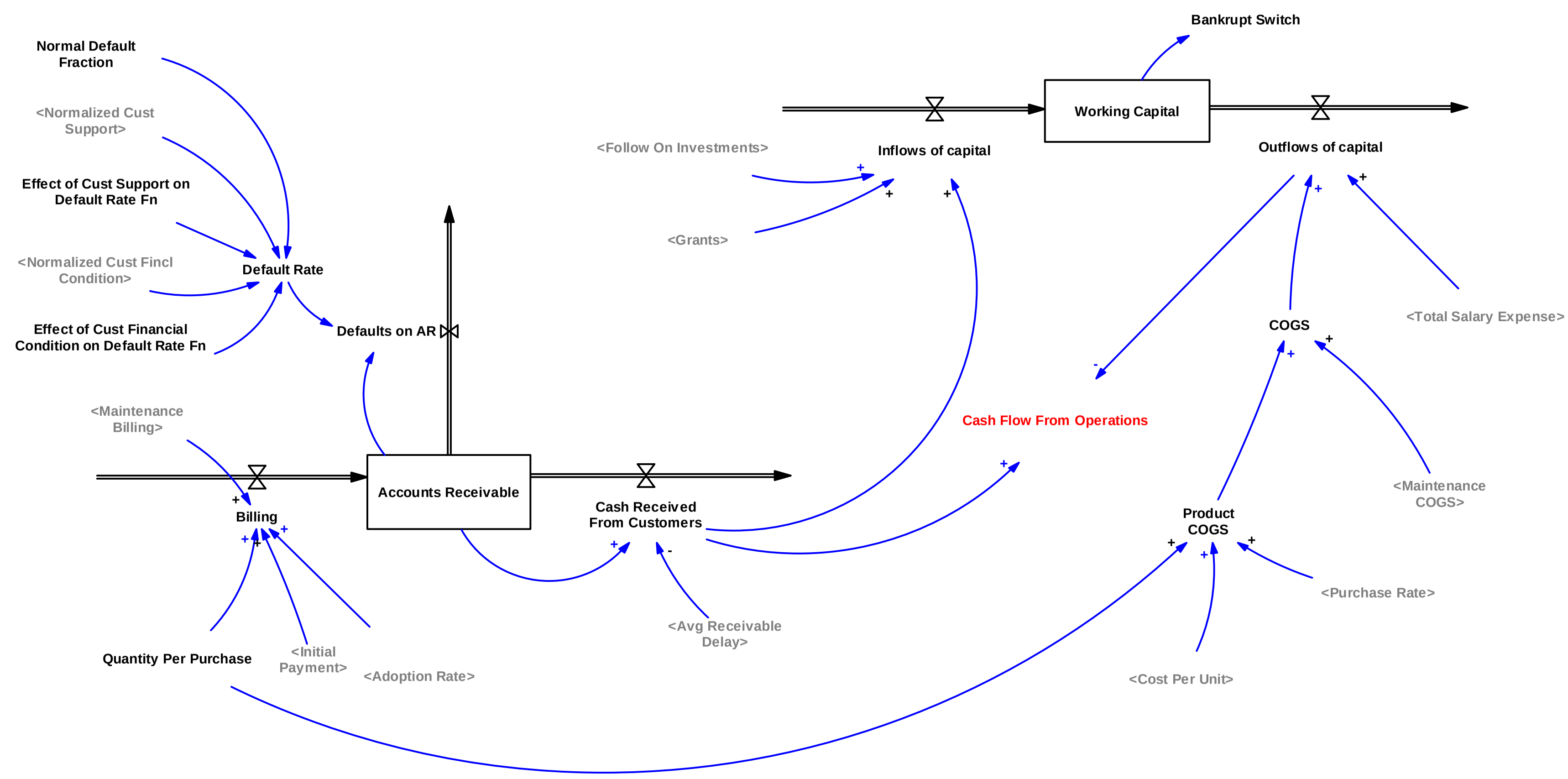

Figure 5-2: Cash Flow Sector

See Figure 5-2 for the diagram of the cash flow sector. The primary stock is Working Capital[3] (which can be considered as cash). At the outset, its value is based on an Initial Investment, and it may be increased by Follow On Investments, Grants, and Cash Received From Customers. Working Capital is decreased by Total Salary Expense and COGS, which are the direct costs to produce the products that are sold and to provide maintenance for the products. Cash Flow From Operations is determined by subtracting these Outflows Of Capital from the Cash Received From Customers. In the absence of investments or grants, these calculations determine whether Working Capital increases or decreases in any given period.

The other stock represented in the cash flow sector is Accounts Receivable, the amount of cash owed to the firm by its customers, which is increased by Billing and decreased by Cash Received From Customers, and by Defaults on AR. The equation for Billing is:

(4) Billing = Quantity Per Purchase * Adoption Rate * Initial Payment + Maintenance Billing

(5) Initial Payment = Price * Initial Payment Fraction

(6) Maintenance Billing = Adopters * Quantity Per Purchase * Price * Maintenance Fraction * Maintenance Period

The Initial Payment Fraction is the fraction of the price the customer pays up front for the product, and the Maintenance Fraction is the fraction of the price the customer pays per Maintenance Period as long as that firm continues to use the product. These two fractions do not need to sum to one, as in the case where the customer pays the full price of the product up front plus an annual 20% maintenance charge, which are the default parameters based on the practice of firms interviewed. Defaults On AR occur when a customer fails or refuses to pay a bill. The equation is:

(7) Defaults On AR = Accounts Receivable * Default Rate

[3] For ease of reference for the reader, parameters of the model (which can be seen in the diagrams and tables to follow) will be capitalized in the text

(8) Default Rate = Normal Default Fraction *
Effect of Cust Support on Default Rate Fn(Normalized Cust Support) *
Effect of Cust Financial Condition on Default Rate Fn(Normalized Cust Fincl Condition)

The Default Rate is the Normal Default Fraction (the usual fraction of customers who would default) modified by the current level of customer support and the financial condition of customers.

See Figure 5-3 for the Effect of Cust Support on Default Rate Fn. With no customer support, a very large percentage of customers default, with normal customer support the normal default fraction applies, and with very high customer support only 25% of the normal default rate applies.

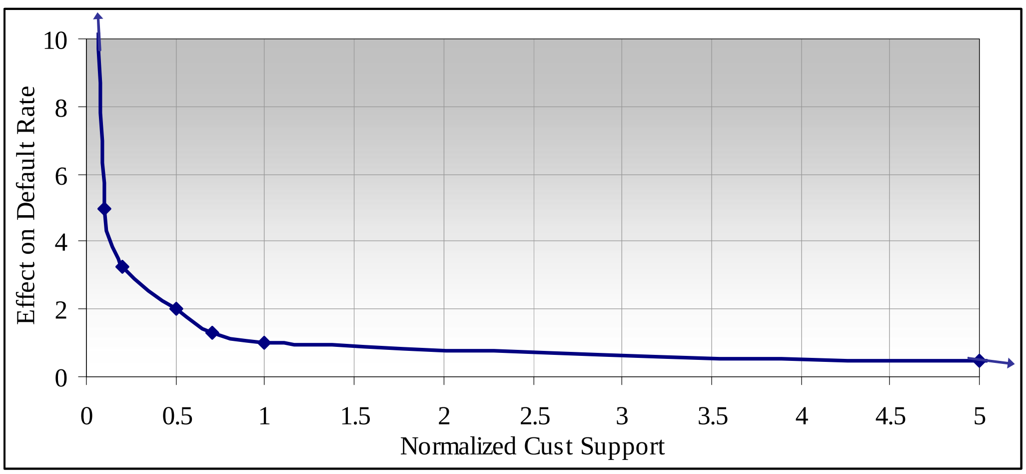

Figure 5-3: Effect of Cust Support on Default Rate Fn

See Figure 5-4 for the Effect of Cust Financial Condition on Default Rate function. If customers are bankrupt then a very large percentage of them default, if customers are in normal financial condition, the normal default fraction applies, and if customers are in extraordinarily good financial condition, then 1% of the normal default fraction applies.

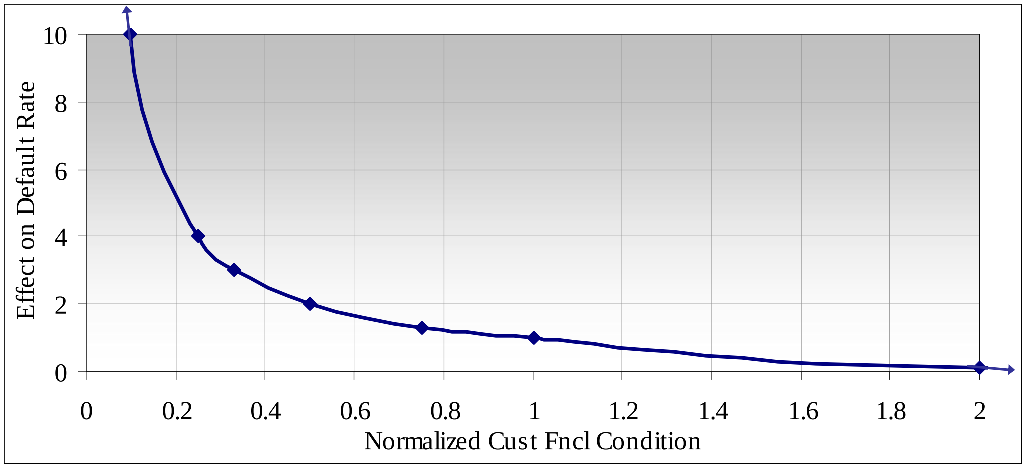

Figure 5-4: Effect of Cust Financial Condition on Default Rate Fn

See Table 5-1 for the parameters used in the cash flow sector of the model, their default values, and the range of values used for sensitivity analysis in Chapter 6. As can be seen in Figure 2-3, startup and seed VC investments have averaged approximately $3M the last 10 years (which establishes the default Initial Investment). The model also includes placeholders for subsequent investments and grants that are set to zero by default. The default parameters assume that customers pay for the product up front (Initial Payment Fraction of 100%), and then pay a standard 20% annual maintenance charge for as long as they are using the product (Maintenance Fraction). Other models for payment are discussed in Section 7.2.4. The model assumes that one unit of the product is purchased at a time (Quantity Per Purchase). The default receivable delay (how long it takes for payments to be received once billed) is 45 days, which is a common delay when working with larger customers. The Normalized Cust Fincl Condition represents how capable customers are of paying their bills, and the value of one represents normal or average conditions (during a recession this value could be less than one, and during a boom the value could be greater than one). The Normal Default Fraction is the number of customers who normally default on paying their bills per month and at 0.002 (~2.4% of customers per year), is relatively low, but consistent with a strong commercial customer base.

The result of sensitivity analysis on the receivable delay and financial condition of customers is in Section 6.3.4.

Parameter	Value	Units	Min	Max
Initial Investment	3.00E+06	Dollars	1E+06	1E+07
Inv2 Amt	0	Dollars/Month		
Inv2 Time	12	Months		
Inv3 Amt	0	Dollars/Month		
Inv3 Time	24	Months		
Inv4 Amt	0	Dollars/Month		
Inv4 Time	36	Months		
Grants	0	Dollars/Month		
Initial Payment Fraction	1	Dmnl	0	1
Maintenance Fraction	0.2	Dmnl	0	1
Quantity Per Purchase	1	Units/Prospect		
Avg Receivable Delay	1.5	Months	0.1	12
Normalized Cust Fincl Condition	1	Dimensionless	0.1	10
Normal Default Fraction	0.002	1/Month		

Table 5-1: Parameters Used in Cash Flow Sector

5.4 Product Development

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). The stocks and most of the parameters in this sector of the model apply to both the firm and the aggregate competitor (i.e. both the firm and the competitor have Features Under Development that are increased in response to the activities of the other). See Figure 5-5 for a diagram of the product development sector, and Table 5-2 for the parameter values for this sector.

5.4.1 Features

The primary stock of this sector is Features, which is a representation of the characteristics of the firm's product that are attractive to customers. Features can be appropriable or non-appropriable. Appropriable features are relatively easy for competitors to copy and tend to make less of a difference to customers when they compare products. Non-appropriable features are assumed to be protected in some way (e.g. through patents or trade secrets) and are assumed to be much more valuable to customers. The numeric values for Features are arbitrary and are only meaningful in comparison to each other. It is assumed that the venture starts off with superior features compared to competition, and that translates in the parameters to a 10% advantage in appropriable Initial Features and a 100% advantage in non-appropriable Initial Features.

The Feature Value is given by:

(9) Feature Value[company] = Features[company,appropriable] + Features[company,nonappropriable] * Nonappropriable Feature Multiple

The default value of the Nonappropriable Feature Multiple is 100, which signifies the far greater value and differentiation ability of non-appropriable features.

Normalized Features is a representation of how the firm's features compare to the competition, and is simply:

(10) Normalized Features = Feature Value[self] / Feature Value[competitor]

All features obsolesce over time based on the Average Feature Lifetime, which is assumed to be two years for appropriable features, and ten years for non-appropriable features:

(11) Feature Obsolescence Rate[company,featuretype] = Features[company,featuretype] / Avg Feature Lifetime[company,featuretype]

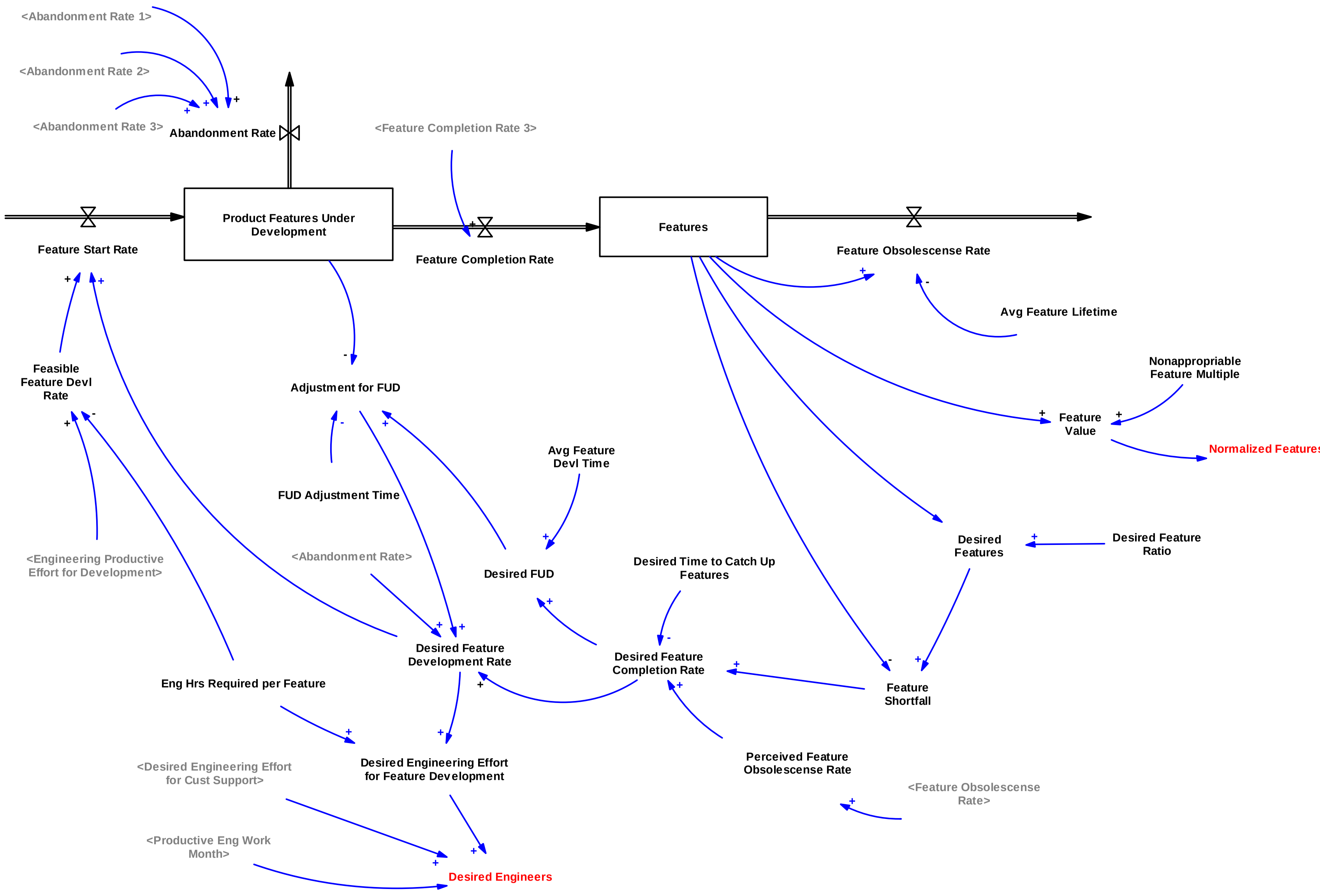

Figure 5-5: Product Development Sector

5.4.2 Desired Feature Completion Rate

To drive the development of new features, both the firm and the competitors have a Desired Feature Completion Rate:

(12) Desired Feature Completion Rate[company,featuretype] =
Feature Shortfall[company,featuretype] /
Desired Time to Catch Up Features[company,featuretype] +
Perceived Feature Obsolescence Rate[company,featuretype]

(13) Feature Shortfall[company,featuretype] = Desired Features[company,featuretype]-
Features[company,featuretype]

(14) Desired Features[self,featuretype] = Features[competitor,featuretype] *
Desired Feature Ratio[self,featuretype]

(15) Perceived Feature Obsolescence Rate[company,featuretype] =
Feature Obsolescence Rate[company,featuretype]

As per equation (14), each firm desires its products features to be better than those of the competition (assuming that the Desired Feature Ratio is greater than 1). The venture starts with a desire to have features 25% better than competition and competition starts with a desire for its features to be 10% better (reflecting that the competition is more mature and does not react strongly to new participants in the market). If the features are not sufficiently better, a Feature Shortfall is created (equation (13)), which the firm attempts to remedy in the Desired Time to Catch Up Features. As per the Desired Feature Ratio, the new venture is much more reactive than competition and by default wishes to catch up features in two or four months as opposed to six or twelve months for the more conservative competition. In addition, each firm desires to develop new features to compensate for features that management perceives to be obsolescing (which for the purpose of this model we assume to be the actual rate of obsolescence – equation (15)).

5.4.3 Desired Feature Development Rate and Desired Engineers

To achieve the Desired Feature Completion rate, the firm and competitors have a Desired Feature Development Rate, which is the desired completion rate plus adjustments for features already under development (FUD) and for features being abandoned (Abandonment Rate):

(16) Desired Feature Development Rate [company,featuretype] = MAX(0,
Desired Feature Completion Rate[company,featuretype] +
Abandonment Rate[company,featuretype] +
Adjustment for FUD[company,featuretype])

(17) Adjustment for FUD[company,featuretype] = (Desired FUD[company,featuretype] -
Product Features Under Development[company,featuretype]) /
FUD Adjustment Time[company,featuretype]

(18) Desired FUD[company,featuretype] =
Desired Feature Completion Rate[company,featuretype] *
Avg Feature Devl Time[company,featuretype]

The Desired Feature Development Rate determines the Desired Engineering Effort for Feature Development for the firm. This is based in part on the Avg Feature Devl Time which by default is two and 12 months for the venture and four and 24 months for the competition to reflect the increased agility of a startup compared to entrenched competition. This result is the basis for calculating the number of Desired Engineers that the firm would need on staff to develop the features needed. Since we do not model the labor force of the competition endogenously, we only calculate the Desired Engineers for the firm:

(19) Desired Engineers = (Desired Engineering Effort for Feature Development +
Desired Engineering Effort for Cust Support) / Productive Eng Work Month

(20) Desired Engineering Effort for Feature Development =
Feature Development Rate[self,appropriable] *
Eng Hrs Required per Feature[self,appropriable] +
Desired Feature Development Rate[self,nonappropriable] *
Eng Hrs Required per Feature[self,nonappropriable]

Note that the number of Desired Engineers also takes into account those needed for customer support and the productivity of the engineers. The Desired Engineering Effort for Feature Development accommodates the different development times needed for appropriable and non-appropriable features. It is assumed that non-appropriable features take considerably more engineering hours to develop than appropriable features for both the venture and its competitors.

5.4.4 Product Features under Development

The Desired Feature Development Rate and the engineering resources available drive the input to the stock of Product Features Under Development:

(21) Feature Start Rate[company,featuretype] = MIN
(Feasible Feature Devl Rate[company,featuretype],
Desired Feature Development Rate[company,featuretype])

(22) Feasible Feature Devl Rate[company,featuretype] =
Engineering Productive Effort for Development[company,featuretype] /
Eng Hrs Required per Feature[company,featuretype]

(23) Engineering Productive Effort for Development[self,nonappropriable] =
Nonappropriable Devl Fraction *
(Effective Engineering Effort - Engineering Effort for Cust Support)

(24) Engineering Productive Effort for Development[self,appropriable] =
(1-Nonappropriable Devl Fraction) *
(Effective Engineering Effort-Engineering Effort for Cust Support)

The Nonappropriable Devl Fraction models the management decision about what percentage of engineering resources to devote to intellectual property development, and is by default, 50%. The Effective Engineering Effort is discussed in Section 5.5.2

The Engineering Productive Effort for Development for the competition is exogenous to the model, and is assumed to be very large compared to that of the firm being modeled (since the competition is assumed to be a large incumbent company).

The Features Under Development stock is itself a third-order structure that represents a multi-stage development process in which each of the three stages takes 1/3 of the total average feature development time to complete and during which features may be abandoned at any of the three stages. The total Feature Abandonment Fraction for all features is assumed to be 10%. See Figure 5-6 for a depiction of this structure. The outflow of Product Features Under Development is the Feature Completion Rate, which in turn is the inflow to the stock of Features.

Table 5-2 contains the parameters used in the product development sector of the model, their default values, and the ranges of values used for the sensitivity analysis in Chapter 6.

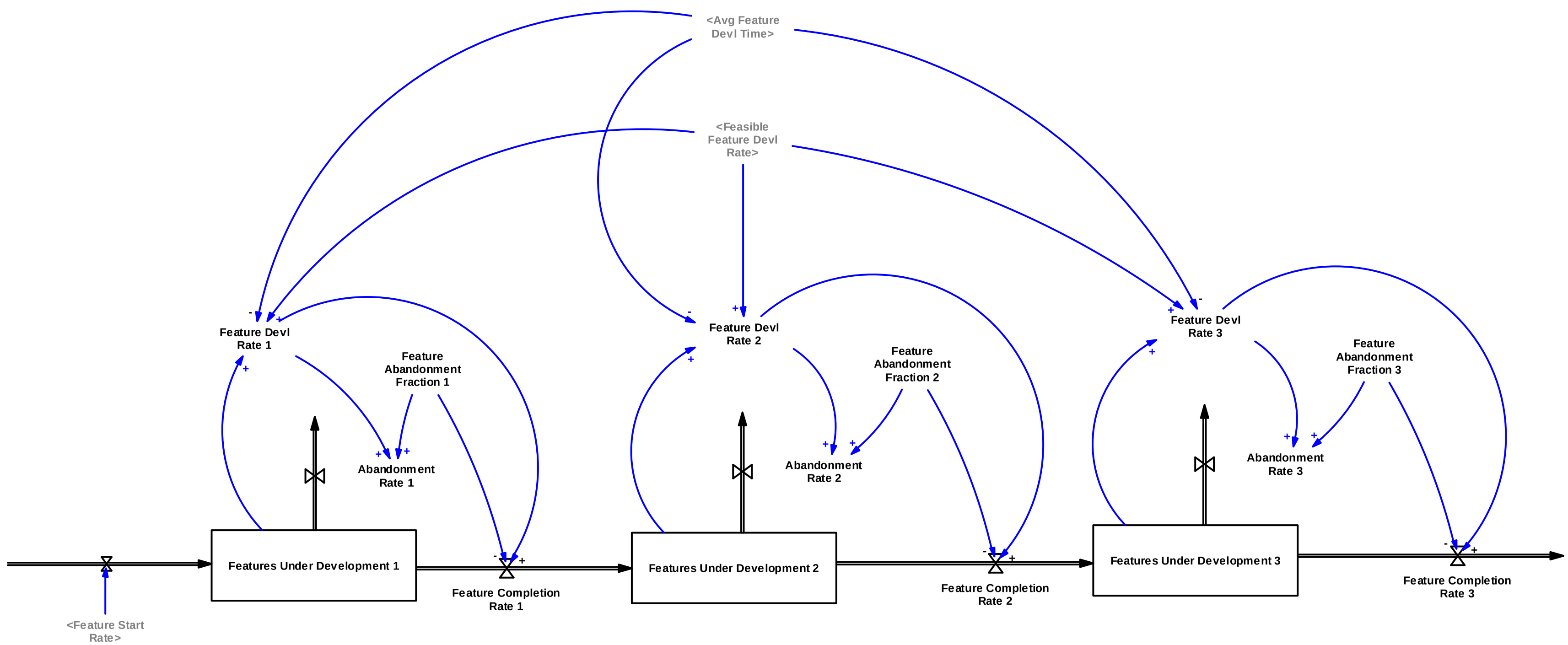

Figure 5-6: Features Under Development

Parameter	Value	Units	Min	Max
Initial Features[self,appropriable]	110	Features	0	200
Initial Features[self,nonappropriable]	4	Features	0	20
Initial Features[competitor,appropriable]	100	Features	0	200
Initial Features[competitor,nonappropriable]	2	Features	0	20
Avg Feature Devl Time[self,appropriable]	2	Months	.25	12
Avg Feature Devl Time[self,nonappropriable]	12	Months	1	120
Avg Feature Devl Time[competitor,appropriable]	4	Months	.25	12
Avg Feature Devl Time [competitor,nonappropriable]	24	Months	1	120
Avg Feature Lifetime[self,appropriable]	24	Months	.25	60
Avg Feature Lifetime[self,nonappropriable]	120	Months	2	240
Avg Feature Lifetime[competitor,appropriable]	24	Months	.25	60
Avg Feature Lifetime[competitor,nonappropriable]	120	Months	2	240
Desired Feature Ratio[self,appropriable]	1.25	Dmnl	1	10
Desired Feature Ratio[self,nonappropriable]	1.25	Dmnl	1	10
Desired Feature Ratio[competitor,appropriable]	1.1	Dmnl	1	10
Desired Feature Ratio [competitor,nonappropriable]	1.1	Dmnl	1	10
Desired Time to Catch Up Features [self,appropriable]	2	Months	.25	24
Desired Time to Catch Up Features [self,nonappropriable]	4	Months	1	120
Desired Time to Catch Up Features [competitor,appropriable]	6	Months	.25	60
Desired Time to Catch Up Features [competitor,nonappropriable]	12	Months	1	240
Eng Hrs Required per Feature [self,appropriable]	350	Hours*Person/Feature	35	3500
Eng Hrs Required per Feature [self,nonappropriable]	35000	Hours*Person/Feature	350	1820000
Eng Hrs Required per Feature [competitor,appropriable]	350	Hours*Person/Feature	35	3500
Eng Hrs Required per Feature [competitor,nonappropriable]	35000	Hours*Person/Feature	350	1820000
FUD Adjustment Time[self,appropriable]	2	Months	.1	36
FUD Adjustment Time[self,nonappropriable]	2	Months	.1	36
FUD Adjustment Time[competitor,appropriable]	2	Months	.1	36
FUD Adjustment Time [competitor,nonappropriable]	2	Months	.1	36
Feature Abandonment Fraction[self,appropriable]	0.10	Dmnl	0	.9
Feature Abandonment Fraction [self,nonappropriable]	0.10	Dmnl	0	.9
Feature Abandonment Fraction [competitor,appropriable]	0.10	Dmnl	0	.9
Feature Abandonment Fraction [competitor,nonappropriable]	0.10	Dmnl	0	.9

Table 5-2: Parameters for Product Development Sector

5.5 *Labor*

The labor sector of the model is closely based on the labor supply chain introduced in Section 19.1 of Sterman (2000). Two types of employees are represented in the model: engineers and sales people. Engineers are considered to be employees with any technical or product development responsibilities including customer and technical support, engineering or technology management and strategy positions, etc. Sales people are considered employees with any sales or marketing responsibilities, including sales or marketing management, production of materials, etc. Administrative employees (from the CEO to support personnel) are considered to be split up between the engineering and sales functions (e.g. a CEO who focuses on technical strategy and product development, but spends 25% of her time meeting with prospective customers may be considered 75% an engineer and 25% a sales person). The stocks in this sector of the model are Engineering Vacancies, Sales Vacancies, Engineers, Engineer Experience, Sales Force and Sales Experience. Two key parameters are Max Eng Hires and Max Sales Hires, which are calculated based on the Working Capital available to hire or maintain the workforce, and which constrain hiring or generate layoffs.

5.5.1 Engineering and Sales Vacancies

The engineering and sales vacancies structures are based largely on the Inventory-workforce model in Sterman (2000). See Figure 5-7 for a diagram of the structure, which is the same for engineers and for the sales force, and see Table 5-3 and Table 5-4 for the parameter values. In summary, it is a stock management structure applied to human resources. In the case of engineers, Desired Engineers (see Section 5.4.3), adjusted by the current stock of engineers, the Engineering Attrition Rate, and constrained by Max Engineering Hires (see Section 5.5.3), and influenced by the Engineers Adjustment Time and Expected Time to Fill Engineering Vacancies determines the Desired Engineering Vacancies. As a simplification, the expected time to fill vacancies is set to the average time to fill vacancies, which is 2.5 months (in line with the experience of startup companies, though this can vary widely based on the state of the labor market). The adjustment time is a management parameter, and is set to 6 months by default.

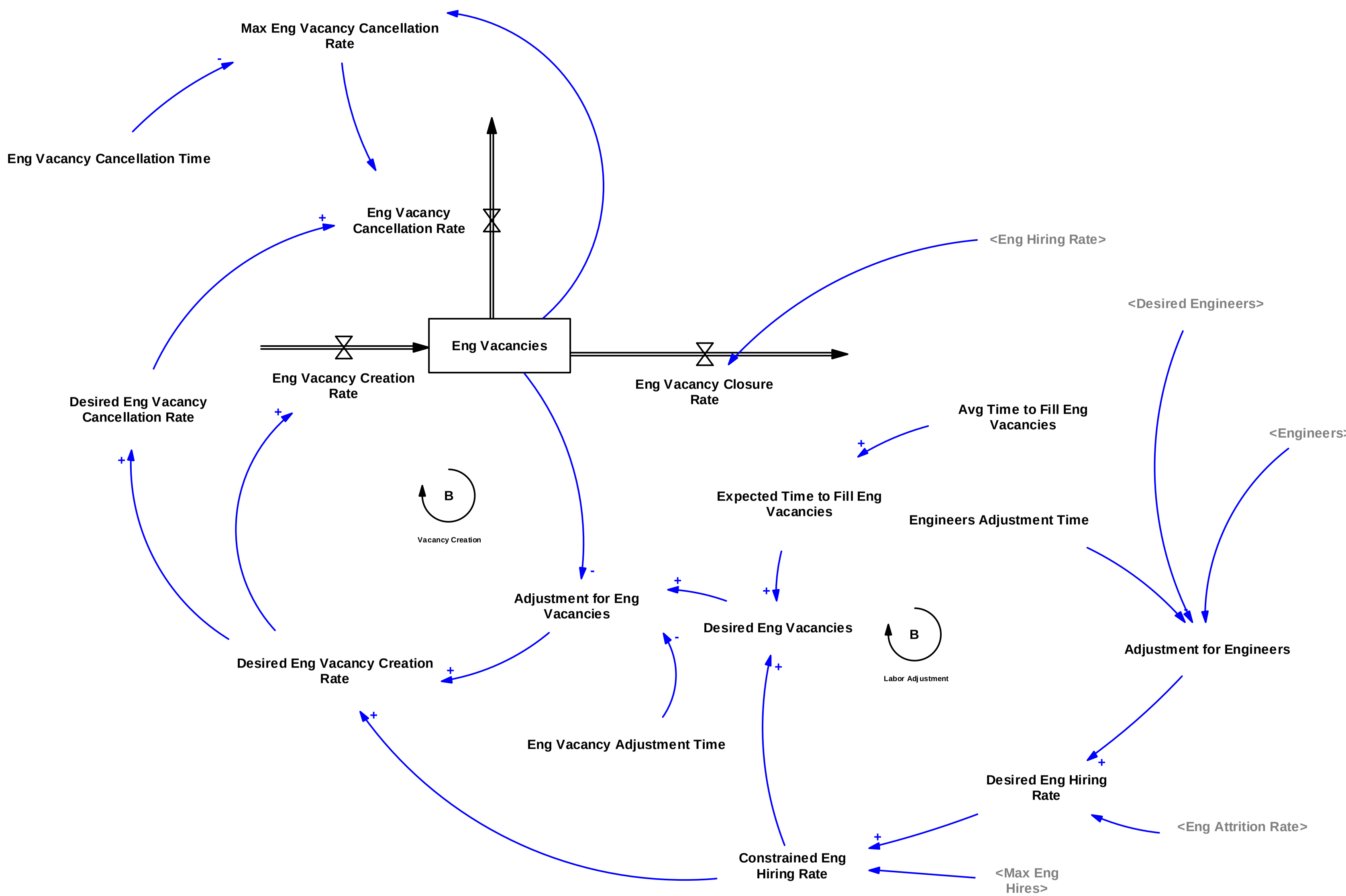

Figure 5-7: Labor Vacancy Structure

The Desired Engineering Vacancies, adjusted by the current stock of Engineering Vacancies and the Engineering Vacancy Adjustment Time, determines the Desired Engineering Vacancy Creation Rate (or in the case of a desire to reduce vacancies, the Desired Engineering Vacancy Cancellation Rate). These rates flow into (or out of) the stock of Engineering Vacancies which is diminished by the Engineering Hiring Rate as vacancies are filled in the Average Time to Fill Engineering Vacancies. An equivalent structure and logic applies to Sales Vacancies, which is driven by the Desired Sales Force, and the "output" of which is the Sales Hiring Rate.

5.5.2 Engineers, Sales Force and Experience

The engineering and sales force labor structures, which take into account the experience of the labor forces, is based on the labor coflow structure detailed in Section 12.2 of Sterman (2000). See Figure 5-8 for a diagram of the structure, which is the same for Engineers and for Sales Force. The case of Engineers is used here to describe the structure.

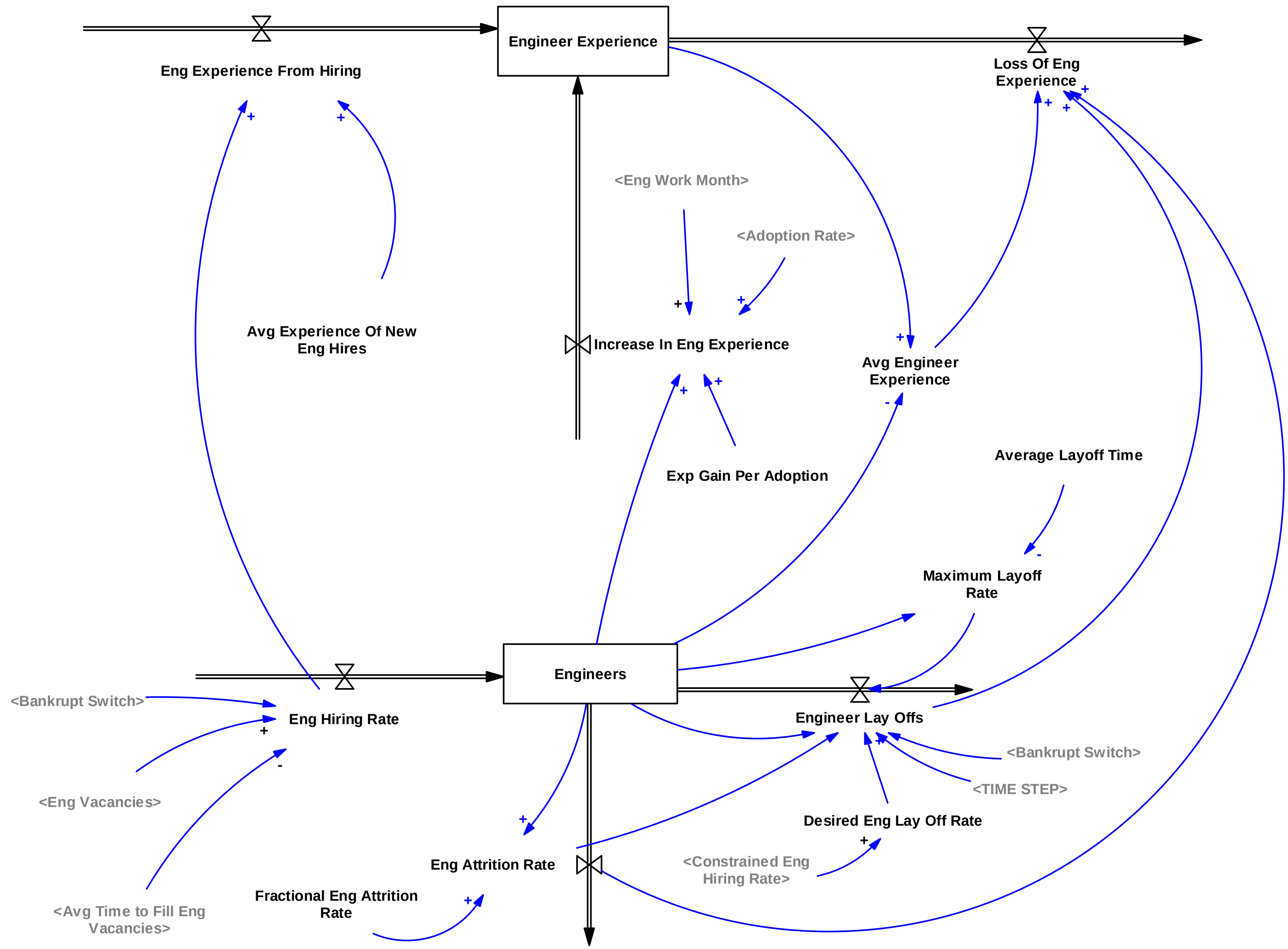

Figure 5-8: Labor and Labor Experience Structure

As described in Section 5.5.1, the filling of vacancies drives the inflow to the Engineers stock. The stock is diminished by the Engineering Attrition Rate, which is controlled by the Fractional Engineering Attrition Rate, the average percent of Engineers that leave the firm every month. It is also diminished by Engineer Lay Offs, which is driven by Max Engineering Hires, described in Section 5.5.3.

The Engineer Experience stock is a coflow of the Engineers stock that represents the average job experience of Engineers employed by the firm. When Engineers are hired, the Avg Experience of New Eng Hires is added to the stock for each new hire, and when Engineers are laid off or leave due to attrition, the current Avg Engineer Experience is removed from the stock for each engineer lost. Engineering Experience increases over time as engineers gain experience from working at the firm. Engineering Experience also increases for each adoption of the product, assuming that the product development and customer support personnel gain valuable experience from working with customers who are using the product in the field. In the experience of the author and those interviewed for the research, the experience gain from working with customers is considerably more valuable than experience gained from working on the product in isolation. When working with customers, engineers learn which features, and which aspects of the features are truly valuable, which are less necessary, and which additional features are needed most. That information enables them to be much more effective at developing new features for the product. That idea is reflected in the parameterization of the model.

The Effective Engineering Effort, referenced in Section 5.4.4, is derived from the Engineers and Engineer Experience stocks:

(25) Effective Engineering Effort = Engineering Effort *
Engineering Experience Productivity Multiplier

(26) Engineering Effort = Engineers * Eng Work Month

(27) Engineering Experience Productivity Multiplier =
(Avg Engineer Experience / Engineering Experience Reference) ^
(LN (1 + Eng Productivity Change Per Double Experience) / LN(2))

(28) Avg Engineer Experience = Engineer Experience / Engineers[4]

The equation for Engineering Experience Productivity Multiplier is based on learning curve theory referenced in Section 12.2 of Sterman (2000) and derived in Zangwill & Kantor (1998). The theory posits that productivity will rise by a given amount for every doubling of experience from an initial reference value.

The Sales Force and Sales Experience structures are analogous to the Engineering structures, except that extra sales experience is gained per purchase of the product rather than at the time of adoption. The distinction between purchase and adoption is explained in Section 5.6. In an analogous fashion to the above, based on the experience of the author and those interviewed for the research, sales and marketing personnel gain much more valuable experience when they interact with customers and achieve a sale (i.e. a purchase). And Sales Experience becomes the basis for Sales & Marketing Effort:

(29) Sales & Mktg Effort = Sales Force * Sales Work Month *
Sales Experience Productivity Multiplier

(30) Sales Experience Productivity Multiplier = MIN(Max Sales Productivity Multiplier,
(Avg Sales Experience / Sales experience reference) ^
(LN(1 + Sales Productivity Change Per Double Experience) / LN(2)))

(31) Avg Sales Experience = Sales Experience / Sales Force[5]

As above, the Sales Experience Productivity Multiplier is derived from a learning-curve equation based on Avg Sales Experience. The only distinction is that the multiplier is limited to a maximum value. (There is only so much productivity gain the sales force can have based on experience.)

5.5.3 Runway: Maximum Engineering and Sales Hires

An attribute that distinguishes this model from others is that hiring is constrained by, and layoffs are generated by, the level of working capital in the firm. Given that this is an early stage technology venture, it is assumed that the company cannot easily borrow money. If working

[4] Assuming Engineers > 0

[5] Assuming Sales Force > 0

capital runs out, the company will not be able to pay its bills or its employees, and the firm will be bankrupt. As long as the firm is not generating positive cash flow, management must be aware of the firm's "runway" – the amount of time the firm has, given its working capital and the rate of negative cash flow, before the firm will run out of money:

(32) Months of Runway = Working Capital / Burn Rate

(33) Burn Rate = -Cash Flow From Operations[6]

The model assumes that management must have a minimum runway before it can allow any new hires (Min Runway In Order To Hire). The default value is 12 months, meaning that the firm must have more than 12 months worth of working capital at its current rate of negative cash flow before it will allow any new hires. The model also assumes that at an absolute minimum runway, management will lay off employees in order to maintain Min Runway. The default value is three months; when the firm has less than three months of working capital left at its current rate of burn, it must lay off employees to reduce burn enough to preserve a viable level of working capital. The Max Hires per Month is then derived primarily from the Change in Burn Rate Required and the current Avg Salary

(34) Max Hires Per Month = MIN(
Change in Workforce Required / Months for Runway Adjustment,
Total Labor * Maximum Workforce Growth Rate)[7]

(35) Change in Workforce Required = Change in Salary Required / Avg Salary

(36) Change in Salary Required = Burn Rate * (Change in Burn Rate Required-1)

(37) Change in Burn Rate Required = IF THEN ELSE(
Months of Runway > Min Runway In Order To Hire,
Months of Runway / Min Runway In Order To Hire,
IF THEN ELSE(Months of Runway < Min Runway,
Months of Runway / (Min Runway+1), 1))

---

[6] When cash flow is negative Burn Rate will be positive. If cash flow is positive, Burn Rate is set to be a very small number, and therefore Months of Runway will be a very large number

[7] Hiring is constrained to not grow faster than a maximum rate

The Change in Burn Rate Required is based on the notion that if the firm has more than enough months of capital to burn, it can adjust the burn rate up. However, if the firm has less than Min Runway months of capital, it must adjust the burn rate down. Otherwise it should not adjust the burn rate at all. Once management knows how much to adjust the burn rate, and assuming that the burn rate is primarily driven by salaries (which take into account all the operating costs of the firm), managers will know how much to adjust salary expenses, and therefore how much to adjust the workforce (Max Hires Per Month can be positive or negative).

Once management knows how much to adjust the workforce, it is necessary to split the constraint into Engineering and Sales. If the firm is hiring, the split will be based on the amount of engineering or sales people management wants to hire; if the firm is laying employees off, the split will be based on the current stock of engineers and sales people:

(38) Max Eng Hires = IF THEN ELSE(Max Hires Per Month>0,
Max Hires Per Month * Desired Eng Proportion,
Max Hires Per Month * Eng Proportion)

(39) Desired Eng Proportion = Desired Eng Hiring Rate / Desired Hiring Rate[8]

(40) Eng Proportion = Engineers / Total Labor

(41) Desired Hiring Rate = Desired Eng Hiring Rate + Desired Sales Hiring Rate

(42) Total Labor = Engineers + Sales Force

(43) Max Sales Hires = IF THEN ELSE(Max Hires Per Month>0,
Max Hires Per Month * Desired Sales Proportion,
Max Hires Per Month * Sales Proportion)

(44) Desired Sales Proportion = Desired Sales Hiring Rate / Desired Hiring Rate[9]

(45) Sales Proportion = Sales Force / Total Labor

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[8] Assuming Desired Hiring Rate > 0

[9] Assuming Desired Hiring Rate > 0

Sections 5.5.1 and 5.5.2 show how the Max Eng Hires and Max Sales Hires constrain the respective hiring rates. These calculations may increase vacancies, or set vacancies to zero and increase the number of layoffs if the maximum hiring values are negative:

(46) Constrained Eng Hiring Rate = MIN(Desired Eng Hiring Rate, Max Eng Hires)

(47) Desired Eng Vacancies MAX(0, Expected Time to Fill Eng Vacancies * Constrained Eng Hiring Rate)

(48) Desired Eng Lay Off Rate = MAX(0, -Constrained Eng Hiring Rate)

This formulation represents a rational management strategy that improves the chances that the firm will survive a negative cash flow for an extended period of time. It enables the firm to cut down on expenses during lean times, and then increase expenses (and production) when the cash is available. Of course, this assumes that management is willing to engage in layoffs preemptively, but when the alternative is bankruptcy, layoffs are the better alternative.

See Table 5-2 for the parameters used in the labor sector of the model, their default values, and the minimum and maximum values used for sensitivity analysis in Chapter 6.

Parameter	**Value**	**Units**	**Min**	**Max**
Initial Avg Engineering Experience	10000	Hours	1000	40000
Avg Experience Of New Eng Hires	2000	Hours	450	20000
Eng Productivity Change Per Double Experience	0.33	Dmnl	0.01	0.67
Engineering Experience Reference	2000	Hours	450	20000
Exp Gain Per Adoption	910	Hours*Person/Prospect	0	4000
Initial Engineers	4	Persons	0	20
Eng Work Month	175	Hours/Month	100	300
Eng Vacancy Adjustment Time	1	Months	0.10	6.00
Eng Vacancy Cancellation Time	1	Months	0.10	6.00
Engineers Adjustment Time	6	Months	1.00	12.00
Fractional Eng Attrition Rate	0.02	1/Month	0.00	0.20
Avg Time to Fill Eng Vacancies	2.50	Months	0.25	12.00
Average Layoff Time	2.00	Months	0.10	4.00

Table 5-3: Engineering Labor Parameters

Parameter	Value	Units	Min	Max
Initial Avg Sales Experience	1,500	Hours	0	10,000
Avg Experience Of New Sales Hires	1,000	Hours	0	10,000
Exp Gain Per Purchase	910	Hours*Person/Prospect	0.00	4,000
Sales experience reference	2,000	Hours	450	5,000
Max Sales Productivity Multiplier	10	Dmnl	2.00	20
Sales Productivity Change Per Double Experience	0.40	Dmnl	0.01	0.80
Initial Sales Force	2	Persons	0.00	20
Sales Work Month	175	Hours/Month	100	300
Avg Time to Fill Sales Vacancies	2.5	Months	0.25	12
Sales Average Layoff Time	2	Months	0.10	4
Sales Force Adjustment Time	6	Months	1.00	12
Sales Fractional Attrition Rate	0.02	1/Month	0.00	0.20
Sales Vacancy Adjustment Time	1	Months	0.10	6
Sales Vacancy Cancellation Time	1	Months	0.10	6

Table 5-4: Sales Labor Parameters

Parameter	Value	Units	Min	Max
Avg Salary	17000	Dollars/(Month*Person)		
Maximum Workforce Growth Rate	0.25	1/Months	0	1
Min Runway	3	Months	0	36
Min Runway In Order To Hire	12	Months	0	48
Months for Runway Adjustment	2	Months	0.1	12

Table 5-5: Runway Parameters

5.6 The Market and Prospect Chain

As discussed in Chapter 2 and in the introduction to this chapter, the market sector of the model is based on the Bass diffusion model (F. M. Bass, 1969). The model has been extended to more closely approximate the sales cycle of the clean energy technology companies investigated in the interview phase of this research, and those presented in the case studies in Chapter 3. The parameters for this sector of the model are presented in Table 5-6 and described below. See Figure 5-9 for a depiction of the stocks and flows of the prospect chain.

The stocks of prospects along the chain are based on the sales experiences of the companies interviewed; the research indicated points at which prospects get "stuck" and where prospects are lost. The units of the stocks, which are "prospects," represent commercial enterprises that are capable of purchasing and adopting the product of the clean energy venture being modeled. The primary driver for prospects to move along the prospect chain is the sales and marketing effort of the new venture, which is made more or less productive by the attributes of the firm's product as compared to the products of competitors, marketing effort, word of mouth, and customer support.

Following Figure 5-9 is a description of the stocks.

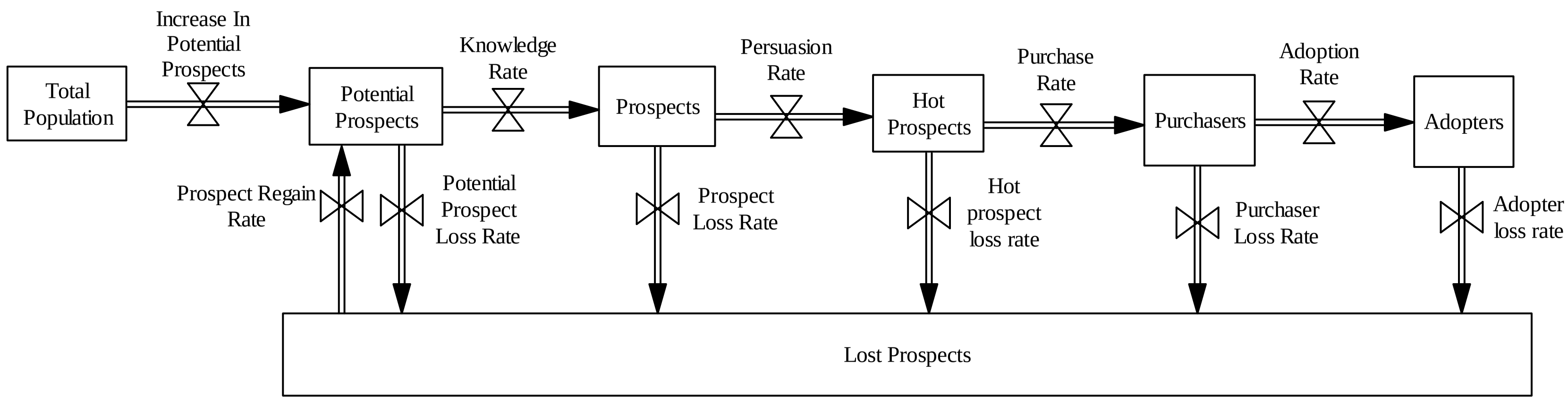

Figure 5-9: Prospect Chain Flows

Prospect stocks include:

- Total Population: This is the group of firms that can possibly adopt the clean energy product or a variation of the product at some point in the future. It is assumed that there are many firms that fit in this category, and this is a much larger stock than the initial market for the product. If firms continue to flow from this stock to become "Potential Prospects" (market growth) then market saturation will not become a factor for the purposes of this model. The rise and fall of Total Population as firms are created and fail are factors exogenous to the model. This will have little effect as long as the resulting percent change in total population remains low.
- Potential Prospects: These are firms that are capable of adopting the current version of the product. The new venture has identified these firms and chosen to apply sales effort to persuade them to learn more about the product.
- Prospects: These 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. The new venture has decided to apply sales effort to persuade these firms to trial the product or otherwise to learn enough about it to be able to make the decision to adopt it or not.
- Hot Prospects: These are firms that have expressed interest in adopting the product and are either actively trialing it or evaluating it in some other fashion.
- Purchasers: These are firms that have purchased the product, but have not yet started using it.
- Adopters: These are firms that have purchased and are actively using the product.
- Lost Prospects: These are firms that were prospects (anywhere from potential prospects to adopters), but then lost interest in adopting the product or actively made the decision not to adopt.

The nature and descriptions of the flows between the stocks are primarily based on Rogers' innovation-decision process (Rogers, 2003). The only distinctions are that the units of adoption for the new model are firms instead of individuals, and a flow from total population has been added at the first stage of the process.

5.6.1 Increase in Potential Prospects

The flow out of Total Population into Potential Prospects ("Increase in Potential Prospects") is governed by the rate of firms becoming capable of adopting the clean energy technology product and by efforts of the new venture to extend its addressable market.

(49) Increase In Potential Prospects = Total Population *
Increase In Addressable Market * Fraction Of Firms Capable Of Adopting

(50) Increase In Addressable Market =
Effect of Marketing Effort on Market Size Fn(Normalized Marketing)

(51) Normalized Marketing = Marketing Effort / Desired Marketing Effort

(52) Fraction Of Firms Capable Of Adopting = Initial Capab of Firms to Adopt *
Effect Of Features On Capab of Adoption Fn(SUM(Features[company!,featuretype!]) / SUM(Initial Features[company!,featuretype!])) +
Increase Of Capab Of Firms To Adopt Due To Policy

The increase in addressable market for the venture is dependent on the firm's marketing effort. See Figure 5-10 for Effect of Marketing Effort on Market Size Fn. With no marketing effort, there is no increase in the addressable market due to marketing, with normal marketing effort the increase is 0.1%, and as marketing effort increases the effect on the market size increases at a decreasing rate.

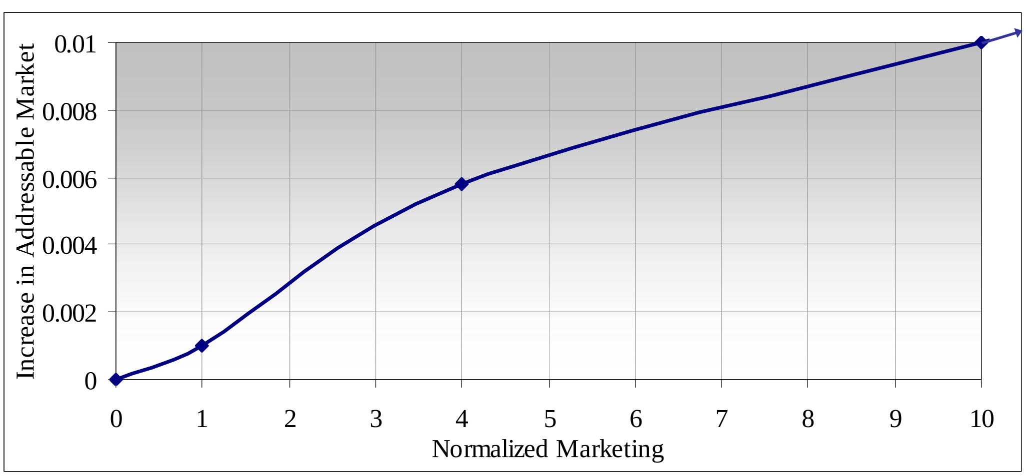

Figure 5-10: Effect of Marketing Effort on Market Size Fn

The Fraction Of Firms Capable Of Adopting is dependent on the sum of the features of the new venture and its competitors since this is when the potential customers are not looking at any one firm's products, but are just becoming capable of adopting the technology in general. And as the ratio between the current level of features and the initial features increases, the effect on the fraction of firms capable of adopting increases on a linear basis. The features of the product of the particular venture being modeled only become more important than the features of competitors when the firm becomes a Prospect of the venture.

5.6.2 Knowledge Rate

The flow from Potential Prospects to Prospects ("Knowledge Rate") is based on the *knowledge* stage of Rogers' innovation decision process. At this point, the prospective customer gains an understanding of the clean energy technology product. This rate is dependent on sales and marketing effort and attributes of the product that affect the productivity of the sales effort:

(53) Knowledge Rate = Norm Knowledge Rate *
Prospect Conversion Fn(Potential Knowledge From Sales Effort / Norm Knowledge Rate)

(54) Potential Prospect Loss Rate = MAX(0, Norm Knowledge Rate - Knowledge Rate)

(55) Norm Knowledge Rate = Potential Prospects / Avg Potential Prospect Lifetime

(56) Potential Knowledge From Sales Effort = Knowledge Sales Effort *
Knowledge Productivity Of Sales Effort

(57) Knowledge Sales Effort = Fraction effort for knowledge * Sales Effort

(58) Sales Effort = Sales & Mktg Effort - Marketing Effort

(59) Knowledge Productivity Of Sales Effort = MIN(Max Knowledge Productivity From Sales,
Sales Experience Productivity Multiplier * Max Knowledge Productivity From Sales *
Effect Of Features On Knowledge Efficiency *
Effect Of Price On Knowledge Efficiency * Effect Of Marketing On Knowledge Efficiency
* Effect Of Word Of Mouth On Knowledge Efficiency)

The Norm Knowledge Rate is the rate at which prospects leave the stock of Potential Prospects (where they stay, on average, the Avg Potential Prospect Lifetime). As per equation (54), if the

Knowledge Rate is less than the Norm Knowledge Rate (i.e. Potential Prospects are becoming Prospects at too slow a rate), they become Lost Prospects at the Potential Prospect Loss Rate.

When the value of the Potential Knowledge From Sales Effort rate is low compared to the Norm Knowledge Rate, the Knowledge Rate will equal the Potential Knowledge From Sales Effort. However, as the rate of Potential Knowledge From Sales Effort approaches the Norm Knowledge Rate, the Prospect Conversion Fn tempers its rise so that the Knowledge Rate will not equal the Norm Knowledge Rate until the Potential Knowledge From Sales Effort is 150% of the Normal Rate (See equation (53) and Figure 5-11).

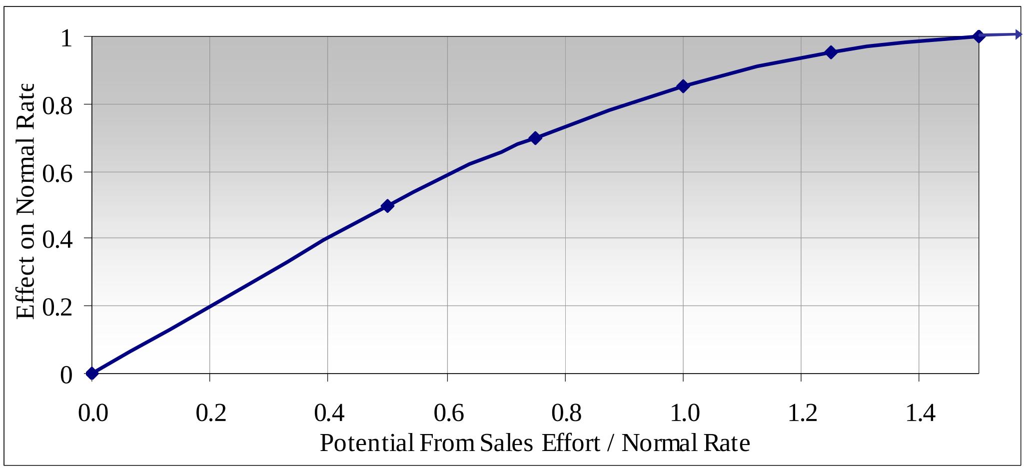

Figure 5-11: Prospect Conversion Fn

The Potential Knowledge From Sales Effort is the productive effort being applied by the new venture to convert Potential Prospects to Prospects. As per equation (56), it is simply the product of the sales effort being applied towards this step in the sales cycle and the productivity of that effort. As per equations (57) and (58), the Knowledge Sales Effort is the portion of the total sales effort that is being applied to convert Potential Prospects to Prospects; the total sales effort is the total sales and marketing effort (equation (27)) minus the Marketing Effort.

The Knowledge Productivity Of Sales Effort can be no larger than the Max Knowledge Productivity From Sales--the maximum number of Prospects that can be gained per person hour of sales effort. The Sales Experience Productivity Multiplier (equation (28)) can increase or decrease the productivity of sales effort, depending on the experience of the venture's sales force. Four additional attributes of the venture's product and efforts can affect how well the product can be sold:

(60) Effect Of Features On Knowledge Efficiency =
Effect Of Features On Knowledge Efficiency Fn(Normalized Features)

(61) Normalized Features: = Feature Value[self] / Feature Value[competitor]

(62) Effect Of Price On Knowledge Efficiency =
Effect Of Price On Knowledge Efficiency Fn(Normalized Price)

(63) Normalized Price: = Price / Competitor Price

(64) Effect Of Word of Mouth On Knowledge Efficiency =
Effect Of Word of Mouth On Knowledge Efficiency Fn(Normalized Word of Mouth)

(65) Normalized Word of Mouth: = (Contact Rate * Potential Prospects * Adopters / Total Population) / Word of Mouth Reference

(66) Effect Of Marketing On Knowledge Efficiency =
Effect Of Marketing On Knowledge Efficiency Fn(Normalized Marketing)

(67) Normalized Marketing: = Marketing Effort / Desired Marketing Effort

The selection of these attributes, their default values, and the functions that translate the normalized values to efficiency values are based on the interviews with clean energy entrepreneurs. Extremely poor values of important attributes (such as a product with no attractive features or a price that is many times that of the competition, or no marketing effort) result in extremely low efficiency, and therefore an extremely low number of prospects. Very good values for these parameters such as a product with better features than the competition, a lower price, a good marketing effort, and good word of mouth result in very high efficiency, which can result in achieving close to the maximum productivity of converting Potential Prospects to Prospects.

See Figure 5-12 for the Effect Of Features On Knowledge Efficiency Fn. The effect has a classic S-shaped curve. If the product has no features, the sales productivity will be zero. Then as features increase, the effect on sales productivity will rise at an increasing rate until when normalized features are one (product has same features as competition), and sales productivity will be 50% of its value. Then as features increase, the effect on sales productivity will increase at a decreasing rate until the product has twice the features of the competition at which point sales productivity will not be reduced at all.

See Figure 5-13 for the Effect Of Price On Knowledge Efficiency Fn. The effect is analogous to that of features, except in the reverse direction. If the price is zero, then sales productivity will be at its maximum value. Then as the price increases, the sales productivity falls at an increasing rate until the point at which the normalized price is one (product has the same price as competition), where sales productivity is reduced by 50%. Then as price increases further, sales productivity falls at a decreasing rate, until a point at which the price is 10 times that of the competition and sales productivity is zero.

The effect of word of mouth (Figure 5-14) and marketing (Figure 5-15) on sales productivity are linear. If there is no word of mouth, sales productivity is reduced by 85%, and if there is no marketing sales productivity is reduced by 90%. The selections of these values are based on the fact that word of mouth and marketing will have a significant impact on sales productivity, but that complete lack of these efforts will not cut off sales completely. And marketing has a slightly larger impact than word of mouth. Sales productivity rises linearly with increased word of mouth or marketing until the point at which they reach their normal values and sales productivity is not affected. The “normal” values of word of mouth and marketing are defined as the points at which additional efforts in these areas will no longer have an effect on sales productivity.

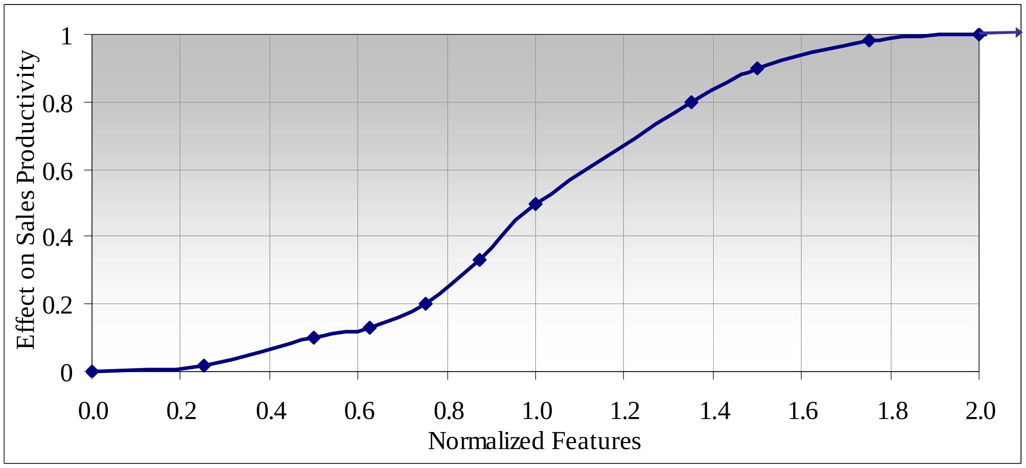

Figure 5-12: Effect Of Features On Knowledge Efficiency Fn

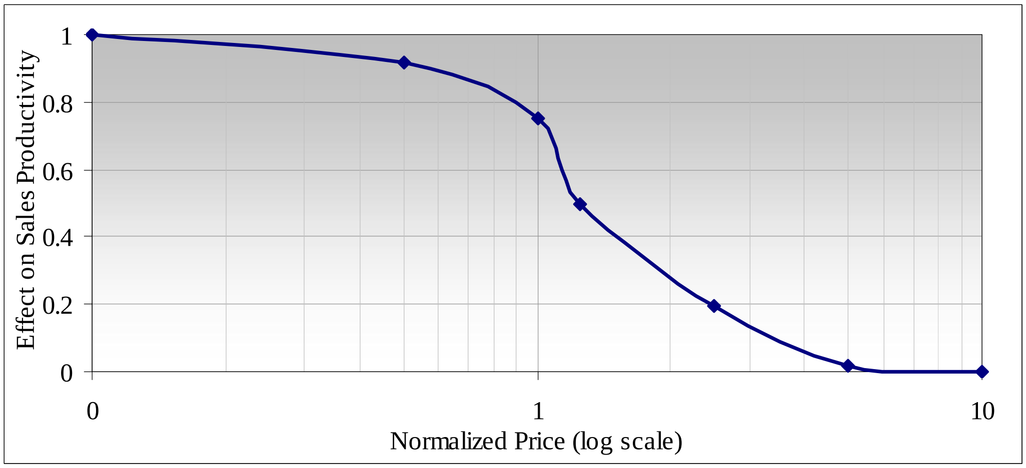

Figure 5-13: Effect Of Price On Knowledge Efficiency Fn

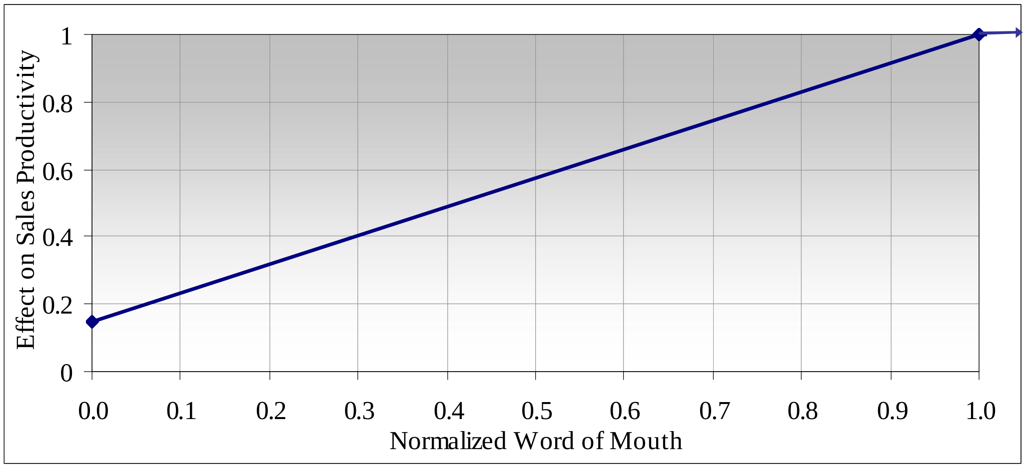

Figure 5-14: Effect Of Word Of Mouth On Knowledge Efficiency Fn

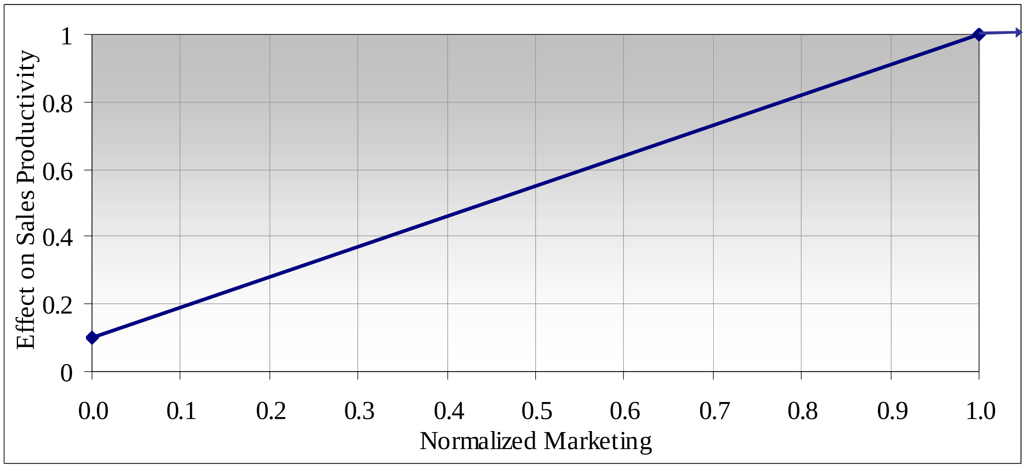

Figure 5-15: Effect Of Marketing On Knowledge Efficiency Fn

5.6.3 Persuasion Rate

The flow from Prospects to Hot Prospects ("Persuasion Rate") is based on the *persuasion* stage of Rogers' innovation decision process. At this point, the prospective customer forms a favorable opinion of the clean energy technology product. In a manner analogous to the Knowledge Rate, the flow is dependent on sales effort, the price and features of the product, marketing effort, and word of mouth.

The only difference between this structure and the structure and equations detailed in Section 5.6.2 is the parameterization. For example, the Avg Prospect Lifetime is only one month, while the Avg Potential Prospect Lifetime is six months. This reflects the fact that while it may take a long time to find and contact Potential Prospects, once a potential customer has become a Prospect, they will form a favorable or unfavorable opinion relatively quickly, and become either a Hot Prospect or a Lost Prospect. However, the Max Persuasion Productivity From Sales is only half the rate of the Max Knowledge Productivity From Sales because it takes considerably more effort to persuade a prospect to have a favorable opinion of a product than it does to simply impart the knowledge to them of what the product is.

The effect of features and price on persuasion productivity is the same as they are on knowledge productivity (as the potential customer is still considering the price and features of the product to determine whether or not to trial it). Word of mouth and marketing, however, have less of an effect. The persuasion efficiency with no word of mouth is 33% and with no marketing is 50%, and as before linearly rise to 100% as these attributes reach their normal values. These attributes have less of an impact on persuasion as they do on knowledge, as the customer is already aware of the product at this point. And word of mouth has more of an impact than marketing as the customer seeks to validate the value of the product with peers.

5.6.4 Purchase Rate

The flow from Hot Prospects to Purchasers ("Purchase Rate") is based on the *decision* stage of Rogers' innovation decision process. At this point, the prospective customer decides to adopt or reject the clean energy technology product. In a manner analogous to the Knowledge and Persuasion Rates, the Purchase Rate is dependent on sales effort, and the features and price of the product (Figure 5-12 and Figure 5-13). It is also affected by word of mouth, though to a lesser degree (no word of mouth results in 50% of sales productivity). However, while marketing is no longer a factor at this point in the sales cycle, Customer Support becomes important:

(68) Effect Of Customer Support On Decision Efficiency =
Effect Of Customer Support On Decision Efficiency Fn(Normalized Cust Support)

(69) Normalized Cust Support = Engineering Effort for Cust Support / Cust Support Needed[10]

The Effect Of Customer Support On Decision Efficiency Fn reduces sales productivity by 50% if there is no customer support, and then raises sales productivity linearly until Normalized Cust Support is one (at which point increasing customer support no longer increases sales productivity).

The Avg Hot Prospect lifetime is four months, reflecting the length of time needed to convince the average customer to purchase the product. The Max Decision Productivity From Sales rate is half the Max Persuasion Productivity From Sales rate, reflecting that it takes twice as much effort again to convince an interested prospect to actually decide to purchase.

5.6.5 Adoption Rate

Once a customer has purchased the product, it is still not certain that the customer will adopt the product. Clean energy technology products typically take considerable time and effort to install and to put into operation. During that period of time, a Purchaser may still choose not to adopt the technology. The flow from Purchasers to Adopters ("Adoption Rate") is based on the

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[10] Assuming Cust Support Needed > 0

implementation stage of Rogers' innovation decision process—the point at which the prospective customer actually puts the technology into use. In a manner analogous to the Purchase Rate, the Adoption Rate depends on sales effort, the features of the product, and the level of customer support. At this point, price and word of mouth are no longer relevant, as the purchase decision has already been made. However, customer support is now critical for implementation. With no customer support, the adoption efficiency will fall to zero. And as customer support improves, the adoption efficiency rises linearly, until customer support is its full normal value at which point adoption efficiency will not be reduced.

The Avg Purchaser Lifetime is one month, reflecting the amount of time it takes to begin using the product, and the Max Adoption Productivity From Sales is very high because once the purchase is made, sales effort no longer necessary. However, considerable customer support effort is now required (see Section 5.7).

5.6.6 Adopter Loss Rate

A customer may not remain an adopter forever. The Adopter Loss Rate captures the rate of Adopters who stop using the product and become Lost Prospects:

(70) Adopter Loss Rate = Adopters * Adopter Loss Fraction

(71) Adopter Loss Fraction = Normal Adopter Loss Fraction *
Effect of Customer Support on Adopter Loss Fraction(Normalized Cust Support) *
Effect of Features on Adopter Loss Fraction(Normalized Features)

As per equation (71), the features of and customer support for the product affect the Adopter Loss Rate. If the features become deficient compared to competing products, or if customer support falls below the needed level, the Adopter Loss Rate will increase significantly. However, even with the best of features and customer support some (though relatively fewer) customers will stop using the product.

5.6.7 Word of Mouth

As more Adopters use the product personnel at those firms will come in contact with personnel from other firms and spread word about the product. In fact, some firms will not adopt the product without having seen it in use, or heard about its use, at other similar firms. The word of mouth equation is restated here:

(72) Normalized Word of Mouth: = (Contact Rate * Potential Prospects * Adopters / Total Population) / Word of Mouth Reference

Word of mouth is based on the number of Adopters and Potential Prospects and how often they come into contact (the Contact Rate) based on the Total Population. Sales will be affected positively or negatively depending on whether the calculated value is above or below the reference value.

See Table 5-6 for all the parameters used in the market sector of the model, their default values, and the minimum and maximum values used for sensitivity analysis in Chapter 6.

Parameter	Value	Units	Min	Max
Avg Potential Prospect Lifetime	6	Months	0.01	24
Avg Prospect Lifetime	1	Months	0.01	12
Avg Hot Prospect Lifetime	4	Months	0.01	12
Avg Purchaser Lifetime	1	Months	0.01	12
Initial Adopters	0	Prospects		
Initial Capab of Firms to Adopt	0.05	Dmnl	0	1
Initial Hot Prospects	0	Prospects		
Initial Potential Prospects	100	Prospects	0	1E+05
Initial Prospects	0	Prospects		
Initial Purchasers	0	Prospects		
Initial Total Population	100000	Prospects		
Lost Prospect Lifetime	12	Months		
Max Knowledge Productivity From Sales	0.25	Prospects/ (Person*Hour)		
Max Persuasion Productivity From Sales	0.13	Prospects/ (Person*Hour)		
Max Decision Productivity From Sales	0.06	Prospects/ (Person*Hour)		
Max Adoption Productivity From Sales	1	Prospects/ (Person*Hour)		
Normal Adopter Loss Fraction	0.01	1/Months		
Normal Default Fraction	0.002	1/Month		
Contact Rate	0.25	1/Month	0.01	100
Word of Mouth Reference	0.1	Prospects/ Month	0.01	10

Table 5-6: Market Sector Parameters

5.7 Customer Support

As detailed in Section 5.6, customer support is critical to convince customers to purchase and adopt the product. Normalized customer support is calculated as follows:

(73) Normalized Cust Support = Engineering Effort for Cust Support / Cust Support Needed[11]

(74) Engineering Effort for Cust Support = MIN(Cust Support Needed, Effective Engineering Effort(22) * (1 - Min Development Fraction))

(75) Cust Support Needed = Adopters * Cust Support Needed per Adopter + Purchasers * Cust Support Needed Per Purchaser

The model presumes that a minimum fraction of engineering effort will be applied towards product development (the default value is 50%). Out of the engineering effort that remains available, the amount of customer support applied will be based on the number of purchasers and adopters and how much support they need. But if the effort available is not enough to fill the need, sales and adoptions will be reduced, and as per Section 5.6.6, Adopters will be lost.

Table 5-7 contains the customer support parameters, which are measured in how many person hours of sales effort are needed per prospect per month. Note that purchasers (who have not yet adopted) require five times as much effort, as this includes the effort required for installation, initial maintenance of the system, and to help new customers learn to operate the system correctly.

Parameter	Value	Units
Cust Support Needed per Adopter	8	Person*Hours/ (Month*Prospect)
Cust Support Needed Per Purchaser	40	Person*Hours/ (Month*Prospect)

Table 5-7: Customer Support Parameters

5.8 Pricing

A key factor in the decision to purchase the product, and for the profitability of the new venture, is the pricing of the product. The price is determined based on the cost to produce the product and on the price the competitor charges:

(76) Price = MAX(Target Price, Min Price)

(77) Min Price = Cost Per Unit / (1-Min Gross Margin)

[11] Assuming Cust Support Needed > 0

(78) Cost Per Unit = (Initial Cost Per Unit*
(Cumulative Purchases / Reference Production for Initial Cost) ^
(LN(1 - Decrease in Costs per Double Purchases) / LN(2))) *
Cost Adjustment Fraction Due To Policy

(79) Cumulative Purchases = INTEGRAL(Purchase Rate)

(80) Target Price = Target Norm Price * Competitor Price

(81) Competitor Price = (Initial Competitor Cost Per Unit *
Competitor Cost Adjustment Fraction Due To Policy) / (1-Competitor Margin)

(82) Competitor Margin = Max Competitor Margin –
Competitor Margin Adjustment Fn(Delay3i(Normalized Price,Competitor Margin Adjust Time,1)) * (Max Competitor Margin - Min Competitor Margin)

The new venture wishes to charge a price based on its costs to produce the product and which will undercut the competitor's price. To assure that the venture will not lose too much money, it charges the maximum of the price it wishes to charge to undercut competition (Target Price) and a Min Price which reflects the venture's costs (equation (76)). The Min Price is calculated by charging the Min Gross Margin above its cost to produce the product (equation (77)). The Min Gross Margin could be negative if the venture is willing to lose money to gain market share, but is zero by default so that the venture can at least recoup its costs (See Table 5-8).

Over time, the learning curve reduces the cost to produce the product as described in Section 5.5.2 (equation (78)). The initial cost is $100,000, which is the same as the competitor's initial cost, but it is assumed that cost is reduced by 10% for every doubling of production from the first unit. Many studies have shown that production costs are reduced between 10% and 30% over a wide range of industries for every doubling of experience (P. Ghemawat, 1985), and 10% was chosen here as a conservative estimate. The production cost may also be affected by government policies that provide subsidies to the venture to apply towards its development and production costs. This is discussed further in Chapter 6.

If the competitor is charging more than the Min Price, the venture can raise its price to the Target Price, which is a fraction of the price the competitor is charging. The default fraction is 75%.

The competitor does not benefit from a learning curve to reduce its costs, since it is presumed that its product is mature or perhaps a commodity. However, the competitor can reduce its margin in response to price pressure from the new venture. By default, the competitor will charge their maximum margin, but if the new venture has a lower price, then, after a delay, the competitor may respond by lowering its margin, down to the minimum margin they are able to charge. The Competitor Margin Adjustment Fn is shown in Figure 5-16. The competitor does not lower their margin at all if normalized price is one (venture and competitor charging same price). As the venture's price becomes lower in comparison to the competitor's price, the competitor lowers their margin at an increasing rate until the normalized price is 75%. Then the competitor lowers their margin at a decreasing rate until their price reaches its minimum level when the venture is charging half the price of the competitor. The competitor price may also be affected by government policy, which is also discussed in Chapter 6.

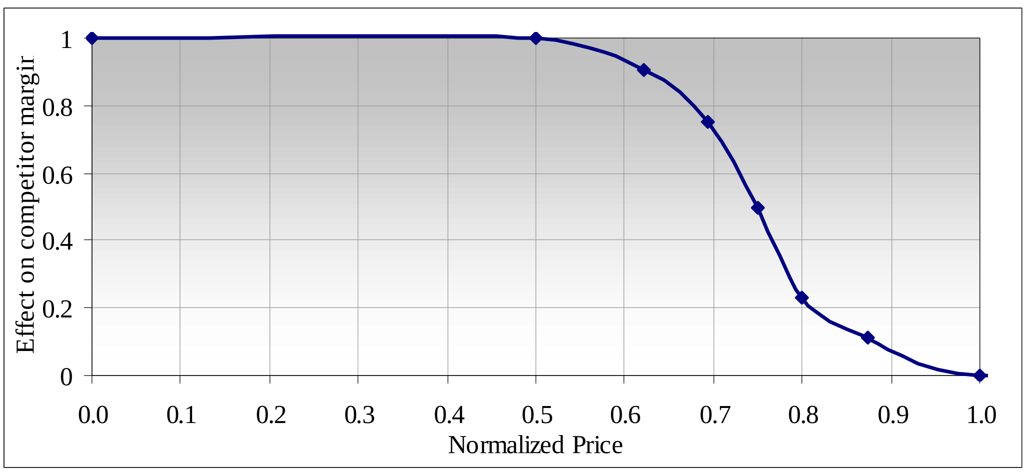


Figure 5-16: Competitor Margin Adjustment Fn

See Table 5-8 for the parameters used in the pricing sector of the model, their default values, and the minimum and maximum values used for sensitivity analysis in Chapter 6.

Parameter	Value	Units	Min	Max
Competitor Margin Adjust Time	3	Months	0.1	36
Decrease in Costs per Double Purchases	0.1	Dmnl	0.001	0.9
Initial Competitor Cost Per Unit	1E+05	Dollars/Unit	1.E+04	2.E+05
Initial Cost Per Unit	1E+05	Dollars/Unit	1.E+04	2.E+05
Maintenance Margin	0.8	Dmnl	0.01	0.99
Max Competitor Margin	0.3	Dmnl	0	1
Min Competitor Margin	0.3	Dmnl	-0.5	0.5
Min Gross Margin	0	Dmnl	-0.5	0.5
Reference Production for Initial Cost	1	Prospects	0.01	1000
Target Norm Price	0.75	Dmnl	0.1	1

Table 5-8: Pricing Parameters

5.9 Conclusion

This chapter presented a detailed overview of the important sectors of the clean energy technology venture simulation model. For a complete listing of the equations and parameter values of the model please see Appendix C.

The next chapter will present the results of running the model with default parameters for a prototypical clean energy technology venture. The results of sensitivity analysis on the parameters will be presented, and analysis of the simulation will be used to determine what factors have the greatest impact on the success or failure of the venture.

6 Analysis of Simulation Model

This chapter presents an analysis of the new venture simulation model. Observing the behavior of the model will provide insights into the real world scenarios the model represents.

The model will be used to uncover the factors most important to the success of a new clean energy technology venture. While many of these factors will be intuitive to some readers, others may not be, and there is value in verifying the importance of these factors in a new way and using the model to identify their relative strength. Further, it is instructive to observe the sensitivity of the simulated venture's success to the initial value of parameters in the model.

The chapter starts by setting the stage for the simulated venture.

6.1 The Base Case Venture

Table 6-1 presents business projections taken from the investor presentation for a clean energy technology startup (and is fairly 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.

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. The amount of initial capital invested is 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 the product. There are 100,000 firms that could conceivably adopt the new product, 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 the venture has 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 6-1 secured a $4M initial investment and an additional $1.5 M 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 6-1 shows a graph of the working capital based on the projections in Table 6-1. 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 6-2), then the simulation model comes close to replicating the pro forma performance (See Figure 6-2).

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 6-1: Business Plan

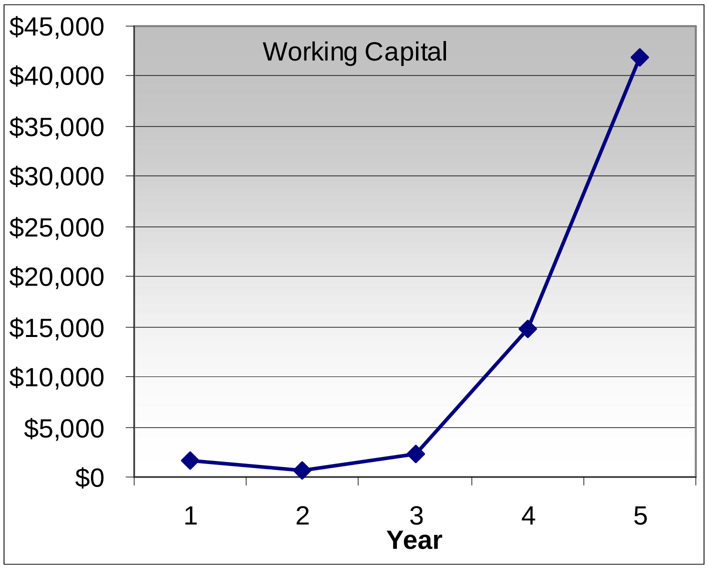


Figure 6-1: Projected Working Capital from Business Plan ($1,000s)

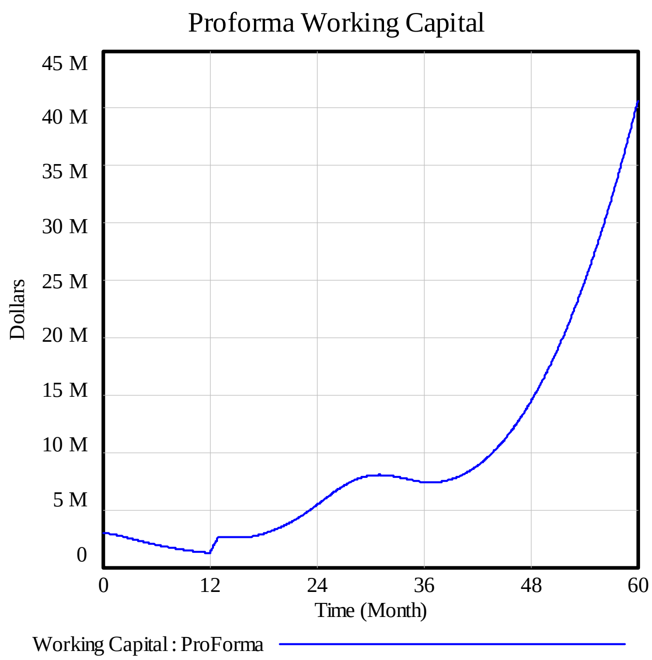


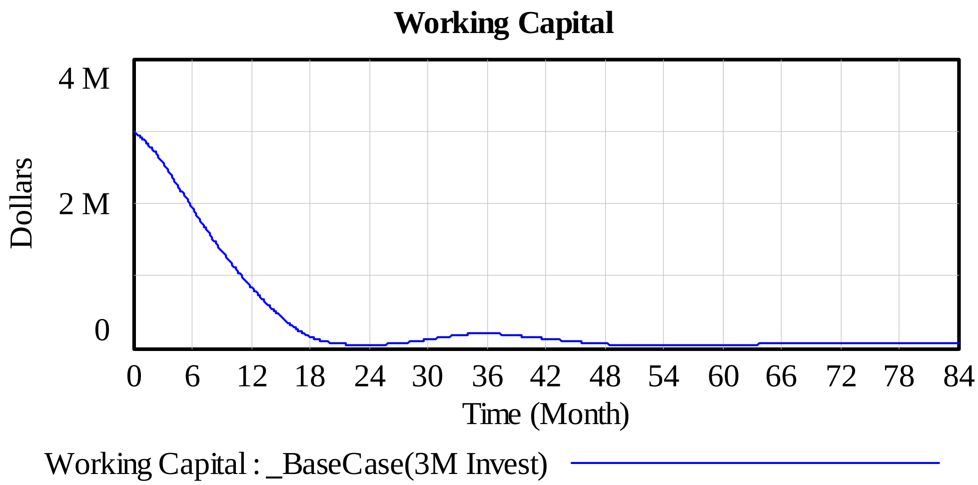
Figure 6-2: Working Capital from Model with Relaxed Assumptions

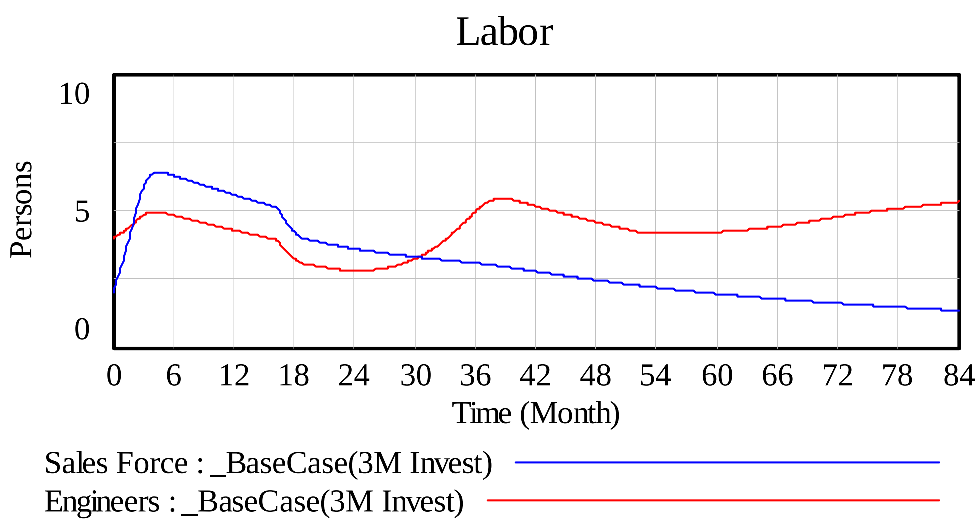
Avg Prospect Lifetime	0.1
Avg Hot Prospect Lifetime	0.1
Avg Purchaser Lifetime	0.1
Initial Capab of Firms to Adopt	0.15
Avg Experience of New Eng Hires	10,000

Table 6-2: Assumptions Necessary to Replicate Business Plan Projections

6.2 The Valley of Death

Our base case firm expects the results seen in Figure 6-1 or Figure 6-2. Unfortunately, the assumptions in Table 6-2 are not realistic. Though the founders are probably not making these assumptions explicitly, they are necessary to achieve those results given the nature of the market. Given more realistic assumptions, things do not work out as the founders of the venture firm had planned. Figure 6-3 shows the simulation model results of the performance of the firm for the first seven years of its existence. The venture spends almost all of the initial $3M of working capital in the first 18 months. Assuming the venture is not able to attract additional investments, management needs to lay off employees, and continue with a total of only about seven employees for most of the firm's existence. The firm does not go bankrupt, but barely ekes out an existence by attracting just enough adopters to pay for its few employees. Unfortunately, the average of one sale every two months is not enough to enable the new venture to grow. After an excessive amount of persistence and patience the entrepreneurs and/or investors are likely to pull the plug on the venture after the seventh consecutive year of no significant positive cash flow.





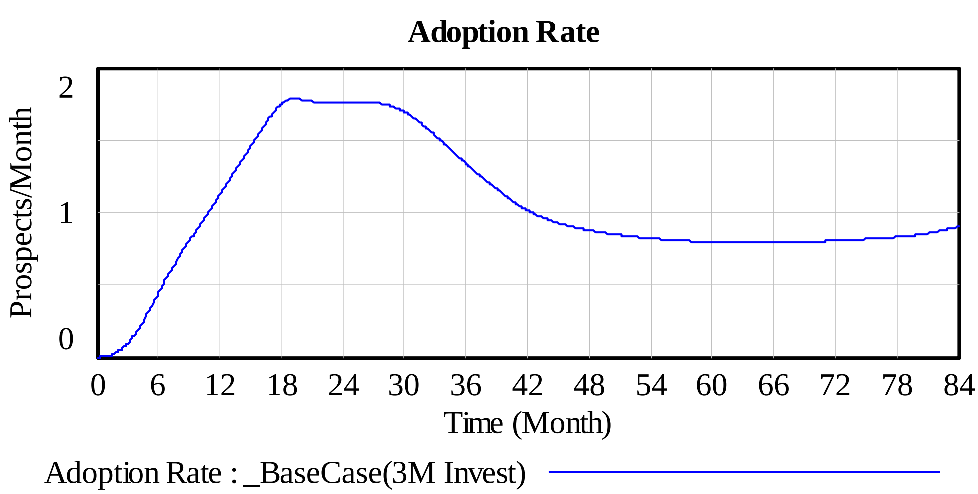


Figure 6-3: Fate of Firm after 7 Years

Figure 6-5 presents the cumulative probability of the investors or entrepreneurs giving up on the venture over seven years of its operation based on the accumulation over time of a hazard rate of failure (Figure 6-4). The hazard rate of failure is the inverse of the expected life of the venture at any point in time and is based on 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:

(83) Hazard Rate of Failure = MAX(0, (
Hazard Rate from Current Ratio / Hazard Rate from Current Ratio Ref +
Hazard Rate from Features / Hazard Rate from Features Ref +
Hazard Rate from Prospects / Hazard Rate from Prospects Ref) *
(Normal Hazard Rate / 3)) *
(Time / Hazard Rate Time Reference)

(84) Hazard Rate from Current Ratio = 1/Current Ratio

(85) Current Ratio[12] = ((Working Capital + Hazard Rate AR Perc*Accounts Receivable) /
-Cash Flow From Operations) / Current Ratio Timeframe)

(86) Hazard Rate from Features = 1/Normalized Features – 1

(87) Hazard Rate from Prospects = 1/Effective Prospects – 1

(88) Effective Prospects = Total Prospects/Initial Potential Prospects

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). However, the overall hazard rate will always be greater or equal to zero.

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[12] 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)

The overall hazard rate is scaled according to the length of time the venture has been in operation. It is very unlikely that investors or entrepreneurs will give up on a firm after just a few months of operation. However, if the firm has negative characteristics after many years of operation, the investors or entrepreneurs are much more likely to lose their patience.

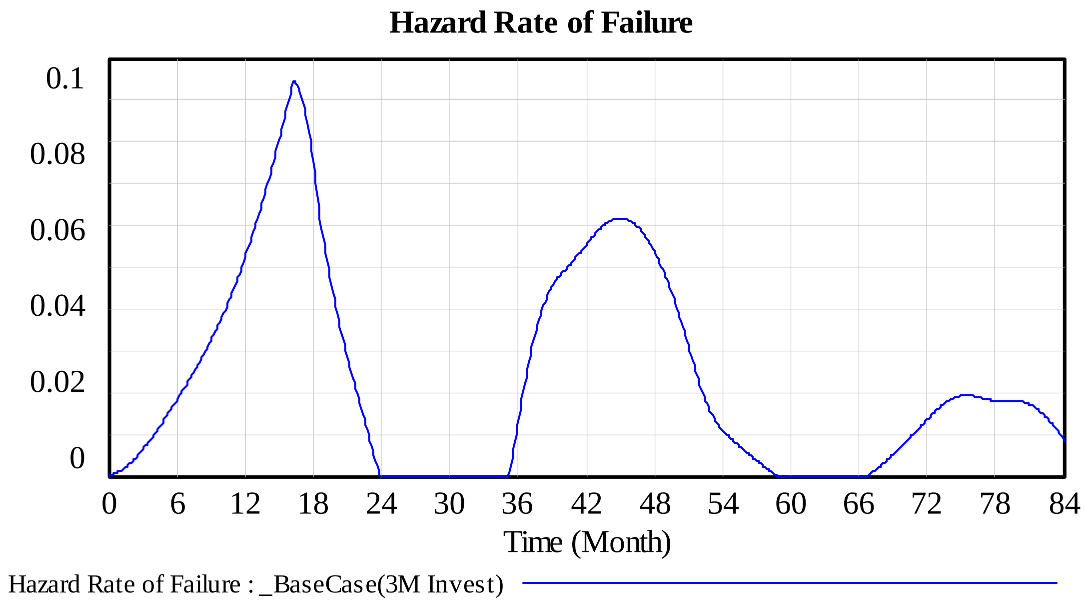

Figure 6-4: Hazard Rate of Failure for Base Case Venture

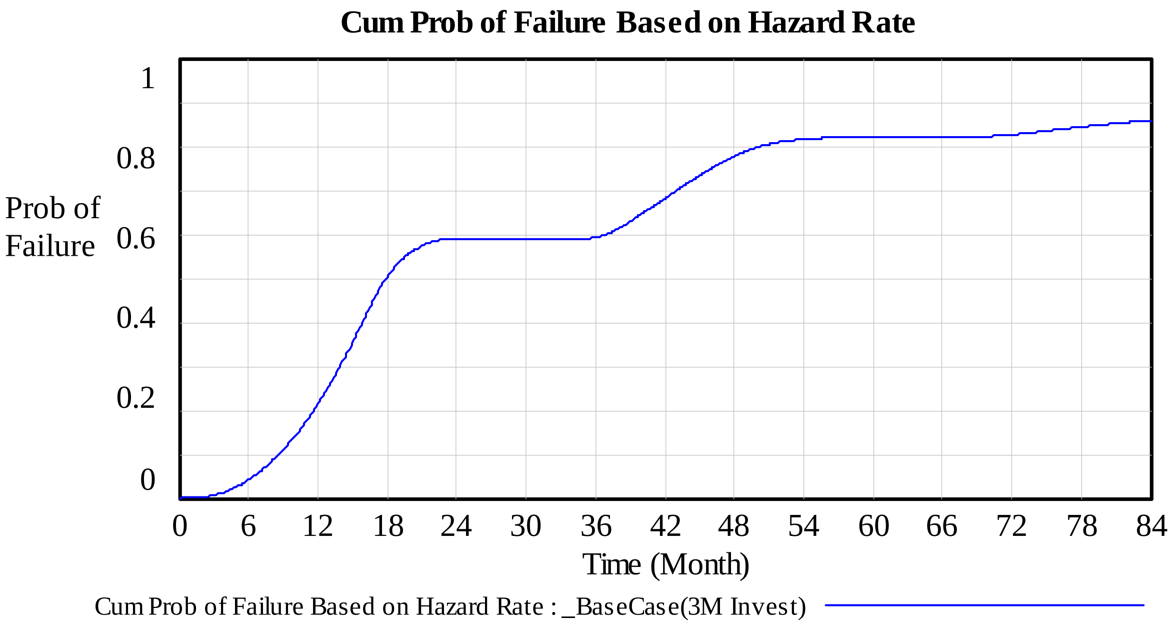

Figure 6-5: Cumulative Probability for Firm to Fail

The natural way to help the base case venture succeed appears to be an additional infusion of cash to prevent the minimization of working capital and reduction of the work force at around 18 months. Given that this new venture has a product with better features at lower cost than competitors do; it would seem that if the venture has enough capital to maintain their engineering, support and sales force, they will succeed. Yet, as we see in Figure 6-6, even with a cash infusion of another $1.5M after 12 months, the additional money is spent and the venture is left with little working capital and no record of positive cash flow after five years (a long time for investors to be patient, especially after having made two investments). Given the same hazard rate assumptions as before, approximately 80% of firms would fail under those conditions.

Of course, the story doesn't really end there. If we never give up, and allow the new venture in the base case scenario 14 years to find its footing, it develops a strongly positive cash flow. See Figure 6-7. The additional cash infusion enables the firm to develop a strongly positive cash flow after "only" about nine years (Figure 6-8). However, in the experience of the entrepreneurs and investors interviewed for this research, most startup companies that have investors to pay back do not get that many years before they need to start showing results. Hence the new venture in this example is likely to fail since it will not have nine to 14 years to show results.

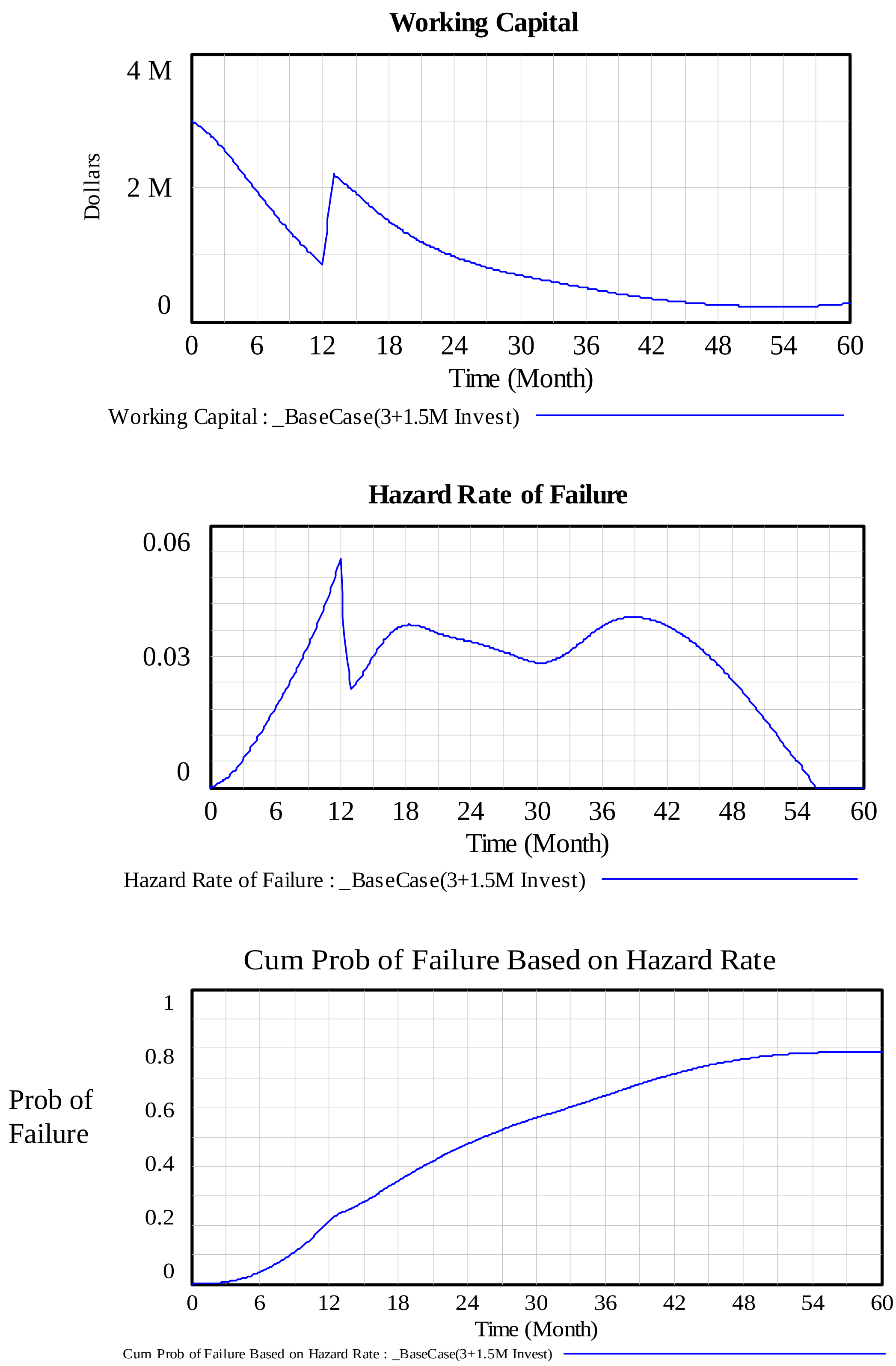

Figure 6-6: Fate of Firm with Additional Investment

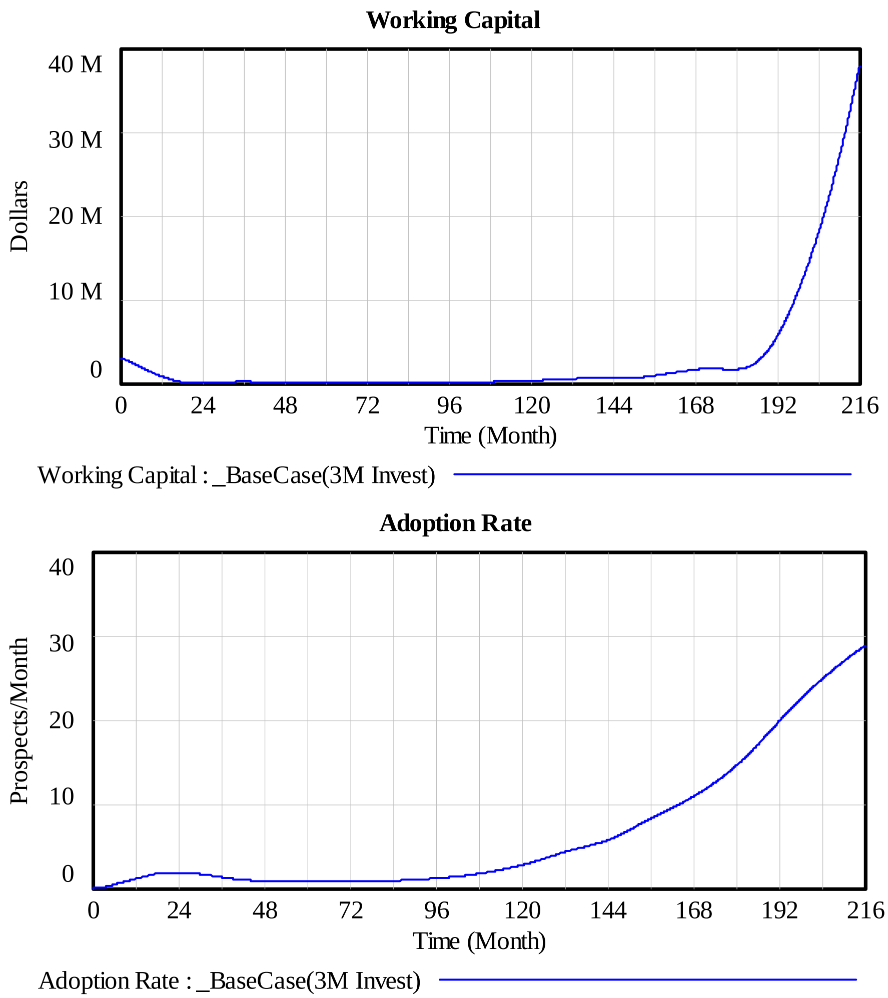

Figure 6-7: Fate of Firm with Single Investment after 18 Years

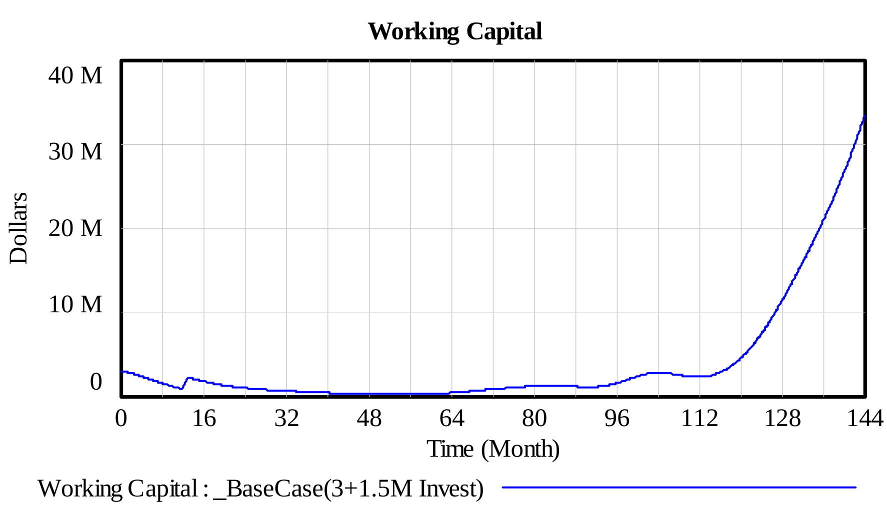

Figure 6-8: Fate of Firm with Additional Investment after 12 Years

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. The valley is clearly visible in Figure 6-7 and Figure 6-8. In fact, it appears over a wide range of scenarios for clean energy technology companies. Figure 6-9 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 6-10 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 through four years. It is called the valley of death because small companies that are not growing and not able to attract investment dollars often “die” during this period of time.

Of course, these simulations all assume that the new venture starts out with a product having a significant feature advantage to the competition. If the product is no better than the competition, the story is very different (and much simpler since the firm is almost certain to fail). Figure 6-11 presents a sensitivity analysis of a uniform distribution of initial investments between $1M and $10M with the product of the new venture being the same as that of the competition.

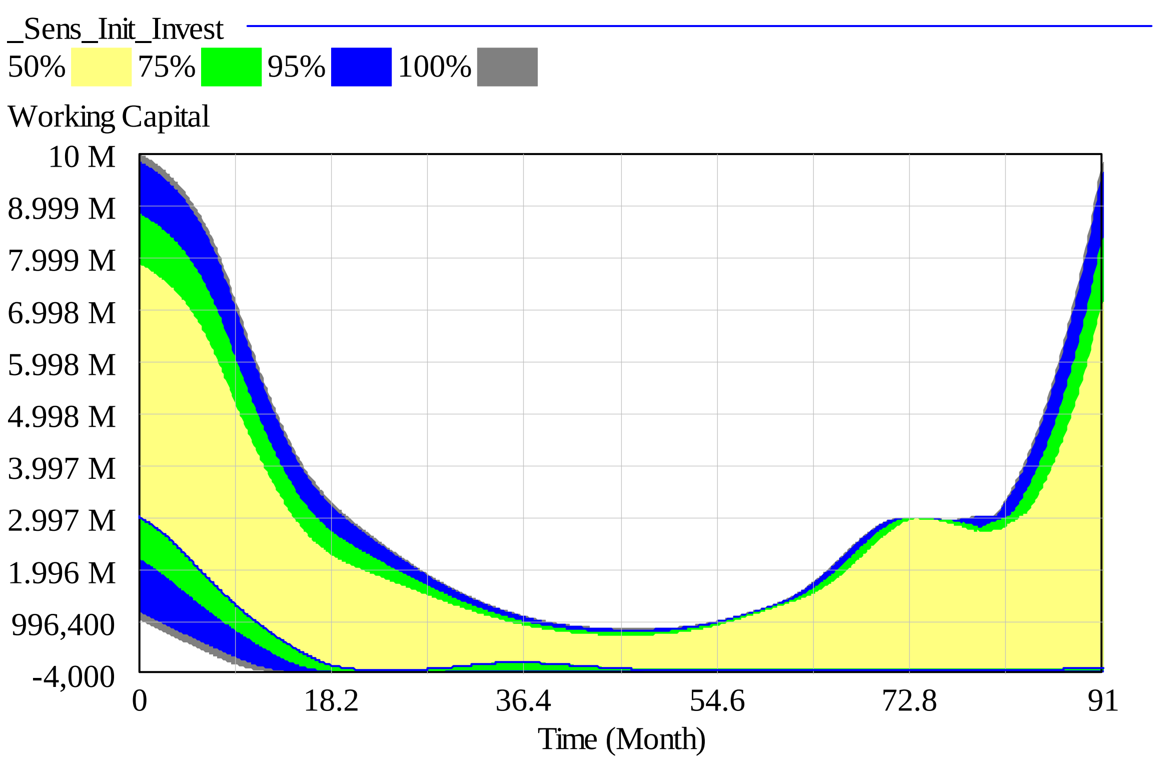

Figure 6-9: Sensitivity Analysis Over Range of Initial Investments

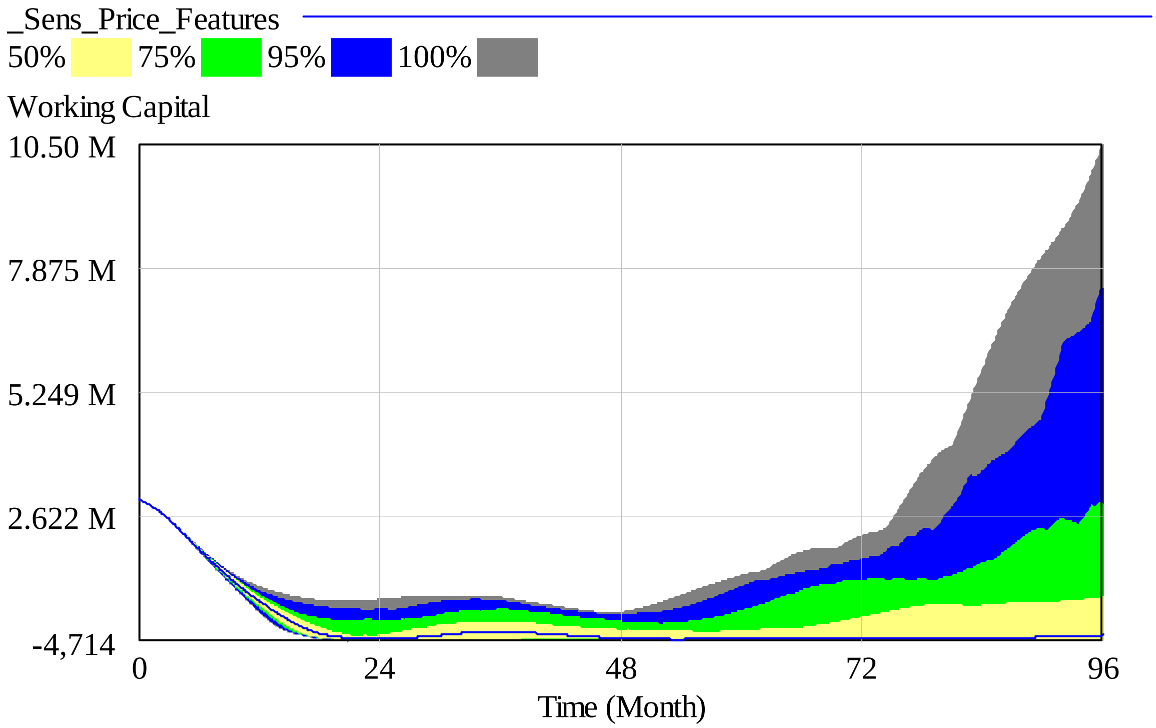

Figure 6-10: Sensitivity Analysis over Initial Costs and Features

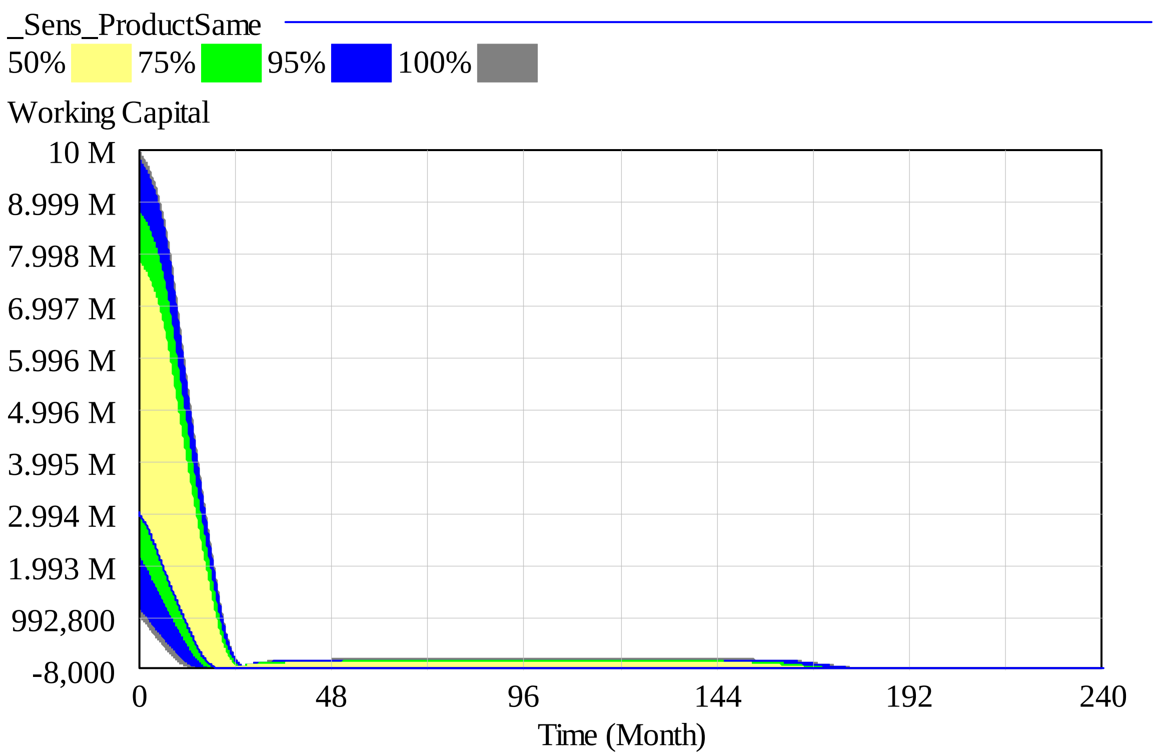

Figure 6-11: Sensitivity Analysis Assuming Product is Same as Competitor's

The valley of death is an especially pronounced problem for clean energy technology startup companies for two reasons. First, for companies that will eventually succeed given enough time, the time in the valley is considerably longer than other technology companies with similar advantages in features and price. While an innovative enterprise software company may experience six to twelve months in the valley before catching on in the market, a clean energy technology company may experience six to twelve years in the valley due to the significant barriers to adoption that these companies face.

Second, the stakes are much higher for the products of these companies to be adopted on a widespread basis. There are not likely to be strong negative repercussions to society if a new venture with more effective corporate accounting software fails before its time. However, there are very strong environmental reasons for clean energy technologies to be adopted on a widespread basis. As discussed previously, new ventures may be the best option for introducing disruptive technology that will enable a new clean energy industry to emerge.

Given the prevalence of the valley of death, and the importance for innovative clean energy technology companies to emerge from the valley, we will now address the factors that are most likely to make that possible.

6.3 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? It would be instructive to look at the state of the model at three points (See Figure 6-7 for reference):

- Month 0, when the venture has working capital due to the initial investment, but has not yet entered the market;
- Month 90, when the venture has spent most of its capital, is in the middle of the valley of death, and is surviving, but with no significant positive cash flow; and
- Month 180, when the venture is leaving the valley with strong and accelerating positive cash flow.

Analysis was performed to determine which of the stocks in the model make the most difference. Table 6-3 shows the stocks that distinguish between negative, neutral, and positive cash flow. The values of these parameters at month 0 result in negative cash flow, at month 90 in relatively neutral cash flow, and at month 180 in accelerating positive cash flow. The fact that these parameters are sufficient to generate the desired cash flow is demonstrated by setting their initial values to their month 180 values and observing the behavior of the model. Setting these values results in instant positive cash flow, with a similar trajectory to the arc that occurs after 15 years in the base case model (See Figure 6-12).

Time (Month)	**0**	**90**	**180**
Working Capital	$3,000,000	$82,889	$1,671,947
Accounts Receivable	$0	$288,831	$3,327,312
Engineers	4	5.6	79.1
Avg Engineer Experience	10,000	15,112.4	9,298.0
Avg Sales Experience	1,500	43,102.2	42,201.3
Cumulative Purchases	1	94.2	607.5
Potential Prospects	100	44.2	101.7
Hot Prospects	0	4.2	59.7
Purchasers	0	1.0	14.6
Adopters	0	49.2	420.6
Features [self,appropriable]	110	50.3	385.1
Features [self,nonappropriable]	4	2.7	6.0
Features [competitor,nonappropriable]	2	3.4	5.3
FUD [self,appropriable][13]	0	5.0	59.7
FUD [self,nonappropriable]	0	0.3	2.3
FUD [competitor,nonappropriable]	0	0.0	3.7

Table 6-3: Conditions Needed to Achieve Profitability

[13] FUD stands for Features Under Development – see Chapter 5 for more details

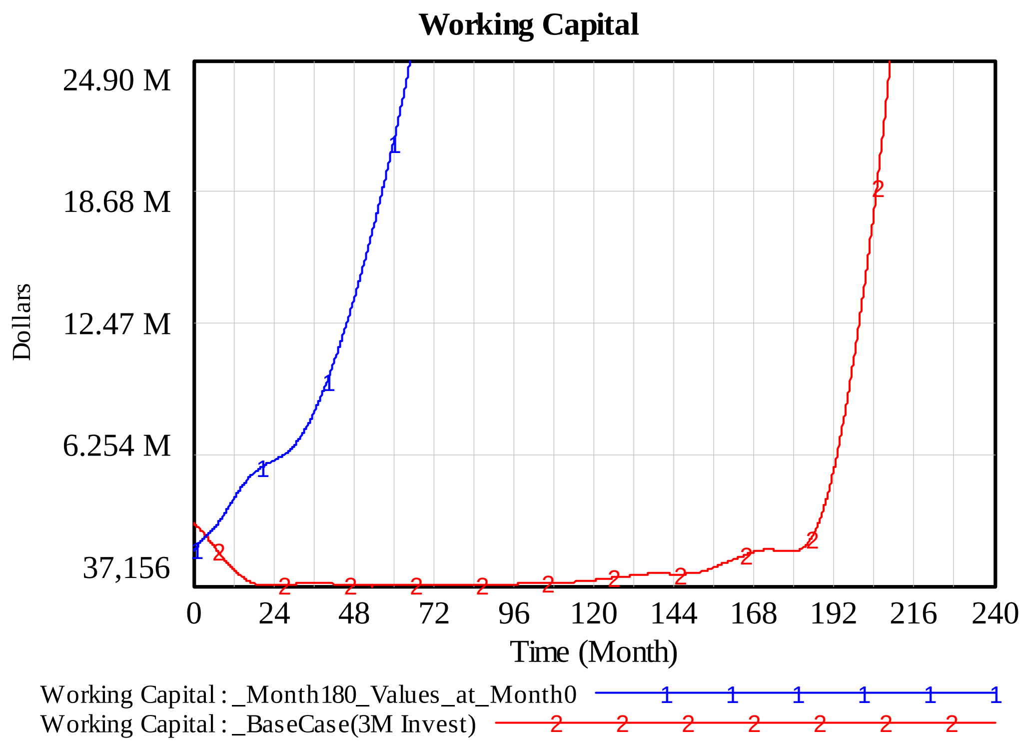

Figure 6-12: Performance of Firm with Month 180 Values Set at Time 0

These parameters are not only sufficient, but are *necessary* to reach the state of an accelerating positive cash flow. Sensitivity testing shows that 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 6-4 summarizes what happens when any of these parameters are reduced by 50% at Time 0 of the "Month180_Values_at_Month0" model run shown in Figure 6-12. The table shows the percent reduction in working capital at one, three, and five years into the run. The values during the first few years are important because we want to know how much the immediate accelerating positive cash flow is interrupted by a reduction in each parameter. Because we are beginning with the Year 15 values, and the model duration is 20 years, we also look at the five-year values of the parameters. Percent reductions of greater than 50% are highlighted in the table. Note that engineering experience, number of adopters, and non-appropriable features tend to make the most difference. However, all of the parameters listed in Table 6-4 are essential to achieving the positive cash flow shown in Figure 6-12.

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 6-4: Percent Reduction in Working Capital from 50% Reduction in Parameter

There are two notable omissions from this list of parameters. The number of sales employees is not included, since a very large sales experience gain coupled with a full pipeline is sufficient for profitability. The stock of Prospects is not included since a sufficient number of Potential Prospects and Hot Prospects, coupled with the relatively short Avg Prospect Lifetime is sufficient to keep the sales pipeline full.

Because in reality it would not be possible for a venture to start off with the Month 180 parameter values, an initial negative cash flow is unavoidable. A venture cannot start with a positive accounts receivable, a full pipeline, and existing customers. 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.

The below sections describe what the model tells us a venture needs to achieve profitability and emerge from the valley.

6.3.1 Working Capital

First and foremost, the venture requires enough working capital to maintain and augment its work force and cover the costs of production and other necessary costs of doing business.

A new venture may have every advantage in the world, but if the venture does not have enough working capital, it cannot grow. Working capital is the lifeblood of a small company. In Figure 6-9 we saw the effect of initial investment (the initial stock of working capital) over the first seven years of the venture. Figure 6-13 shows the sensitivity to initial working capital over the 20-year duration of the model. Note that the results range from bankruptcy (negative working capital) to a working capital stock of nearly $700M at Year 20. The large 50% band demonstrates that the results of the model are sensitive to changes in initial working capital within the range of $1M and $10M.

As subsequent sections will show, sufficient working capital is a prerequisite for any other parameter or management or policy intervention to have a positive effect.

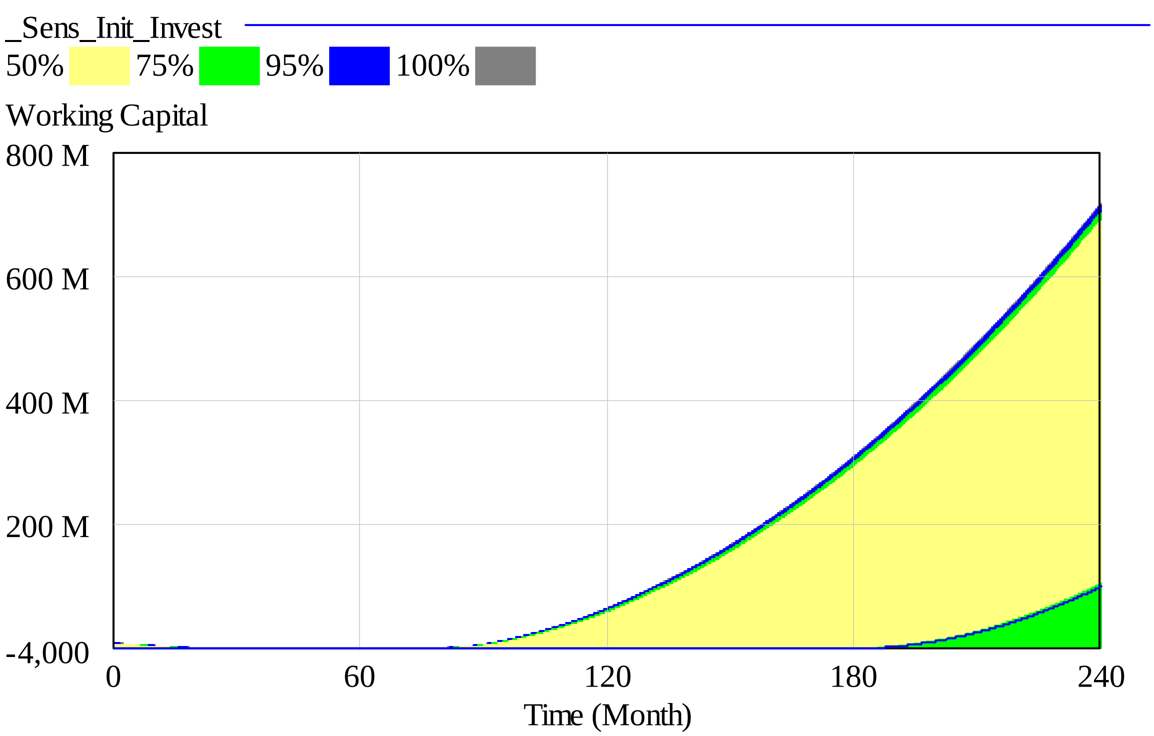

Figure 6-13: Sensitivity to Initial Working Capital

6.3.2 Full Pipeline

As discussed in previous chapters, the customers for clean energy technologies will rarely purchase and adopt a technology without an extensive introduction to it. If sufficient potential prospects have not progressed down the sales cycle to become prospects, hot prospects, and purchasers, the time required to accumulate enough adopters to drive revenue for the new venture will be lengthy. Note that when the firms is accelerating its profitability in month 180, it has nearly 15 times the number of hot prospects as it does when it is struggling in month 90.

Figure 6-14 presents the result of a sensitivity analysis of the durations of the various stages in the sales cycle. As per Table 5-6, the Avg Potential Prospect Lifetime is varied between 0.1 and 24 months, and each of Avg Prospect Lifetime, Avg Hot Prospect Lifetime, and Avg Purchaser Lifetime are varied between 0.1 and 12 months. Note that the 50% band is not visible, as most of the runs are with sales cycle durations that are too long and result in bankruptcy. As can be seen, the duration of the sales cycle determines whether the venture will have between zero and over five times the working capital of the base case venture by Year 20.

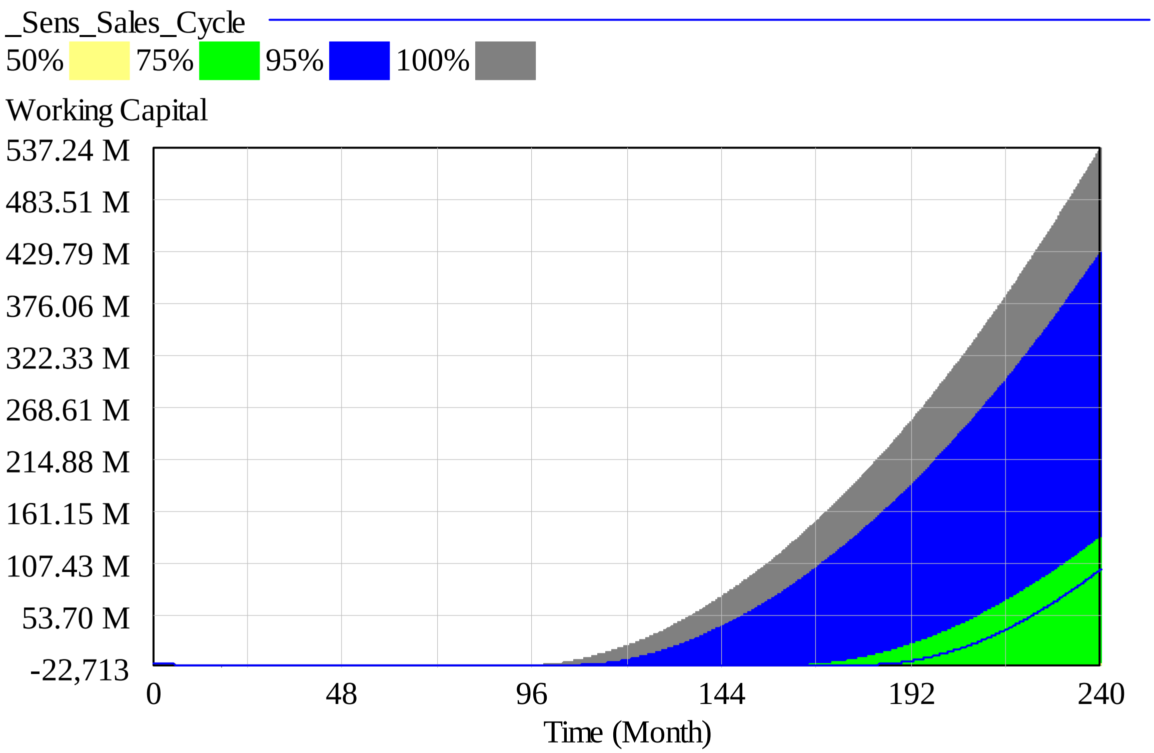

Figure 6-14: Sensitivity Analysis of Sales Cycle Delays

An initial condition that is critical to the pipeline and hence to the success of the venture is the number of initial potential prospects (all of the prospects that start out in the pipeline). Figure 6-15 graphs the line between success[14] and failure based on the number of initial prospects (on a log scale) and the initial investment. Note that a number of initial potential prospects are needed for the venture to succeed, regardless of the initial investment. And if the venture has very large numbers of initial prospects, it can succeed with a much smaller initial investment.

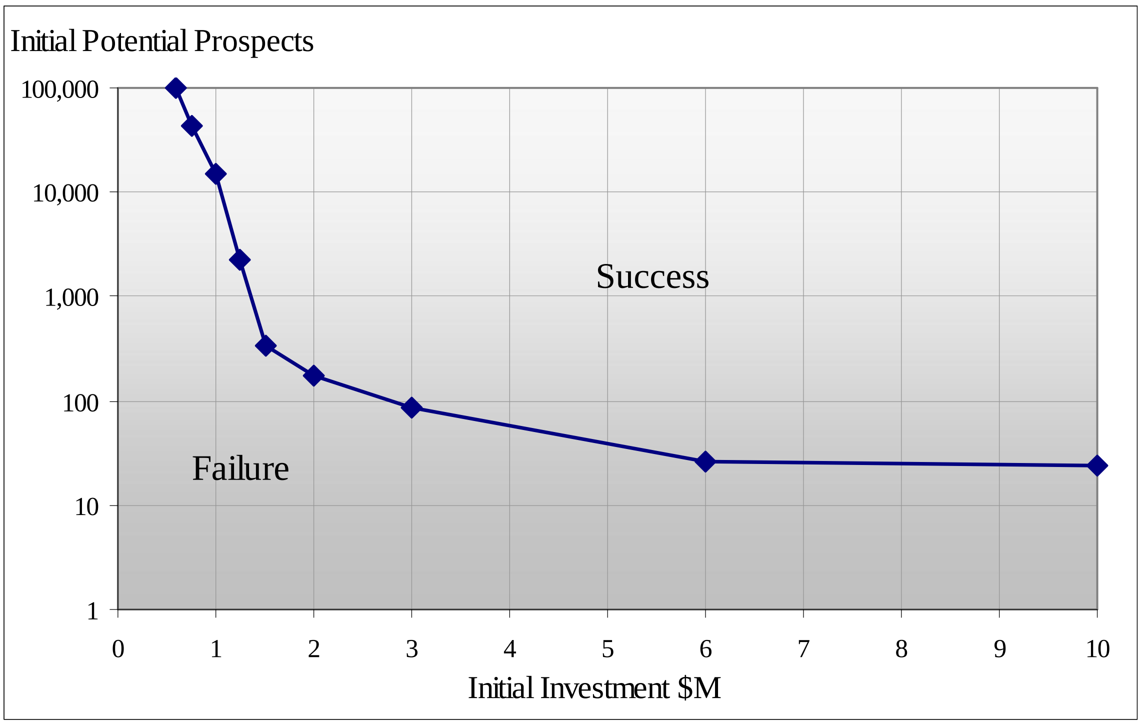

Figure 6-15: Initial Potential Prospects vs. Initial Investment

6.3.3 Feeding the Pipeline with New Firms Capable of Adopting the Technology

Whether or not the new venture's pipeline is full, in order to maintain and increase the number of adopters and the new venture's revenue, new potential prospects have to replace the potential prospects who have become adopters or who have been lost. For that to happen, new firms have to become capable of adopting the new venture's product and the new venture has to be able to access those firms (e.g. the firms have to be in the geographical market the new venture serves).

[14] For the Base Case firm, where success is defined as a positive NPV at Time 0 with a 10% discount rate, and taking into account 20x multiple of monthly cash flow in addition to the value of working capital at Month 240. This is not a perfect measure of success, but is a better measure than lack of bankruptcy.

In short, assuming the market of potential prospects starts relatively small compared to the total population, it needs to grow.

The Initial Capability to Adopt determines the rate at which firms in the general population will become potential prospects. Figure 6-16 presents a sensitivity analysis for a uniform distribution of values of initial capability to adopt between 0 and 100%. Figure 6-17 graphs the line between success and failure based on values of the initial capability to adopt and the initial investment. Note that some capability to adopt is required for the venture to succeed, regardless of the initial investment. With very high percentages of adoption capability, the venture can succeed with a smaller initial investment, and the base case firm can end up with over 100 times the working capital of the base case venture by Year 20.

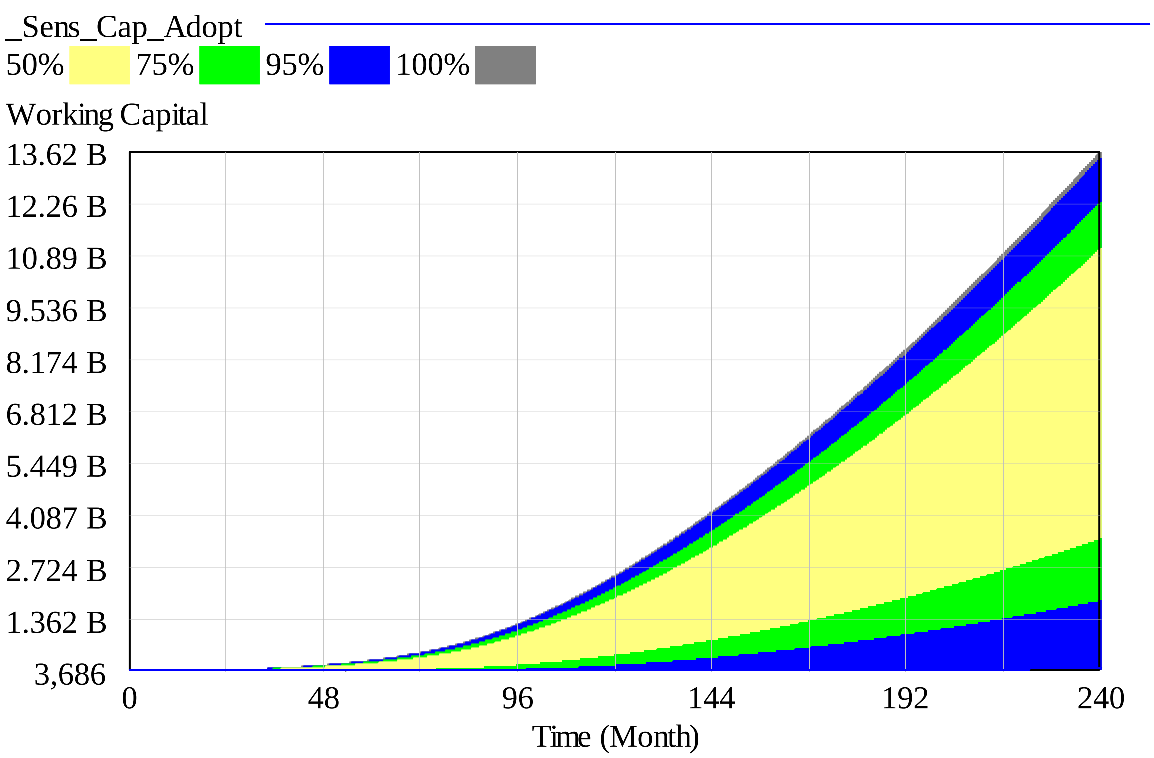

Figure 6-16: Sensitivity to Initial Capability to Adopt

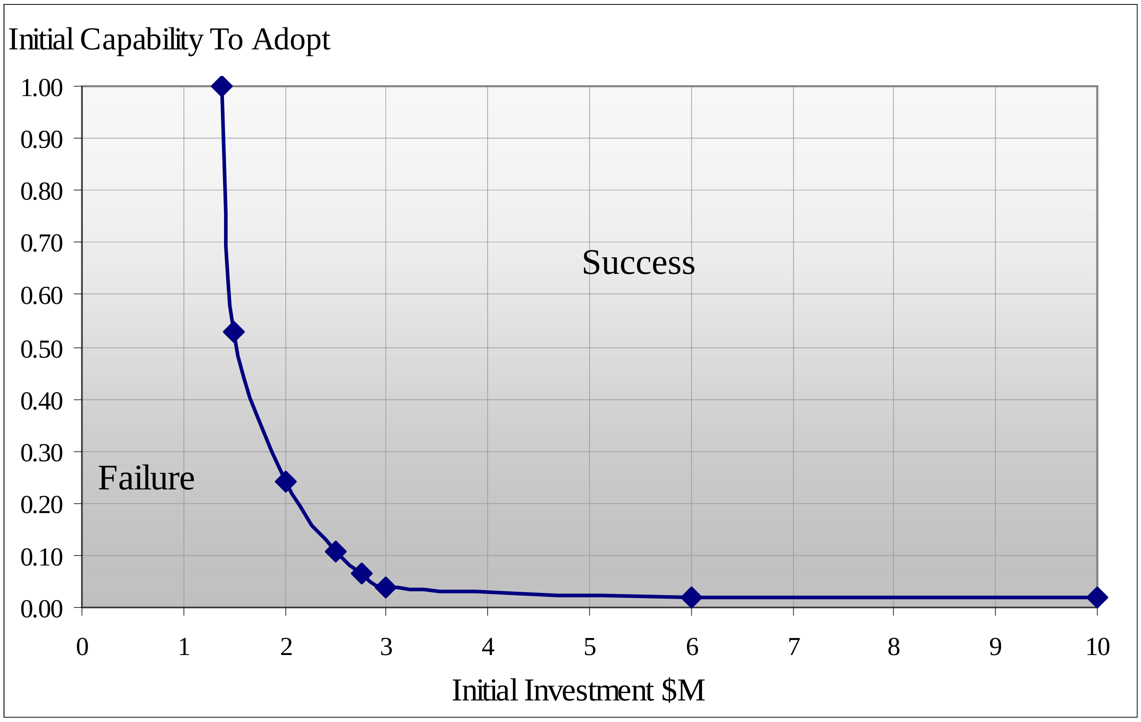

Figure 6-17: Initial Capability to Adopt vs. Initial Investment

6.3.4 Payment of Accounts Receivable

Assuming that there are enough firms adopting the new venture's products, in order for the venture to succeed, it needs to be paid in a reasonably timely fashion. If too many customers default or take too long to pay, the venture may not generate sufficient cash flow to maintain its workforce. For the new venture to emerge from the valley, a steady stream of its customers need to be paying their bills. Furthermore, though the new venture may be tempted to "give away" its product at low cost to grow the market, unlike software companies that have low costs and high margins, energy technology companies generally cannot afford to do this for very long.

Figure 6-18 presents a sensitivity analysis of the average receivable delay and normalized customer financial condition over a uniform distribution of the ranges of values provided for these parameters in Table 5-1. Note that most of the range of values result in bankruptcy (e.g. from customers taking too long to pay), but advantageous values for these parameters result in over triple the baseline working capital at month 240.

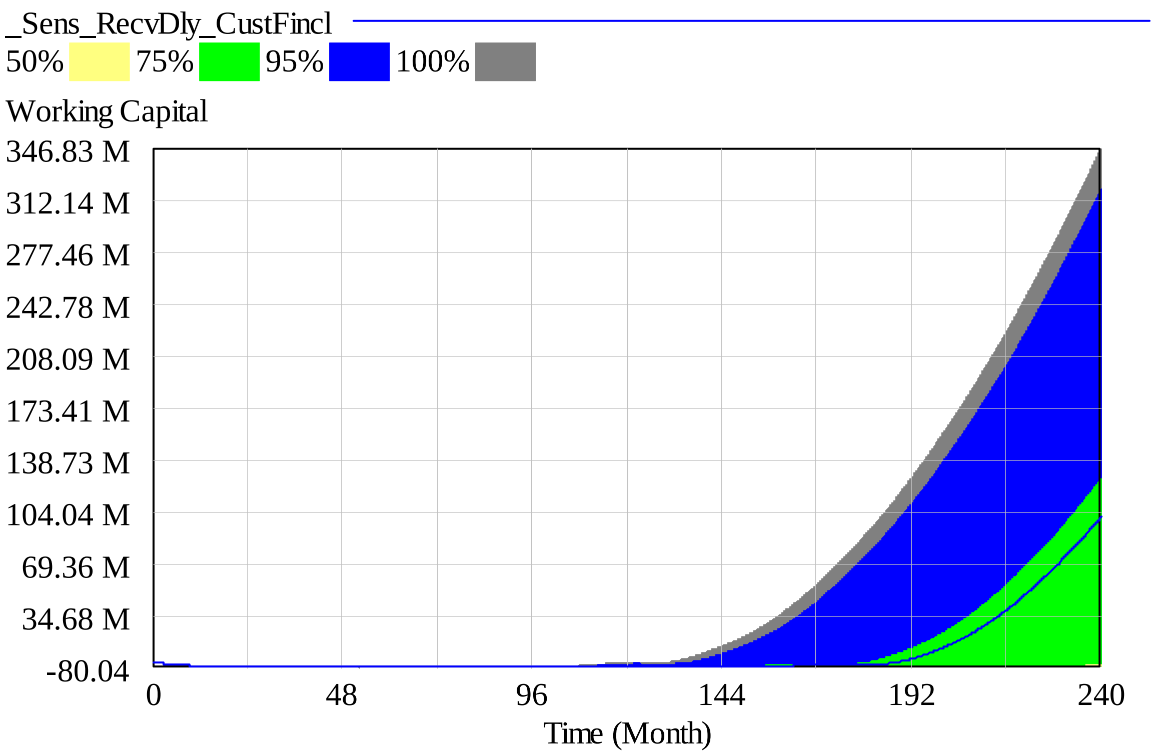

Figure 6-18: Sensitivity Analysis of Accounts Receivable Parameters

6.3.5 Enough Experienced Sales People (but not too many)

Unfortunately, clean energy technology products do not sell themselves. If the new venture does not have enough sales and marketing personnel who are skillful and experienced enough to effectively market to and sell into their target market, then the venture will not escape the valley. The venture should also avoid an overabundance of sales and marketing personnel, as that would put a drag on their cash flow. Figure 6-19 presents a sensitivity analysis of all parameters related to the size and experience of the sales force over a uniform distribution of the ranges of values provided in Table 5-4. Figure 6-20 and Figure 6-21 graph the line between success and failure based on the initial investment and the size of the initial sales force and the initial average sales experience respectively. Note that the firm fails with too few or too many sales people for a range of initial investments.

With too few sales people, the firm is unable to fill the pipeline and build up revenue, and with too many sales people, the firm is unable to afford their salaries. However, with a large proportion of its labor force made up of sales people the venture can succeed with a much smaller initial investment.

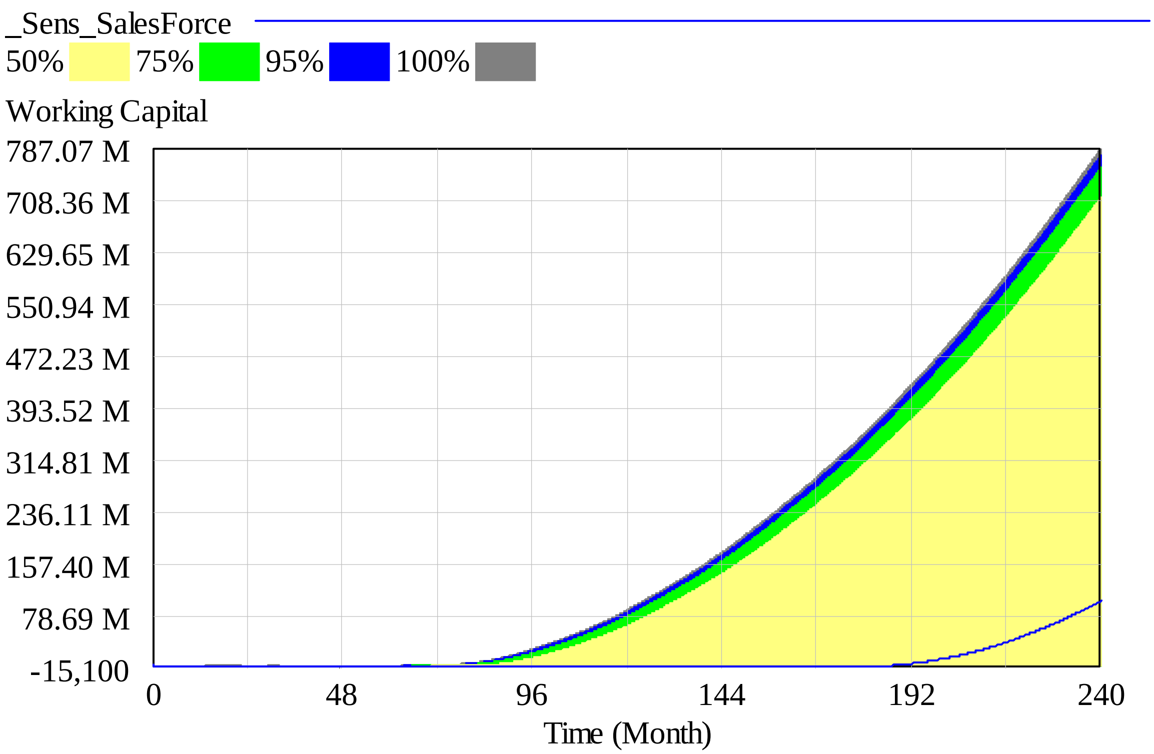

Figure 6-19: Sensitivity Analysis of Sales Force Parameters

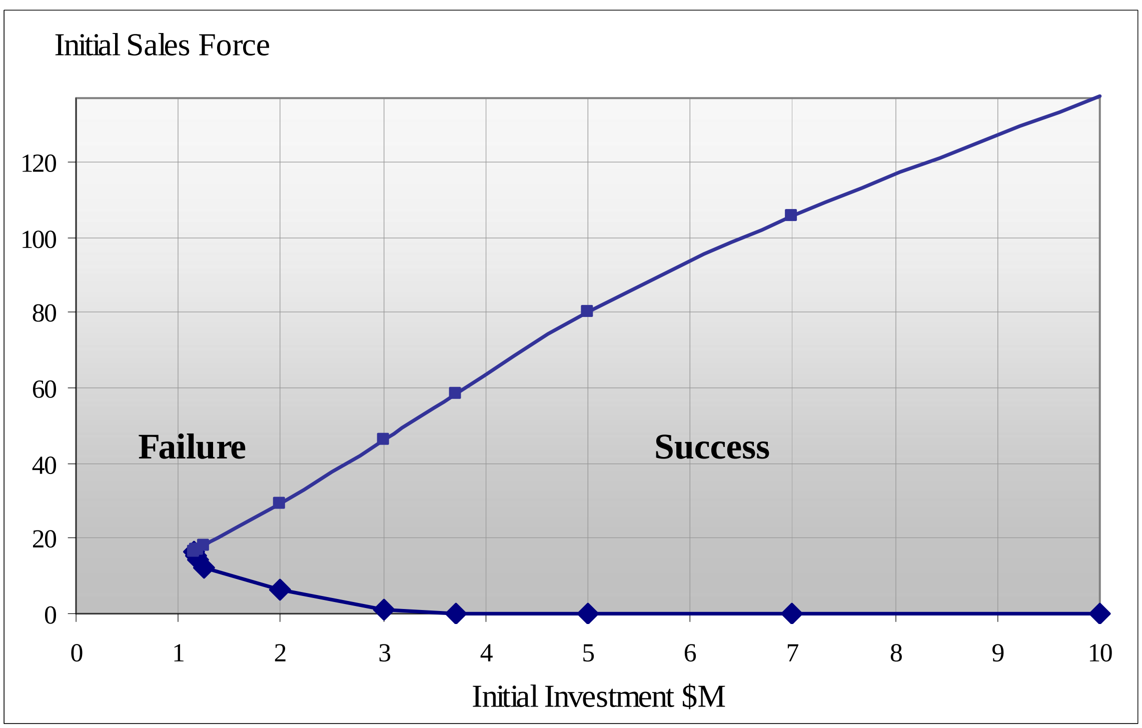

Figure 6-20: Initial Sales Force vs. Initial Investment

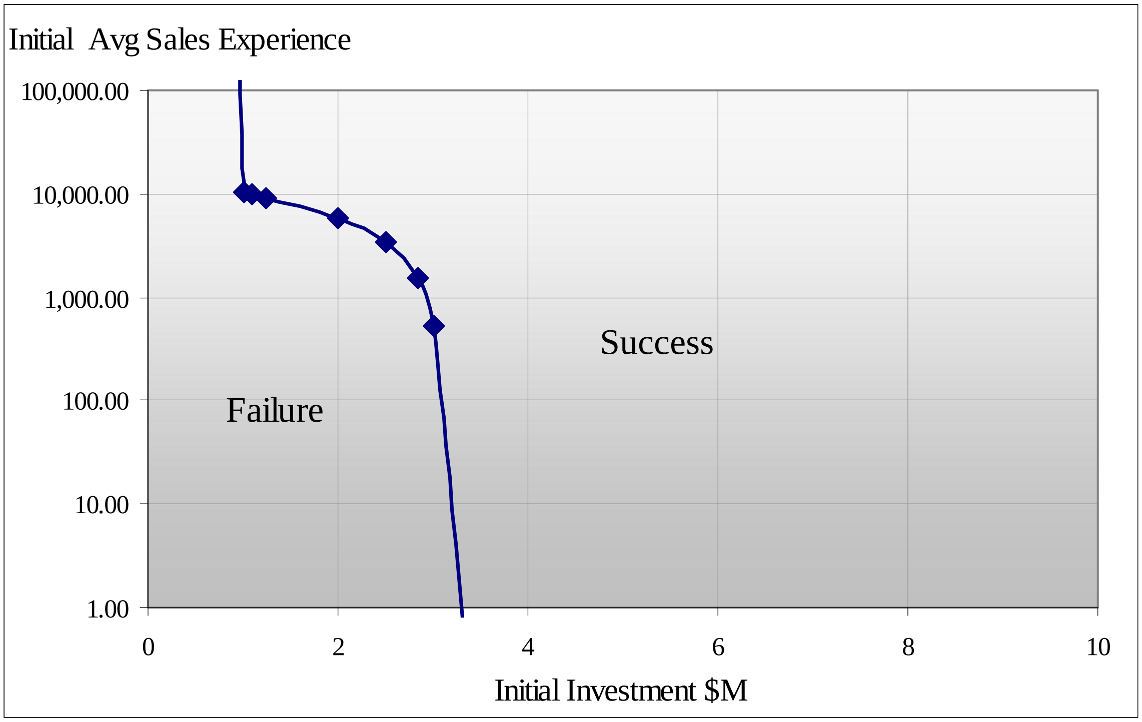

Figure 6-21: Initial Avg Sales Experience (log scale) vs. Initial Investment

6.3.6 Enough Experienced Engineers (but not too many)

Though the new venture may start with a feature advantage, it will still require a skilled and experienced technical staff to provide a high level of support for its products and to develop new features to keep ahead of the competition. Experience is important, as experienced employees are significantly more efficient and therefore are significantly more cost effective to employ. If the staff of the new venture is too inexperienced or too large, the venture may be unable to generate sufficient positive cash flow.

Figure 6-22 presents a sensitivity analysis of all parameters related to the size and experience of the engineering labor force over a uniform distribution of the ranges of values provided in Table 5-3. Note that the 50% and 75% bands are barely visible, meaning that most of the simulation runs result in little to no working capital at month 240. However, for some combination of the engineering-related parameters, the firm can end up with over 10 times the working capital of the base case venture. We will explore in Chapter 7 what can be done to help the firm come closer to this level.

Figure 6-23 and Figure 6-24 graph the line between success and failure based on the initial investment and the size of the initial engineering staff and the initial average engineering experience respectively. Note that the firm fails with too few or too many engineers for smaller initial investments. For the smallest initial investments, the firm will only succeed with approximately one engineer on staff. As the initial investments rises, the number of engineers the venture can initially employ rises linearly. The base case firm fails with a lesser amount of initial average engineering experience, but the firm will succeed regardless of initial engineering experience with higher initial investments. Also, the firm can succeed with a smaller initial investment given sufficiently high engineering experience.

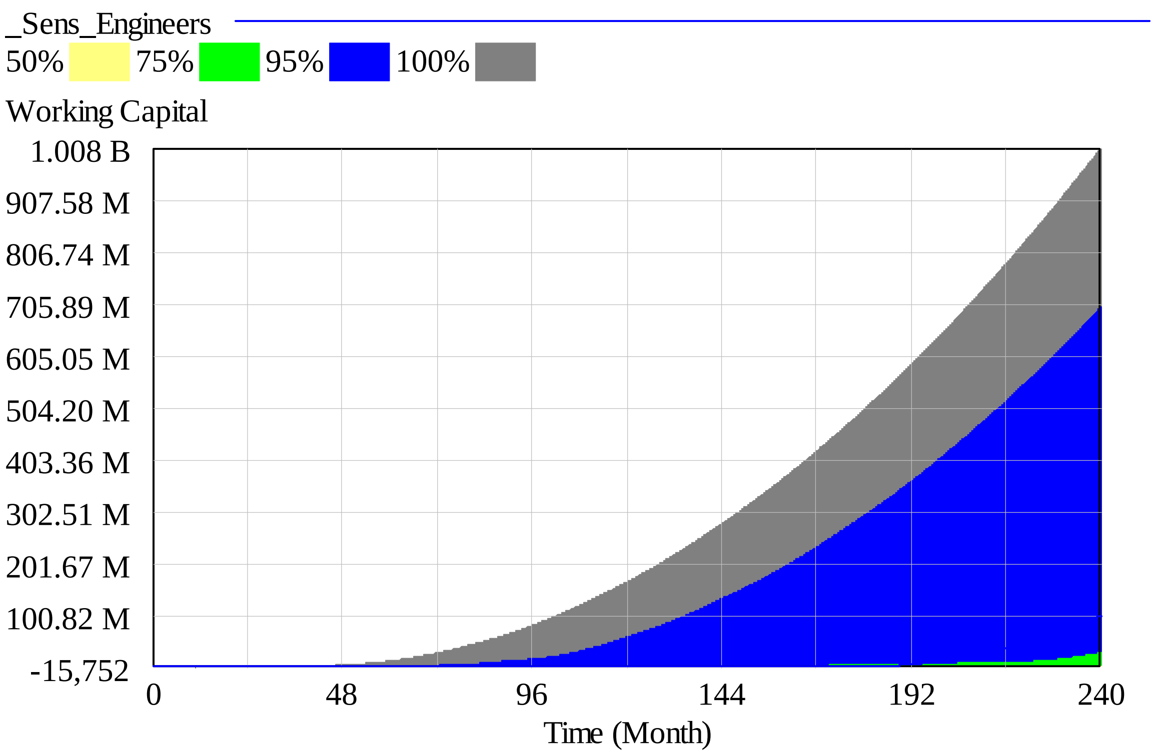

Figure 6-22: Sensitivity Analysis of Engineering Labor Force Parameters

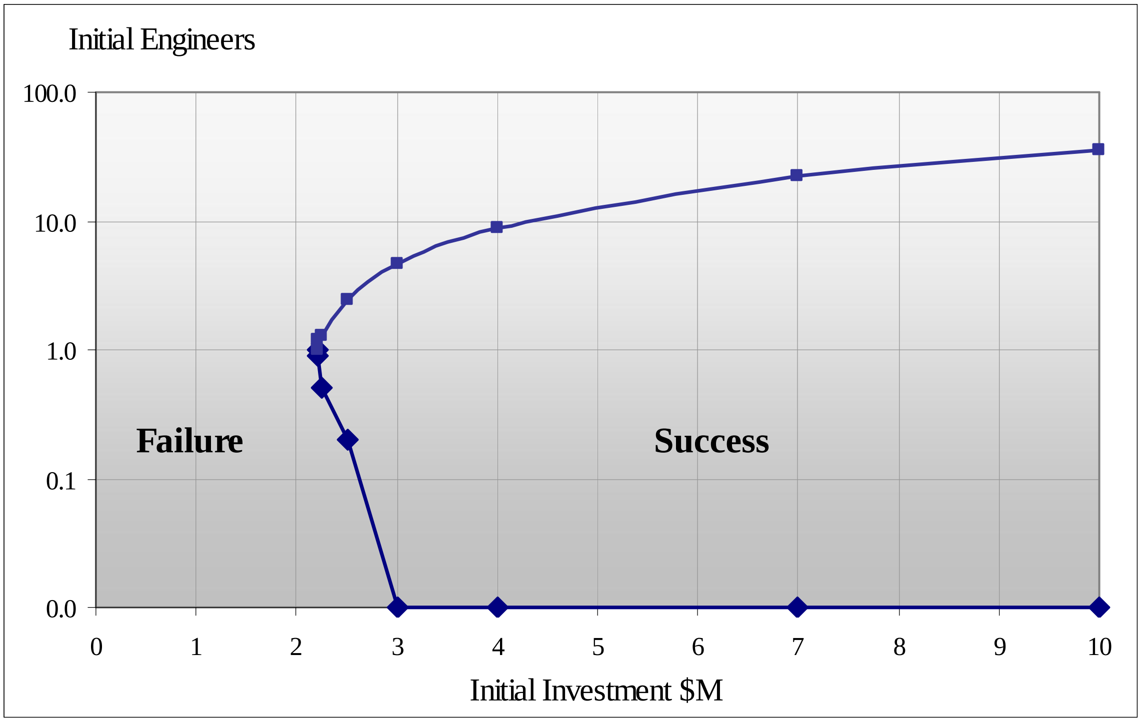

Figure 6-23: Initial Engineers (log scale) vs. Initial Investment

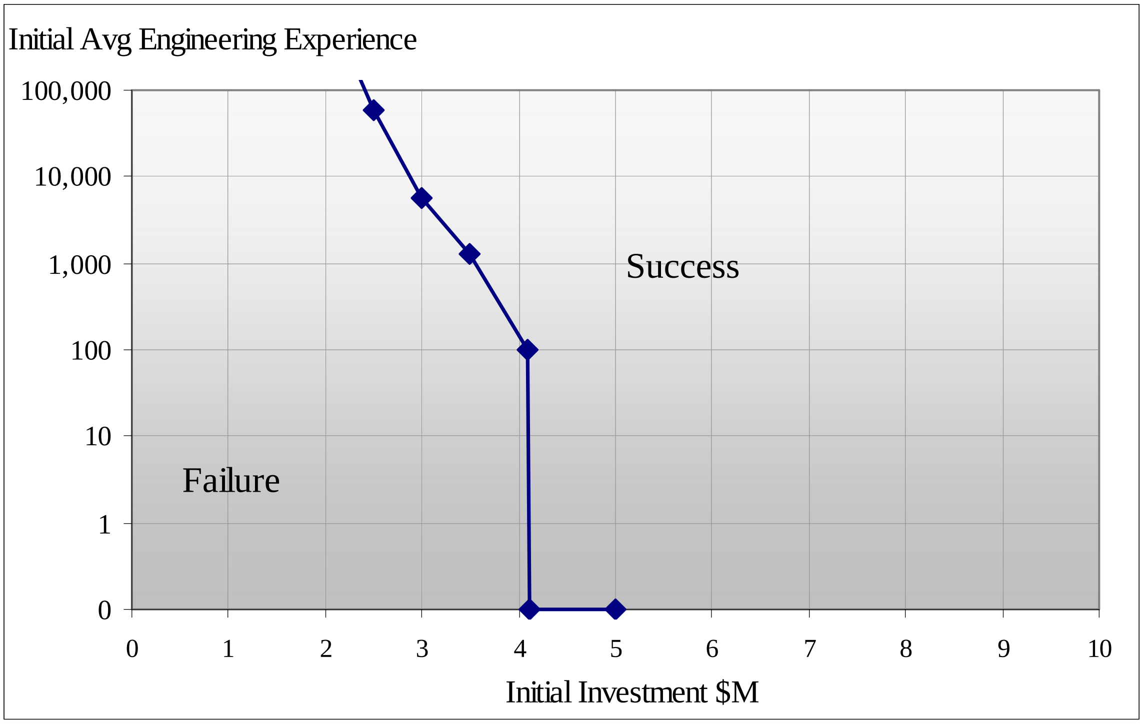

Figure 6-24: Initial Avg Engineering Experience (log scale) vs. Initial Investment

6.3.7 Feature Advantage

In order for potential customers to choose to adopt the new venture's products, they must perceive them to have significant advantages compared to the current solution and to competitive solutions. This is especially true for the conservative customers of clean energy technology products, for whom a small or even medium advantage may not be sufficient to provoke action.

As we saw in Figure 6-11, if the venture does not start with a feature advantage, it will fail. Figure 6-25 illustrates that if a competitor has a non-appropriable feature value of two, the new venture must begin with a non-appropriable feature value of greater than two in order to succeed. Higher non-appropriable feature values enable the venture to succeed with a smaller initial investment. Initial appropriable feature values do not have as large an effect (see Figure 6-26). The venture succeeds with higher initial investments even with no appropriable features. This is because appropriable features can be developed fairly quickly and have less of an impact on customers' purchase decisions.

Figure 6-27 presents a sensitivity analysis of all parameters related to product development for both the venture and its competitors over a uniform distribution of the ranges of values provided in Table 5-2. Note that almost all combinations of values of these parameters result in little to no working capital at month 240 (not even the 95% band is visible). However, a combination of these parameters results in the firm achieving over 15 times the working capital of the base case venture by month 240. This combination is likely a case where the competitor has very few features, and the venture achieves a very high level of features with little effort and is therefore unlikely to occur in reality. However, product development strategies that will optimize the success of the new venture under realistic conditions will be discussed in Chapter 7.

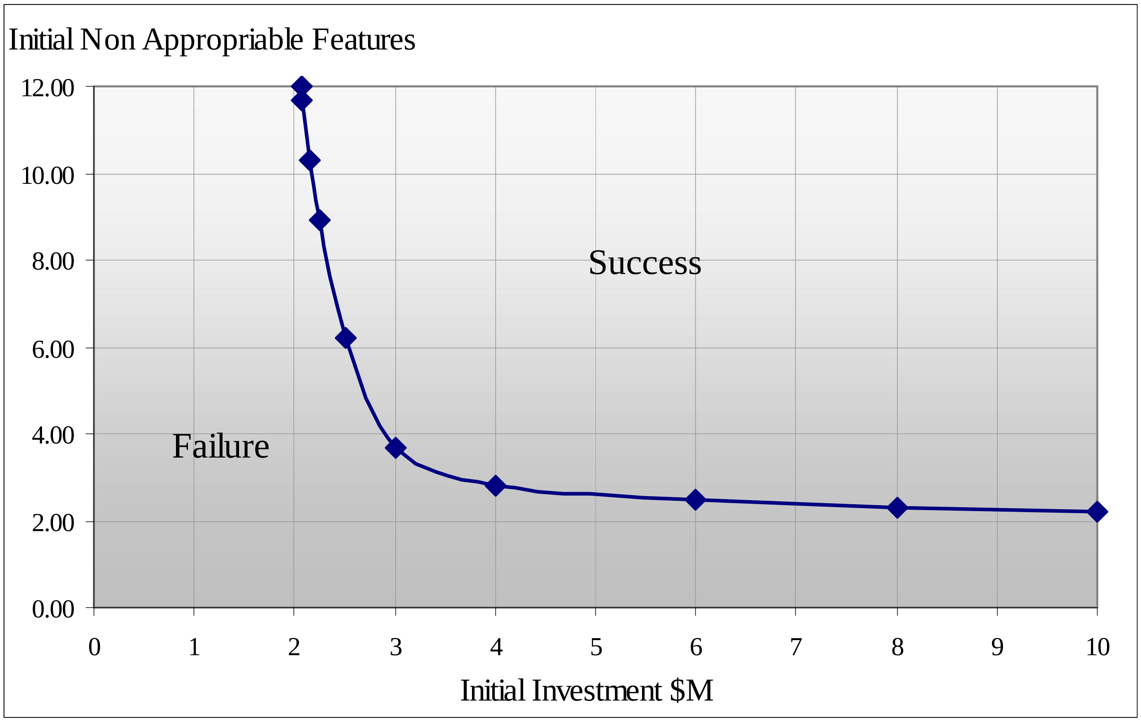

Figure 6-25: Non-Appropriable Features vs. Initial Investment

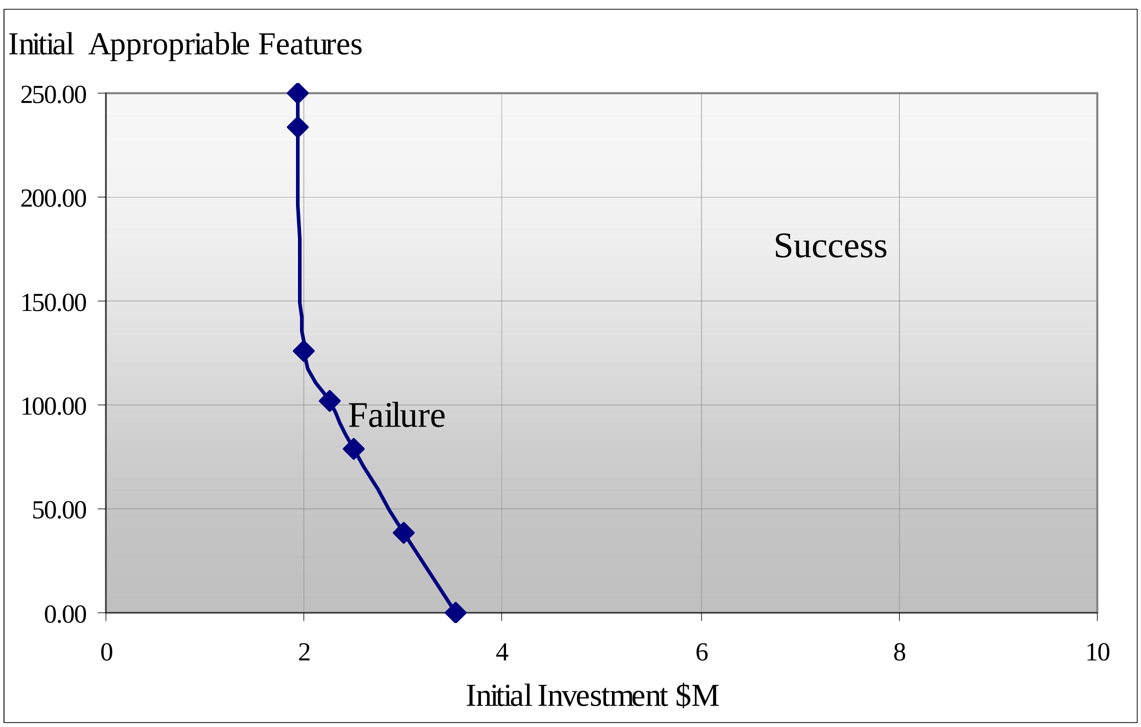

Figure 6-26: Appropriable Features vs. Initial Investment

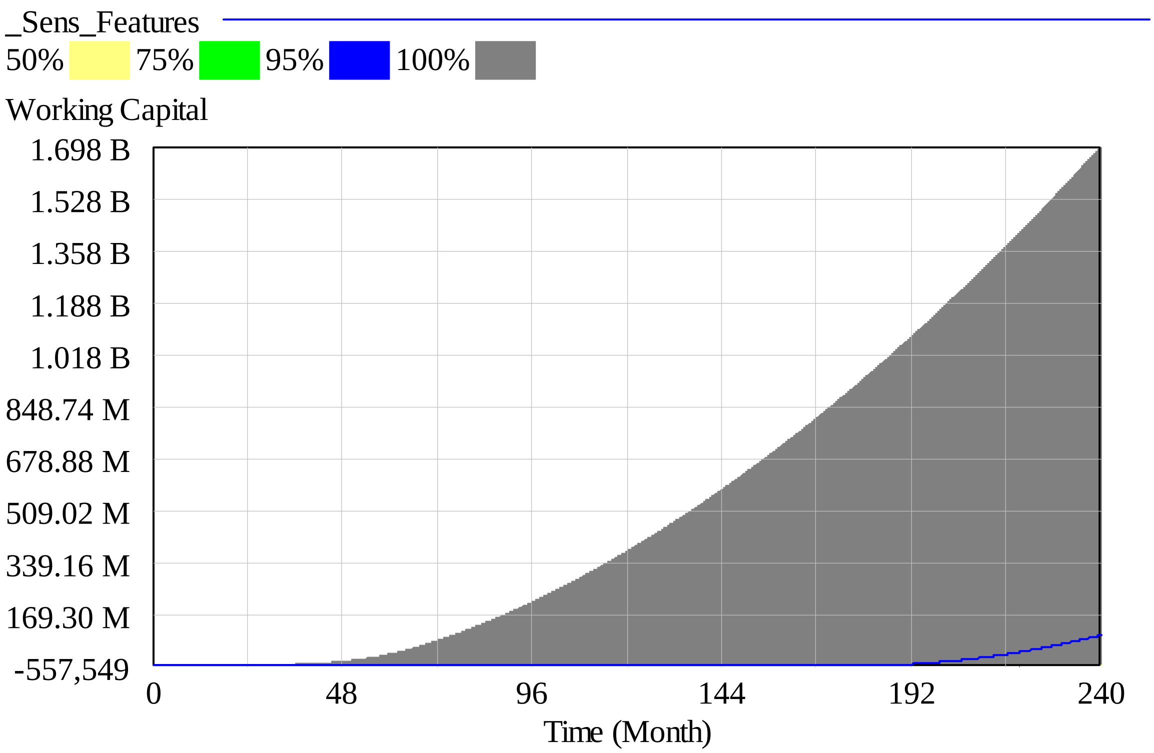

Figure 6-27: Sensitivity Analysis of Product Development Parameters

6.3.8 Price Advantage

Customers always consider a feature advantage in the context of price. Absent a compelling reason for the customer to adopt the product (such as a regulation compelling them to adopt, or if the product meets an essential function for which there is no substitute), customers compare the price of the new product to competitive solutions, and strongly take into account the payback period (how long it will take for the advantages of the product to pay back its initial cost) and their return on investment for purchasing the product. A firm with strong brand recognition may be able to justify a higher price than its competition, but new ventures rarely have that advantage.

Figure 6-28 shows the sensitivity of the model to price parameters over a uniform distribution of the ranges of the parameters provided in Table 5-8. There is tremendous variability in the response, as over 75% of the simulation runs end in bankruptcy.

One simulation run results in working capital of over $14B by Month 240. If the venture has an order of magnitude advantage or more in cost to produce the product and is able to extract most of that difference as margin, given the feature advantage it starts with, the venture should become very profitable. However, this is not a realistic scenario, given the market forces that would address such a pricing imbalance, and given limits to growth of a new venture.

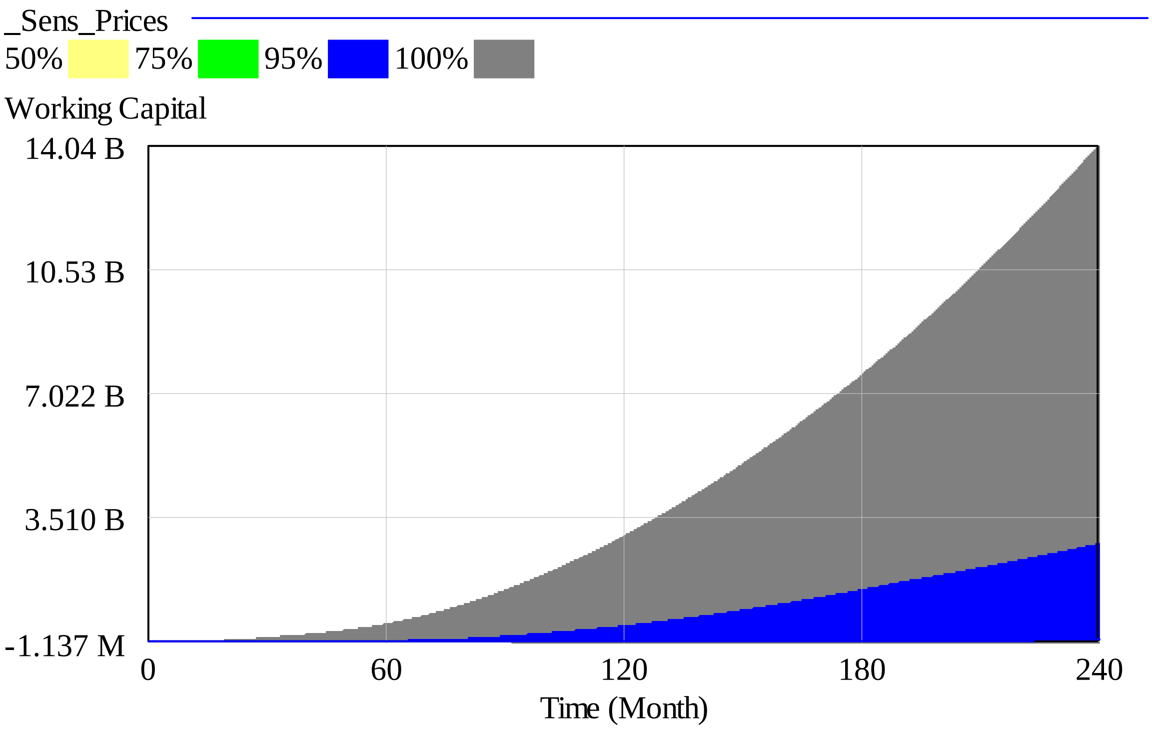

Figure 6-28: Sensitivity to Price Parameters

6.3.9 Positive Word of Mouth

Regardless of price or feature advantage, conservative customers often will not consider a new technology or product unless their peers have tried it and recommend it. For a clean energy technology venture to overcome this barrier, the venture must convince initial customers to trial the product and make sure the trials go extremely well. In this way, it may it may be possible to get some initial adopters and then build positive word of mouth from their experience. It is critical, in this strategy, that there be no justification for negative word of mouth. In a relatively small community of conservative customers, negative reactions could kill the prospects for the product and perhaps for the entire new venture.

Figure 6-29 presents the sensitivity analysis for the word of mouth parameters (contact rate and word of mouth reference) over a uniform distribution of the ranges provided in Table 5-6. As can be seen, for certain values of these parameters, the venture will fail, but for most values the firm will end up with between ~$150M and $450M at month 240.

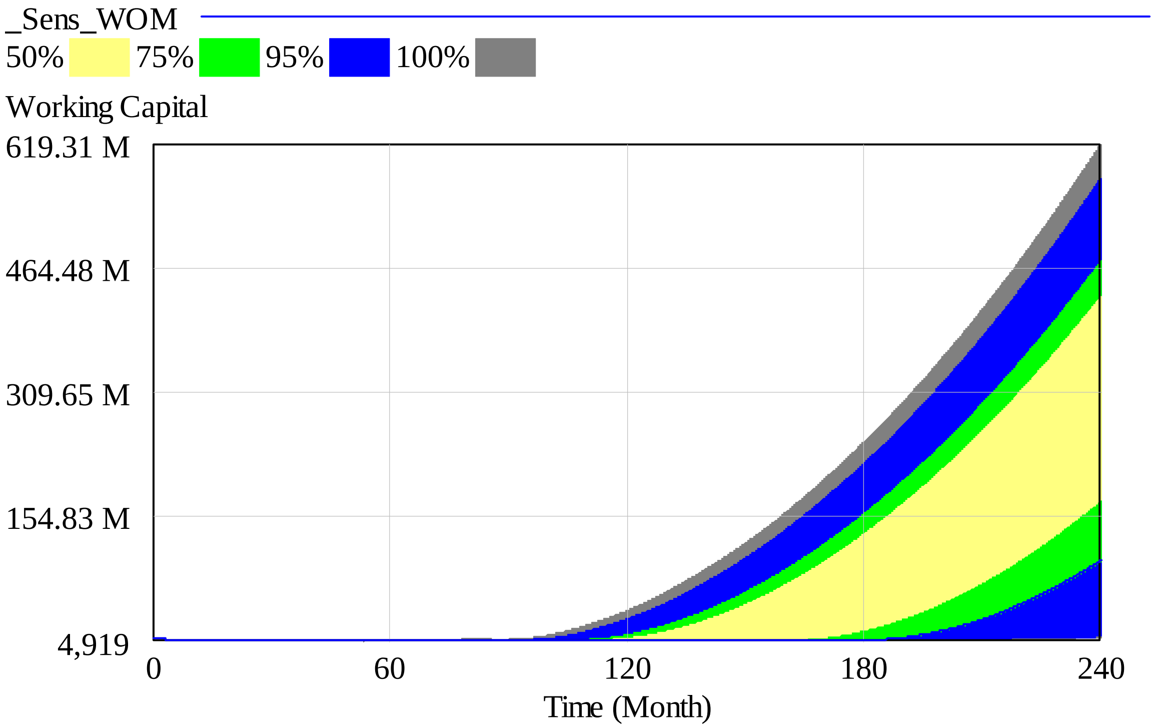

Figure 6-29: Sensitivity to Word of Mouth Parameters

6.3.10 Summary of Factors

Note that for each of these sectors of analysis, the "valley of death" is evident on the sensitivity analysis graphs. This demonstrates that optimal conditions in one area alone (whether it is price, features, sales cycle delays, etc.) will not be enough to avoid the valley. As described in the introduction to this section, it takes a combination of factors to emerge from the valley.

Table 6-5 summarizes the month 240 results of the sensitivity analyses. As can be seen, each of these analyses contains some (and usually most) scenarios in which failure is near certain. This follows from intuition since the base case firm has an 88% cumulative probability of failure, so setting any important parameters to values that make it more difficult for the firm to succeed are likely to result in failure. Also note that, with the exception of very favorable pricing, even the most favorable conditions for each sector result in at least a 30% chance of failure. On the positive side, favorable parameter values result in at least 3.5 times the baseline working capital.

	Min Working Capital	Low end of 50% band	High end of 50% band	Max Working Capital	Min Cum Prob Failure	Low end of 50% band	Low end of 50% band	Max Cum Prob Failure
Baseline	$100	$100	$100	$100	88%	88%	88%	88%
Initial Investment	$0	$106	$689	$717	56%	60%	87%	100%
Sales Cycle	$0	$0	$2	$537	35%	88%	100%	100%
Init Capab to Adopt	$0	$3,500	$11,000	$1,362	30%	32%	56%	100%
Receivables	$0	$0	$1.40	$347	87%	95%	100%	100%
SalesForce	$0	$0	$708	$787	30%	45%	100%	100%
Engineers	$0	$0	$0.065	$1,000	32%	100%	100%	100%
Features	$0	$0	$0.002	$1,698	48%	100%	100%	100%
Price	$0	$0	$0	$14,000	2%	100%	100%	100%
Word of Mouth	$3	$170	$425	$619	53%	77%	87%	95%

Table 6-5: Summary of Month 240 Results of Sensitivity Analyses ($M)

In addition to the essential factors discussed here, there are likely to be others that are important for the success of clean energy technology ventures in particular instances. Because it is not possible for a new venture to start with all of these attributes in place (in particular, having a full pipeline; having the requisite experience selling and working with the product and technology; and having earned positive word of mouth), it is important that the venture develop these attributes as quickly as possible. In the next chapter we will explore strategies the entrepreneurs and investors may employ to do so.

6.4 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. U.S. government policies currently provide substantial subsidies to the fossil fuel industries, and present 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:

6.4.1 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 emitted by humankind). 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 U.S. 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 in order to impose a cost. 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.

(89) Competitor Price = (Initial Competitor Cost Per Unit *
Competitor Cost Adjustment Fraction Due To Policy) / (1-Competitor Margin)

(90) Competitor Cost Adjustment Fraction Due To Policy = 1 +
(Carbon Policy Switch *
RAMP(Carbon Policy Effect on Comp Cost / Carbon Policy Ramp Time,
Carbon Policy Start Time, (Carbon Policy Start Time + Carbon Policy Ramp Time)))

As per Table 6-6, the default Carbon Policy Effect on Comp Cost is 20%, and is implemented over a period of 10 months starting at time 0. Sensitivity analysis is performed on these parameters below. The Carbon Policy Switch is used to turn the effects of the carbon policy on (1) or off (0) in the model.

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.

6.4.2 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).[15] The result of this policy is to lower the cost of providing the clean energy technology, enabling higher profits for the firm without raising the price to the consumer.

(91) Cost Adjustment Fraction Due To Policy = 1 +
(Subsidy Policy Switch *
RAMP(Subsidy Policy Effect on Cost/Subsidy Policy Ramp Time,
Subsidy Policy Start Time, (Subsidy Policy Start Time + Subsidy Policy Ramp Time)))

As per Table 6-6, the default Subsidy Policy Effect on Cost is -20%, and is implemented over a period of 10 months starting at time 0. Sensitivity analysis is performed on these parameters below. The Subsidy Policy Switch is used to turn the effects of the subsidy policy on (1) or off (0) in the model.

6.4.3 Increasing Adoption Capability

The final classes of policies are those policies that 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. And examples of regulatory incentives are ones that provide tax breaks for companies that implement energy efficiency measures, or tax credits for the development of 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.

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

(92) Increase Of Capab Of Firms To Adopt Due To Policy = Increase Adoption Capab Switch * RAMP(Increase of Adoption Capab/Adoption Capab Increase Ramp Time, Adoption Capab Increase Start Time, (Adoption Capab Increase Start Time + Adoption Capab Increase Ramp Time))

As per Table 6-6, the default Increase of Adoption Capab is 5%, and is implemented over a period of 3 months starting at time 0. Sensitivity analysis is performed on these parameters below. The Increase Adoption Capab Switch is used to turn the effects of the policy on (1) or off (0) in the model.

Parameter	Value	Units	Min	Max
Carbon Policy Switch	0	Dimensionless		
Carbon Policy Effect on Comp Cost	0.2	Dimensionless	0.01	10
Carbon Policy Start Time	0	Months	0	120
Carbon Policy Ramp Time	10	Months	0.01	240
Subsidy Policy Switch	0	Dimensionless		
Subsidy Policy Effect on Cost	-0.2	Dimensionless	-0.9	0
Subsidy Policy Start Time	0	Months	0	120
Subsidy Policy Ramp Time	10	Months	0.001	240
Increase Adoption Capab Switch	0	Dimensionless		
Increase of Adoption Capab	0.05	Dimensionless	0.001	0.95
Adoption Capab Increase Start Time	0	Months	0	120
Adoption Capab Increase Ramp Time	3	Months	0.01	240

Table 6-6: Policy Parameters

6.4.4 Effects of Policies

The following figures assume all the baseline parameter values, with a $3M initial investment and no follow on investments. Figure 6-30 illustrates a comparison of three policies: a carbon policy that causes competing solutions to be 20% more expensive than the base case; a subsidy policy that reduces production costs for the new venture by 20%; and a policy that enables 5% more firms to become capable of adopting the product. Note that the carbon policy and the 5% increase in adoption capability have nearly the same effectiveness. Figure 6-31, Figure 6-32, and Figure 6-33 show sensitivity analyses of each of the policies performed over a uniform distribution of the ranges of values in Table 6-6. Note that the maximum effectiveness of the carbon policy is the greatest, followed by the increased adoption policy, and finally by the subsidy policy.

Figure 6-34 demonstrates the effect on working capital of implementing all three policies together, and Figure 6-35 presents the effect on probability of failure. Note that each of the policies in isolation reduce the probability of failure by approximately a third, and all three policies together reduce the probability of failure by about half..

Figure 6-36 presents a multivariate sensitivity analysis of all the policy parameters, and Table 6-7 presents a summary of the sensitivity analyses. These show the potential synergistic effect of implementing these policies together. Their effectiveness together has the potential to be far greater than their individual effects combined.

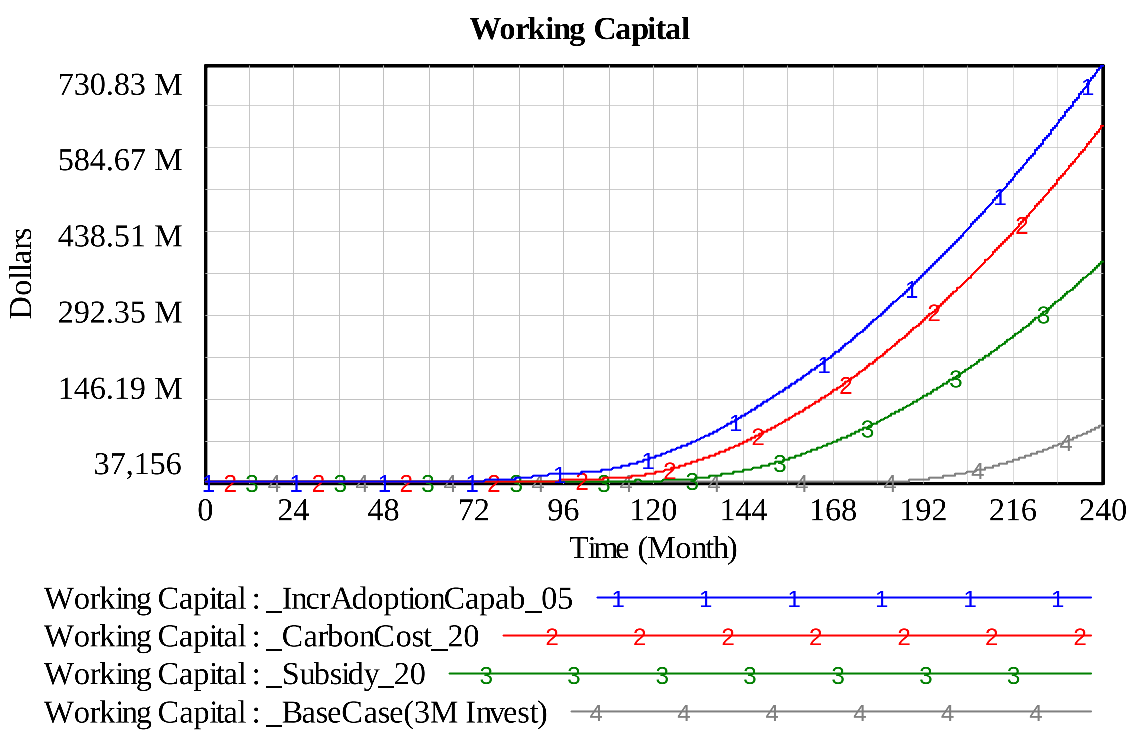

Figure 6-30: Comparison of Policies

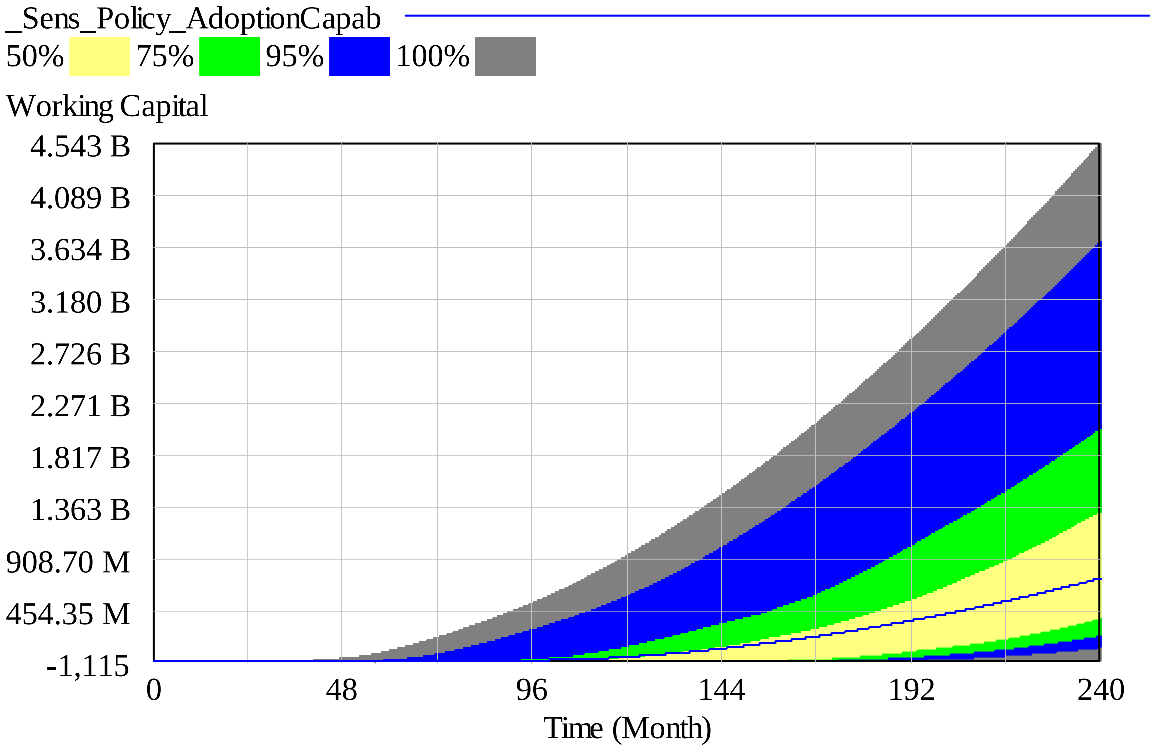

Figure 6-31: Sensitivity Analysis of Policy to Increase Adoption Capability

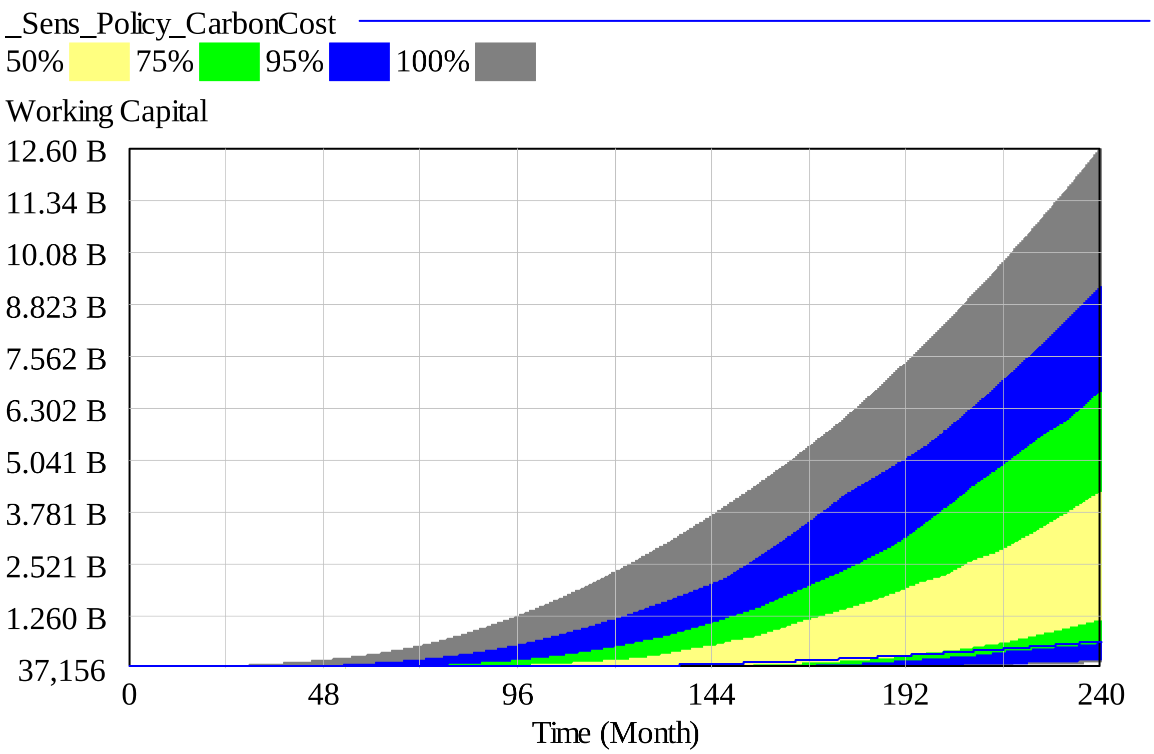

Figure 6-32: Sensitivity Analysis of Policy to Increase Cost of Carbon

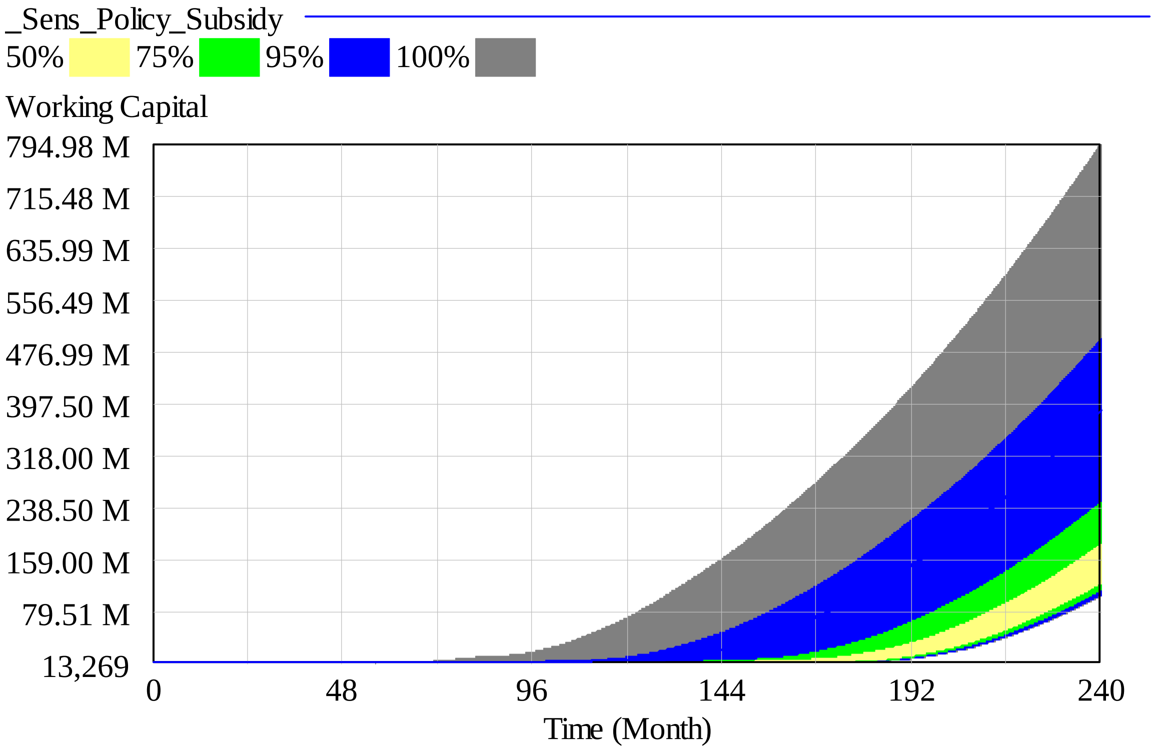

Figure 6-33: Sensitivity Analysis of Policy to Subsidize Costs

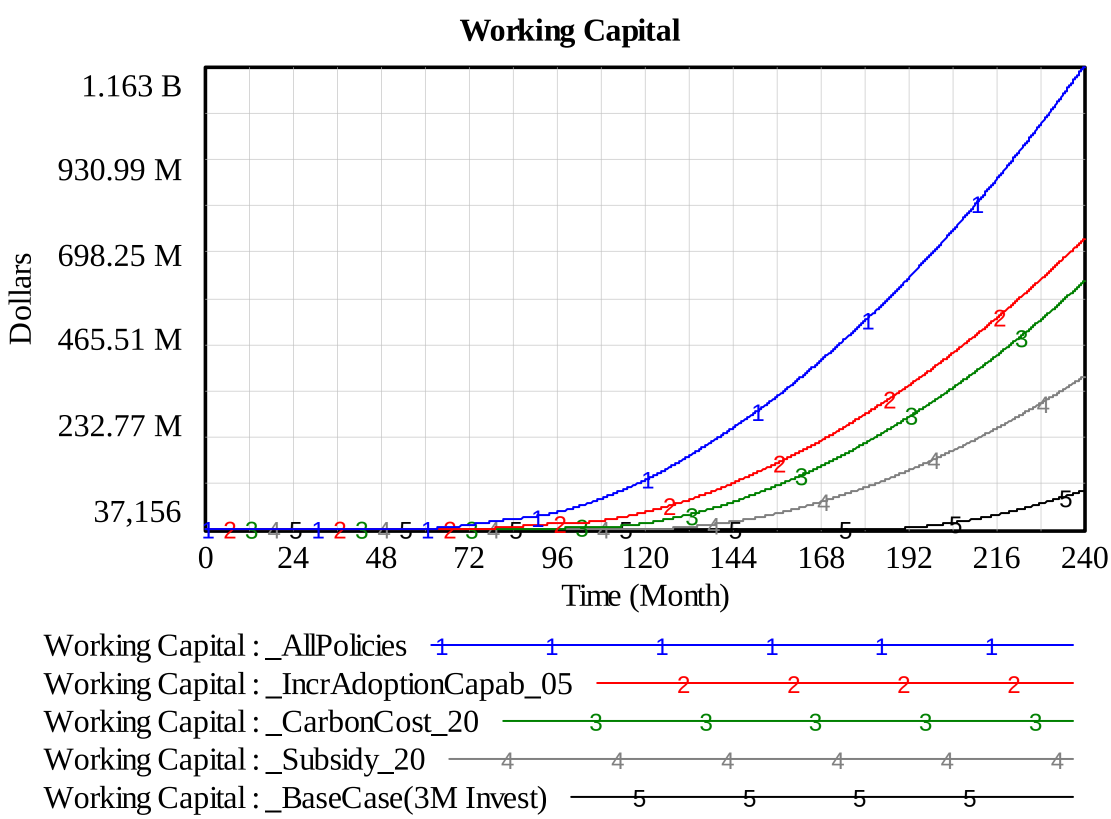

Figure 6-34: Effect of All Policies Implemented Together

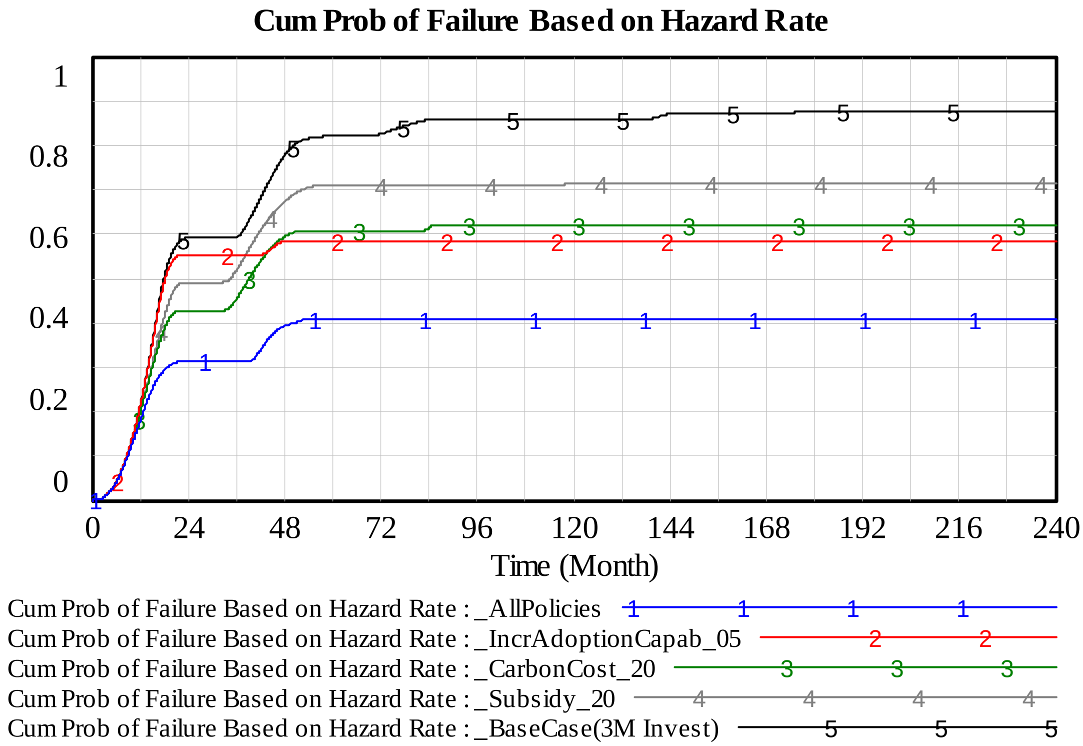

Figure 6-35: Probability of Failure with Policies

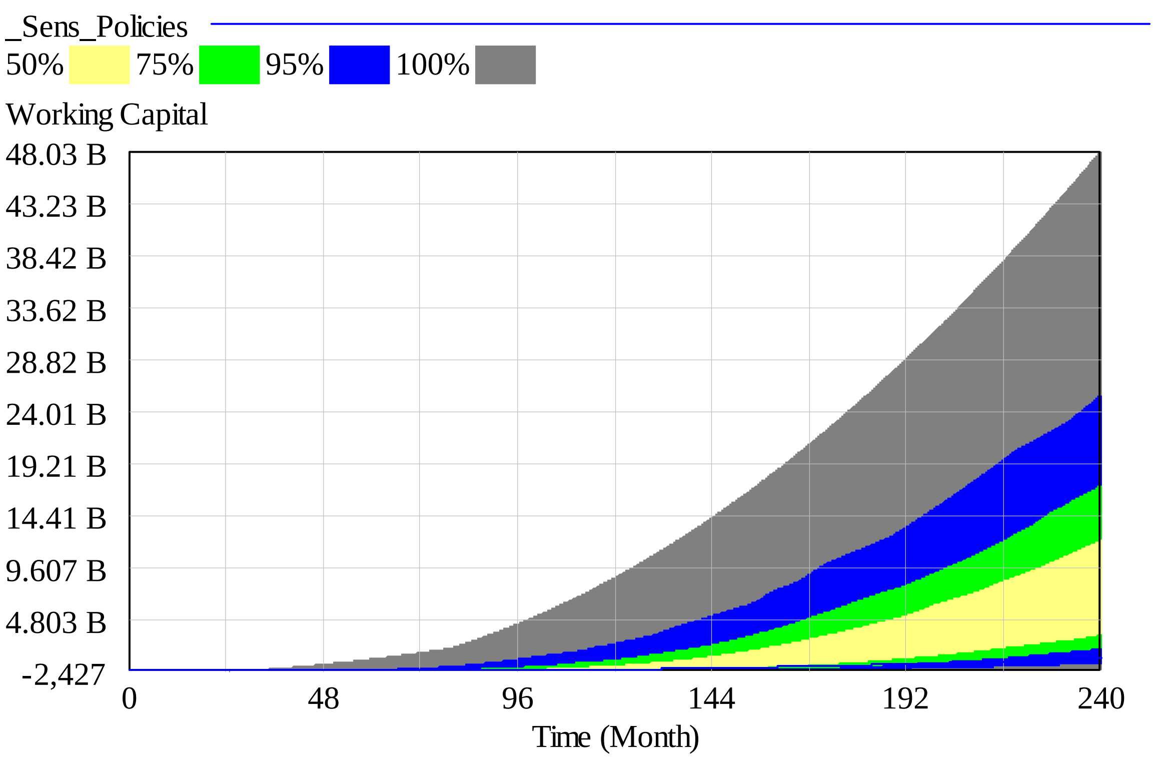

Figure 6-36: Sensitivity Analysis of Combined Effect of Policies

	Min Working Capital	Low end of 50% band	High end of 50% band	Max Working Capital	Min Cum Prob Failure	Low end of 50% band	High end of 50% band	Max Cum Prob Failure
Policy to Incr Capab to Adopt	$112	$377	$1,315	$4,543	50%	80%	86%	100%
Policy to Incr Carbon Cost	$105	$1,100	$4,266	$1,260	9%	72%	86%	87%
Policy to provide Subsidy	$101	$120	$180	$795	40%	84%	87%	90%
All Policies	$256	$3,400	$12,000	$48,000	5.00%	67%	83%	100%

Table 6-7: Summary of Month 240 Results of Policy Sensitivity Analyses

6.4.5 New Competition Brought on by Policies

The above scenarios assume that the clean energy technology venture is competing only with companies that offer fossil-fuel-based solutions. But what if the creation of these policies causes competitors to offer non-fossil-fuel-based solutions that compete with the new venture? There would be two principal competing effects:

- The price advantages to the new venture created by the policy may be negated or even reversed as larger, more capable firms enter the market.
- The market may expand as the new competitors market the new technology and increase the total number of potential prospects for the product.

If the new venture does not have a significant non-appropriable feature advantage compared to the new competitors, under this scenario it may be doomed if its price advantage erodes and competitors have as good or better brand recognition. In this case, though the policies may have the intended effect of encouraging the development and adoption of clean energy technologies, the new venture may not share in that success.

However, if the venture does have a significant non-appropriable feature advantage (or established brand), the entrance of competitors may help the firm by feeding its pipeline with a larger market of potential prospects (assuming that the market is in an early stage and not close to saturation). Given the time delays inherent in developing non-appropriable features that are attractive to the market, and in establishing positive word of mouth, the new venture will have a significant competitive advantage if it is far ahead of competitors along these dimensions. This suggests that it may be advantageous for clean energy technology ventures to enter the market in advance of the implementation of favorable policies in order to establish an early lead.

6.4.6 Why the "Free Market" May Not Be Sufficient

Another question that may be posed is why government intervention should be necessary if a technology is truly advantageous. Won't the free market decide? The first answer to this question is that the market for energy products and services has never been truly free of government intervention. Fossil fuel exploration and development, and the security of its supply, has been heavily subsidized by governments (Lillis et al., 1999). So, for a new energy service to compete on a level playing field, either government support for fossil-fuel-based solutions has to be diminished, or an equivalent amount of support has to be provided for the new technology.

Furthermore, it is often in society's interest for governments to support the development and commercialization of beneficial new technologies that otherwise would take too long (or are too expensive) for the market to develop on its own. For example, the Internet started as a government research project. It is unlikely that the current level of the benefits the Internet has brought to the U.S. economy would have occurred without the initial government support.

Because the nation's current energy infrastructure has been shaped by government policies, it is reasonable that government policies should be used to accelerate beneficial innovations including those needed to address climate issues. A strong case can be made that the government should play a very active role in creating policies that will spur the development of clean energy technologies and the growth of new clean energy technology ventures.

6.5 Sources of Danger: Oscillatory and Exponential Growth

As can be seen in Figure 6-2 and Figure 6-8, when the venture succeeds, some oscillation occurs in the working capital before it grows at an exponential rate. Both of these behaviors are sources of danger: downturns in the oscillatory growth may be mistaken as signs of failure, and exponential growth may not be sustainable.

6.5.1 Oscillatory Growth

The oscillatory growth of working capital is more evident in Figure 6-37. What causes working capital to fall several times after it starts to grow? As can be seen in Figure 6-38, several factors may cause working capital to fall once it begins to rise.

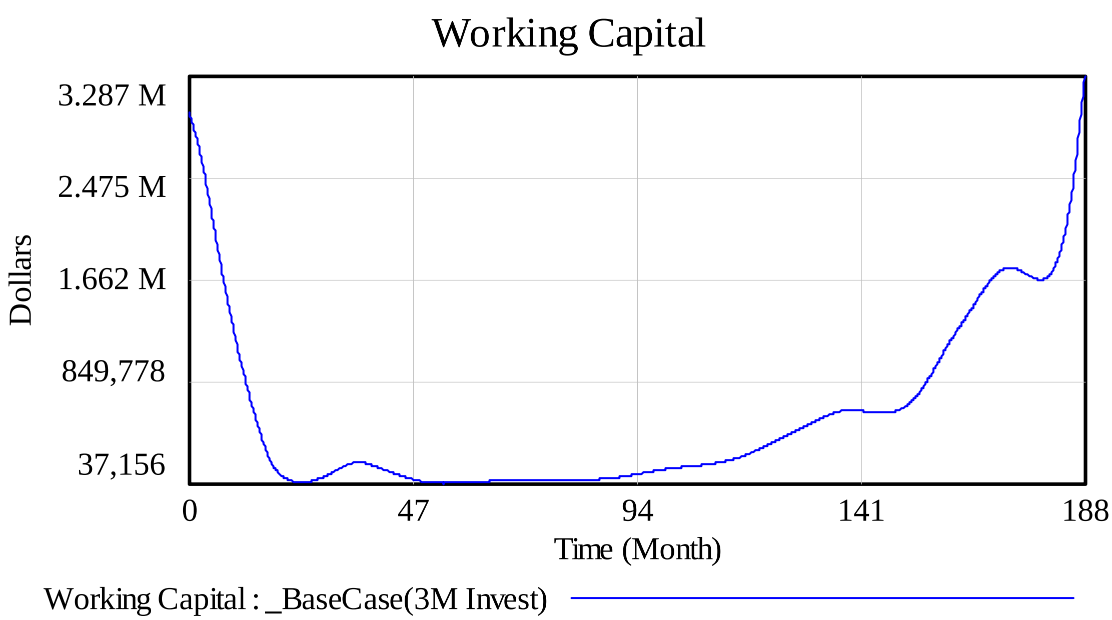

Figure 6-37: Oscillatory Growth of Working Capital

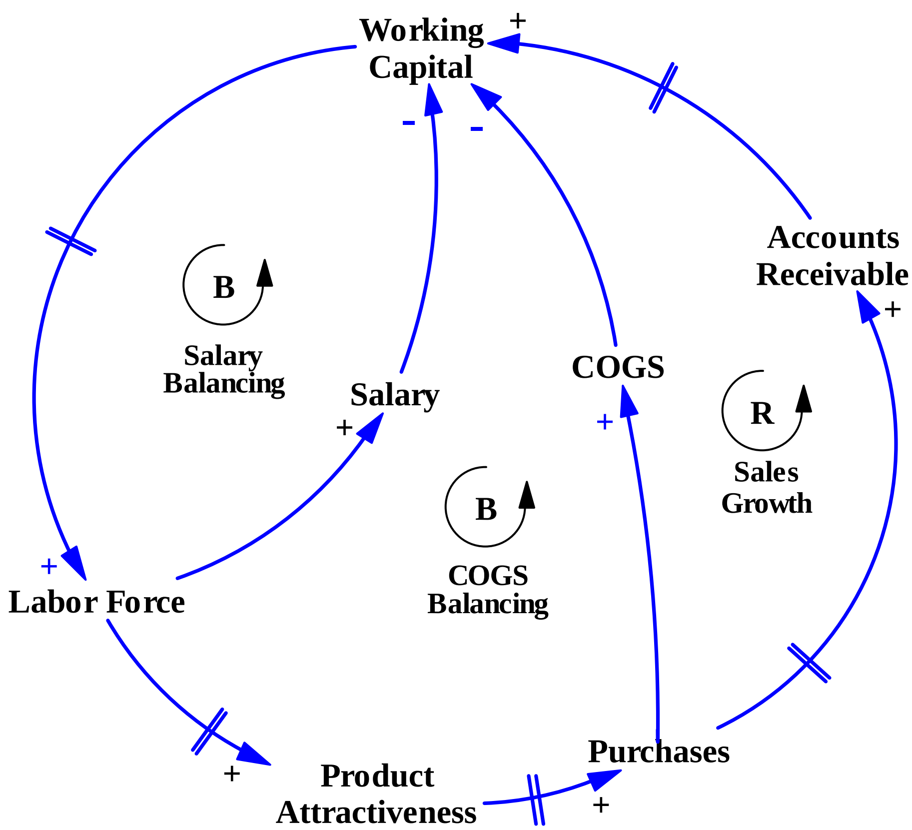

Figure 6-38: Loops that Cause Oscillatory Growth

The first is due to salary expense. As working capital increases, the venture is able to hire more personnel. Though these workers will eventually be able to make the product more attractive and therefore generate more sales and working capital, their salaries are, at first, a drain on working capital.

The second is due to the cost of goods sold. When customers order products from the venture, the venture must incur the costs of producing and delivering them. The venture then bills the customer. Only after a delay proportional to the average receivable delay does the venture receive the payment that increases its working capital.

In some cases, as employees' efforts pay off and bills are paid, the reinforcing loop of sales growth dominates, causing exponential growth, but only after a few downturns caused by the balancing loops. The downturns can be eliminated by weakening the balancing loops and strengthening the reinforcing loop. If we extend the time it takes to increase the labor force after working capital increases, we weaken all the loops, as increases in working capital have less immediate effect. This can be achieved by increasing the Engineer Adjustment Time and the Sales Force Adjustment Time. Decreasing the time it takes to receive cash from purchases by decreasing the Avg Receivable Delay will strengthen the sales growth reinforcing loop.

These actions combine to create the behavior in Figure 6-39, with the parameter values provided in Table 6-8. Note that the oscillations have been dampened. Lowering the receivable delay improves the performance of the venture, and increasing the labor adjustment time (particularly for the sales force) hurts the performance of the venture, and the result is slightly better performance than the base case venture, as it escapes the valley of death at month 172 as opposed to month 188.

Conversely, increasing the receivable delay and decreasing the sales force adjustment time exacerbates the oscillations. Figure 6-40 compares the increased oscillations to the base case results, and Table 6-9 presents the parameter values necessary to cause the increased oscillations.

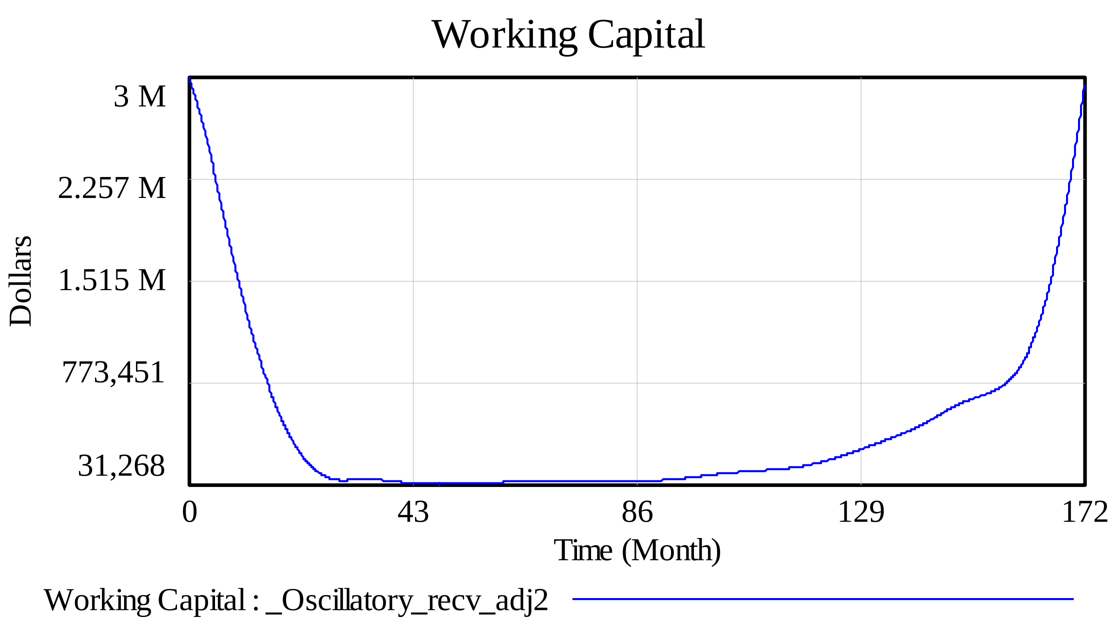

Figure 6-39: Growth Of Working Capital with Oscillation Dampened

Avg Receivable Delay	0.1
Engineers Adjustment Time	120
Sales Force Adjustment Time	120

Table 6-8: Parameter Values to Dampen Oscillation

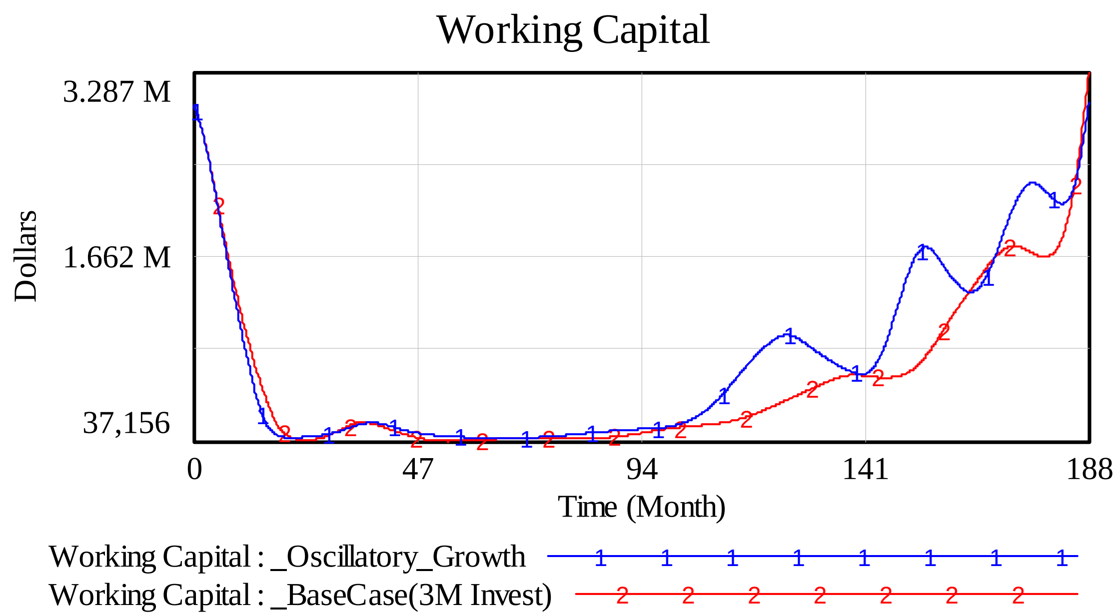

Figure 6-40: Growth Of Working Capital with Oscillation Exacerbated

Avg Receivable Delay	4.2
Engineers Adjustment Time	6
Sales Force Adjustment Time	0.5

Table 6-9: Parameter Values to Exacerbate Oscillation

The parameter values in Table 6-8 are not realistic; in real life, the venture is likely to go through some oscillatory growth. In fact, the parameter values in Table 6-9 and therefore the exacerbated oscillations shown in Figure 6-40 are much more feasible. In any case, it is helpful to understand the reasons behind this phenomenon, and how slower hiring and shorter receivable delays may dampen the oscillations.

6.5.2 Exponential Growth

As most of the figures in this chapter show, once working capital begins to rise, it follows a roughly exponential arc. The positive loops of additional working capital enabling additional resources and experience lead to better product development and sales that contribute additional working capital. Furthermore, the more engineers and sales people are working for the firm, the more experience they gain in aggregate, and the more effective they become at developing and selling their products. See Figure 6-41 for a simplified depiction of these positive loops.

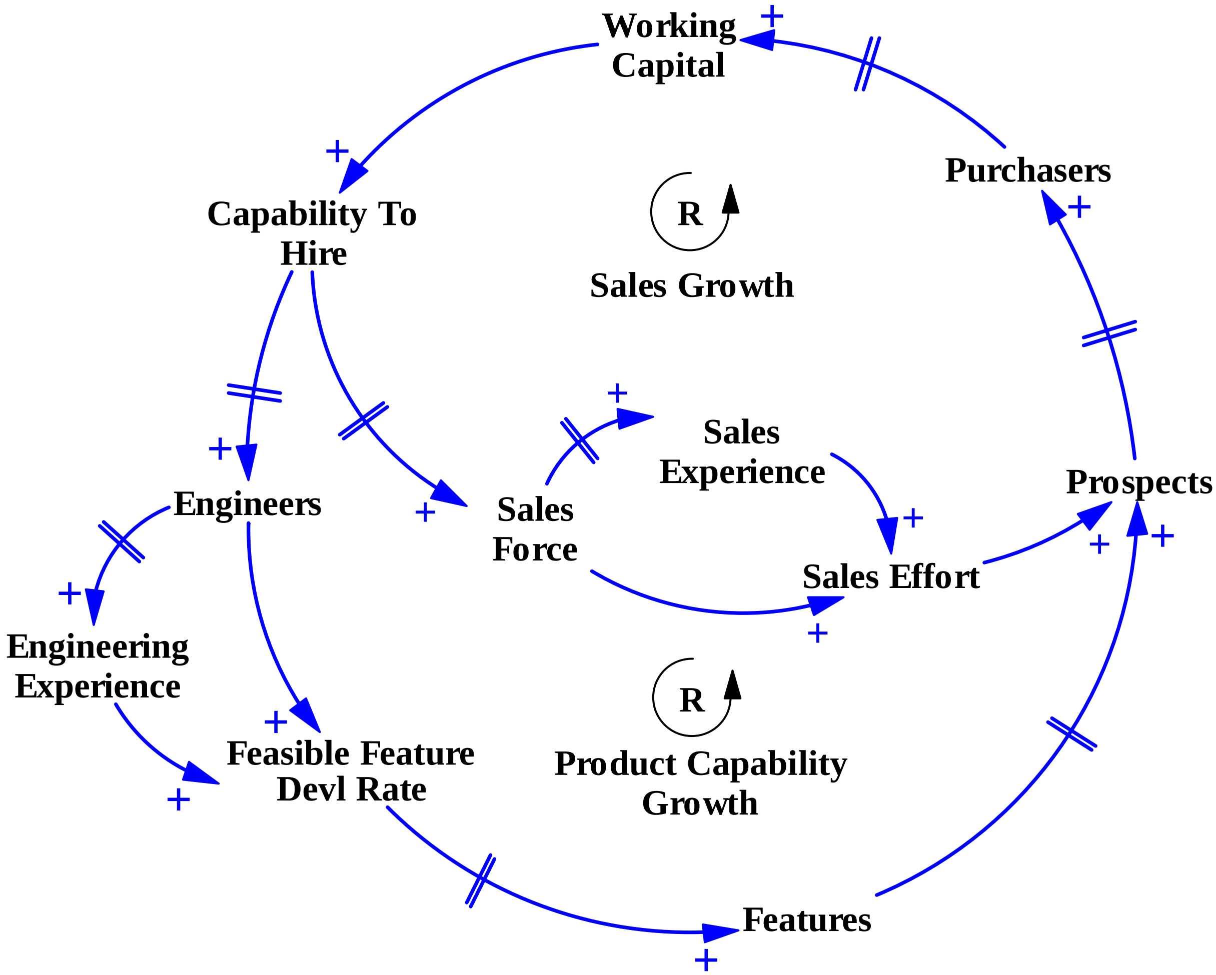

Figure 6-41: Positive Loop Diagrams

Of course, once any firm reaches a period of exponential growth, it may encounter many dangers. These include, but are not limited to:

- Obtaining more customers than the firm is able to service well, leading to loss of customers and a poor reputation (see Sterman 1988);
- Being unable to hire and train enough well qualified engineers and sales people, and therefore lowering the productivity of the firm;
- Inspiring competition to poach experienced employees, thereby increasing the cost of labor (to reduce poaching) and enabling competitors to catch up more quickly;
- Inspiring new competitors to enter the market and existing competitors to step up production, leading to pressure to reduce prices (and therefore reduce profitability); and

- Saturating one or more segments of the market (for example, early adopters), and enduring a period of time when sales growth is unsustainable but costs remain high.

Since the purpose of our model is primarily to determine whether an early stage clean energy technology firm can achieve exponential growth, and not what it should do once it gets there, these scenarios, though important to acknowledge, are outside the scope of this model and research. Furthermore, these scenarios have been studied before (Oliva et al., 2003).

6.6 The Investment Market

An important question is how important the state of the investment market is for clean energy technology ventures. As mentioned previously, venture and other early stage investments move in cycles. The factors that control these cycles (the state of public markets, capital availability, experience of venture and early stage investors) are exogenous to the model, but the level of investment has a significant impact on the results.

Table 6-10 and Figure 6-42 shows investment returns at 5, 10, 15, and 20 years for the base case venture with initial investments ranging from $3M to $100M. (The base case initial investment, $3M, is close to the smallest investment that will enable the base case company to survive.) The investment returns are calculated as the annual IRR of the initial $3M investment over the given period of time, with the capital at the end of the period being the sum of the working capital of the venture and five times annualized positive cash flow. These returns are not necessarily indicative of the actual returns an investor would receive given that the model does not contain enough detail to accurately value a business. However, the differences between the returns for various levels of investment, and the patterns of the returns over time can provide us with meaningful insights. Note that most returns are negative after five years (due to the valley of death), but other than the $3M base case, returns are positive after ten years.

	60	120	180	240
3M Invest	-42.8%	-7.4%	0.4%	25.7%
3.5M_Invest	-15.8%	29.3%	36.2%	31.3%
4M_Invest	**10.5%**	39.4%	**37.2%**	**31.6%**
5M_Invest	-7.3%	**41.4%**	36.6%	30.8%
10M_Invest	-10.1%	37.0%	31.9%	27.1%
50M_Invest	-13.1%	19.3%	19.5%	17.8%
100M_Invest	-16.3%	13.1%	14.7%	14.0%

Table 6-10: Investment Returns by Initial Investment and Month

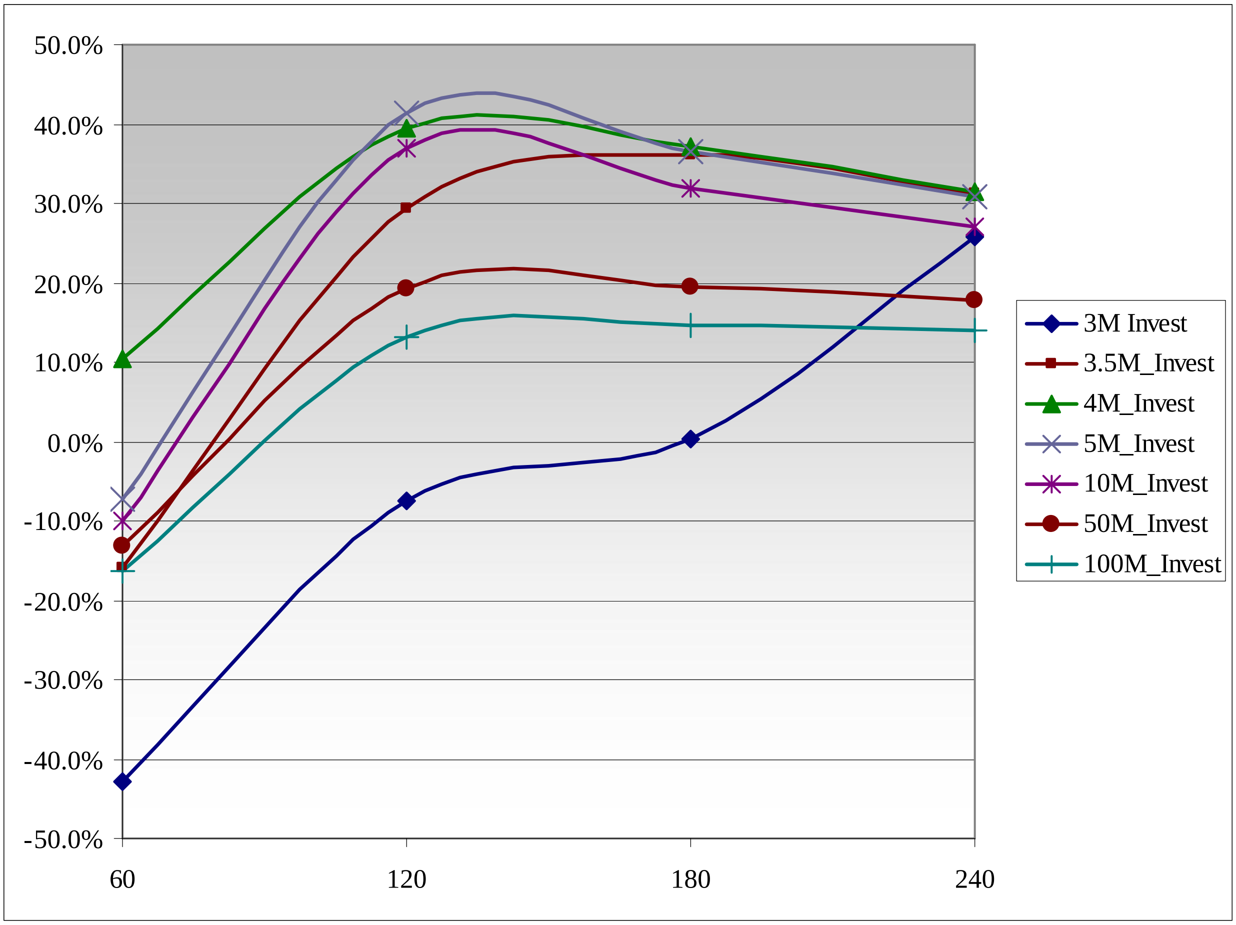

Figure 6-42: Investment Returns by Initial Investment

The additional $500,000 investment between $3M and $3.5M makes a significant difference in investment returns. Figure 6-43 shows the month 60, 120, 180 and 240 returns with the initial investment along the x-axis. The best returns are for initial investments between $3.5M and $5M. This pattern indicates that up to a point providing the venture with greater initial capital makes a very large difference in performance, but that it is not in the interest of the investor to invest significantly more capital than is necessary. Note that returns generally go down the higher the initial investment rises above $5M.

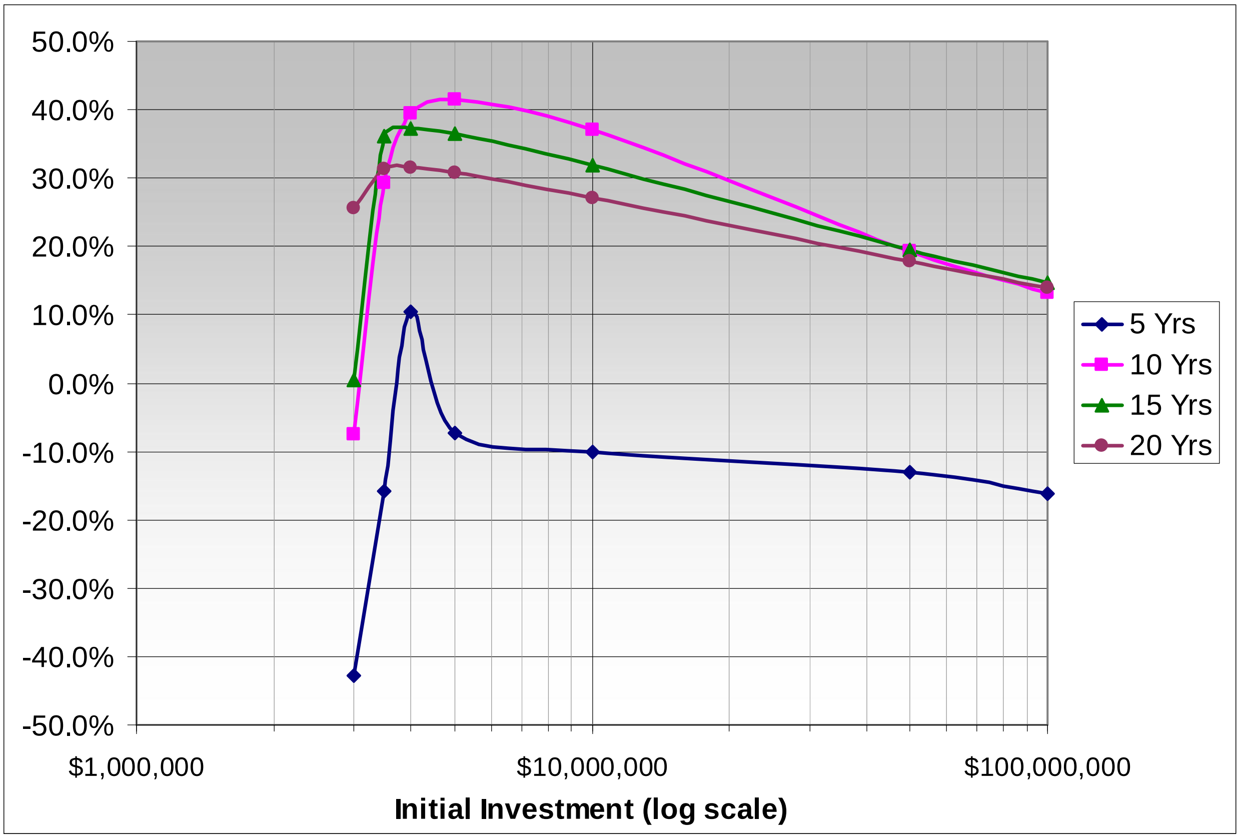

Figure 6-43: Investment Returns by Month

Figure 6-44 shows the probability of failure for the various initial investments. Note that generally larger investments result in a lower probability of failure. However, this is not always the case, as the probability of failure is based on the cash position of the company as compared to the initial investment.

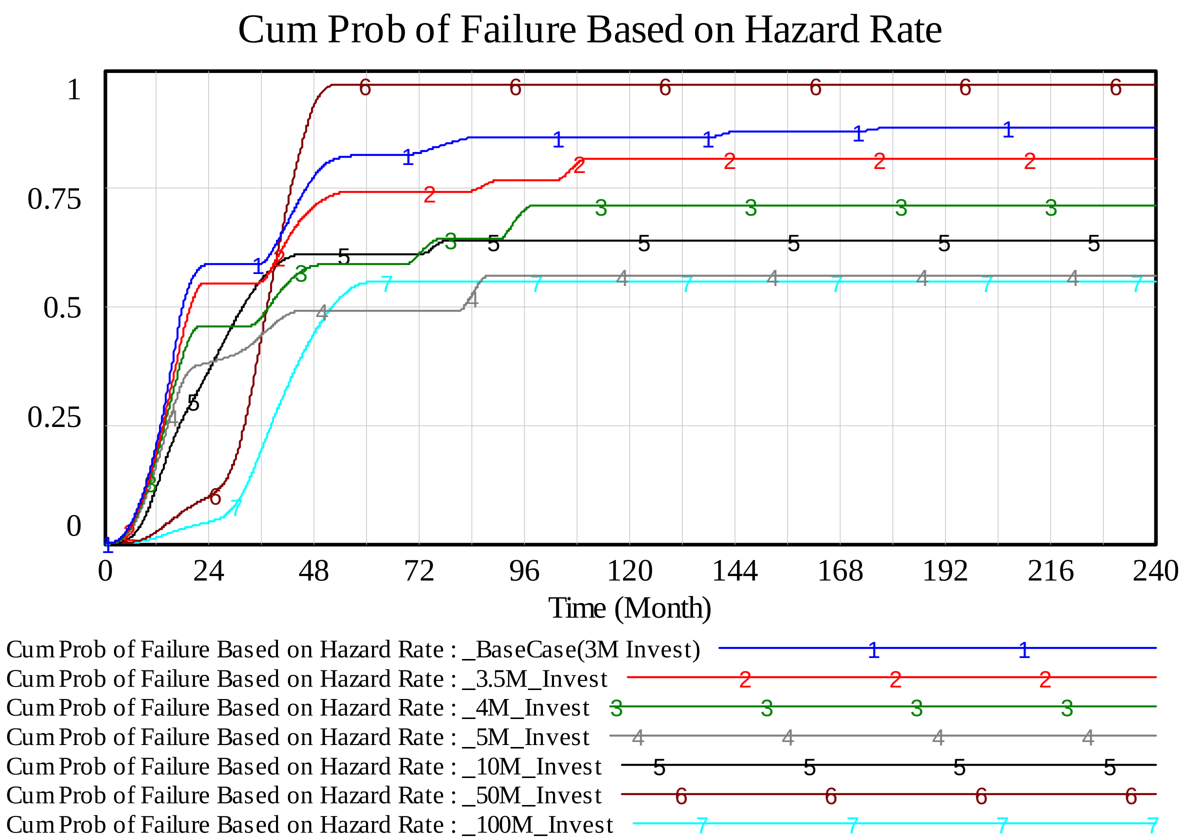

Figure 6-44: Probability Of Failure based on Initial Investment

Clearly investment size by itself will not determine whether the company will be successful. However the investment market and other factors that determine investment size will have a significant impact on the company's fortunes. Once the venture has enough capital to succeed, relatively small percentage larger investments may make a significant difference, but much larger investments are unlikely to pay off for the investors.

6.7 *Conclusion*

This chapter showed how a clean energy technology venture with superior technology at an attractive price can fail as it traverses the "valley of death." This occurs because the venture needs many years to develop a sales pipeline and gain experience, during which time its working capital is depleted. Looking at the state the venture and its market needs to be in for the venture to achieve profitability, we saw that among the list of 15 critical parameters the ones that made the most difference were engineering experience, the number of customers, and non-appropriable features. The analysis also showed how the amount of initial potential prospects, capability of new market entrants to adopt a new technology, and non-appropriable features determine whether the venture can be successful regardless of the initial investment. Too many or too few sales or engineering personnel can result in failure of the venture. Optimal values of any one parameter do not enable the venture to avoid the valley of death. It takes a combination of all the critical factors discussed to achieve profitability and emerge from the valley.

Government policies that increase the cost of carbon emissions; reduce barriers and increase incentives for adoption of clean energy technologies; and subsidize the development of clean energy technologies have a substantial effect on the fortunes of the venture. Advantageous public policy can reduce a firm's chance of failure by more than half.

Given what we know about the factors that determine success or failure, what can and should be done to increase the adoption of clean energy technologies commercialized by new ventures? This will be the focus of the next chapter.

7 Conclusion and Strategy Suggestions

This chapter presents a summary of the research and analysis, presents strategy and policy recommendations to foster the success of clean energy technology startups, summarizes the contributions of this work, and discusses directions for future research.

7.1 Summary of Research

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; efficient energy storage; green building technologies; biofuels; and ancillary products and services that reduce emissions associated with power generation, transmission and distribution.

The wide adoption and use of these technologies is critical to reduce the emissions of greenhouse gases (most notably CO_2) from energy production in order to address the serious risks of climate change. Furthermore, the use of many of these technologies is economically efficient. Numerous advantages to end users include lower and less volatile energy costs and a more stable and reliable energy supply. However, clean energy 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.

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 new 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 that have not been specifically studied or modeled before now.

7.1.1 Methods

Interviews were conducted with a wide variety of stakeholders related to the adoption of clean energy technologies, including clean energy entrepreneurs, the customers of clean energy technology, energy service providers, investors in clean energy ventures, and participants in policymaking processes related to clean energy technologies. A number of 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, lack of certainty regarding 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.

The history of three clean energy technology firms were studied, including 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.

7.1.2 Model Development

A simulation model was developed to better understand the factors that would most contribute to the success or failure of any new clean energy technology venture. The model was also designed to help uncover strategies and policies that would increase the odds of success and of wider adoption of clean energy technologies. The modeling methodology used was system dynamics, a powerful tool for studying and understanding complex real world systems that makes use of feedback loops, accumulation of flows into stocks, and time delays. The stocks of the model include the working capital of the new venture, its labor force, the product development pipeline of the venture and competitors, and the various stages of prospective customers in the venture's sales pipeline.

The model was structured and tuned to focus on issues important to new clean energy technology ventures and was based on the information collected in the interviews. The simulated venture is market driven. For example, a desire to develop feature-rich products and intellectual property that is attractive to prospective customers drives a desire to hire engineers, yet the amount of working capital constrains hiring. Sales and marketing effort drives prospective customers through the sales cycle, and is more effective when the price and features and word of mouth about the product are attractive and as the sales force gains experience. Engineers also become more effective with experience, and in particular, after working with customers.

The stages and time delays of the sales cycle reflect the experience of the companies interviewed. Levers are included which reflect policies that would affect clean energy technology ventures, such as carbon cap and trade regulations, clean energy subsidies, or policies that would remove barriers to adoption. The model represents an idealized venture in which management always follows the strategy set forth, no personality conflicts disrupt the firm, etc., and is therefore meant to be reflective a venture with an extremely effective and experienced management team.

When the values of the parameters in the model are set to reflect the parameters of the clean energy technology ventures interviewed, the behavior of the model reflects the experience of those firms. Even with a product with very attractive pricing and features compared to that of the competition, the output of the model shows a long sales cycle that drains the working capital of the venture. With a sufficiently large initial investment, and pruning of the workforce, the venture may survive and eventually achieve great success and wide adoption of their technology, but only after many years spent struggling in "the valley of death" as the management team and employees of the venture gain the experience and develop the sales pipeline necessary for success.

7.1.3 Analysis

The attributes that determine the profitability of the clean energy technology venture and enable it to emerge from the valley of death in the simulation model are summarized in Section 6.3. 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 in order for the venture to make sales and generate revenue. The market for the venture's products must be growing in order 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. Government policies designed to reduce emissions and support clean energy technologies play a significant role in the fortunes of the venture and may make the difference whether it succeeds or fails.

Unfortunately, the venture does not have direct control over most of these parameters. New ventures generally have little say over the design and implementation of government policies. And entrepreneurs cannot start a venture off with a full pipeline, employees experienced producing and selling the product, and with positive word of mouth. If they could, perhaps they could achieve the instant positive cash flow shown in Figure 6-12. But since they cannot do these things, what can they do realistically to achieve these conditions as soon as possible and maximize their cash flow? The next section will answer this question.

7.2 *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; Michael E. Porter, 1985; Roberts, 1991; J. 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 (Section 6.3.5 and Section 6.3.6).

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 capture 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. And as we see in Section 6.3.5, Section 6.3.3, and Section 6.3.2 these factors indeed play a significant role in whether and how successful the venture will be.

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". We can see how the simulation model captures the importance of both appropriable and non-appropriable features in Section 6.3.7, of price in Section 6.3.8, and of word of mouth in Section 6.3.9.

It is a validation of the simulation model that it 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.

7.2.1 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?

Given the amount of capital that clean energy technology companies typically burn through, it is generally in their interest to take in as much capital as possible. Even though some of the investments come in the future, 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.

All else being equal, a venture with an investment having an NPV of over $4M should have a much better chance of succeeding than a venture with an investment of $3M. Staging the investments also has advantages for both the entrepreneur and investor.

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 7-1, 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 reason the venture goes bankrupt is because the venture 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.

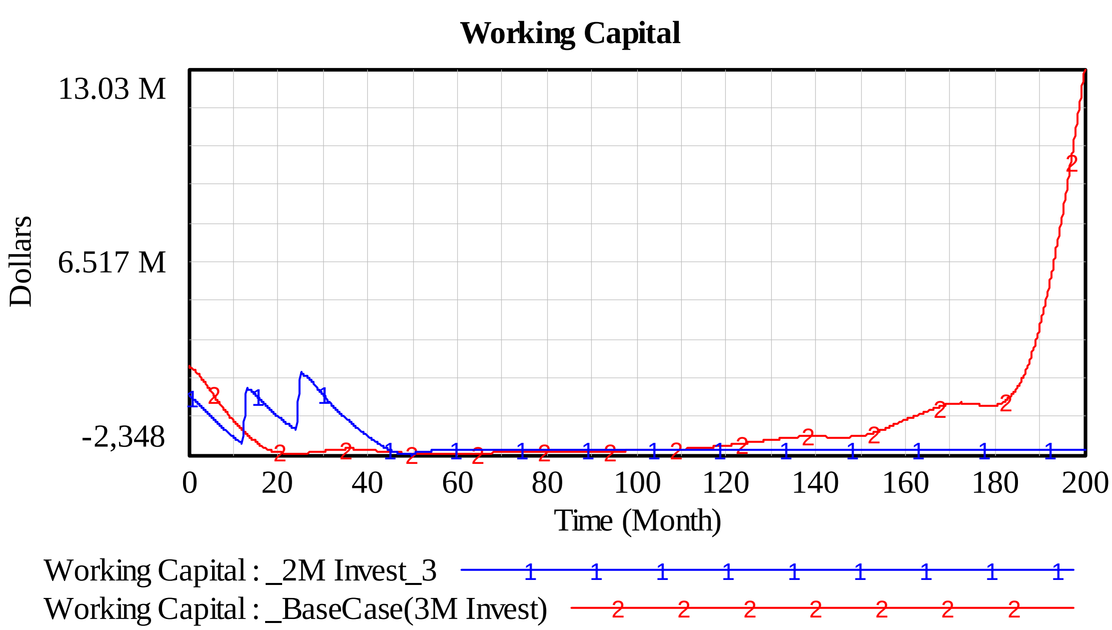

Figure 7-1: Comparison of $3M Investment vs. Three $2M Investments

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. 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 attributes addressed at the start of this section, and the factors detailed in Chapter 6 that the model shows have the largest effect on the fortunes of a clean energy technology venture (Table 6-4) and that may be evident at the start of the venture. The more a venture can demonstrate that it has a non-appropriable 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 big, rewarding the investment made by the early investors.

7.2.2 Make Up of Labor Force

What should the ratio be between the engineering staff and sales staff?

The base case clean energy technology venture starts with four engineers and two sales persons. 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. In fact, this is a common ratio for technology startups.

However, it turns out that this common ratio is suboptimal. If the venture is constrained to six employees, it would do much better with four sales people and two engineers (See Figure 7-2). This is because initially the most important task for the company is to develop a market and fill the pipeline; 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.

A venture is more likely to be successful if it hires more sales people up front. Though lack of capital ultimately constrains the size of the labor force, we saw in Figure 6-20 that the venture can support an initial sales force as large as 16 with a relatively small initial investment (This is because a sales force can start paying for itself by generating additional revenue). Figure 7-3 shows the impact of doubling the sales force three times from two to four to eight to 16. As the number of sales personnel is increased from two to 16 the results significantly improve. And note that the venture does better with fewer engineers (two rather than four), given four sales people. This tells us that 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 to cut costs if necessary in order to do so.

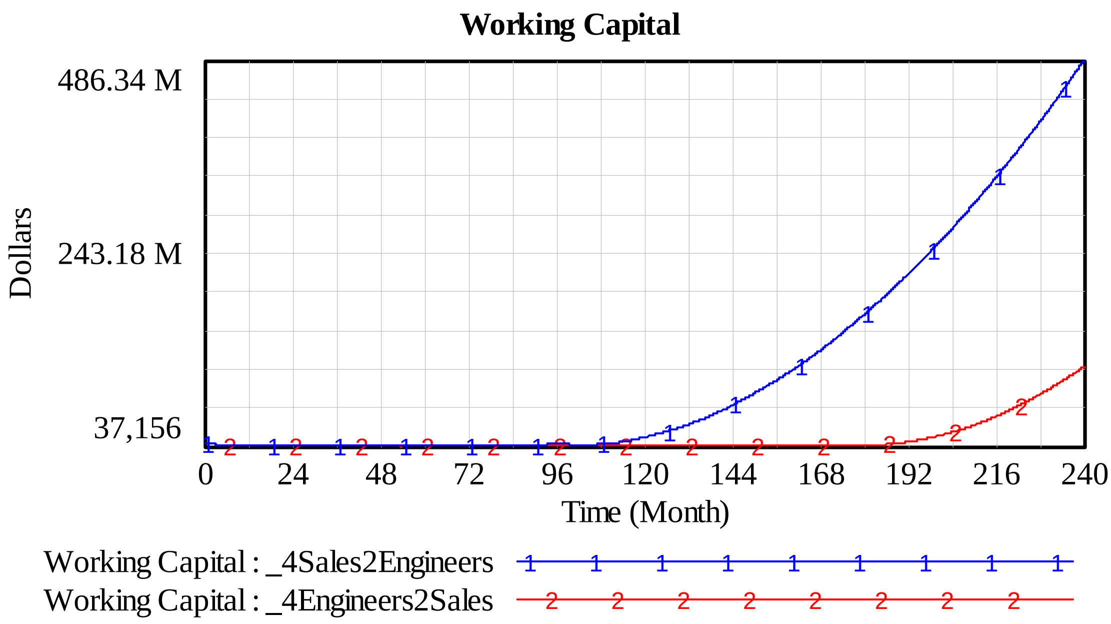

Figure 7-2: Sales vs. Engineering Focus

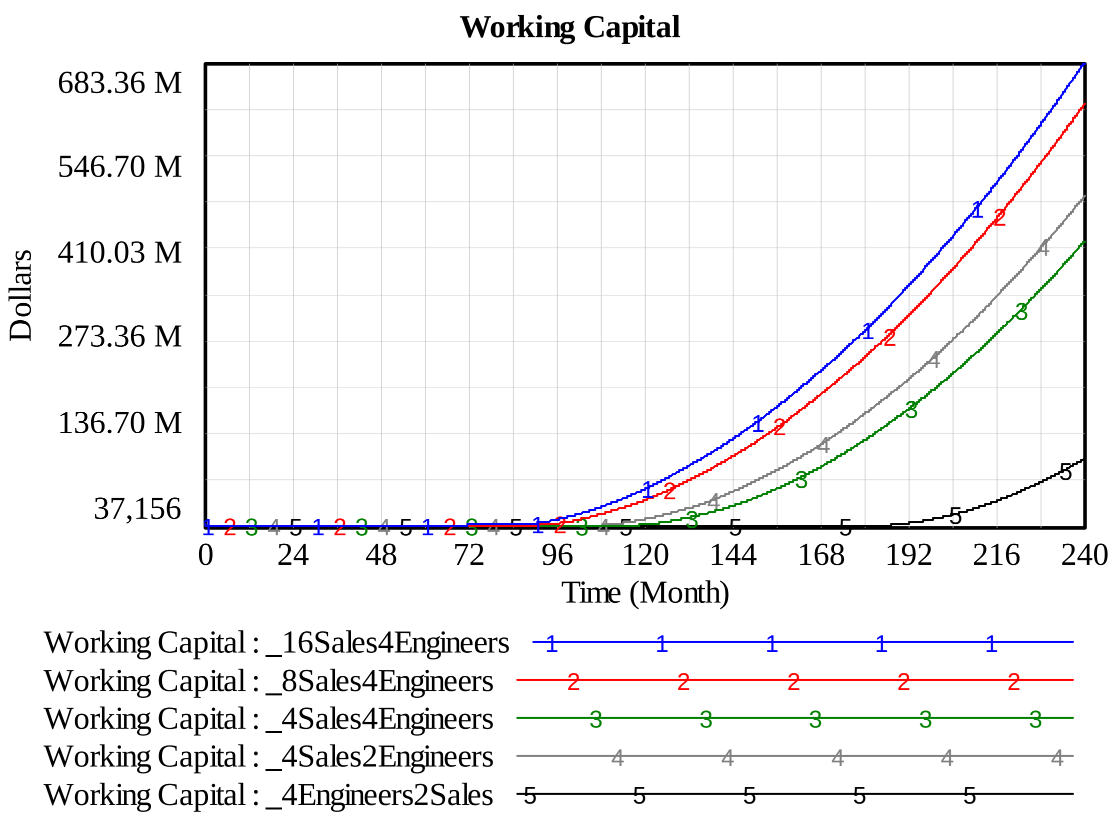

Figure 7-3: Results of Adding Initial Sales Persons

7.2.3 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 of the venture 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 7-4 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.[16]

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[16] 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

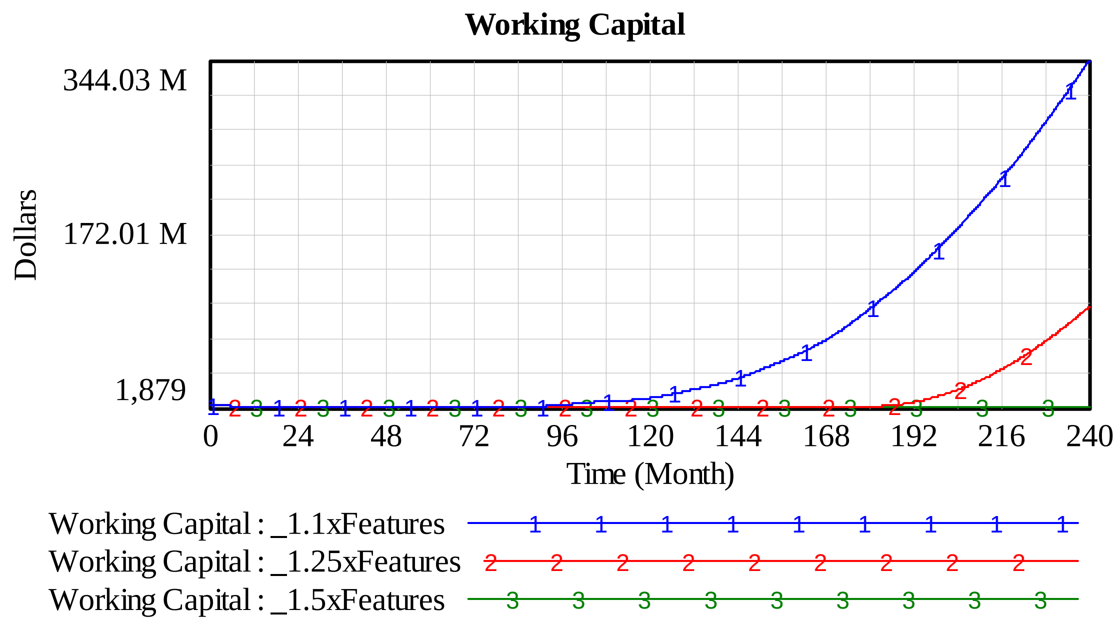

Figure 7-4: Comparison of Desired Features

7.2.4 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 price 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[17] as long as the customer is using the product in addition to the 20% maintenance charge, and compare the following two scenarios:

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

(94) 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, and has a payback period of only a little over three years. But in the life of a new venture, those three years are

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[17] A typical annual rate for a five year general equipment lease is ~25%. See http://www.unistarleasing.com/calculator.html for an example.

critical, and that choice would be wrong. Under the leasing scenario, the venture would go bankrupt.

Figure 7-5 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 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.

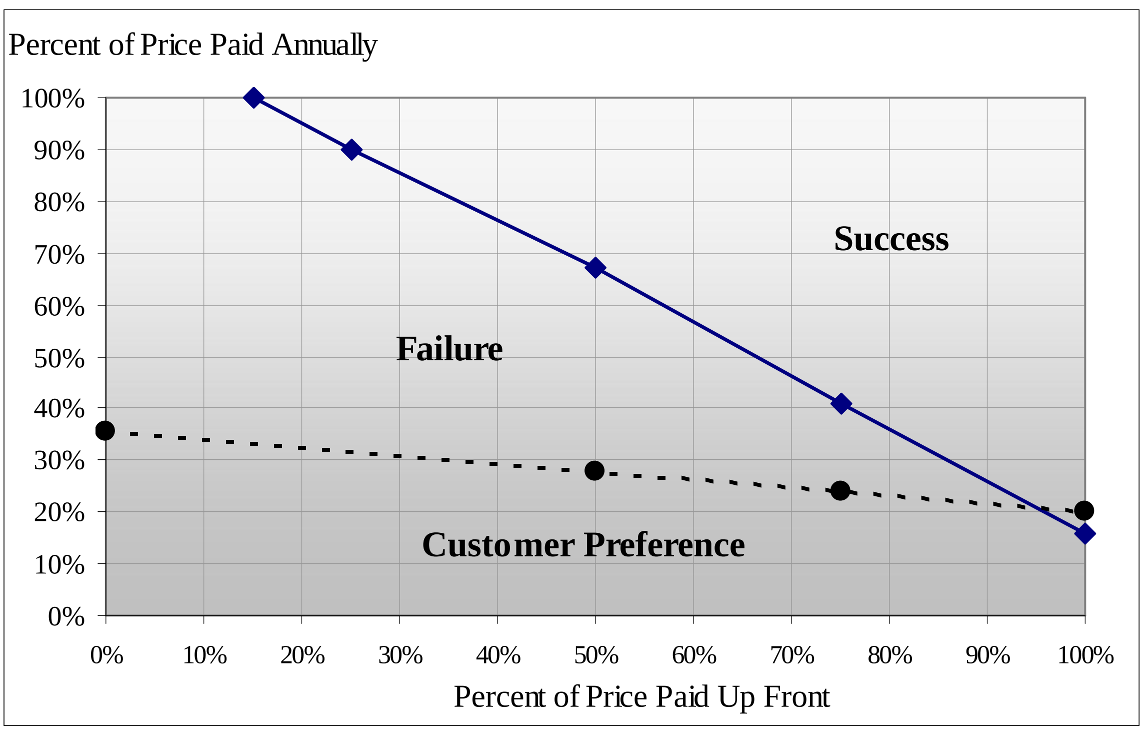


Figure 7-5: Up Front Payment vs. Annual Lease and Maintenance Payment

7.2.5 Pricing vs. Competition

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

We assume that one 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 7-6).

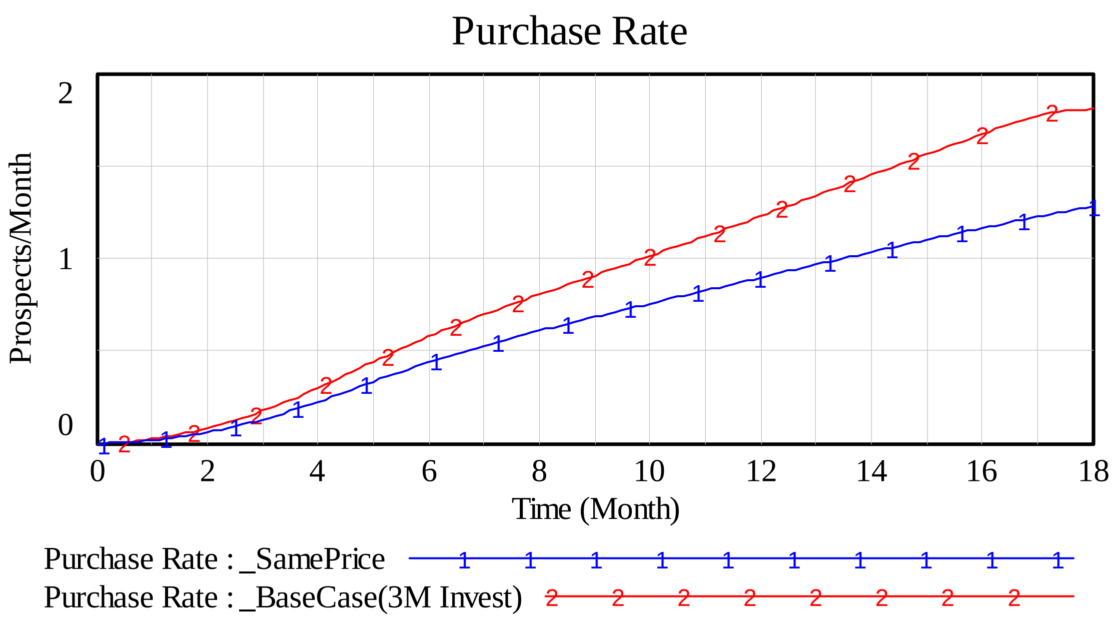
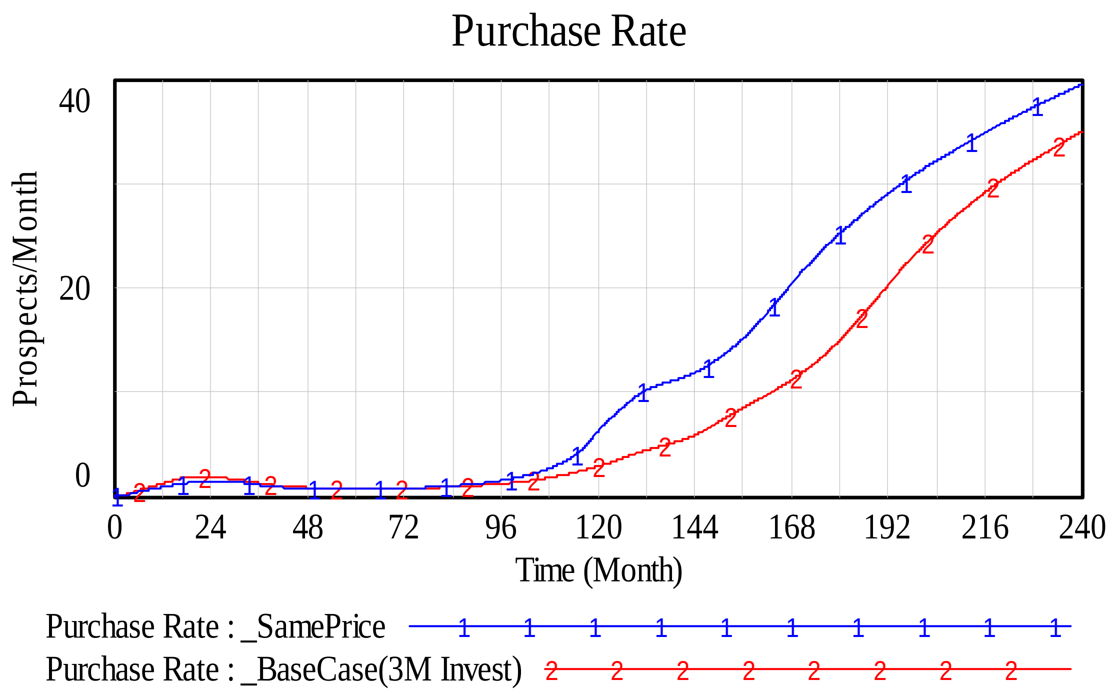


Figure 7-6: Comparison of Purchase Rate over 18 Months

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 7-7 shows a comparison over the 20 years of the simulation of purchase rate and working capital 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 increases 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.



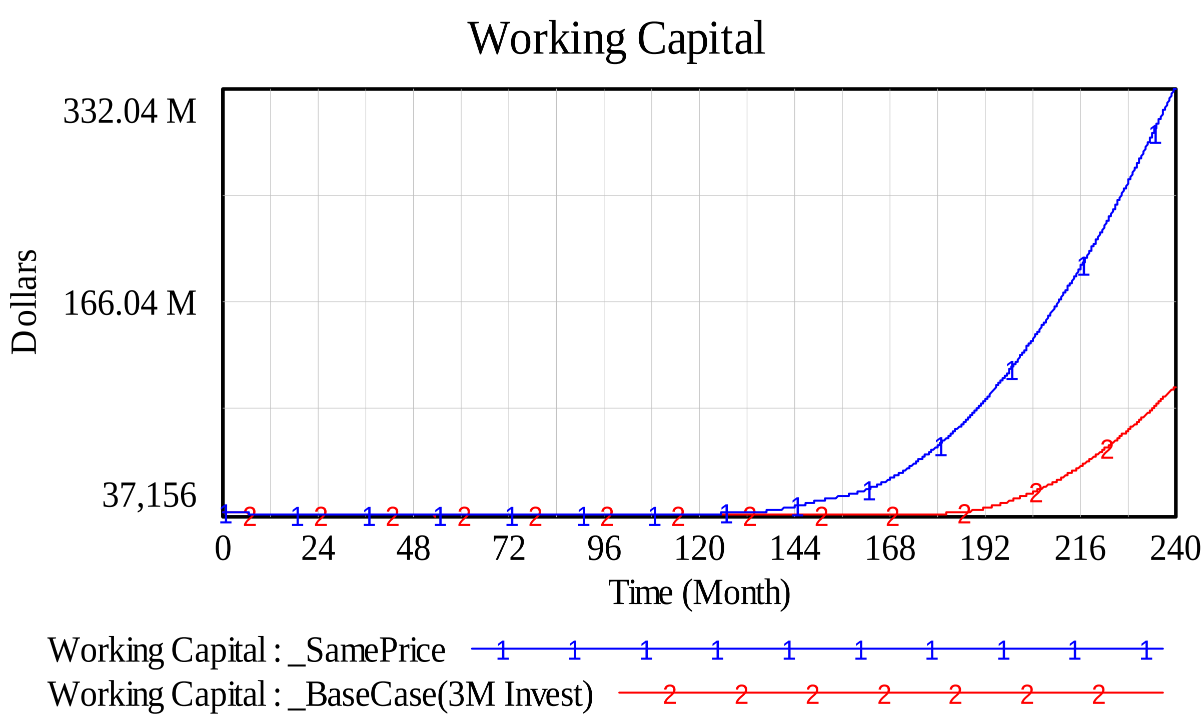


Figure 7-7: Charging Same Price as Competitors vs. Charging 25% Less in Base Case

7.3 *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 the above management strategies with the government policies described in Chapter 6.

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 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 7-8, 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 successful.

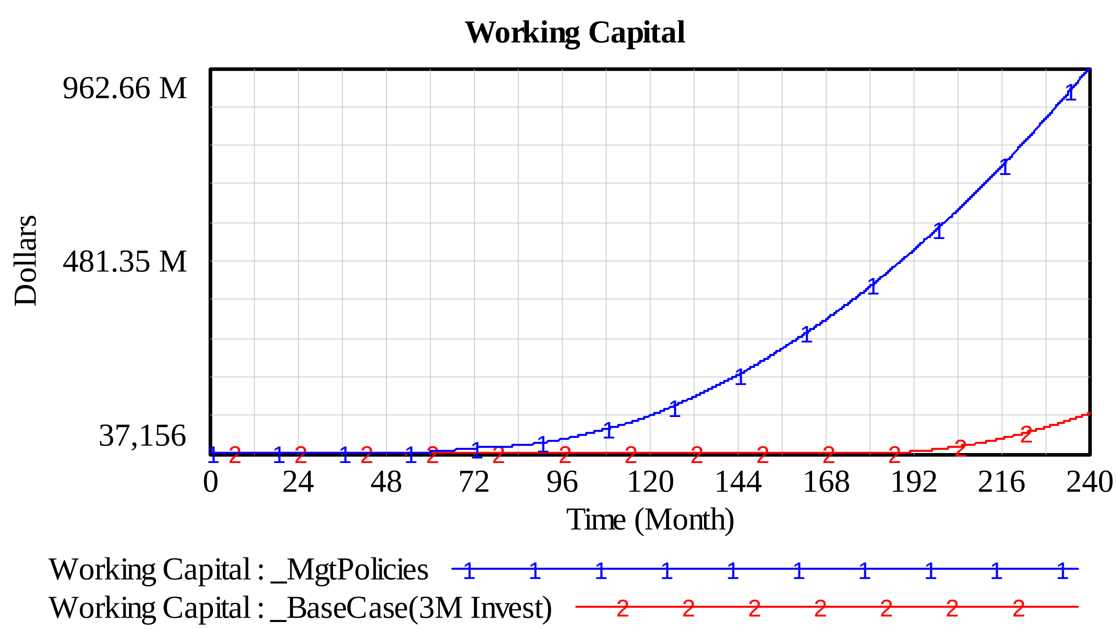


Figure 7-8: Results of Implementing Management Strategies

However, Figure 7-9 shows that 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.

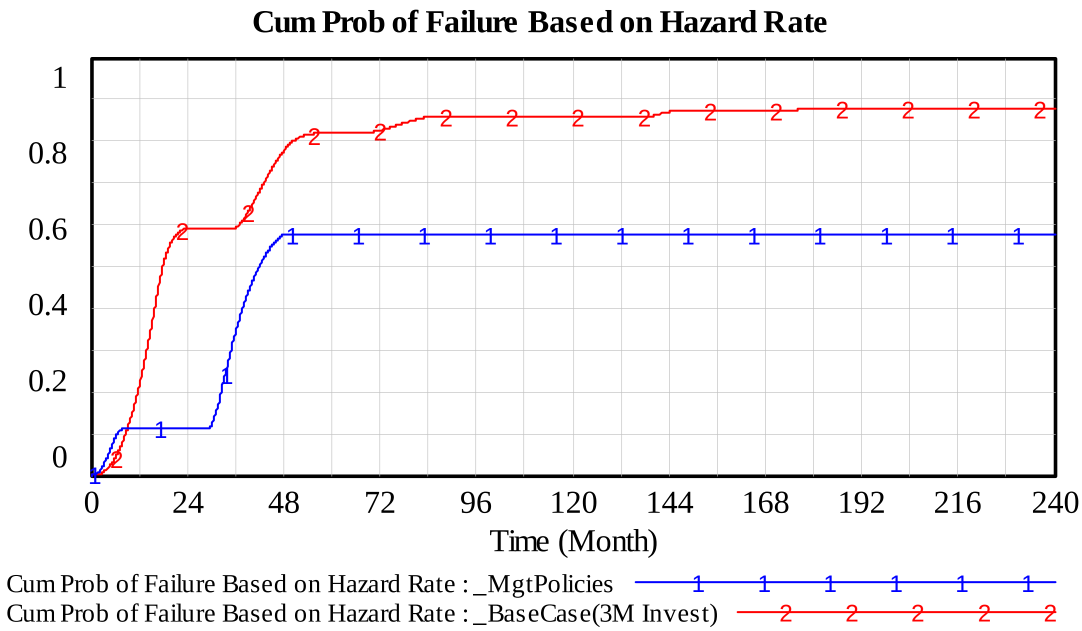


Figure 7-9: Cumulative Probability of Failure with Management Strategies

The implementation of the government policies described and analyzed in Section 6.4 can change this story. As shown in Figure 7-10, the venture leaves the valley of death much sooner in the presence of favorable policy than it might with the management strategies alone. Most importantly, the venture's probability of failure has been reduced substantially (see Figure 7-11).

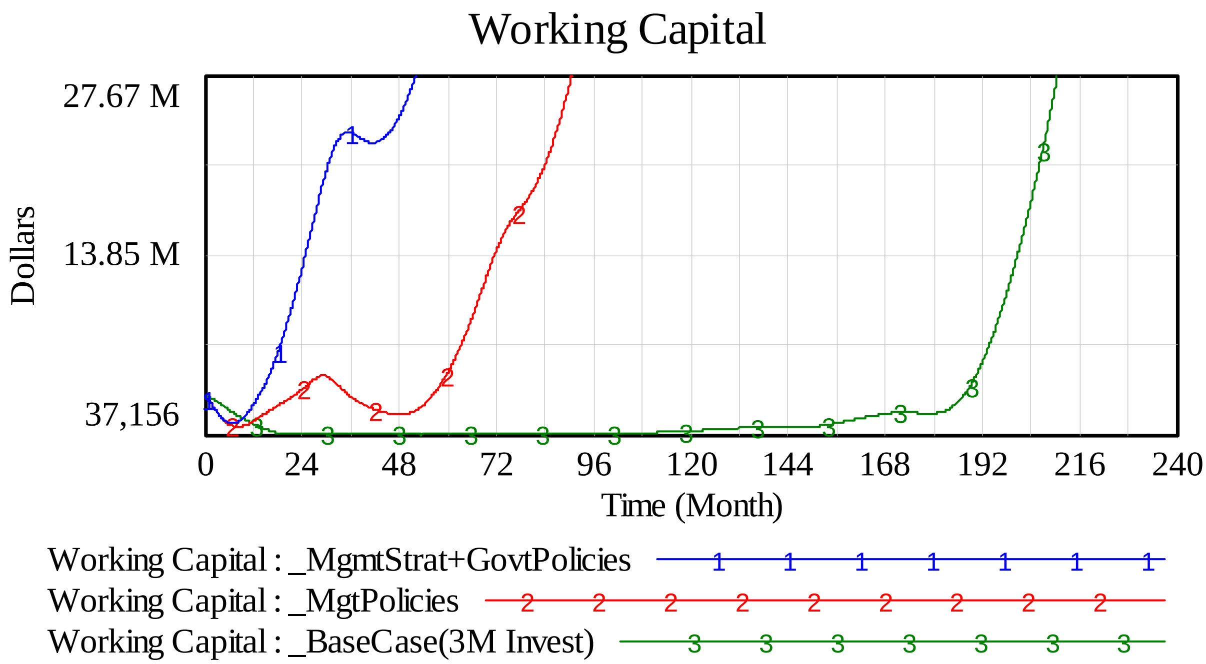


Figure 7-10: Results of Government Policies in Addition to Management Strategies

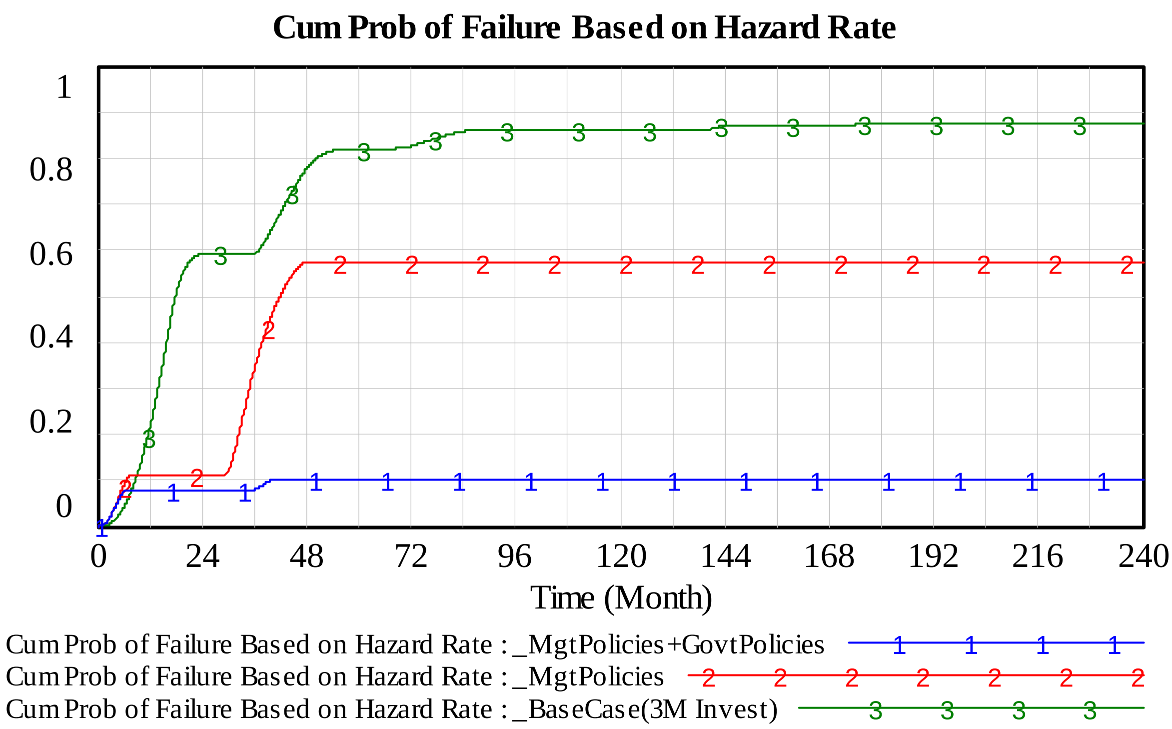


Figure 7-11: Probability of Failure with Govt Policies in Addition to Mgmt Strategies

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 model shows that such a venture would have less than a 50% chance of doing so. Supportive government policies 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. Therefore the numerical values of a 10% probability of failure and nearly $2B of working capital after 20 years for the simulated venture will not necessarily come to pass for any real company. Though it is possible a real company could do better than the simulated one, there are many factors that 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 economic 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. Whereas an industry slowdown or disruption to the venture's labor force may cause some ventures to fail, those with the above management strategies and policies in place are more likely to weather these inevitable storms and survive.

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).

7.3.1 Investment Returns

Given the challenges that clean energy technology ventures face, and the results and probabilities of failure shown at the beginning of Chapter 6, it's a valid question to ask whether it is rational for private investors to invest in these companies at all. For the base case venture, which takes 15 years before achieving profitability, the answer is likely no. Though the investment in the base case venture does pay off after 20 years, too many hazards could occur over that period of time that would cause the company to fail. However, if the above management strategies are followed and the referenced government policies are in place, then it would be a good decision to invest in a clean energy technology venture with attributes similar to the one modeled.

Figure 7-12 shows the investment returns at five, 10, 15 and 20 years for the base case venture for scenarios in which only management strategies are implemented; only government policies are in place; or when both the management strategies and government policies are in place. The investment returns are the IRR of the initial $3M investment over the given period of time, with the capital at the end of the period being the sum of the working capital of the venture at that time and five times annualized cash flow.

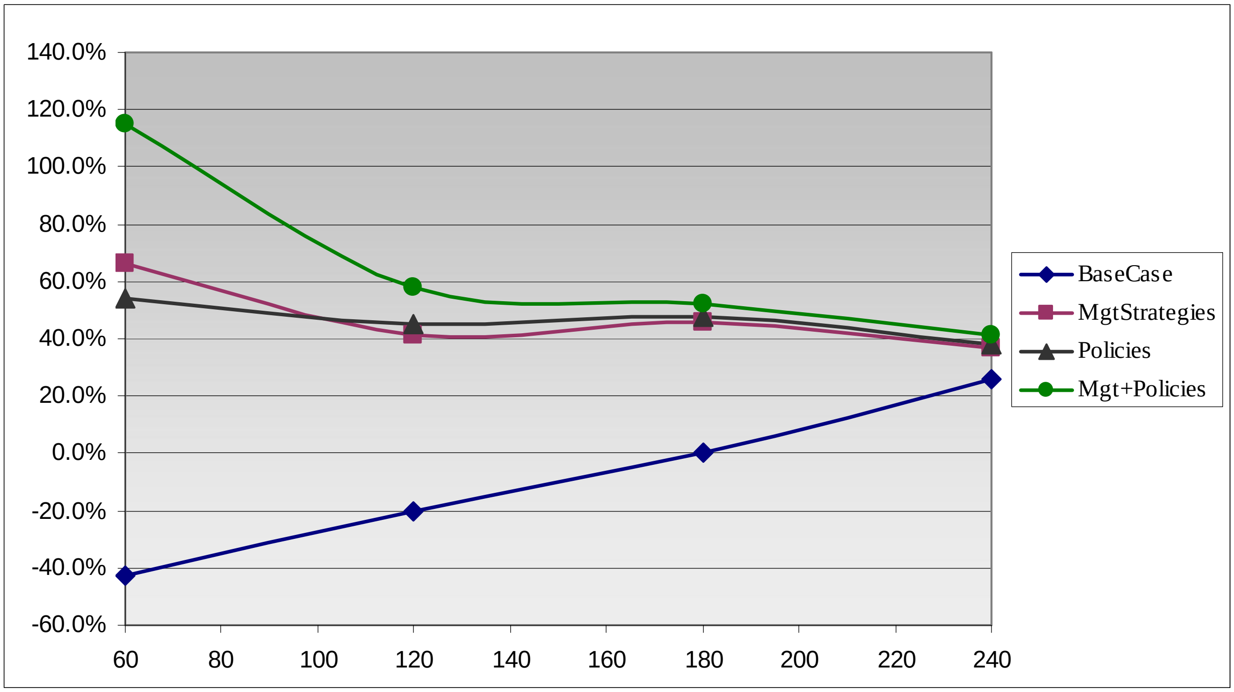


Figure 7-12: Investment Returns with Mgmt Strategies and Govt Policies

Note that with the management strategies or policies in place, the investment has strong positive returns after five years and 10 years. However, the results shown in Figure 6-35 and Figure 7-9 must be kept in mind. These show that if investors are not patient, the venture may fail under these scenarios as it takes at least four years before the venture leaves the valley of death and starts to show positive returns. However analysis of the model shows us that the combination of the management strategies and policies produces much higher potential investment returns after a relatively short period of time.

It must be emphasized that the simulation is not reality, and actual investment returns will vary quite widely and be sensitive to factors outside the scope of this model. However, the simulation model does provide evidence that the combination of the recommended management strategies and government policies will both significantly reduce the probability of failure of clean energy ventures (Figure 7-11) and significantly increase the return on investments in these companies over shorter investment horizons.

7.3.2 Aggressive Competitor Scenarios

The base case parameters used for analysis in this and the prior chapter assume that the aggregate competitor to the clean energy technology venture behaves like a large and bureaucratic firm that is relatively slow to respond and has relatively long development cycles. What if we relax these assumptions and assume a more competent and aggressive competitor? Under the base case, if the competitor starts with better features, shorter development times, and larger desired feature ratios, a shorter desired time to catch up to the venture's features, or with greater development resources, the venture will fail (these parameter values are shown in Table 7-1). However, with the above management strategies in place the only individual parameter changes that will result in bankruptcy are if the venture starts with significantly worse features than the competition (either appropriable or non-appropriable). And with the government policies in place, the venture would have to start with its features even further behind in order to fail (values in Table 7-1).

Parameter	Default Value for Venture	Default Value for Competition	Bankrupt in BaseCase	Bankrupt w/ Mgmt Strategies	Bankrupt w/ Strategies & Policies
Initial Features(NA)	4	2	*2.62*	4.6	*6*
Initial Features(A)	110	100	*122.5*	450	*630*
Avg Feature Devl Time(NA)	12	24	*14.5*	-	-
Avg Feature Devl Time(A)	2	4	*0.1*	-	-
Desired Feature Ratio (NA)	1.25, 1.1	1.1	*1.3*	-	-
Desired Feature Ratio (A)	1.25, 1.1	1.1	*1.8*	-	-
Desired Time to Catch up Features (NA)	4	12	*8.3*	-	-
Desired Time to Catch up Features (A)	2	6	*0.1*	-	-
Eng Effort for Development(NA)	Variable	8,750	*16,500*	-	-
Eng Effort for Development(A)	Variable	8,750	-	-	-
NA = Non-appropriable, A= Appropriable					

Table 7-1: Competitor Attribute Values that will Bankrupt Venture

If the competition has both large enough development resources and the desire and ability to catch up to the features of the new venture quickly enough, the new venture will fail under every scenario. However, the management strategies and government polices described above make the venture significantly more robust to failure. See Figure 7-13 for a depiction of the regions of success vs. failure depending on the competition's development resources, desired time to catch up features, and whether the management strategies are in place, or both the strategies and government policies are in place.

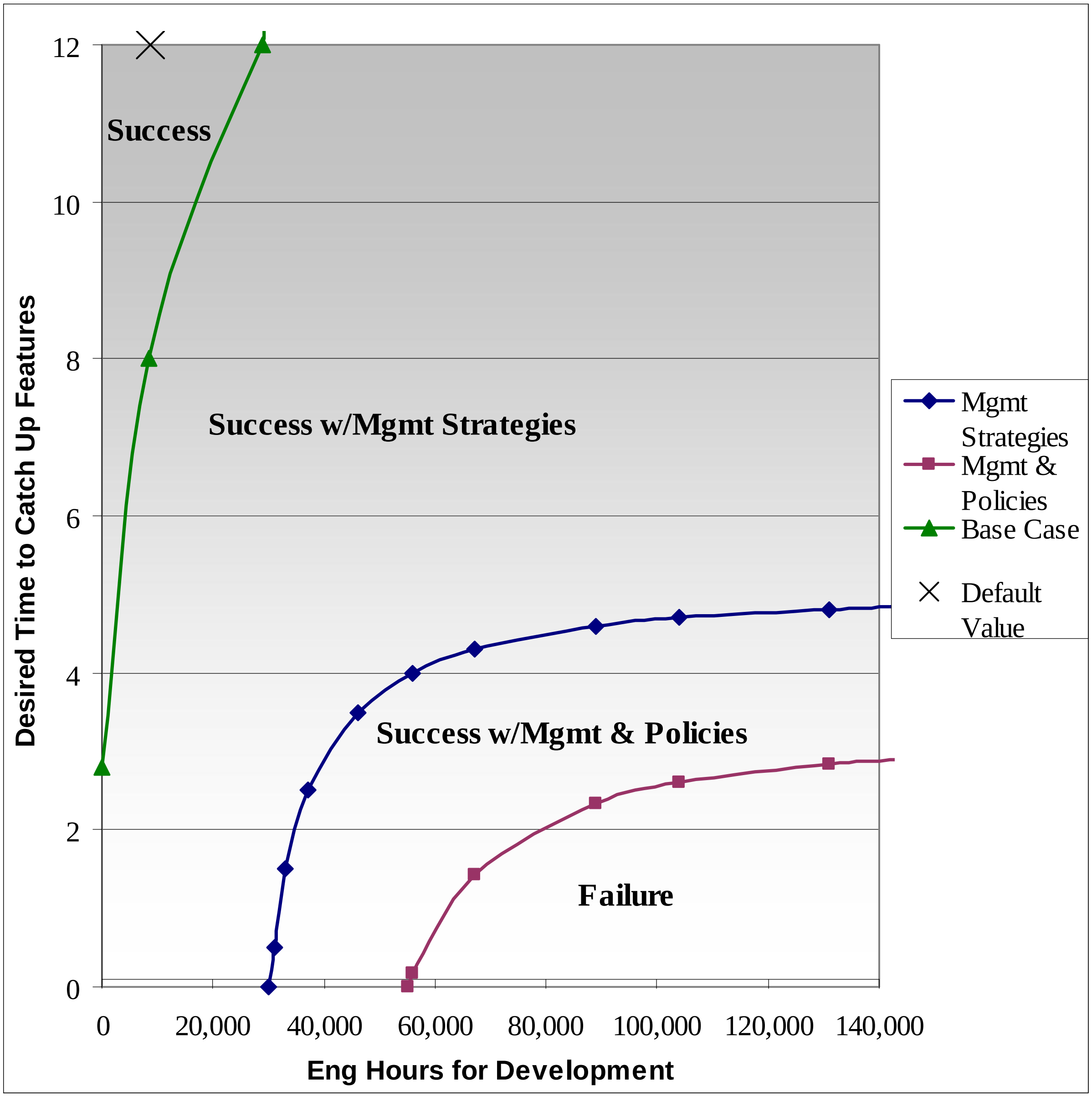


Figure 7-13: Success vs. Failure Depending on Attributes of Competitor

Clearly, if the new venture has inferior features and inferior development resources compared to competition, the new venture will fail. However, if the new venture has superior features coupled with a cost advantage due to learning (see Section 7.2.5), the strategies and policies outlined above will provide the venture with a greater chance of success even in the face of resourceful and aggressive competition.

7.4 Contributions Of This Research

The contributions of this research effort include the development of an empirically based simulation model for clean energy technology ventures; a better understanding of the challenges faced by these companies and the factors that most contribute to their success or failure; the determination of management strategies and government policies that would dramatically improve the odds of success of these ventures, and the effect that each of these strategies and policies has. The analysis shows that even optimal management strategies may not be sufficient for a clean energy technology venture with a superior technology to succeed. A combination of these strategies and government policies may be needed to overcome the barriers to success.

7.4.1 Simulation Model

An empirically based simulation model of a prototypical new clean energy technology venture was developed that reflects the experience of the ventures interviewed for this research. 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 adequately 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 issues

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 non-appropriable features, a product development sector was developed that takes into account varying values and development resources needed for appropriable and non-appropriable 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. These 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.

7.4.2 Factors that Contribute to Success or Failure

As a result of extensive interviews of clean energy technology entrepreneurs and related stakeholders, and of analysis of the simulation model, a better understanding was developed of why clean energy technologies are not as widely adopted as their benefits suggest they should be, and of the challenges faced by new clean energy technology ventures. Analysis of the simulation model uncovered factors that are most likely to contribute to the success or failure of clean energy technology ventures and detailed the strength and sensitivity of those factors. It is extremely valuable to become aware of and understand the relative strength of these factors in order to improve the odds of success of these firms.

7.4.3 Management Strategies that Increase Odds of Success

Further analysis of the simulation model, coupled with insights from the interviews and direct experience working with ventures enabled the development of a number of management strategies that would significantly increase the odds of success of a clean energy technology venture. These strategies may appear to be obvious in hindsight, but are counter-intuitive in many ways and generally have not been followed by new ventures. This research may help future new clean energy technology ventures to adopt these strategies and therefore accelerate their profitability and the adoption of clean energy technologies.

7.4.4 Importance of Government Policies to Success

There has been considerable focus on how policies that impose a cost to carbon emissions or that remove barriers to the adoption of clean energy technology affect existing firms, but relatively little focus and understanding of how these policies affect new clean energy technology ventures. The model developed here provides new insights into this issue. The model shows that policies that impose a cost to existing energy firms may provide great benefit to new energy ventures and their investors, and can result in very strong economic growth. It is critical for policy makers to be aware of this.

7.5 Opportunities for Further Research

Much more work could be done to understand how best to increase the odds of success of clean energy technology ventures and to increase the adoption of clean energy technologies. In particular, more data, particularly quantitative data, is needed on the attributes and outcomes of clean energy technology ventures; the simulation model developed here can be enhanced in many ways; and the theories outlined here should be tested.

7.5.1 Quantitative Data on Clean Energy Technology Ventures

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.

7.5.2 Further Development of Model

The simulation model developed here could be enhanced in many ways.

- As detailed in Section 6.4.5, 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).

- As detailed in Section 6.5, 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.

7.5.3 Use of the Model for More General Analysis of New Ventures

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.

7.5.4 Behavioral Analysis of New Ventures

If new ventures were aware of the benefits of the management strategies outlined in this research but chose not to follow them, it would be interesting to find out why. Is it because they do not trust the results, or because implementations of these strategies are too difficult? Are there other psychological or practical reasons?

7.5.5 Testing of Theories

This research used empirical information and the development of a simulation model to substantiate theories on which management strategies and policies would best promote the adoption of clean energy technologies. However, these theories have not been tested for their effect on real world clean energy technology ventures. The long time frames and costs involved add to the challenges of accomplishing this goal. However, it would be extremely instructive to test the validity and strength of the theories developed here.

7.6 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 very much 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.

Appendix A: Consent Form

CONSENT TO PARTICIPATE IN INTERVIEW

New Venture Commercialization of Clean Energy Technologies

You have been asked to participate in a research study conducted by David Miller from the Laboratory for Energy and the Environment at the Massachusetts Institute of Technology (M.I.T.). The purpose of the study is to better understand and improve the adoption of clean energy technologies. The results of this study will be included in David Miller's PhD thesis. You were selected as a participant in this study because of your knowledge of, experience in and participation in the industry. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

• This interview is voluntary. You have the right not to answer any question, and to stop the interview at any time. We expect that the interview will take about 2 to 3 hours.

• You will not be compensated for this interview.

• If you give permission for the interview to be taped, the tape will be kept confidential.

• Unless you give me permission to use your name or any identifying information in any publications that may result from this research, your identity and the identity of your company will be kept anonymous.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

(*Please check all that apply*)

[] I give permission for the interview to be taped

[] I give permission for the following information to be included in publications resulting from this study:

[] my name [] my title [] direct quotes from this interview

Name of Subject

Signature of Subject ____ Date _____________

Signature of Investigator ____________________________________ Date _____________

Please contact David Miller with any questions or concerns.

If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E32-335, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

Appendix B: Interview Questions

Intro & Consent Form
- Permission to tape record?
- When do we need to finish?

Background
- History of company?

General
- Define Clean Energy Technology
- Has your company been successful?
- How do you define success?
- Why has your company been successful or not?
- What are the factors that most brought on success?
- What are the factors that most hindered success?
- What have been the most significant surprises?
- If you were starting business today, what would you focus on to make it successful?
- What are the most valuable lessons you've learned through this business?
- What are your priorities in running the business?
- When things went wrong, what caused the problems and what did you do to solve the problems?

Business Model
- What is your business model/strategy?
- How has your business model/strategy changed over time?

Markets
- Tell me about your market(s)?
- How has the market response been different than expected over time? Why?
- How would you define "wide adoption" for your product? When do/did you expect to attain this?
- Describe your competition

Sales
- How long is your sales cycle, and how does that break down?
- Describe your prospect chain
- What factors determine whether you'll make a sale?

Regulations
- Do regulations have an impact on your business?
- What government policies and regulations would be helpful?

Other factors
- What factors outside of your control affect the prospects of your business?
- How is an energy technology business different from other technology businesses?

Personnel
- Have you had the right personnel? Why or why not?
- How experienced is your team? In the industry?
- Has your team worked together before?

How experienced/good are your advisors and/or board?

Products/Technology

What value does your product or service provide to your customers?
How does your product compare to competitive solutions? (in cost and value)
How valuable is your IP and how have you protected it?
How much does it cost (in time and money) to maintain your product?
How much have you spent in time and money on supporting your product(s)?
How much have you spent in time and money on R&D?

Customers

How much expertise do your customers have to have to use your product?
What does it cost your customers to acquire and use your product, in terms of time and money?
How difficult is it for your customers to learn and to use your product?
How do your customers find out about you?
What level of the organization needs to approve the purchase of your product?

Financial

How long before you expect to be profitable?
What is your exit strategy?

Conclusion

Anything I should have asked you but didn't? Anything to add?
Who else to interview??
Would it be possible to obtain historical financial data (to be kept confidential)?

Appendix C: Model Documentation

Note: The parameters are listed below in alphabetical order. Many of these equations are placed into context and described in detail in Chapter 5, and the entire model is available as a computer file.

Abandonment Rate[company,featuretype] = Abandonment Rate 1[company,featuretype] + Abandonment Rate 2[company,featuretype] + Abandonment Rate 3[company,featuretype]
Units: Features/Month
Rate at which feature ideas are abandoned

Abandonment Rate 1[company,featuretype] = Feature Devl Rate 1[company,featuretype] * Feature Abandonment Fraction 1[company,featuretype]
Units: Features/Month
Rate at which feature ideas are abandoned in 1st stage of product development

Abandonment Rate 2[company,featuretype] = Feature Devl Rate 2[company,featuretype] * Feature Abandonment Fraction 2[company,featuretype]
Units: Features/Month
Rate at which feature ideas are abandoned in 2nd stage of product development

Abandonment Rate 3[company,featuretype] = Feature Devl Rate 3[company,featuretype] * Feature Abandonment Fraction 3[company,featuretype]
Units: Features/Month
Rate at which feature ideas are abandoned in 3rd stage of product development

Accounts Receivable = INTEG(Billing - Cash Received From Customers - Defaults on AR , 0)
Units: Dollars
Revenue waiting to be received in cash

Addl Investments = Follow On Investments
Units: Dollars/Month
New investments to add to Total Investments

Adjustment for Eng Vacancies = (Desired Eng Vacancies - Eng Vacancies) / Eng Vacancy Adjustment Time
Units: Persons/Month
Adjusts eng vacancy creation to have the desired number of vacancies.

Adjustment for Engineers = (Desired Engineers - Engineers) / Engineers Adjustment Time
Units: Persons/Month
Adjusts the desired hiring rate of engineers to bring the number employed to the desired level.

Adjustment for FUD[company,featuretype] = (Desired FUD[company,featuretype] – Product Features Under Development[company,featuretype]) / FUD Adjustment Time[company,featuretype]
Units: Features/Month
How many features per month we need to add (or subtract) from FUD

Adjustment for Sales Force = (Desired Sales Force - Sales Force) / Sales Force Adjustment Time
Units: Persons/Month
Adjusts the desired hiring rate of sales people to bring the number employed to the desired level.

Adjustment for Sales Vacancies = (Desired Sales Vacancies - Sales Vacancies) / Sales Vacancy Adjustment Time
Units: Persons/Month
Adjusts sales vacancy creation to have the desired number of vacancies.

Adopter Loss Fraction = Normal Adopter Loss Fraction * Effect of Customer Support on Adopter Loss Fraction (Normalized Cust Support) * Effect of Features on Adopter Loss Fraction (Normalized Features)
Units: 1/Months
What fraction of adopters we lose every month

Adopter loss rate = Adopters * Adopter Loss Fraction
Units: Prospects/Month
Rate at which adopters stop using the product

Adopters = INTEG(Adoption Rate - Adopter loss rate , Initial Adopters)
Units: Prospects
Prospects who are now using the product

Adoption Capab Increase Ramp Time = 3
Units: Months
Time it takes for policy to take full effect

Adoption Capab Increase Start Time = 0
Units: Months
Time at which policy starts having an effect

Adoption Productivity Of Sales Effort = MIN (Max Adoption Productivity From Sales , Sales Experience Productivity Multiplier * Max Adoption Productivity From Sales * Effect Of Customer Support On Adoption Efficiency * Effect Of Features On Adoption Efficiency)
Units: Prospects/(Person*Hour)
The decision rate of sales effort as effected by price, features, cust support (for trials), and word-of-mouth

Adoption Rate = IF THEN ELSE (Norm Adoption Rate > 0, Norm Adoption Rate * Prospect Conversion Fn (Potential Adoption From Sales Effort / Norm Adoption Rate) , 0)
Units: Prospects/Month
The rate at which purchasers start to use the product

Adoption Sales Effort = Fraction effort for adoption * Sales Effort
Units: Persons*Hours/Month
Total number of hours spent by the sales force on decisions per month

Allow Layoffs = 1
Units: Dmnl
Whether or not to allow layoffs to occur (0=no, 1=yes)

Average Layoff Time = 2
Units: Months
The average time required to lay off an engineer

Avg Engineer Experience = ZIDZ (Engineer Experience , Engineers)
Units: Hours
How many hours of experience the avg engineer has

Avg Experience Of New Eng Hires = 2000
Units: Hours [0,10000,35]
Average relevant experience of new engineering hires

Avg Experience Of New Sales Hires = 1000
Units: Hours
Average relevant experience of new sales hires

Avg Feature Devl Time[company,featuretype] = 2, 12; 4, 24;
Units: Months [0,20]
How long, on average, does it take to develop a feature, regardless of how many engineers are working on it

Avg Feature Lifetime[company,featuretype] = 24, 120; 24, 120;
Units: Months
Avg amount of time a feature is useful for

Avg Hot Prospect Lifetime = 4
Units: Months [1,?]
Mininum amount of time it takes to persuade a prospect to trial the product

Avg Potential Prospect Lifetime = 6
Units: Months [1,?]
Average amount of time it takes for a potential prospect to become aware of product and become a prospect

Avg Prospect Lifetime = 1
Units: Months [1,?]
Average amount of time it takes to persuade a prospect to seriously consider purchasing

Avg Purchaser Lifetime = 1
Units: Months [1,?]
Mininum amount of time it takes to persuade a purchaser to start using product

Avg Receivable Delay = 1.5
Units: Months [0.1,12,0.1]
How long it takes on average to get paid

Avg Salary = 17000
Units: Dollars/(Month*Person)
Average loaded salary across all employees (includes office and admin costs)

Avg Sales Experience = ZIDZ (Sales Experience , Sales Force)
Units: Hours
Avg hours of experience of sales force

Avg Time to Fill Eng Vacancies = 2.5
Units: Months
The average time required to fill an engineering vacancy

Avg Time to Fill Sales Vacancies = 2.5
Units: Months
The average time required to fill a sales vacancy

Bankrupt Switch = IF THEN ELSE (Working Capital <= 0, 1, 0)
Units: Dmnl
If cash goes to 0 (or less!), then company is bankrupt

Billing = Quantity Per Purchase * Adoption Rate * Initial Payment + Maintenance Billing
Units: Dollars/Month
Amount of money customers obligated to pay

Burn Rate = IF THEN ELSE (Cash Flow From Operations < 0, - Cash Flow From Operations , 1e-007)
Units: Dollars/Month
If cash flow is negative, burn rate is simply the inverse, otherwise we're not burning money, but set the burn rate to very low number so as not to divide by 0...

Carbon Policy Effect on Comp Cost = 0.2
Units: Dimensionless [0,1,0.01]
What fraction initial competitor cost will change based on carbon policy (0.1 = 10% increase, 1 = double, -1 means it goes to 0)

Carbon Policy Ramp Time = 10
Units: Months
Time it takes for carbon policy to take full effect

Carbon Policy Start Time = 0
Units: Months
Time at which carbon policy starts having an effect

Carbon Policy Switch = 0
Units: Dimensionless [0,1,1]
Whether's there's a carbon policy or not that will effect competitor's prices

Cash Flow From Operations = Cash Received From Customers - Outflows Of Capital
Units: Dollars/Month
Amount of cash coming in or out of the company from operations per month

Cash Received From Customers = Accounts Receivable / Avg Receivable Delay
Units: Dollars/Month
Amount of cash coming in from customers

Change in Burn Rate Required = IF THEN ELSE (Months of Runway > Min Runway In Order To Hire , Months of Runway / Min Runway In Order To Hire , IF THEN ELSE (Months of Runway < Min Runway , Months of Runway / (Min Runway + 1) , 1))

Units: Dmnl

If we have more than enough months of capital to burn, we can adjust the burn up, but if we have less than the min runway months of capital, we must adjust the burn down, otherwise don't adjust the burn

Change in Salary Required = Burn Rate * (Change in Burn Rate Required - 1)

Units: Dollars/Month

How much to adjust salary payments to make the required adjustment in burn rate

Change in Workforce Required = Change in Salary Required / Avg Salary

Units: People

How many people do we need to lay off to change salary payments by the required amount

COGS = Product COGS + Maintenance COGS

Units: Dollars/Month

Total cost of goods sold

Competitor Cost Adjustment Fraction Due To Policy = 1 + (Carbon Policy Switch * RAMP (Carbon Policy Effect on Comp Cost / Carbon Policy Ramp Time , Carbon Policy Start Time , (Carbon Policy Start Time + Carbon Policy Ramp Time)))

Units: Dimensionless

If there's a carbon policy, then effect on competitors cost will ramp up to it's full effect starting at start time and taking the amount of time specified by ramp time.

Competitor Margin = Max Competitor Margin - Competitor Margin Adjustment Fn (Delay3i (Normalized Price , Competitor Margin Adjust Time , 1)) * (Max Competitor Margin - Min Competitor Margin)

Units: Dmnl

Competitor will charge their max margin unless our price is below theirs in which case the Competitor Margin Adjustment Fn will determine how far to move towards the min margin they could charge

Competitor Margin Adjust Time = 3

Units: Months [0.1,36,0.1]

How long it takes for competitor to adjust their margin in response to venture's change in price

Competitor Margin Adjustment Fn ([(0.5,0)-(1,1)],(0,1),(0.5,1),(0.620795,0.907895),(0.69419,0.754386),(0.75,0.5),(0.799694,0.232456),(0.874618,0.109649),(1,0),(1000,0))

Units: Dimensionless

Input is ratio between price and competitor's price and output is how much to adjust competitor's margin. If ratio >=1, then no need to adjust at all, and if ratio <=0.5 (competitor is charging twice as much) then adjust the maximum amount, and s-shaped curve in between

Competitor Price = (Initial Competitor Cost Per Unit * Competitor Cost Adjustment Fraction Due To Policy) / (1 - Competitor Margin)

Units: Dollars/Unit

How much competitor charges (reference price)

Constrained Eng Hiring Rate = MIN (Desired Eng Hiring Rate , Max Eng Hires)
Units: People/Month
If we want to hire more people than we could afford, then if we don't want to hire anyone else, we can hire the maximum allowed number of engineers, otherwise we hire the proportional number we're allowed

Constrained Sales Hiring Rate = MIN (Desired Sales Hiring Rate , Max Sales Hires)
Units: People/Month
If we want to hire more people than we could afford, then if we don't want to hire anyone else, we can hire the maximum allowed number of sales people, otherwise we hire the proportional number we're allowed

Contact Rate = 0.25
Units: 1/Month
Rate of contact between adopters and potential prospects (relatively high)

Cost Adjustment Fraction Due To Policy = 1 + (Subsidy Policy Switch * RAMP (Subsidy Policy Effect on Cost / Subsidy Policy Ramp Time , Subsidy Policy Start Time , (Subsidy Policy Start Time + Subsidy Policy Ramp Time)))
Units: Dimensionless
If there's a subsidy policy, then effect on our cost will ramp up to it's full effect starting at start time and taking the amount of time specified by ramp time.

Cost Per Unit = (Initial Cost Per Unit * (Cumulative Purchases / Reference Production for Initial Cost) ^ (LN (1 - Decrease in Costs per Double Purchases) / LN (2))) * Cost Adjustment Fraction Due To Policy
Units: Dollars/Unit
Cost to manufacture/produce/provide product to purchasers

Cum Prob of Failure Based on Hazard Rate = INTEG(Hazard Rate Incr , 0)
Units: Dimensionless
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

Cumulative Purchases = INTEG(Purchase Rate , 1)
Units: Prospects
Total number of purchases made (regardless of how purchases used)

Current Ratio = IF THEN ELSE (Working Capital < 0, 1e-007, ((Working Capital + Hazard Rate AR Perc * Accounts Receivable) / - Cash Flow From Operations) / Current Ratio Timeframe)
Units: Dimensionless
Measure of cash relative to burn rate

Current Ratio Timeframe = 1
Units: Month
Timeframe over which to calculate current ratio

Cust Support Needed = Adopters * Cust Support Needed per Adopter + Purchasers * Cust Support Needed Per Purchaser
Units: Persons*Hours/Month

Total cust support needed for customers who have purchased and adopted the product (includes time needed to deliver the product)

Cust Support Needed per Adopter = 8
Units: Hours*Person/(Month*Prospect)
Person-Hours needed per month needed to support each adopter

Cust Support Needed Per Purchaser = 40
Units: Hours*Person/(Month*Prospect)
Person-Hours needed per month needed to support each purchaser (in process of adoption)

Decision Productivity Of Sales Effort = MIN (Max Decision Productivity From Sales , Sales Experience Productivity Multiplier * Max Decision Productivity From Sales * Effect Of Features On Decision Efficiency * Effect Of Price On Decision Efficiency * Effect Of Word Of Mouth On Decision Efficiency * Effect Of Customer Support On Decision Efficiency)
Units: Prospects/(Person*Hour)
The decision rate of sales effort as effected by price, features, cust support (for trials), and word-of-mouth

Decision sales effort = Fraction effort for decision * Sales Effort
Units: Persons*Hours/Month
Total number of hours spent by the sales force on decisions per month

Decrease in Costs per Double Purchases = 0.1
Units: Dmnl
Fractional decrease in costs to produce the products per double the amount produced (i.e. sold)

Default Rate = Normal Default Fraction * Effect of Cust Support on Default Rate Fn (Normalized Cust Support) * Effect of Cust Financial Condition on Default Rate Fn (Normalized Cust Fincl Condition)
Units: 1/Month
Rate at which customers are defaulting based on our cust support and their financial condition

Defaults on AR = Accounts Receivable * Default Rate
Units: Dollars/Month
Dollars per month we're losing due to customer defaults on their bills

Desired Eng Hiring Rate = MAX (0, Adjustment for Engineers + Eng Attrition Rate)
Units: Persons/Month
Hire enough people to replace expected attrition and adjust number of engineers to the desired level (and if need to reduce them, then do so through attrition)

Desired Eng Lay Off Rate = Allow Layoffs * MAX (0, - Constrained Eng Hiring Rate)
Units: Persons/Month
If hiring rate is negative, means we want to get rid of engineers

Desired Eng Proportion = ZIDZ (Desired Eng Hiring Rate , Desired Hiring Rate)
Units: Dimensionless
Proportion of all new hires we want for engineering

Desired Eng Vacancies = MAX (0, Expected Time to Fill Eng Vacancies * Constrained Eng Hiring Rate)
Units: People

Number of engineering vacancies needed to generate the desired hiring rate, given the expected time required to fill an engineering vacancy.

Desired Eng Vacancy Cancellation Rate = MAX (0, - Desired Eng Vacancy Creation Rate)
Units: Persons/Month
The desired rate of engineering vacancy cancellation, given by the desired vacancy creation rate whenever that rate is negative.

Desired Eng Vacancy Creation Rate = Constrained Eng Hiring Rate + Adjustment for Eng Vacancies
Units: Persons/Month
Create enough engineering vacancies to result in the desired hiring rate, adjusted to bring the stock of vacancies in line with the desired level.

Desired Engineering Effort for Cust Support = Cust Support Needed
Units: Persons*Hours/Month
Assume for now that we desire engineers just for the cust support that's needed now

Desired Engineering Effort for Feature Development = Desired Feature Development Rate[self,appropriable] * Eng Hrs Required per Feature[self,appropriable] + Desired Feature Development Rate[self,nonappropriable] * Eng Hrs Required per Feature[self,nonappropriable]
Units: Persons*Hours/Month
How many person hours are needed to develop the features we desire

Desired Engineers = xIDZ ((Desired Engineering Effort for Feature Development + Desired Engineering Effort for Cust Support) , Productive Eng Work Month , 100)
Units: People
How many Engineers we need to make up the feature shortfall, based on their productivity and how many hours are needed for cust support (current engineering) (but can't be negative if too many featues)

Desired Feature Completion Rate[company,featuretype] = Feature Shortfall[company,featuretype] / Desired Time to Catch Up Features[company,featuretype] + Perceived Feature Obsolescense Rate[company,featuretype]
Units: Features/Month
How many features we'd like to develop per month to obtain stock of features we'd like (taking into account features we're losing from obsolescense) -- allowed to go negative

Desired Feature Development Rate[company,featuretype] = MAX (0, Desired Feature Completion Rate[company,featuretype] + Abandonment Rate[company,featuretype] + Adjustment for FUD[company,featuretype])
Units: Feature/Month
At what rate do we want to be starting feature development, taking into account the features already under development, and the ones being abandoned

Desired Feature Ratio[self,appropriable] = 1.25
Desired Feature Ratio[self,nonappropriable] = 1.25
Desired Feature Ratio[competitor,featuretype] = 1.1, 1.1
Units: Dmnl [0,8,0.05]
Desired ratio between our features and competitors features (to drive product attractiveeness)

Desired Features[self,featuretype] = Features[competitor,featuretype] * Desired Feature Ratio[self,featuretype]
Desired Features[competitor,featuretype] = Features[self,featuretype] * Desired Feature Ratio[competitor,featuretype]

Units: Features

How many features we desire (based on how many features competitors have, and how we want to compare to competitors)

Desired FUD[company,featuretype] = Desired Feature Completion Rate[company,featuretype] * Avg Feature Devl Time[company,featuretype]

Units: Features

How many features we need under development to maintain the rate of feature development we desire

Desired Hiring Rate = Desired Eng Hiring Rate + Desired Sales Hiring Rate

Units: People/Month

The total amount of hires we desire to make per month

Desired Marketing Effort = Min Marketing Effort * Portion of Min Effort for Marketing Fn (Prospect to Population Ratio)

Units: Hours*Person/Month

Devote at least min hours, or the multiple of the min effort determined by the function

Desired Sales Effort = Desired Sales Hours / Time to Apply Effort

Units: Hours*Person/Month

How many person-hours of effort do we want the sales force to apply per month

Desired Sales Force = (Desired Sales Effort + Desired Marketing Effort) / Sales Work Month

Units: People

How many people do we want for sales and marketing

Desired Sales Hiring Rate = MAX (0, Adjustment for Sales Force + Sales Attrition Rate)

Units: Persons/Month

Hire enough people to replace expected attrition and adjust number of sales people to the desired level (and if need to reduce them, then do so through attrition)

Desired Sales Hours = ZIDZ (Potential Prospects , (Knowledge Productivity Of Sales Effort / Effect Of Features On Knowledge Efficiency)) + ZIDZ (Prospects , (Persuasion Productivity Of Sales Effort / Effect Of Features On Persuasion Efficiency)) + ZIDZ (Hot Prospects , (Decision Productivity Of Sales Effort / Effect Of Features On Decision Efficiency)) + ZIDZ (Purchasers , (Adoption Productivity Of Sales Effort / Effect Of Features On Adoption Efficiency))

Units: Hours*Person

How many person-hours of sales effort do we need based on our sales productivity and the number of prospects at each stage of the sales cycle

Desired Sales Lay Off Rate = Allow Layoffs * MAX (0, - Constrained Sales Hiring Rate)

Units: Persons/Month

If hiring rate is negative, means we want to get rid of sales people as long as we're willing to make lay offs

Desired Sales Proportion = ZIDZ (Desired Sales Hiring Rate , Desired Hiring Rate)

Units: Dimensionless
Proportion of all new hires we want for sales

Desired Sales Vacancies = MAX (0, Expected Time to Fill Sales Vacancies * Constrained Sales Hiring Rate)
Units: People
Number of sales vacancies needed to generate the desired hiring rate, given the expected time required to fill a sales vacancy.

Desired Sales Vacancy Cancellation Rate = MAX (0, - Desired Sales Vacancy Creation Rate)
Units: Persons/Month
The desired rate of sales vacancy cancellation, given by the desired vacancy creation rate whenever that rate is negative.

Desired Sales Vacancy Creation Rate = Constrained Sales Hiring Rate + Adjustment for Sales Vacancies
Units: Persons/Month
Create enough sales vacancies to result in the desired hiring rate, adjusted to bring the stock of vacancies in line with the desired level.

Desired Time to Catch Up Features[company,featuretype] = 2, 4; 6, 12;
Units: Months [0,80,0.1]
How soon we'd like our features to reach the desired level

Discount Rate = 0.1
Units: Dimensionless [0,1,0.005]
Discount Rate of the investor for determining NPV of investment in the venture

Earning Mult = 60
Units: Months
How many months of earnings (cash flow) to add to working capital to calculate the value of the venture

Effect of Cust Financial Condition on Default Rate Fn ([(0,0)-(3,10)],(0,100),(0.1,10),(0.25,4),(0.33,3),(0.5,2),(0.75,1.33),(1,1),(2,0.1),(100,0.01))
Units: Dmnl
If customers are bankrupt, then 100* default rate, and if customers have tons of cash, then 1% of default rate, and asymptotic in between\!\!

Effect of Cust Support on Default Rate Fn ([(0,0)-(5,20)],(0,1000),(0.05,20),(0.1,5),(0.2,3.25),(0.5,2),(0.7,1.3),(1,1),(5,0.5),(100,0.25))
Units: Dimensionless
With no customer support at all, all customers default, with norm cust support, defaults are normal, and with maximum cust support, curve is asymptotic to one quarter the default rate\!\!\!

Effect of Customer Support on Adopter Loss Fraction ([(0,0)-(3,10)],(0,10),(0.06,5.5),(0.125,3.5),(0.25,2.25),(0.5,1.5),(1,1),(1.44037,0.473684),(2,0.1),(100,0.1))
Units: Dmnl
If no cust support we lose everyone, and if great cust support we lose much fewer adopters than normal, and asymptotic curve in between\!\!\!

Effect Of Customer Support On Adoption Efficiency = Effect Of Customer Support On Adoption Efficiency Fn (Normalized Cust Support)
Units: Dmnl
How the efficiency of implementation is affected by the level of customer support

Effect Of Customer Support On Adoption Efficiency Fn ([(0,0)-(1,1)],(0,0),(1,1))
Units: Dmnl
Assuming cust support is needed to help purchaser to use product, linear relationship between cust support and adoption efficiency

Effect Of Customer Support On Decision Efficiency = Effect Of Customer Support On Decision Efficiency Fn (Normalized Cust Support)
Units: Dmnl
How the efficiency of sales at the decision stage is affected by the level of customer support

Effect Of Customer Support On Decision Efficiency Fn ([(0,0)-(10,10)],(0,0.5),(1,1),(10,1))
Units: Dmnl
Assuming only a portion of hot prospects are trialing, 0 cust support will only cut decision productivity in half, and then it will rise linearly to 1

Effect of Features on Adopter Loss Fraction ([(0,0)-(3,100)],(0,100),(0.06,32),(0.125,16),(0.25,8),(0.5,2),(1,1),(1.44037,0.473684),(2,0.1),(100,0.1))
Units: Dmnl
If no features, we lose everyone, and if great features we lose much less, and asymptotic curve in between

Effect Of Features On Adoption Efficiency = Effect Of Features On Adoption Efficiency Fn (Normalized Features)
Units: Dmnl [0,1]
How the efficiency of sales at the adoption stage is affected by normalized features

Effect Of Features On Adoption Efficiency Fn ([(0,0)-(1,1)],(0,0),(0.5,0.5),(1.5,0.9),(2,1),(100,1))
Units: Dmnl
No features still equals no sales, but given that they've already purchased, lack of some features will have less of a negative effect

Effect Of Features On Capab of Adoption Fn ([(0,0)-(10,10)],(0,0),(1,1),(10,10))
Units: Dmnl
Assume linear increase in capability

Effect Of Features On Decision Efficiency = Effect Of Features On Decision Efficiency Fn (Normalized Features)
Units: Dmnl [0,1]
How the efficiency of sales at the decision stage is affected by normalized features

Effect Of Features On Decision Efficiency Fn ([(0,0)-(1,1),(0,0),(0.125,0.02),(0.25,0.1),(0.375,0.2),(0.5,0.5),(0.675,0.8),(0.75,0.9),(0.875,0.98),(1,1)],(0,0),(0.25,0.02),(0.5,0.1),(0.75,0.2),(1,0.5),(1.35,0.8),(1.5,0.9),(1.75,0.98),(2,1),(100,1))
Units: Dmnl
S curve with no features = no sales, normal features = 50% sales, double features = 100% sales

Effect Of Features On Knowledge Efficiency = Effect Of Features On Knowledge Efficiency Fn (Normalized Features)

Units: Dmnl [0,1]

How the efficiency of sales at the knowledge stage is affected by the normalized features

Effect Of Features On Knowledge Efficiency Fn ([(0.5,0)-(1,0.5),(0,0),(0.125,0.02),(0.25,0.1),(0.375,0.2),(0.5,0.5),(0.675,0.8),(0.75,0.9),(0.875,0.98),(1,1)],(0,0),(0.25,0.02),(0.5,0.1),(0.625382,0.129386),(0.75,0.2),(0.874618,0.33114),(1,0.5),(1.35,0.8),(1.5,0.9),(1.75,0.98),(2,1),(100,1))

Units: Dmnl

S curve with no features = no sales, normal features = 50% sales, double features = 100% sales

Effect Of Features On Persuasion Efficiency = Effect Of Features On Persuasion Efficiency Fn (Normalized Features)

Units: Dmnl [0,1]

How the efficiency of sales at the persuasion stage is affected by normalized features

Effect Of Features On Persuasion Efficiency Fn ([(0,0)-(1,1),(0,0),(0.125,0.02),(0.25,0.1),(0.375,0.2),(0.5,0.5),(0.675,0.8),(0.75,0.9),(0.875,0.98),(1,1)],(0,0),(0.25,0.02),(0.5,0.1),(0.75,0.2),(1,0.5),(1.35,0.8),(1.5,0.9),(1.75,0.98),(2,1),(100,1))

Units: Dmnl

S curve with no features = no sales, normal features = 50% sales, double features = 100% sales

Effect of Marketing Effort on Market Size Fn ([(0,0)-(100,0.06)],(0,0),(1,0.001),(4,0.00578947),(10,0.01),(17,0.0147368),(26,0.02),(40.0612,0.0310526),(58.7156,0.0413158),(76.1468,0.0463158),(100,0.05))

Units: 1/Month

No marketing effort has 0 effect, normalized has a tenth of a percent, and the most effect we can have is 5% (with hundreds of marketing people) and asymptotic in between\!\!\!

Effect Of Marketing On Knowledge Efficiency = Effect Of Marketing On Knowledge Efficiency Fn (Normalized Marketing)

Units: Dmnl

How the efficiency of sales at the knowledge stage is affected by marketing

Effect Of Marketing On Knowledge Efficiency Fn ([(0,0)-(10,10)],(0,0.1),(1,1))

Units: Dmnl

If no marketing, cuts sales producitivity in by 90%, then linear up to 1

Effect Of Marketing On Persuasion Efficiency = Effect Of Marketing On Persuasion Efficiency Fn (Normalized Marketing)

Units: Dmnl

How the efficiency of sales at the persuasion stage is affected by marketing

Effect Of Marketing On Persuasion Efficiency Fn ([(0,0)-(10,10)],(0,0.5),(1,1))

Units: Dmnl

If no marketing, cuts sales producitivity in half, then linear up to 1

Effect Of Price On Decision Efficiency = Effect Of Price On Decision Efficiency Fn (Normalized Price)

Units: Dmnl [0,1]

How the efficiency of sales at the decision stage is affected by normalized price

Effect Of Price On Decision Efficiency Fn ([(0,0)-(10,1)],(0,1),(0.5,0.92),(1,0.75),(1.25,0.5),(2.50765,0.197368),(5,0.02),(10,0))
Units: Dmnl
S-curve, If price is 0, get 100% sales efficiency, if it's normal, get 75% efficiency, and as price approaches 10x normal, efficiency goes to 0\!\!\!

Effect Of Price On Knowledge Efficiency = Effect Of Price On Knowledge Efficiency Fn (Normalized Price)
Units: Dmnl [0,1]
How the efficiency of sales at the knowledge stage is affected by normalized price

Effect Of Price On Knowledge Efficiency Fn ([(0,0)-(10,1)],(0,1),(0.5,0.9),(1,0.5),(1.25,0.33),(1.55963,0.22),(2.50765,0.09),(3.42508,0.055),(5,0.01),(10,0))
Units: Dmnl
S-curve, If price is 0, get 100% sales efficiency, if it's normal, get 50% efficiency, and as price approaches 10x normal, efficiency goes to 0\!\!\!

Effect Of Price On Persuasion Efficiency = Effect Of Price On Persuasion Efficiency Fn (Normalized Price)
Units: Dmnl [0,1]
How the efficiency of sales at the persuasion stage is affected by normalized price

Effect Of Price On Persuasion Efficiency Fn ([(0,0)-(10,1)],(0,1),(0.5,0.9),(1,0.5),(1.25,0.33),(1.55963,0.22),(2.50765,0.09),(3.42508,0.055),(5,0.01),(10,0))
Units: Dmnl
S-curve, If price is 0, get 100% sales efficiency, if it's normal, get 50% efficiency, and as price approaches 10x normal, efficiency goes to 0\!\!

Effect Of Word Of Mouth On Decision Efficiency = Effect Of Word Of Mouth On Decision Efficiency Fn (Normalized Word of Mouth)
Units: Dmnl
How the efficiency of sales at the decision stage is affected by word of mouth

Effect Of Word Of Mouth On Decision Efficiency Fn ([(0,0)-(100,10)],(0,0.5),(1,1),(100,1))
Units: Dmnl
0 word of mouth will cut decision efficiency in half, and then it will rise linearly to 1\!\!

Effect Of Word Of Mouth On Knowledge Efficiency = Effect Of Word Of Mouth On Knowledge Efficiency Fn (Normalized Word of Mouth)
Units: Dmnl
How the efficiency of sales at the knowledge stage is affected by word of mouth

Effect Of Word Of Mouth On Knowledge Efficiency Fn ([(0,0)-(2,1)],(0,0.15),(1,1),(100,1))
Units: Dmnl
If no word of mouth, sales productivity only 15%, then linear up to 1

Effect Of Word Of Mouth On Persuasion Efficiency = Effect Of Word Of Mouth On Persuasion Efficiency Fn (Normalized Word of Mouth)
Units: Dmnl
How the efficiency of sales at the persuasion stage is affected by word of mouth

Effect Of Word Of Mouth On Persuasion Efficiency Fn ([(0,0)-(1,1)],(0,0.33),(1,1),(100,1))
Units: Dmnl
If no word of mouth, sales productivity only 1/3, then linear up to 1

Effective Engineering Effort = Engineering Effort * Engineering Experience Productivity Multiplier
Units: Persons*Hours/Month
How many productive hours engineers work

Effective Prospects = Total Prospects / Initial Potential Prospects
Units: Dimensionless
Current number of prospects compared to the initial number of prospects

Eng Attrition Rate = Engineers * Fractional Eng Attrition Rate
Units: Persons/Month
Rate at which engineers leave (quit)

Eng Experience From Hiring = Eng Hiring Rate * Avg Experience Of New Eng Hires
Units: Persons*Hours/Month
Experience gain from hiring

Eng Hiring Rate = (Eng Vacancies / Avg Time to Fill Eng Vacancies) * (1 - Bankrupt Switch)
Units: Persons/Month
Hire engineers based on how many vacancies have been created and the avg time to fill them

Eng Hrs Required per Feature[self,featuretype] = 350, 35000
Eng Hrs Required per Feature[competitor,featuretype] = 350, 35000
Units: Hours*Person/Feature
How many hours it would take one engineer to develop a feature

Eng Productivity Change Per Double Experience = 0.33
Units: Dmnl
The fractional change in productivity of engineers for every doubling of their effective experience

Eng Proportion = ZIDZ (Engineers , Total Labor)
Units: Dimensionless
Proportion of workforce made up of engineers

Eng Vacancies = INTEG(Eng Vacancy Creation Rate - Eng Vacancy Closure Rate - Eng Vacancy Cancellation Rate , Desired Eng Vacancies)
Units: People
The number of open positions the firm seeks to fill.

Eng Vacancy Adjustment Time = 1
Units: Months
The average time over which to adjust the actual number of engineering vacancies to the desired level.

Eng Vacancy Cancellation Rate = MIN (Desired Eng Vacancy Cancellation Rate , Max Eng Vacancy Cancellation Rate)
Units: Persons/Month

The rate at which to cancel existing engineering vacancies prior to filling them.

Eng Vacancy Cancellation Time = 1
Units: Months
The average time required to cancel an engineering vacancy.

Eng Vacancy Closure Rate = Eng Hiring Rate
Units: Persons/Month
Vacancies are closed when the employee is hired

Eng Vacancy Creation Rate = MAX (0, Desired Eng Vacancy Creation Rate)
Units: Persons/Month
The rate at which to create new engineering positions and begins to recruit for them.

Eng Work Month = 175
Units: Hours/Month
How many hours engineers work per month

Engineer Experience = INTEG(Increase In Eng Experience + Eng Experience From Hiring - Loss Of Eng Experience , Initial Engineers * Initial Avg Engineering Experience)
Units: Persons*Hours
Cumulative sales experience of organization

Engineer Lay Offs = MAX (Bankrupt Switch * ((Engineers / TIME STEP) - Eng Attrition Rate) , MIN (Desired Eng Lay Off Rate , Maximum Layoff Rate))
Units: Persons/Month
Engineers being layed off per month

Engineering Effort = Engineers * Eng Work Month
Units: Persons*Hours/Month
How many total hours engineers work per month

Engineering Effort for Cust Support = MIN (Cust Support Needed , Effective Engineering Effort * (1 - Min Development Fraction))
Units: Persons*Hours/Month
After allocating the min percentage of engineering effort to development, then use engineering effort to satisfy cust support (current engineering) needs

Engineering Experience Productivity Multiplier = (Avg Engineer Experience / Engineering Experience Reference) ^ (LN (1 + Eng Productivity Change Per Double Experience) / LN (2))
Units: Dmnl
Learning curve for productivity from experience (from Sterman pg 507, from Zangwill and Kantor (1998))

Engineering Experience Reference = 2000
Units: Hours
'Normal' engineering experience

Engineering Productive Effort for Development[self,appropriable] = (1 - Nonappropriable Devl Fraction) * (Effective Engineering Effort - Engineering Effort for Cust Support)

Engineering Productive Effort for Development[self,nonappropriable] = Nonappropriable Devl Fraction * (Effective Engineering Effort - Engineering Effort for Cust Support)
Engineering Productive Effort for Development[competitor,featuretype] = 8750, 8750
Units: Persons*Hours/Month
Assume competitor has 50 people each for approb and nonapprob feature devl

Engineers = INTEG(Eng Hiring Rate - Eng Attrition Rate - Engineer Lay Offs , Initial Engineers)
Units: Persons
Number of engineers

Engineers Adjustment Time = 6
Units: Months [0,1000,10]
The time period over which the firm seeks to bring the labor force in line with the desired level.

Exp Gain Per Adoption = 910
Units: Hours*Person/Prospect [0,6000,35]
How much of a boost in experience does each adopter provide

Exp Gain Per Purchase = 910
Units: Hours*Person/Prospect [0,6000,35]
How much of a boost in experience does each purchase provide to the sales force

Expected Time to Fill Eng Vacancies = Avg Time to Fill Eng Vacancies
Units: Months
For simplicity, assume managers know the real avg time to fill vacancies (i.e. no information delay)

Expected Time to Fill Sales Vacancies = Avg Time to Fill Sales Vacancies
Units: Months
For simplicity, assume managers know the real avg time to fill vacancies (i.e. no information delay)

Feasible Feature Devl Rate[company,featuretype] = Engineering Productive Effort for Development[company,featuretype] / Eng Hrs Required per Feature[company,featuretype]
Units: Features/Month
Given the engineering resources we have, and the amount of time it takes to develop a feature, how many features can we develop per month

Feature Abandonment Fraction[company,featuretype] = 0.099
Units: Dimensionless
Fraction of features under development that are abandoned

Feature Abandonment Fraction 1[company,featuretype] = Feature Abandonment Fraction[company,featuretype] / 3
Units: Dmnl
Fraction of features under development that are abandoned at 1st stage of product development

Feature Abandonment Fraction 2[company,featuretype] = Feature Abandonment Fraction[company,featuretype] / 3
Units: Dmnl
Fraction of features under development that are abandoned at 2nd stage of product development

Feature Abandonment Fraction 3[company,featuretype] = Feature Abandonment Fraction[company,featuretype] / 3

Units: Dmnl

Fraction of features under development that are abandoned at 3rd stage of product development

Feature Completion Rate[company,featuretype] = Feature Completion Rate 3[company,featuretype]

Units: Features/Month

The rate at which features are developed into the product determined by how many features were started and providing a 3rd order delay to complete them in the avg feature devl time

Feature Completion Rate 1[company,featuretype] = Feature Devl Rate 1[company,featuretype] * (1 - Feature Abandonment Fraction 1[company,featuretype])

Units: Features/Month

The rate at which features are developed into the product determined by how many features were started and providing a 3rd order delay to complete them in the avg feature devl time

Feature Completion Rate 2[company,featuretype] = Feature Devl Rate 2[company,featuretype] * (1 - Feature Abandonment Fraction 2[company,featuretype])

Units: Features/Month

The rate at which features are developed into the product determined by how many features were started and providing a 3rd order delay to complete them in the avg feature devl time

Feature Completion Rate 3[company,featuretype] = Feature Devl Rate 3[company,featuretype] * (1 - Feature Abandonment Fraction 3[company,featuretype])

Units: Features/Month

The rate at which features are developed into the product determined by how many features were started and providing a 3rd order delay to complete them in the avg feature devl time

Feature Devl Rate 1[company,featuretype] = MIN (Features Under Development 1[company,featuretype] / Avg Feature Devl Time[company,featuretype] , Feasible Feature Devl Rate[company,featuretype]) * 3

Units: Features/Month

Develop 1/3 of features in minimum of 1/3 the avg feature development time or 1/3 the amount of time it takes given the resources we have to develop features

Feature Devl Rate 2[company,featuretype] = MIN (Features Under Development 2[company,featuretype] / Avg Feature Devl Time[company,featuretype] , Feasible Feature Devl Rate[company,featuretype]) * 3

Units: Features/Month

Develop 1/3 of features in minimum of 1/3 the avg feature development time or 1/3 the amount of time it takes given the resources we have to develop features

Feature Devl Rate 3[company,featuretype] = MIN (Features Under Development 3[company,featuretype] / Avg Feature Devl Time[company,featuretype] , Feasible Feature Devl Rate[company,featuretype]) * 3

Units: Features/Month

Develop 1/3 of features in minimum of 1/3 the avg feature development time or 1/3 the amount of time it takes given the resources we have to develop features

Feature Obsolescense Rate[company,featuretype] = Features[company,featuretype] / Avg Feature Lifetime[company,featuretype]

Units: Features/Month

Features that go out of date per month

Feature Shortfall[company,featuretype] = Desired Features[company,featuretype] - Features[company,featuretype]

Units: Features

How many features we're missing compared to what we desire.

Feature Start Rate[company,featuretype] = MIN (Feasible Feature Devl Rate[company,featuretype] , Desired Feature Development Rate[company,featuretype])

Units: Features/Month

Start features at the rate at which we can develop them

Feature Value[company] = Features[company,nonappropriable] * Nonappropriable Feature Multiple + Features[company,appropriable]

Units: Features

Value of combined approbriable and nonapprobriable features

Features[company,featuretype] = INTEG(Feature Completion Rate[company,featuretype] - Feature Obsolescense Rate[company,featuretype] , Initial Features[company,featuretype])

Units: Features

Features of the product

Features Under Development 1[company,featuretype] = INTEG(Feature Start Rate[company,featuretype] - Abandonment Rate 1[company,featuretype] - Feature Completion Rate 1[company,featuretype] , 0)

Units: Features

1st stage of feature development

Features Under Development 2[company,featuretype] = INTEG(Feature Completion Rate 1[company,featuretype] - Abandonment Rate 2[company,featuretype] - Feature Completion Rate 2[company,featuretype] , 0)

Units: Features

2nd stage of feature development

Features Under Development 3[company,featuretype] = INTEG(Feature Completion Rate 2[company,featuretype] - Abandonment Rate 3[company,featuretype] - Feature Completion Rate 3[company,featuretype] , 0)

Units: Features

3rd stage of feature development

FINAL TIME = 240

Units: Month

The final time for the simulation.

Follow On Investments = Inv2 Amt * PULSE (Inv2 Time , 1) + Inv3 Amt * PULSE (Inv3 Time , 1) + Inv4 Amt * PULSE (Inv4 Time , 1)

Units: Dollars/Month

Investments made after the initial investment

Fraction effort for adoption = IF THEN ELSE (Weighted total prospects > 0, ((1 - Fraction effort for knowledge) * (Purchasers Emphasis Multiplier * Purchasers) / Weighted total prospects) , 0)
Units: Dmnl
Fraction of sales effort to make sure purchasers start using product

Fraction effort for decision = IF THEN ELSE (Weighted total prospects > 0, ((1 - Fraction effort for knowledge) * (Hot Prospect Emphasis Multiplier * Hot Prospects) / Weighted total prospects) , 0)
Units: Dmnl [0,1]
Percent of effort of sales people applied to persuading prospects to seriously consider purchasing

Fraction effort for knowledge = 0.25
Units: Dmnl
Percent of sales effort devoted to converting potential prospects to prospects

Fraction effort for persuasion = IF THEN ELSE (Weighted total prospects > 0, ((1 - Fraction effort for knowledge) * (Prospect Emphasis Multiplier * Prospects) / Weighted total prospects) , 0)
Units: Dmnl [0,1]
Percent of effort of sales people applied to persuading prospects to trial

Fraction Of Firms Capable Of Adopting = Initial Capab of Firms to Adopt * Effect Of Features On Capab of Adoption Fn (SUM (Features[company!,featuretype!]) / SUM (Initial Features[company!,featuretype!])) + Increase Of Capab Of Firms To Adopt Due To Policy
Units: Dmnl
Initial capability of firms to adopt is affected by features relative to the initial features

Fractional Eng Attrition Rate = 0.02
Units: 1/Month
Percent of engineers that leave per month

FUD Adjustment Time[company,featuretype] = 2
Units: Months [0,10,0.1]
How long to take to adjust FUD to desired level

Grants = 0
Units: Dollars/Month
Grants from government and other agencies (don't need to be paid back)

Hazard Rate AR Perc = 0.8
Units: Dmnl
Percent of AR to add to Working Cap for failure rate calc

Hazard Rate from Current Ratio = 1 / Current Ratio
Units: Dmnl
Hazard of failure of venture based on the current ratio

Hazard Rate from Current Ratio Ref = 0.01
Units: Dimensionless [0,0.5,0.005]
Value of Hazard Rate from Current Ratio for which Hazard Rate will have normal value

Hazard Rate from Features = 1 / Normalized Features - 1

Units: Dimensionless

As features approach 0, the hazard rate approaches infinity (if the venture has no features, it's likely to fail). If features are same as competition (norm features=1), then hazard rate is 0, and if features are better, then hazard rate is negative (less likely to fail)

Hazard Rate from Features Ref = 2

Units: Dimensionless

Value of Hazard Rate from Features for which Hazard Rate will have normal value

Hazard Rate from Prospects = 1 / Effective Prospects - 1

Units: Dimensionless

As prospects approach 0, the hazard rate approaches infinity (if the venture has no prospects it's likely to fail). If prospects are normal (1), then hazard rate is 0, and if venture has more prospects then hazard rate is negative (less likely to fail)

Hazard Rate from Prospects Ref = 2

Units: Dimensionless

Value of Hazard Rate from Prospects for which Hazard Rate will have normal value

Hazard Rate Incr = IF THEN ELSE (Cum Prob of Failure Based on Hazard Rate < 1, MIN ((1 - Cum Prob of Failure Based on Hazard Rate / Time to Max Prob of Failure) , Hazard Rate of Failure * (1 - Cum Prob of Failure Based on Hazard Rate)) , 0)

Units: 1/Month

If haven't reached 100% prob of failure, incremental prob of failure based on the cum prob of failure so far and the current hazard rate of failure

Hazard Rate of Failure = MAX (0, (Hazard Rate from Current Ratio / Hazard Rate from Current Ratio Ref + Hazard Rate from Features / Hazard Rate from Features Ref + Hazard Rate from Prospects / Hazard Rate from Prospects Ref) * (Normal Hazard Rate / 3)) * (Time / Hazard Rate Time Reference)

Units: 1/Month

Sum of hazard rates from current ratio, features, prospects scaled based on the normal hzard rate and the time the venture has been in operation

Hazard Rate Time Reference = 60

Units: Months

Normal time of operation for venture (hazard rate for times less than this will be decreased, and for times greater than this, increased)

Hot Prospect Emphasis Multiplier = 4

Units: Dmnl

Emphasis sales force places on hot prospects

Hot prospect loss rate = MAX (0, Norm Decision Rate - Purchase Rate)

Units: Prospects/Month

If rate of persuasion is not great enough to keep prospects from remaining the maximum prospect lifetime, then this is the rate they will be lost at

Hot Prospects = INTEG(Persuasion Rate - Hot prospect loss rate - Purchase Rate , Initial Hot Prospects)

Units: Prospects

Prospects who have been qualified to be more likely to purchase and/or are trialing the product

Increase Adoption Capab Switch = 0
Units: Dimensionless [0,1,1]
Whether's there's a policy that will effect firms capab to adopt

Increase In Addressable Market = Effect of Marketing Effort on Market Size Fn (Normalized Marketing)
Units: 1/Month
Increase in market (potential prospects) based on the effectiveness of marketing efforts

Increase In Eng Experience = Engineers * Eng Work Month + Adoption Rate * Exp Gain Per Adoption
Units: Persons*Hours/Month
Engineers learn from time spent working and from experience with adopters

Increase In Potential Prospects = Total Population * Increase In Addressable Market * Fraction Of Firms Capable Of Adopting
Units: Prospects/Month
Tracks increase in size of potential market by fraction of total firms that we are able to address that are capable of adopting product per time period

Increase In Sales Experience = Sales Force * Sales Work Month + Adoption Rate * Exp Gain Per Purchase
Units: Persons*Hours/Month
Sales people learn from time spent working and from experience making sales (purchases)

Increase of Adoption Capab = 0.05
Units: Dimensionless [0,1,0.01]
What additional fraction of firms will be capab of adopting per month

Increase Of Capab Of Firms To Adopt Due To Policy = Increase Adoption Capab Switch * RAMP (Increase of Adoption Capab / Adoption Capab Increase Ramp Time , Adoption Capab Increase Start Time , (Adoption Capab Increase Start Time + Adoption Capab Increase Ramp Time))
Units: Dimensionless
Ramp up effect of policy to increase capab of adoption

Inflows Of Capital = Follow On Investments + Grants + Cash Received From Customers
Units: Dollars/Month
Cash coming in per month

Initial Adopters = 0
Units: Prospects
Start with no adopters

Initial Avg Engineering Experience = 10000
Units: Hours [0,60000,50]
How much relevant experience initial engineers have on average

Initial Avg Sales Experience = 1500
Units: Hours
How much experience initial sales people have on average

Initial Capab of Firms to Adopt = 0.05

Units: Dmnl [0,1,0.01]
Fraction of firms initially that are capable of adopting product

Initial Competitor Cost Per Unit = 100000
Units: Dollars/Unit
How much it costs competitor to produce the competing unit. Assume this is a mature technology and that learning does not reduce their costs

Initial Cost Per Unit = 100000
Units: Dollars/Unit

Initial Engineers = 4
Units: Persons [0,40,0.1]
Number of engineers company initially has

Initial Features[company,featuretype] = 110, 4; 100, 2;
Units: Features [0,300,0.1]
Amount of features product has when firm starts compared to competiors

Initial Hot Prospects = 0
Units: Prospects [0,1000,1]

Initial Investment = 3e+006
Units: Dollars [0,1e+007,10000]

Initial Payment = Price * Initial Payment Fraction
Units: Dollars/Unit
Amount that customer pays up front

Initial Payment Fraction = 1
Units: Dmnl [0,1,0.01]
Fraction of price that is paid by customer up front

Initial Potential Prospects = 100
Units: Prospects

Initial Prospects = 0
Units: Prospects [0,1000,1]
Start with no prospects

Initial Purchasers = 0
Units: Prospects [0,1000,1]
Start with no purchasers

Initial Sales Force = 2
Units: Persons [0,20,0.1]
Number of sales people company initially has

INITIAL TIME = 0
Units: Month
The initial time for the simulation.

Initial Total Population = 100000
Units: Prospects
Max possible number of adopters

Inv2 Amt = 0
Units: Dollars/Month [0,1e+007,10000]
1.5e+006

Inv2 Time = 12
Units: Months [0,200,0.0002]

Inv3 Amt = 0
Units: Dollars/Month [0,1e+007,100000]

Inv3 Time = 24
Units: Months

Inv4 Amt = 0
Units: Dollars/Month

Inv4 Time = 36
Units: Months

Knowledge Productivity Of Sales Effort = MIN (Max Knowledge Productivity From Sales , Sales Experience Productivity Multiplier * Max Knowledge Productivity From Sales * Effect Of Features On Knowledge Efficiency * Effect Of Price On Knowledge Efficiency * Effect Of Marketing On Knowledge Efficiency * Effect Of Word Of Mouth On Knowledge Efficiency)
Units: Prospects/(Person*Hour)
The persuasion rate of sales effort as effected by price and features

Knowledge Rate = Norm Knowledge Rate * Prospect Conversion Fn (Potential Knowledge From Sales Effort / Norm Knowledge Rate)
Units: Prospects/Month
The rate of persuading prospects to become hot prospects is determined by the persuasion from sales effort until it asymptotically approaches the normal conversion rate (prospects are not persuaded faster than that)

Knowledge Sales Effort = Fraction effort for knowledge * Sales Effort
Units: Persons*Hours/Month
Total number of hours spent by the sales force on persuasion per month

Loss Of Eng Experience = (Engineer Lay Offs + Eng Attrition Rate) * Avg Engineer Experience
Units: Persons*Hours/Month
Experience lost when engineers leave

Loss Of Sales Experience = (Sales Layoffs + Sales Attrition Rate) * Avg Sales Experience
Units: Persons*Hours/Month
Experience lost when sales people leave

Lost Prospect Lifetime = 12

Units: Months
Amount of time before a lost prospect will reconsider becoming a prospect

Lost Prospects = INTEG(Adopter loss rate + Hot prospect loss rate + Potential Prospect Loss Rate + Prospect Loss Rate + Purchaser Loss Rate - Prospect Regain Rate , 0)
Units: Prospects
Former prospects who currently are not considering adopting the product

Maintenance Billing = Adopters * Quantity Per Purchase * Price * Maintenance Fraction * Maintenance Period
Units: Dollars/Month
Amount being charged to adopters per month for maintenance

Maintenance COGS = Maintenance Billing * (1 - Maintenance Margin)
Units: Dollars/Month
The costs for maintenance

Maintenance Fraction = 0.2
Units: Dmnl
The fraction of the price that is charged per period

Maintenance Margin = 0.8
Units: Dmnl
The fraction of the maintenace charge which is profit

Maintenance Period = 1 / 12
Units: 1/Month
The period over which the maintenance charge is made (i.e. 1/12 of a yearly fee is charged monthly)

Marketing Effort = MIN (Desired Marketing Effort , 0.5 * "Sales & Mktg Effort")
Units: Persons*Hours/Month
Spend no more than 50% of total sales effort on marketing, up to the desired marketing effort

Max Adoption Productivity From Sales = 1
Units: Prospects/(Person*Hour) [0,?]
Maximum number of purchasers that will able to start using product per hour of sales effort

Max Competitor Margin = 0.3
Units: Dmnl
Maximum margin competitor will extract

Max Decision Productivity From Sales = 1 / 16
Units: Prospects/(Person*Hour) [0,?]
Maximum number of prospects that can be persuaded per person-hour of sales effort

Max Eng Hires = IF THEN ELSE (Max Hires Per Month > 0, Max Hires Per Month * Desired Eng Proportion , Max Hires Per Month * Eng Proportion)
Units: People/Month
Max number of engineers we can afford to hire based on ratio of how many we want to hire, or if we need to layoff people, the number of engineers we need to layoff based on ratio of existing engineers

Max Eng Vacancy Cancellation Rate = Eng Vacancies / Eng Vacancy Cancellation Time
Units: Persons/Month
The maximum engineering vacancy cancellation rate is determined by the number of vacancies outstanding and the minimum cancellation time.

Max Hires Per Month = MIN (Change in Workforce Required / Months for Runway Adjustment , Total Labor * Maximum Workforce Growth Rate)
Units: People/Month
Maximum number of people to be added (or if negative, subtracted) from work force. Constrained to be less than the maximum fractional assimilation/growth rate for the labor force.

Max Knowledge Productivity From Sales = 1 / 4
Units: Prospects/(Person*Hour) [0,?]
Maximum number of prospects that can be created per person-hour of sales effort

Max Persuasion Productivity From Sales = 1 / 8
Units: Prospects/(Person*Hour) [0,?]
Maximum number of prospects that can be persuaded per person-hour of sales effort

Max Sales Hires = IF THEN ELSE (Max Hires Per Month > 0, Max Hires Per Month * Desired Sales Proportion , Max Hires Per Month * Sales Proportion)
Units: People/Month
Max number of sales people we can afford to hire based on ratio of how many we want to hire, or if we need to layoff people, the number of sales people we need to layoff based on ratio of existing employees

Max Sales Productivity Multiplier = 10
Units: Dmnl
Max amount of productivity multiple that experience can bring

Max Sales Vacancy Cancellation Rate = Sales Vacancies / Sales Vacancy Cancellation Time
Units: Persons/Month
The maximum sales vacancy cancellation rate is determined by the number of vacancies outstanding and the minimum cancellation time.

Maximum Layoff Rate = Engineers / Average Layoff Time
Units: People/Month
Maximum layoff rate is determined by the number of engineers and the layoff time.

Maximum Workforce Growth Rate = 0.25
Units: 1/Months
The maximum fractional rate of expansion for the labor force the firm can achieve/tolerate/assimilate.

Min Competitor Margin = 0.3
Units: Dimensionless [0,0.3,0.01]
Minimum margin competitor needs to charge

Min Development Fraction = 0.5
Units: Dmnl

Min percent of engineering effort to devote to development

Min Gross Margin = 0
Units: Dmnl
Minimum margin company will charge (can be negative if wish to sell at below cost to gain initial sales)

Min Marketing Effort = 350
Units: Hours*Person/Month
Min effort we want to devote to marketing

Min Price = Cost Per Unit / (1 - Min Gross Margin)
Units: Dollars/Unit
Min price will sell at

Min Runway = 3
Units: Months
The min months of runway we need overall, so if less than this will need layoffs

Min Runway In Order To Hire = 12
Units: Months
Minimum number of months of burn we can have in order to hire new employees

Months for Runway Adjustment = 2
Units: Months [0,6,6e-006]
How long to take to adjust hiring/firing based on runway

Months of Runway = Working Capital / Burn Rate
Units: Months
If we're burning cash, then months of cash we have left. If positive cash flow, then this will be a very large number

Nonappropriable Devl Fraction = 0.5
Units: Dimensionless
Fraction of development effort applied to non-approbriable features (as opposed to approbriable features)

Nonappropriable Feature Multiple = 100
Units: Dimensionless
Avg multiple of value of approbriable features that nonapprobriable features have

Norm Adoption Rate = Purchasers / Avg Purchaser Lifetime
Units: Prospects/Month
Rate at which purchasers could start using the product

Norm Decision Rate = Hot Prospects / Avg Hot Prospect Lifetime
Units: Prospects/Month
Rate at which prospects can be persuaded to trial the product

Norm Knowledge Rate = Potential Prospects / Avg Potential Prospect Lifetime
Units: Prospects/Month

Rate at which prospects can be persuaded to trial the product

Norm Persuasion Rate = Prospects / Avg Prospect Lifetime
Units: Prospects/Month
Rate at which prospects can be persuaded to trial the product

Normal Adopter Loss Fraction = 0.01
Units: 1/Months
What fraction of adopters we lose every month normally

Normal Default Fraction = 0.002
Units: 1/Month
The 'normal' fraction of customers that default on what they owe per month

Normal Hazard Rate = 0.05
Units: 1/Month
Given normal values for hazard rate components, the normal hazard rate of failure

Normalized Cust Fincl Condition = 1
Units: Dimensionless
How able customers are able to pay their bills compared to normal (1 is normal, 0 means they are bankrupt, and >1 means they have cash to spare)

Normalized Cust Support = xIDZ (Engineering Effort for Cust Support , Cust Support Needed , 1)
Units: Dmnl
Fraction of max cust support effectiveness (If we don't need any cust support, then we're supplying all that is needed). Also amount of cust support determines how soon product is "delivered".

Normalized Features = Feature Value[self] / Feature Value[competitor]
Units: Dmnl
Features of our company compared to competition (0 is no features, 1 is equiv features to competition)

Normalized Marketing = Marketing Effort / Desired Marketing Effort
Units: Dmnl
Normalized marketing determined by proportion of sales/marketing resources we have compared to desired

Normalized Price = Price / Competitor Price
Units: Dmnl [0,1]
Normalized price (actual price divided by competitor/reference price)

Normalized Word of Mouth = (Contact Rate * Potential Prospects * Adopters / Total Population) / Word of Mouth Reference
Units: Dmnl
Adoption by word of mouth is driven by the contact rate between potential adopters and active adopters. The word of mouth effect is small if the number of active adopters relative to the total population size is small.

NPV Calc Time Step = 1
Units: Month

The time step to use for calculating NPV

Outflows Of Capital = Total Salary Expense + COGS
Units: Dollars/Month
Cash being paid out per month

Output NPV = IF THEN ELSE (((Working Capital + (Earning Mult * Cash Flow From Operations)) >= Initial Investment * ((1 + (Discount Rate / 12)) ^ (Time / NPV Calc Time Step))) , 1, 0)
Units: Dimensionless
The NPV of the initial investment rate given the discount rate, current time, and current working capital and a multiple of the cash flow

Perceived Feature Obsolescense Rate[company,featuretype] = Feature Obsolescense Rate[company,featuretype]
Units: Feature/Month
What managers believe feature obsolescence rate is based on the actual rate (assume perception meets reality)

Persuasion Productivity Of Sales Effort = MIN (Max Persuasion Productivity From Sales , Sales Experience Productivity Multiplier * Max Persuasion Productivity From Sales * Effect Of Features On Persuasion Efficiency * Effect Of Price On Persuasion Efficiency * Effect Of Marketing On Persuasion Efficiency * Effect Of Word Of Mouth On Persuasion Efficiency)
Units: Prospects/(Person*Hour)
The persuasion rate of sales effort as effected by price and features

Persuasion Rate = IF THEN ELSE (Norm Persuasion Rate > 0, Norm Persuasion Rate * Prospect Conversion Fn (Potential Persuasion From Sales Effort / Norm Persuasion Rate) , 0)
Units: Prospects/Month
The rate of persuading prospects to become hot prospects is determined by the persuasion from sales effort until it asymptotically approaches the normal conversion rate (prospects are not persuaded faster than that)

Persuasion Sales Effort = Fraction effort for persuasion * Sales Effort
Units: Persons*Hours/Month
Total number of hours spent by the sales force on persuasion per month

Portion of Min Effort for Marketing Fn ([(0,0)-(0.005,10)],(0,10),(0.001,2),(0.002,1.5),(1,1.2),(1.47401,1.1),(1.85933,1.05),(100,1))
Units: Dmnl
If 0 Prospects, then devote max time to marketing, and if equal or more prospects compared to population, devote most of time to sales, and asymptotic in between\!\!\!

Potential Adoption From Sales Effort = Adoption Sales Effort * Adoption Productivity Of Sales Effort
Units: Prospects/Month
The amount of effort the sales people apply to persuasion times the productivity of that effort (which is determined by attributes of the product)

Potential Decision From Sales Effort = Decision sales effort * Decision Productivity Of Sales Effort
Units: Prospects/Month
The amount of effort the sales people apply to persuasion times the productivity of that effort (which is determined by attributes of the product)

Potential Knowledge From Sales Effort = Knowledge Sales Effort * Knowledge Productivity Of Sales Effort

Units: Prospects/Month

The amount of effort the sales people apply to persuasion times the productivity of that effort (which is determined by attributes of the product)

Potential Persuasion From Sales Effort = Persuasion Sales Effort * Persuasion Productivity Of Sales Effort

Units: Prospects/Month

The amount of effort the sales people apply to persuasion times the productivity of that effort (which is determined by attributes of the product)

Potential Prospect Loss Rate = MAX (0, Norm Knowledge Rate - Knowledge Rate)

Units: Prospects/Month

If rate of persuasion is not great enough to keep prospects from remaining the maximum prospect lifetime, then this is the rate they will be lost at

Potential Prospects = INTEG(Increase In Potential Prospects + Prospect Regain Rate - Knowledge Rate - Potential Prospect Loss Rate , Initial Potential Prospects)

Units: Prospects

Potential customers that have been selected to apply sales effort to persuade to trial the product.

Price = MAX (Target Price , Min Price)

Units: Dollars/Unit

If target price is greater than the min price we can charge, charge that. Otherwise, charge our min price.

Product COGS = Cost Per Unit * Purchase Rate * Quantity Per Purchase

Units: Dollars/Month

Cost of goods sold for products sold

Product Features Under Development[company,featuretype] = INTEG(Feature Start Rate[company,featuretype] - Abandonment Rate[company,featuretype] - Feature Completion Rate[company,featuretype] , 0)

Units: Features

Features that are being worked on by the engineering staff

Productive Eng Work Month = Eng Work Month * Engineering Experience Productivity Multiplier

Units: Hours/Month

Productive hours worked per month by engineers (experienced engineers are more productive)

Prospect Conversion Fn ([(0,0)-(2e+016,1),(0,0),(0.5,0.5),(0.75,0.7),(1,0.85),(1.25,0.95),(1.5,1),(100,1)],(0,0),(0.5,0.5),(0.75,0.7),(1,0.85),(1.25,0.95),(1.5,1),(1e+016,1))

Units: Dmnl

Prospect Emphasis Multiplier = 2

Units: Dmnl

Emphasis sales force places on prospects

Prospect Loss Rate = MAX (0, (Norm Persuasion Rate - Persuasion Rate))
Units: Prospects/Month
If rate of persuasion is not great enough to keep prospects from remaining the maximum prospect lifetime, then this is the rate they will be lost at

Prospect Regain Rate = Lost Prospects / Lost Prospect Lifetime
Units: Prospects/Month
Rate at which lost prospects become potential prospects again

Prospect to Population Ratio = Total Prospects / Total Population
Units: Dmnl
Ratio between all current prospects and total population

Prospects = INTEG(Knowledge Rate - Persuasion Rate - Prospect Loss Rate , Initial Prospects)
Units: Prospects
Potential customers that have been selected to apply sales effort to persuade to trial the product.

Purchase Rate = IF THEN ELSE (Norm Decision Rate > 0, Norm Decision Rate * Prospect Conversion Fn (Potential Decision From Sales Effort / Norm Decision Rate) , 0)
Units: Prospects/Month
The rate of persuading hot prospects to purchase the product

Purchaser Loss Rate = MAX (0, Norm Adoption Rate - Adoption Rate)
Units: Prospects/Month
Rate at which purchasers choose not to use the product

Purchasers = INTEG(Purchase Rate - Adoption Rate - Purchaser Loss Rate , Initial Purchasers)
Units: Prospects
Prospects who have purchased but aren't using

Purchasers Emphasis Multiplier = 1
Units: Dmnl
Emphasis sales force places on purchasers (since they already purchased, relatively less emphasis)

Quantity Per Purchase = 1
Units: Units/Prospect [0,20,2e-005]
Average number of units each adopter purchases/uses at a time

Reference Production for Initial Cost = 1
Units: Prospects
Initial Cost is assuming already produced this many of product

"Sales & Mktg Effort" = Sales Force * Sales Work Month * Sales Experience Productivity Multiplier
Units: Hours*Person/Month
Total effort for sales and marketing

Sales Attrition Rate = Sales Force * Sales Fractional Attrition Rate
Units: Persons/Month
Rate at which sales people leave (quit)

Sales Average Layoff Time = 2
Units: Months
The average time required to lay off a sales person

Sales Effort = "Sales & Mktg Effort" - Marketing Effort
Units: Hours*Person/Month
Effort devoted to direct sales

Sales Experience = INTEG(Increase In Sales Experience + Sales Experience From Hiring - Loss Of Sales Experience , Initial Sales Force * Initial Avg Sales Experience)
Units: Persons*Hours
Cumulative sales experience of organization

Sales Experience From Hiring = Sales Hiring Rate * Avg Experience Of New Sales Hires
Units: Persons*Hours/Month
Experience gain from hiring

Sales Experience Productivity Multiplier = MIN ((Avg Sales Experience / Sales experience reference) ^ (LN (1 + Sales Productivity Change Per Double Experience) / LN (2)) , Max Sales Productivity Multiplier)
Units: Dmnl
Learning curve for productivity from experience (from Sterman pg 507, from Zangwill and Kantor (1998))

Sales experience reference = 2000
Units: Hours
Amount of sales experience which will produce normal productivity

Sales Force = INTEG(Sales Hiring Rate - Sales Attrition Rate - Sales Layoffs , Initial Sales Force)
Units: Persons
Number of sales and marketing employees

Sales Force Adjustment Time = 6
Units: Months [0,90,1]
The time period over which the firm seeks to bring the sales force in line with the desired level.

Sales Fractional Attrition Rate = 0.02
Units: 1/Month
Percent of sales people that leave per month

Sales Hiring Rate = (Sales Vacancies / Avg Time to Fill Sales Vacancies) * (1 - Bankrupt Switch)
Units: Persons/Month
Hire sales people based on how many vacancies have been created and the avg time to fill them

Sales Layoffs = MAX (Bankrupt Switch * ((Sales Force / TIME STEP) - Sales Attrition Rate) , MIN (Desired Sales Lay Off Rate , Sales Maximum Layoff Rate))
Units: Persons/Month
Sales people being layed off per month

Sales Maximum Layoff Rate = Sales Force / Sales Average Layoff Time
Units: People/Month

Maximum layoff rate is determined by the number of sales people and the layoff time.

Sales Productivity Change Per Double Experience = 0.4
Units: Dmnl
Fractional change in productivity of sales people per doubling of their effective experience

Sales Proportion = ZIDZ (Sales Force , Total Labor)
Units: Dimensionless
Proportion of workforce made up of sales people

Sales Vacancies = INTEG(Sales Vacancy Creation Rate - Sales Vacancy Closure Rate - Sales Vacancy Cancellation Rate , Desired Sales Vacancies)
Units: People
The number of open sales positions the firm seeks to fill.

Sales Vacancy Adjustment Time = 1
Units: Months
The average time over which to adjust the actual number of sales vacancies to the desired level.

Sales Vacancy Cancellation Rate = MIN (Desired Sales Vacancy Cancellation Rate , Max Sales Vacancy Cancellation Rate)
Units: Persons/Month
The rate at which to cancel existing sales vacancies prior to filling them.

Sales Vacancy Cancellation Time = 1
Units: Months
The average time required to cancel a sales vacancy.

Sales Vacancy Closure Rate = Sales Hiring Rate
Units: Persons/Month
Vacancies are closed when the employee is hired

Sales Vacancy Creation Rate = MAX (0, Desired Sales Vacancy Creation Rate)
Units: Persons/Month
The rate at which to create new sales positions and begins to recruit for them.

Sales Work Month = 175
Units: Hours/Month
How many hours worked per month by sales people

SAVEPER = TIME STEP
Units: Month [0,?]
The frequency with which output is stored.

Subsidy Policy Effect on Cost = -0.2
Units: Dimensionless [-1,100,0.01]
What fraction our cost will change based on subsidy policy (-0.1 = 10% decrease, 1 = double, -1 means it goes to 0)

Subsidy Policy Ramp Time = 10
Units: Months

Time it takes for subidty policy to take full effect

Subsidy Policy Start Time = 0
Units: Months
Time at which subsidy policy starts having an effect

Subsidy Policy Switch = 0
Units: Dimensionless [0,1,1]
Whether's there's a subidy policy or not that will effect our costs

Target Norm Price = 0.75
Units: Dmnl [0,1,4e-006]
How much venture would like price to be compared to competitor's price

Target Price = Target Norm Price * Competitor Price
Units: Dollars/Unit
Price the venture desires to sell the product for, based on price of competition

TIME STEP = 0.125
Units: Month [0,?]
The time step for the simulation.

Time to Apply Effort = 1
Units: Month
Time period over which to apply desired sales hours of effort

Time to Max Prob of Failure = 1
Units: Month
When Hazard rate of failure is very high, how long for cum prob of failure to reach 100%

Total Investments = INTEG(Addl Investments , Initial Investment)
Units: Dollars
Total amount invested in venture

Total Labor = Engineers + Sales Force
Units: People

Total Layoffs = INTEG(Engineer Lay Offs + Sales Layoffs , 0)
Units: Persons
How many people have been layed off in total

Total Population = INTEG(- Increase In Potential Prospects , Initial Total Population)
Units: Prospects
Total population of firms that can conceivably become a prospect

Total Prospects = Hot Prospects + Potential Prospects + Prospects + Purchasers
Units: Prospects
All current prospects

Total Salary Expense = Avg Salary * Total Labor
Units: Dollars/Month

Total Loaded Salary for entire company

Weighted total prospects = Prospects * Prospect Emphasis Multiplier + Hot Prospects * Hot Prospect Emphasis Multiplier + Purchasers * Purchasers Emphasis Multiplier

Units: Prospects

Number of prospects weighted by relative importance of prospects vs. hot prospects vs. purchasers for the purpose of applying sales effort

Word of Mouth Reference = 0.1

Units: Prospects/Month

Reference value for word of mouth (at which it maximizes sales effectivness)

Working Capital = INTEG(Inflows Of Capital - Outflows Of Capital , Initial Investment)

Units: Dollars

Amount of money venture has available to spend. Increased by investments and revenue, and decreased by spending on salaries and COGS.

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