Business Development, Strategic Analysis and Social Responsibility within the Water Industry
A System Dynamics Approach

by

Thomas F. Gallo

B.A. Physics
Colgate University, 1996

Submitted to the Alfred P. Sloan School of Management on May 9th, 2003 in partial Fulfillment of the Requirements for the Degree of Master of Science in the Management of Technology

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Signature of Author

MIT Sloan School of Management
May 9, 2003

Certified by

Henry Birdseye Weil
Senior Lecturer, Behavioral Policy Science
Thesis Supervisor

Accepted by

David A Weber
Director, Management of Technology Program
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Abstract:

Business developments within the water industry exist in the form of corporate market ventures and governmental initiatives to satisfy municipal needs. The two are infinitely interrelated and with increasing demand, new financing options and heightened regulatory activity they are dynamically shaping the industry’s behavior. As 1) water has become a limited and invaluable resource, 2) once government controlled water operations fragment and reconsolidate under privatization, 3) technological adoption accelerates, and 4) regulation both domestic and internationally tightens, new ventures are at the mercy of increasingly multifaceted system dynamics.

This paper aims to analyze the complexity of these dynamics, by placing weight on the components that are critical in adding value to the system in the face of a shaping environment. Whether entrepreneurial, intrapreneurial or governmentally-driven, understanding truly relevant value propositions and strategic importance will help clarify the various elements that affect decisions on new business venture planes.

Thesis Supervisor: Henry Birdseye Weil
Senior Lecturer, Behavioral Policy Science
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1. Thesis Structure

The intent of this paper is to analyze the water industry specifically with regard to new business opportunities for both large and small firms. The approach will employ formerly used techniques and frameworks utilized by other industries, but will also incorporate a system dynamics model as a means to add insight and substance to the more traditional approaches. Though claiming this analysis can contribute anything more than a snapshot of today's industry developments might be over-reaching, the addition of the model will most certainly create an innovative and dynamic analysis more detailed and comprehensive than conventional methods.

The first two sections are intended to justify the importance of research in the water industry on technological, social and integrative business planes by identifying and briefly describing some of the factors contributing to its development. The latter will offer an initial framework for business developers to consider before attempting to innovate in the water industry. The make up of "the water industry" however is not only multifaceted, but growing to include a variety of business sectors and technologies labeled under Infrastructure (well and reservoir tapping, distribution piping and networks, pumps, etc): Water Treatment (filtration, separation, disinfection etc.), Information Technologies (data acquisition and management, security): Analytical Detection (biological, chemical, particulate) and Resource Management. Though ultimately the research presented here might serve as a starting point to provide frameworks capable of transcending each of the various business sectors, this paper's intended scope is to focus primarily on water treatment technologies. In formulating a mental model of the business environment, noteworthy components will be dissected to answer the following sequence of questions:

1. How does each component of the business environment, whether market growth or the influence of regulation etc., function with regard to structures set up both in the U.S. and internationally? Who are the critical people/organizations operating these components and what are their intentions and motivations?
2. In what way and at what point in the business development lifecycle does each component affect its development? When does it become part of the decision making process?

3. As each of these components become active or inactive, how do they affect the relationships between existing organizational alliances and competitors?

4. What are the recent and significant developments within each of these facets and where do experts/participants expect these to evolve or devolve?

One can already see the connections between these questions and the effect their answers will have on each other and the industry's components -- hence a dynamic relationship. By utilizing a system dynamics approach we can examine more intuitively the linkages between these elements, analyzing how they are influenced and in what magnitude. For example; does a particular polarity in one sector cause a growth response or a contraction in another area? Further complexity arises in such cases when multiple components, polarity swings and cycles are integrated into the industry's evolution. The dynamic feedback structure of the model will also help in identifying key leverage points that may not be initially intuitive or active at time = 0. This first diagram below will serve as an important umbrella under which more specific analyses can be accomplished.

Figure 1: Umbrella Industry Dynamics
This causal diagram illustrates a very general, but important perspective on how the industry is growing and why. Issues/Drivers can be viewed as an initially exogenous input to the model at time $= 0$ which leads to an increase in regulatory activity. Simply put, as problems arise that make people sick or deny citizens the right to water, usually government agencies are tasked to insure change through enforcement. These drivers can influence technology development and adopters directly, but as a general reflection of the strongest links currently evident as well as an attempt to keep the model basic, we will depict the link through regulations. Regulatory Activity is generally realized through effluent standards or price restrictions and is enforced with heavy fines. As such goals require realization and profitable opportunities arise, new technology demand is heightened and subsequently so is industrial participation and Technological Development. New Technology Adopters are also impacted by incentives to avoid penalties. Theoretically, the result will be additional technological innovations that offer Reasonable Solutions to solve Issues/Drivers. As Issues/Drivers is diminished, then the market will also shrink in response. This is the industry’s balancing feedback loop which acts as a market stabilizer, indicated by “B”.

However there are two reinforcing feedback loops, indicated by “R” that are currently building the industry and growing the market. Reasonable Solutions also increases the number of adopters, as “the answer to their prayers” becomes available. This in turn fuels Technological Development by providing dollars to participating firms and creates incentive for both adopters and developers to continue activity.

The second “R” is derived from the final linkage between Reasonable Solutions and Regulatory Activity. This is a very important loop to understand in the industry and as we will see in more detail further on, is a critical leverage point for entrepreneurs to access. Regulatory activity has an internal link with available technologies and will often respond to an Issue/Driver only if there is a feasible and implement able solution with respect to a cost benefit analysis. In some ways Regulation is an “If, Then, Else” operation.
Fortunately for business developers in the water industry the growth outlook is positive, and this is not because the image resembles a “happy face”. The Issues and Drivers are so far and beyond the scope of present solutions that technological development is more adept in strengthening the reinforcing loops than it is at accelerating the Balancing loop. According to sustainability laws, this will not hold forever, but the present environment is still dominated by need and has opened a window of opportunity.

Now that perhaps a certain level of environmental understanding has been achieved, the progression of this paper takes an inward yet reiterative approach towards a company’s competencies and specific business decisions. Illustrated in figure 2, the overall environment needs to be interpreted and applied to a specific market. Can we identify growth and opportunities and what affect does it have on shaping competitive dynamics? An iterative process, shown by the revolving arrows, is necessary because a more specific market analysis may add insight into previously unexplained aspects of the environment. Similarly, the overall industry is constantly changing and shaping each individual market. Growth and adoption in one market may leverage a technology to the point where it becomes attractive to other markets through standardization or cost effectiveness in economies of scale. Section 3 will help provide a tool to further understand a particular market in which a technology or idea can be actuated. At this point a generalized water industry product value chain will be mapped to identify key interactions for opportunity and an identification of competitive forces.
We now focus the lens once again on the specific competencies of an example company. With the hope that a broad understanding of the market and industry is now better understood, the third section of this approach, indicated by the core of Figure 2 is a more specific inclusion of how a company’s product and resources are suited for attacking, penetrating and sustaining in the prescribed market. The approach will begin with a much more detailed model broken into 6 components: Growth and Technological Development, Regulation, Adoption, Internal Operations, Market, and Customer Decision-Making Processes. Within this analysis it is possible to attempt identifying truly significant driving components, which ones are volatile, and to what extent the efficacy of the plan can be affected by swings and cycles in the system; sensitivity analysis. Three different technologies will be applied to the system dynamics model, the first dynamically through integration into the model while the second and third will be analyzed using the findings of the first. A loosely based confidential wastewater treatment technology originally developed at MIT will serve as the first forward-looking test. Ideally the analysis will aid in reinforcing or effectively debunking some of Porter’s 5 Forces.
the strategic and operational choices critical to the venture’s sustainability. The second revolves around **membrane desalinization technology** adoption to provide a level of efficacy to the approach through an historical/current example. The third will explore the possibility of a technology not yet developed – **UV light emitting diodes** as a preliminary investigation into its potential for water disinfection. The first two technologies are somewhat dissociated at the moment but we may experience a convergence if/when a dominant design for water treatment emerges.

As an author’s note to the reader, the final section of this paper highlights the importance of corporate responsibility in light of globalization and sustainability. The context of corporate responsibility is magnified in the water industry and serves to level the playing field in human rights, as well as create a sustainable business environment. It also transcends businesses that operate in the water industry to those that can provide much needed financial assistance as well as those that utilize water treatment technologies in their manufacturing processes. This paper will illustrate that there are many.

### 2. Why Water?

Not much time needs to be spent verifying water as an important issue since the present and eminent difficulties ahead are well covered in media and everyday conversation, especially with the recent conflict between the U.S. and Iraq. Most underdeveloped countries which lack critical water resources are not able to create opportunities for infrastructure projects due to insufficient funds. Evidence of this exists in the World Bank’s statistic that currently 2 billion people lack sufficient water resources. Discussion during the recent Third World Water Forum held in Kyoto Japan revolved around privatization and its role in financing the enormous development costs demanded by the Johannesburg initiative to reduce the amount of inhabitants short of water in half, to one billion by the year 2015. This is a monumental task requiring financial

\[2\] Barney: RBV
innovations, a huge amount of cooperation from governments on local and national levels as well as resources from the scientific and corporate communities.

What is not made common knowledge is the sheer diversity and broader understanding of where water issues arise and opportunities develop. In addition to the incredible demand of water are the dynamics occurring in technological developments and industry evolution. Many refer to water as the next “oil” and in some regions, such as Saudi Arabia, it is already equivalent in price.

The following are a number of quick case examples showing the variety and immeasurable impact of water utilizations for our society.

- Under the realm of global sustainability is the relationship between population increase, financial capacity and again the World Bank’s figures of 1.1 billion inhabitants without clean drinking water and 2.4 billion without sanitation resources. The United Nations Committee on Economic, Cultural and Social Rights recently designated water as a human right which sets a guideline for holding countries accountable for insuring adequate water resources. The committee stated: “The human right to water is indispensable for leading a healthy life in human dignity. It is a pre-requisite to the realization of all other human rights.”¹ On a developmental plane the visionary city planners of New York built 12 foot pipes from distant reservoirs to supply the city which today uses over 1 billion gallons of water per day. Now as water shortages become more frequent further growth for this and many other regions may become stunted. What does this mean for regulatory activity and pricing models? What does this suggest about future government budget allocations for the U.S. and other economies? How quickly will the industry adapt and from where will the necessary innovations develop?

In addition to the world’s demand for drinking water and sanitation on the human level is a technological demand from the industrialized world for water in production facilities. Industries ranging from food and beverage, to automotives to semiconductors all utilize water for their processes whether they are production activities, cleaning, emissions control or heat transfer usage. For a sense of scale, U.S. manufacturers alone use more than nine trillion gallons of fresh water every year.\(^4\) A 2002 report issued by the Global Environmental Management Initiative (GEMI) of which over 40 large multinational companies participate, indicated that 50% of this water demand relies on public or private water systems while the remainder is generated “in-house” from ground, surface or sea water systems. Where ever the water is collected from, the operations of these companies would come to a grinding halt without this resource. A quintessential example is Intel which is actively attacking the problem for environmental and bottom-line reasons, and recognizes its own dependence on water in its day to-day operations. At one point Intel’s New Mexico facilities alone required approximately 4 million gallons per day (MGD) for operational activities of which a single six-inch silicon wafer was reported to require 2,275 gallons of high purity de-ionized water in its production process.\(^5\) As Intel experienced first hand, one must always realize that the demand for the community’s drinking water will always trump the manufacturing needs of a processing plant. The inhabitants of Albuquerque became very active in pursuing their own interests and the environmental impacts of such a demand, eventually forcing Intel under court order to give up their water rights in the area and attain them elsewhere. Countless other examples from U.S. and Chinese agriculture, to facilities along the Rio Grande, to Toyota motor manufacturing plants can be cited where production capacities were greatly reduced due to insufficient water resources. What is the impact that these patterns will have on the development of other technologies such as fuel cells? How can innovators in the industry position themselves to take advantage of the drive for


\(^{5}\) GEMI. Connecting the Drops Toward Creative Water Strategies. 2002
regional industrial growth and where can water solutions aid facilities that do not have sufficient water but are not aware of additional efficiency benefits?

- The Intel-New Mexico case is also a good lead-in to the issue of resource wars on local and national levels. Certainly the drought conditions in the southwest U.S. have been widely publicized for such cases as well as their involvement in the power generation woes of the region. But this trend is escalating on even more politically charged grounds as water sources, especially rivers, tend to cross international boundaries and provide sustenance to communities with significant cultural differences. The U.S. and Mexico continue to squabble over water rights stemming from the Rio Grande. How much right does the owner of the source have to dictate the use of that resource when downstream, other demands are in place, perhaps ones that have been in effect even longer? The issue between Malaysia and Singapore is another example of international industrialized communities who continue to contest each other’s resource rights. Singapore has initiated a first of its kind program and treatment facility under the campaign of “New Water” for reusing purified waste water for drinking water. Are they on the right path for sustainability and what does it say about the need for proper financing capabilities? Perhaps one of the most politically charged debates however is evident in India’s and Pakistan’s conflict over the Kashmir region and its source to the Indus River System. “Pakistan is the home of the largest man-made irrigation system in the world.”6, and is threatened by the fact that its main water source could be diverted by India which currently controls the region and suffers from overpopulation.

One can see the impact that water has on our increasingly globalized society, of which opportunities for both ethical and financial goals can be realized.

As mentioned earlier, the second plane of interest exists are the dynamics that are currently occurring in the water industry and how they might be mapped out and

6 http://www.collegian.psu.edu/archive/2002/01/15-02tdc/01-15-02dnews-05.asp
analyzed in relation to other industries and precedents. The water industry, though highly fragmented, appears to span a range within Utterback/Tushman's technology phase model in a state between a discontinuous phase, fluid phase and partially a transitional phase.⁷

**Figure 5: Industry Technology Phase Model**

<table>
<thead>
<tr>
<th>Fluid Phase:</th>
<th>Transitional Phase:</th>
<th>Mature Phase:</th>
<th>Discontinuous Phase:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Product variability</td>
<td>• Dominant design established</td>
<td>• Remaining companies focus on</td>
<td>• Introduction of Disruptive</td>
</tr>
<tr>
<td>• Competition for dominant design.</td>
<td>• Competition for standardization</td>
<td>process improvements</td>
<td>Technologies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Market Convergence</td>
</tr>
</tbody>
</table>

The Utterback/Tushman model focuses on the evolutionary aspects and cycles of industries/technologies over time. Utterback describes the fluid phase as an industry state with high product variability in the market, yet rapidly increasing demand. The industry also exhibits a high level of product uncertainty as well as innovation. This phase can be identified in the water industry through its current increase in demand and an environment where technologies vie for product certifications in new applications.

The transitional phase marks a point where a dominant design has established itself in the industry and attempts to work towards standardization. Membrane filtration provides a consistent analogy and appears to be emerging as a dominant design in the industry; though it is still hard to tell. There are also multiple players who provide membrane technologies, compete on performance, and battle to establish distribution capabilities.

The mature phase of the industry represents a period where the focus of improvement revolves around process and cost reduction along with product innovations. Profit margins become ever critical as competitive advantages in quality and differentiation disappear. The water industry has historically been dominated by conventional treatment technologies, coagulation, flocculation, sedimentation, and coarse filtration. As things change however, this phase is perhaps the least evident in today’s water industry.

The mature phase’s disappearance is partially due of the emergence of new technologies entering the industry through innovation and cross-market applications. Having become such a critical issue, applications in the water industry have become a primary thought in the minds of many entrepreneurs when directing research or when choosing a market for new technologies without a home. The convergence of multiple technologies used in other industries as well as the applications of other technologies in support of the water industry, are indicative of Tushman’s addition to the framework, the discontinuous phase. As we look back, conventional technologies are becoming obsolete.

The rate of technological development which as mentioned previously has consistently for the last 100 years revolved around conventional coagulation-flocculation-sedimentation-filtration-disinfection treatment, took a leap in the late 1970’s when “high tech” alternatives were first conceived along with the Safe Drinking Water Act (SDWA-1972). Many of these technologies are now emerging as viable products and are trying to establish themselves as dominant designs (ex. Membrane technologies). As incremental advancement in membrane technology is driving its cost down and allowing it to be
considered a feasible solution, other treatment technologies such as mixed film
technology anaerobic bioreactors, enhanced chemical treatments, pulsed blackbody
ultraviolet radiation devices to name a few are also entering the scene. When an
intruding technology enters a market, added incentive for the incumbent creates another
burst of innovation. Some of these are “humps” on older treatment performance curves,
evident in the chemical, anaerobic and UV sectors of the industry and even involve novel
approaches to using products from other industries. Figure 4 below illustrates standard
performance curves and some of the advancements in each technology. Note that placing
them all on the same timeline for comparative purposes would be difficult as each
application may currently have different performance objectives—further proof of a
fragmented industry. They represent the performance of each technology over time and
often, like other technologies, exhibit s-curve behavior. Slow initial growth is shown as
research becomes familiarized and a market focus is attained, followed by rapid
advancements linked to adoption and industry participation rates. Finally the law of
diminishing returns kicks in which marks the end of the product’s ability to advance. Of
particular interest is the estimated relative slope of advancements in membrane research
as compared to other technologies. Membrane technology, specifically hollow fiber
membranes, continues to establish itself as a dominant technology.
3. Understanding the Overall Business Environment

As previously stated, perhaps the most critical component to analyzing long term business sustainability or a successful exit strategy lies in the fundamental aspects of the business environment. Managers can identify opportunities through an entrepreneurial process or by solving their own company’s existing problems through an internal iterative process of 1) determining their needs and competencies and 2) setting them against an external environmental framework. Though these parameters are perhaps common knowledge for experts in the field, it is the dynamics of how they evolve and react with each other that is not always considered by today’s business managers. Ultimately, an overall understanding may perhaps offer insight into the key drivers for business development in light of a firm’s specific resources. Referencing Utterback’s work on technological innovation, it will also shed light on where the product and process development lifecycle of the industry currently resides, fluid, transitional, mature or
discontinuous.\textsuperscript{8} This chapter’s detail of value chains and variables will help give an overview of matters worthy of management consideration to help set up the strategic decision-making process in Chapter 4.

\textbf{3.01 Value Chains}

Developing a “value chain”, defined as the string of participants involved in the distribution of a product from initial component suppliers to the end user, can help identify a clear set of stakeholders and business opportunities. Two sets of value chains should actually be identified as any prospective business team needs to consider both the progression cycle for the implementation of their product as well as the “product’s product”, in this case, water. The first value chain describes a company’s specific production process and the components that will enable it to introduce a product into the market successfully. The product here can be anything from filters, to chemicals, or semiconductors utilizing water in its process. The second refers to the supply chain of the ultimate product, “water” from start to finish, or from source to consumption and discharge. Figure 5 represents a pictorial example of the product chain and the water chain below.

It is important to realize however that the individual aspects of the two value chains are actually linked dynamically. Perhaps small in some connections and greater in others, the associations demand special attention in discontinuous and fluid stages when industrial convergence and technological crossovers emerge. As a hypothetical example, if desalinization technologies grow as expected, there is a high potential that they will lead to very large scale facilities, having a profound effect on distribution methodologies as well as products entering the industry on a security platform.

These dynamics shape the industry, and subsequently work their way back to individual product value chains. Therefore figure 5 outlines the chains as a snapshot view

\textsuperscript{9} Roberts, Edwards.
illustrating the need for its understanding to act in the present, but also implying the potential for dynamic evolution between the two chains and other products.

Figure 8: Water Processing Value Chain and Dynamism

It is important to realize where one fits into both chains to have a firm grasp on where value in the system is added or potentially reduced. Unless a new market niche is discovered, most scenarios in either case tend to have net chain value balances just above zero. An incremental net gain in one area is most likely going to reduce value somewhere else, whether it affects a direct competitor or another component in the
supply chain. Rarely do advantages in market share or new market development come without others incurring costs or consequences. These entities will be provoked into retaliation through cost or other means, and must be identified to tailor one’s product in a way that will minimize their “pain” or establish sufficient defense mechanisms to succeed.

This analysis focuses on the processing/purification sector of the water chain and therefore deals directly with product injections into utilities, as well as an additional subset of the end user segment. The latter can encompass an additional internal chain for manufacturing facilities or homes where more advanced and/or specialized treatment is desired, represented in figure 5 by the recycling arrows. However, since water is destined to travel through all segments of the water chain, consideration must also be taken with regard to how a product influences behavior among governmental, NGO, utility operator, industry and residential sectors.

Taking this a step further GEMI actually views the product chain for all companies, even ones outside the industry from a bottom line perspective. Here, a company is advised to evaluate the value chains within their existing businesses to determine the current impact of water on their products and help mitigate risk. This latter analysis goes as deeply as analyzing the company’s supplier’s water risk. By identifying problematic areas, not only are production and expansion risks reduced, but potentially new business opportunities that affect the top line will also be discovered in the process. This internal operations value chain will vary widely depending on the industry and is outside of the final scope of this paper, but its framework is still a valuable reference (figures 6 & 7).
3.02 Population/Industrial Growth & Global Sustainability

Perhaps one of the most influential driving forces for new technological development in the water industry is felt from the effect of unmanageable population growth and its influence on an unsustainable future. In response, involvement of the World Bank, the United Nations, and governments led to environmental summits first in Rio in 1992 and then again in Johannesburg in 2002. The impacts of these summits were a boost in awareness for water solutions and at times proposals for self regulated global rules such

\[\text{GEMI. Connecting the Drops Toward Creative Water Strategies. 2002}\]

\[\text{ibid.}\]
as a 1 billion person water improvement milestone by 2015. What this milestone fails to consider is the estimated population growth and strain over the same period in which close to a billion more people will likely be short of adequate water resources. Therefore their benchmark will actually need to solve resources for close to 2 billion people to make a difference in the initiative and subsequently give a larger percentage of the population access to equitable “human rights” and “the markets”. Already one can see that even under today’s technological progress, the “needs/drivers” variable in the first causal loop diagram (figure 1) will be growing at a sufficient rate on its own to keep the industry loops active for a long time to come.

Refer to figure 8 below for a depiction of the world’s growth rate for more developed countries (MDC) and less developed countries (LDC).

Figure 14: World Population Growth

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12 McDevitt, Thomas M. World Population Profile. 1998
More important to global sustainability will be the limits to growth based on population consumption, especially with the developmental aspirations of countries such as China and India. As these two giants grow, where will the necessary and already strained water resources come from? There are currently three potential answers; becoming more efficient and demanding less water, reusing water on a much larger scale, and the oceans. These will be discussed in more detail in chapter 6.

On a more localized level, growth within the U.S. is also being hampered as real estate developers are unable to proceed with development plans because of insufficient infrastructure and water sources. Population relocation and growth generally creates higher demand in populated areas, but also new demand in others, and while some water treatment strategies target the need for upgrades in existing plants, others focus on the development of new facilities and small systems. Interestingly, as individual industries are made aware of their dependency on public water systems, many are getting involved and have also become targets for treatment technologists as a means of market entry. As an example many point of entry (POE) and point of use (POU) treatment providers for the home and utilities actively solicit home-builders, a previously segregated demographic from water treatment, for leverage. This pattern takes us back to the GEMI model where very different industries, all with a common dependency on water, are becoming players in the water industry’s evolution and allow for alternative entry strategies.

Population growth and its affect on municipal and industrial demand along with regulation form the two most significant drivers in a utility’s decision to actively seek new technologies in the market.

### 3.03 Infrastructure Development

Infrastructure development is certainly one of the key topics being discussed by any government agency since transportation and treatment are just as critical as finding an adequate water source. Certainly developing nations require significant infrastructure
development and the necessary capital to act. As evidence, many partially completed utilities exist with the hope of continuing the job years down the road when/if more allocations can be granted. As a result of the Johannesburg summit in June 2002, the European Union has been called upon to create a 1 billion dollar fund to provide clean drinking water for the world’s poorest nations. Most of this activity will be focused on African nations, but the need for infrastructure development exists all over the world. Developed nations such as the United States also require significant development and reconstruction to an aging system where much of its current infrastructure is comprised of century old iron pipes. These have finally corroded to such a degree that water loss and cross contamination occurrences have reached intolerable levels.

A loosely defined yet still awakening statistic claimed that three trillion dollars would be needed to rehabilitate America’s entire infrastructure. Further analyses show that the annual financing gap between government allocations and the money needed for capital and O&M will be between 76 and 634 Billion dollars in the next 20 years depending on utilities’ revenue growth scenario. Though this is based on an assumption that government spending will not increase from its present level, numbers such as these highlight a situation where demand is increasing much faster than available funding. The industry now looks towards financial creativity, asset management and technology development to provide more cost-effective alternatives with the hope of closing the gap. Regions such as the U.S., parts of Europe, and especially China, where infrastructure initiatives are able to integrate with sources of available capital (even if less than the total amount required) do however present themselves as prime opportunities for new business.

The tragic events of September 11th have also challenged the way people think of infrastructure and have promoted new design concepts for protection. The new mindset affects both the physical nature of treatment systems as well as the application of sourcing and distribution networks and control, i.e. decentralized treatment strategies. In

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addition, as both surface and ground reservoirs are being depleted, more emphasis is being placed on point source extraction and reintroduction, leading towards smaller system concepts. The arrows pointing towards this model also lessen the financial burden for large scale complex interconnecting infrastructure networks. From a business perspective this model reinforces the degree of industry fragmentation, increasing the level of product distribution complexity, but also creating a higher diversity of niche markets.

Fortunately for new companies, recent trends in privatization and consolidation help mitigate distributional complexity. The evolution of larger, more geographically influential equipment suppliers such as Suez (ONDEO) and Vivendi, and consulting giants such as CH2M Hill, has allowed higher potential for tapping into extensive pools of sales representatives and distribution channels. This is an especially valuable tool for fledgling companies which lack sufficient capital and other resources to get to market before their competitors. On the downside, exclusivity agreements and the leverage these organizations have over smaller companies also create less favorable partnership terms and higher barriers to entry.

**Note 1:** The role of desalinization adoption is an important issue especially with regard to its impact on water distribution models. Please refer to section 5.4 for further discussion.

**Note 2:** The emergence of bottled water has provided some relief on distribution systems as more people opt for the mobility and perceived quality offered by these producers. It has also had a negative impact on source depletion as this volume is ultimately discharged away from the point of origination.

### 3.04 Policy & Regulation

UN initiatives and resolutions declaring water as a human right, broadcasts the importance of maintaining water as a precious commodity. In other words, the public should not be obligated to pay any more that the absolute minimum cost for this life sustaining resource. The UN, NGO’s and other government agencies such as the EPA
also send standard messages to the industry requiring all treatment facilities or organizations to utilize the Best Available Technology (BAT) according to the Safe Drinking Water Act (SDWA), especially with regard to water discharge. Herein lies a conflict when the best available technology is not always financially feasible for implementation, especially on large scale public systems. As a sign of flexibility, rules are now utilizing quotes such as Best Practicable Control Technology (BPT) for compliance. At the same time governments are increasingly being swayed towards the benefits of privatization and allowing the dynamics of competition work to streamline the system, reduce operational costs and promote technological development and implementation. The actions of agencies such as the EPA, though slow in relation to industry developments, are critical in making business decisions. Their rules and regulations ultimately enforce changes in treatment procedures and requirements. Knowing this, the markets constantly have an eye on new regulatory developments, just as regulators watch for new “feasible” technologies and their applicability for dispersion. As such, many firms actively partake in lobbying efforts to promote their own interests.

Recent trends show an unprecedented amount of regulatory activity. Between 1975 and 1992, nine regulations were finalized, yet from 1998 to 2004, 10 new regulations are going through their finalization processes. At the same time, the rate of newly regulated contaminants peaked between 1991 and 1992 and now appears to be slowing down. These two facts indicate a shift in regulatory action from the identification of hazards to a stringency focus based on cost/benefit analyses. Most of these new regulations are induced by new technologies and Maximum Concentration Limit (MCL) targets. Trends such as these are also good reflections of government response to a wave of “feasible” solutions and an acceleration of technological development in the industry.

Recent regulatory initiatives have also been more focused on watershed protection than on drinking water technology. There is currently and rightfully more attention being paid towards discharge limits such as the Total Maximum Daily Load (TMDL) approach than on drinking water requirements. This strategy serves not only to protect the public’s
drinking the water, but also the environment and the reservoir itself as a more sustainable solution.

Also worth noting: As with any regulatory agency, there are interested parties who have significant abilities to influence regulatory behavior. Industry capture is certainly one threat, but many times internal political dynamics also play a significant role. For example, the President has a significant amount of influence on agency efficacy. The EPA has been especially susceptible and sensitive to Presidential and Congressional changes between Democratic and Republican majorities. As an example, the TMDL initiative which is considered the primary program of the Clean Water Act (1972), was placed on hold and viewed by many as weakened upon President G.W. Bush’s inauguration.

In summary, regulatory activity can be influenced by public pressure, interested parties (internal and external) and technological development, each of which require attention when adapting to the industry’s business dynamics.

3.05 Privatization

Privatization is an industry changing innovation that works its way into financing and pricing issues, infrastructure development, technology innovation and regulation. The topic of privatization refers to the movement for governments to outsource the ownership and operation of its utilities. This enables competitive bidding for utilities and a means of cash flow for the government to perhaps allocate to non-privatized utilities. The end goal is to provide capital assistance to revitalizing the country’s infrastructure and perhaps incentives for technological development and price competition. As business and profit minded organizations look to streamline the management of utilities, the overall system infrastructure should theoretically become stronger. Successful implementations of privatization in the U.K., Venezuela, and Australia are creating a buzz about its implementation in the U.S.
The cost savings from outsourcing water-delivery services have typically ranged from 10 to 25 percent. A 1996 study found that investor-owned water companies in California provide water at the same price to consumers as municipal water companies even though the former must pay local, state, and federal taxes; generally cannot make use of tax-exempt debt; and are expected to earn a profit for their shareholders.\textsuperscript{15} The "success story" tables 1 and 2 shed some light on the capital and operational costs between government-owned and investor-owned municipal water providers. Note the extreme differences in staffing expenses.

Table 1:

<table>
<thead>
<tr>
<th>Project</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leominister, Massachusetts (Water and Wastewater)</td>
<td>$3M capital costs $350,000 annual costs (20 Years)</td>
</tr>
<tr>
<td>North Brunswick, New Jersey</td>
<td>$9.9M (concession fees/20 yrs)</td>
</tr>
<tr>
<td>Roanoke, Alabama (Water and Wastewater)</td>
<td>30% annually\textsuperscript{16}</td>
</tr>
</tbody>
</table>

\textsuperscript{15} http://www.privatization.org/Collection/SpecificServiceAreas/Water-local.html
\textsuperscript{16} ibid.
Table 2:

<table>
<thead>
<tr>
<th>Selected Operating Expenses for California Investor-Owned and Government Water Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Investor Owned</strong></td>
</tr>
<tr>
<td><strong>Government Owned</strong></td>
</tr>
<tr>
<td>Total operating expense per connection</td>
</tr>
<tr>
<td>$273</td>
</tr>
<tr>
<td>$330</td>
</tr>
<tr>
<td>Employees per 1,000 connections</td>
</tr>
<tr>
<td>1.62</td>
</tr>
<tr>
<td>3.49</td>
</tr>
<tr>
<td>Salaries as percent of operating revenue</td>
</tr>
<tr>
<td>13.40%</td>
</tr>
<tr>
<td>37.13%</td>
</tr>
<tr>
<td>Maintenance as percent of operating revenue</td>
</tr>
<tr>
<td>5.29%</td>
</tr>
<tr>
<td>9.13%(^{17})</td>
</tr>
</tbody>
</table>

Of course, along with these benefits come the potential threats of instability in economic downturns and anomaly like coincidences such as those that occurred in the California energy market. In order to have cash flow positive operations, price hikes are also not out of the question. This will be described in further detail in the next section. Privatization is expected to gain acceptance and continue in the future.

3.06 Financing Alternatives & Pricing

Perhaps two of the most important factors preventing regions from supplying clean and safe water to its residents are the lack of education and economic anemia. Recognizing this need in the U.S., the field of municipal financial underwriting is also expanding as the demand for financing options booms, indicating yet another industrial convergence. J.P. Morgan, which already underwrote $21 billion in public finance deals in 2002, has gone on an aggressive acquisition and growth strategy to expand its business in what it feels is somewhat of a recession proof industry. Financial products such as revenue,

\(^{17}\) http://www.privatization.org/Collection/SpecificServiceAreas/Water-local.html
pooled, green, general obligation and double barrel bonds as well as new innovations in the derivatives field and drinking water state revolving funds are helping to stimulate infrastructure development by offering interest rates lower than normally commercially available. These bonds are tailored to suit the individual resources of the utilities while at the same time mitigating risk for the lender. Some revenue bonds for example may offer a low interest rate with the stipulation that the utility maintain revenue streams that are 120% of their debt service obligation.

As the financial infrastructure gap widens while the market expands, there has been an emergence of additional government/underwriter collaborations to provide alternative financing options. Interest rates offered by the Clean Water State Revolving Fund (CWSRF) typically range between 0% and market rate through federal grants and a state level matching plan.\(^\text{18}\) This rate differential has translated into an average savings of 22% for utilities and since all principal and interest payments are repaid back to the CWSRF, the fund will remain in perpetuity. Revolving funds also offer greater flexibility on repayment terms and at times principal forgiveness. Originally offered in 1986 and only available for wastewater non-point source applications, the fund has accounted for close to $40 billion in assistance. Financial innovations such as these are steps in the right direction towards providing utilities the capability to fund capital intensive upgrades and operations. Due to its success, a 1996 amendment to the Safe Water Drinking Act expanded the fund to include drinking water applications. While the role of federal intervention vs. state action is a heated debate, collaborative initiatives seem to fit nicely in both party’s agendas and create solutions in a timely manner.

These new lending initiatives and grant programs have opened the door for financially strapped utilities to expand as well as offer leeway in operations for cash flow. This often translates to the utility’s ability to keep pricing at a minimum. Now that privatization has engulfed the UK, Australia and has now become a significant component of the U.S., the role and behavior of pricing takes on a new light. The new

\(^{18}\) CWSRF presentation. Available at: http://yosemite.epa.gov/rt10/ecocomm.nsf/webpage/Clean+Water+State+Revolving+Fund+in+Region+10
perspective of water providers has shifted from purely provisional, to provisional and profit oriented.

Though a regulated commodity, water has gone through somewhat of a revolution in pricing models. The dynamics of competition, supply and demand, and incentives require private utilities to insure positive cash flow. The relative importance of community needs (deemed as a human right) vs. industrial needs, along with a need to remain profitable, has begun to create innovation in pricing models. Lifetime rates for low income users have been proposed along with ideas on whether there should be a split in pricing schemes between industrial and municipal uses. Incentives or penalties such as these will play a role in the dynamic cycles of price and user’s reaction to price through demand. Price hikes have been known to promote conservation, and though this is a good result for the environment, a privately owned utility will now see a subsequent shortfall in demand and revenues. To remain profitable, the utility now must apply an additional rate increase after the customer has already gone through an optimization process. Now the customer is stuck with lower water use and still higher prices. Therefore, we see an attempt to become more efficient through management and technology from the users as well as the utilities and a response from new research and development to solve this dilemma. Most likely however, water rates will increase in time since they are currently such a small expense in relation to the average household income, less than 1%.

Also worth noting is the emergence of bottled water marketing campaigns which have begun an era of unprecedented profits for water. Some entrepreneurs have even gone as far as bottling municipal tap water from other regions and selling it at 1000% profit. The concept of marketing water itself however is an important one. The marketing of water, once seen as the most commonplace resource, has also been adopted by municipal water providers and reflects the heightened importance of water in our society. Thankfully, municipal pricing is still regulated by the government and water utilities continue to provide their product at relatively low rates.
3.07 Security & Terrorism

In 2002, the EPA amended the SDWA to include the Public Health Security and Bioterrorism Preparedness and Response Act which outlines a means standard rulemaking for surveillance, governance and emergency protocol. The potential threat to public water supplies as a means of mass destruction has certainly taken center stage in the public eye. Rethinking the nation’s infrastructure towards point source treatment is a step in the right direction, but even the smaller distributed municipalities serve thousands of citizens where the risk of a disaster to even these is still too great to rely solely on a partitioned distribution system. In response, the issue of security has mobilized a relatively new force in the industry. Development has flourished in the areas of information technologies for system control, learning and response, analytics, multiple technology treatment trains, security systems, home treatment units, tamperproof components and distribution piping/control, to name a few.

Significant capital is being invested from both private and governmental institutions to provide fast and implementable preventative solutions. Additional focus has been placed on the importance of “critical systems”, i.e. the water system leading into the Pentagon or other critical government and infrastructure facilities. In 2002, four suspected terrorists were apprehended in Rome apparently attempting to inject cyanide through a water main leading into the U.S. Embassy. This is perhaps the prime application for treatment train development and business for firms that can provide a suite of technologies in house.

The effects of security are further verification of water as a ubiquitous resource and an area of industry convergence. Water is quickly becoming a hub for technological/intellectual input as well as an enabler of sustainability throughout all industries and geographic regions.

3.08 Technological Development and Adoption

As issues receive increased exposure, analytical proficiencies proliferate public awareness and sheer demand expands, the adoption of new technologies in a traditionally
slow moving industry is rapidly accelerating. This has sparked a new era of emerging technologies and R&D investment. Perhaps in a mature phase for the past century, the industry and its conventional technologies has now entered a disruptive state under newfound regulatory activity and sustainability concerns. Specificity in analytical techniques and a trend towards small systems has further compounded the fragmentation of existing technologies. In turn this effect has created islands of fluid phase technologies, transitional phase technologies and mature phase technologies.

When modeling and strategically planning for technological development, one can evaluate two sets of alternatives; in house development and outsourcing (the degree of which falls along a range of alliance scenarios). Within each of these options development can be incremental, completely new or complementary depending on a firm’s market and adoption targets. A primary focus of this paper will revolve around the balances between strategically important technological development and more generic growth strategies. The way companies, especially start-up organizations, allocate finite and precious resources to this balance could have major impacts on near and long term success.

As analytical techniques and procedures are improved we learn that extremely localized ground waters, surface waters and industries have their own specialized contaminant compositions. Not surprisingly a trend of mass customization has developed in the industry. Localized facilities, homes or firms are requesting tailored solutions when choosing a treatment technology based on cost and removal criteria. This trend plus 1) the fact that new contaminants are becoming increasingly difficult to treat, 2) the threat of large scale terrorism looms in the minds of many, and 3) the need to prevent local reservoir depletion is greater than ever, has created a reinforcing feedback loop for new technological development and the use of smaller systems.

Of critical importance however, when evaluating new technologies, are the rates of product and process improvements that would potentially lead to standardization and a

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dominant design. The ability to benchmark a company’s technology against others, not only helps identify risks but also alternative marketing strategies. The historical evidence of technological evolution on the establishment of a dominant design has been explored in detail. Subsequently the statistics of firm survival with regard to adoption of the dominant design and proper timing show the non-triviality of these trends.20

3.09 Competitive Trends

The industry is really only just learning about the range of capabilities possessed by the plethora of new technologies emerging. It is typical to see a utility, requiring removal of a single specific contaminant, pilot and beta test a range of technologies. Competitors both large and small flock to such opportunities to gain endorsements, third party data, intra-industry exposure and perhaps another critical piece to establishing their product as a dominant design.

While a higher rate of new product development does seem to be evident in smaller start-up organizations, acquisitions and consolidation have been the general competitive themes for the last 5 years. Many smaller successful companies are subsequently gobbled up by larger organizations which provide turnkey design, build and operate (DBO) solutions. The result is an active research engine in the entrepreneurial community and the establishment of substantial product carriers in the larger organizations who create higher barriers to entry. As technologies develop and are proved or disproved, the competitive dynamics continue to evolve.

3.10 Integration System Dynamics Causal Diagram

Below is an intermediary causal loop diagram showing the aforementioned segments contributing to the dynamics of the water industry. The visual model begins to illustrate linkages between the varied aspects of the industry and offers insight into its mechanisms for evolution. The description of the model should also help summarize the elements of

Chapter 3 into a succinct explanation of how they fit together. Please note that its snail-like appearance should not be construed as an indication of the industry's clockspeed.

Figure 16: Simplified Industry Linkages

The model focuses on the two stocks represented by 1) Potential Sales; a measure of opportunity for participating industries and 2) Operational Plants and Upgrades. With regard to the former and industry potential as a whole, Population Growth and Industrial Expansion have created a significant Demand and Quality Gap in the industry. This gap is analogous to Issues/Drivers in figure 1 and serves as the engine for the growth of the industry. This industry performance gap results in Regulatory Stringency as governments become involved, and Potential Sales, i.e. people or utilities interested in buying products. The latter is a function of regulation, demand and the ability to finance capital intensive developments and is polarized to grow with the expansion of these components. The potential for sales create incentives for participating companies to increase their R&D efforts and reasons for new firms to enter the industry. The resulting dynamic
shows the interdependence of regulation and technology development and is represented by the Regulatory Chivalry reinforcing feedback loop. "After you... No, after you." It could also be called the Regulatory Escalation loop, depending on how proactive each component decides to become.

Potential Sales also feeds into the second section of the model represented by Operational Plants and overall Industry Growth, where a number of feedback loops are identified. Potential Sales matched with the industry’s Capacity to Sell Units will form the supply and demand relationships for products and new technologies. As the number of Operational Plants and Upgrades increases, assuming maintenance of performance, buyer confidence should also increase. This is a comfort level loop that is reinforcing and feeds back into the number of Operational Plants sold. The more confidence a buyer has in the efficacy of a technology through exposure and adoption by iconic organizations such as the EPA, the more likely they will be to buy. Additionally, the growth of the industry through Operational Plants, Potential Sales, and Technological Advancement increases the capacity of the industry to sell units, thereby closing any gaps that may exist in the supply chain model.

So far all of these loops identified have been reinforcing and are indicative of the market’s recent expansion, but Operational Sales feeds back into the Potential Sales loop in balancing ways as well. With the establishment of new infrastructure or products, the demand gap should theoretically be diminished creating a Relief loop on the system. It also interacts with an Infrastructure Funding Gap which subsequently reduces Technology Development and New Financing Alternatives and decreases the new market size. The Infrastructure Funding Gap however is also a function of the Demand Gap, and unless there is a cumulative drop in the Demand Gap, the funding gap will continue to expand. In other words, as demand increases and the Supply Chain Architecture changes from a hub and spoke to point treatment model, the Infrastructure Funding Gap between necessary capital and available governmental capital will increase. This conflict is represented by the relative weights of the "relief" loop and the "ignorance is bliss" loop.
The latter of which is driven by unsustainable population growth and the feeling that added Operational Plants is an ultimate solution.

The Infrastructure Funding Gap has also led towards alternative business models such as Privatization which works to place financial burden and revenue opportunity on the shoulders of private firms. Privatization reduces the need for government allocations while increasing interest in new cost effective and efficient technologies from the private sector, with the end goal of profit generation. It also has an effect on price, but can go in either direction. Though more streamlined operations should help reduce cost, private entities are bound by the necessity for cash flow positive environments and therefore might be required to hike prices in order to survive. As price increases, consumers are driven to become more efficient with their water use and reduce their demand. As mentioned in chapter 3, since private utilities are linked to overall profit, they might be forced to raise prices once again to offset the drop in volume. This is an interesting example of an oscillatory relationship in a regulated monopoly where a drop in demand may actually increase price.

In summary, the casual loop relationship illustrates how the industry is being driven by the aspects of supply and demand, unsustainable growth, demand relief and technological/regulatory interactions while simultaneously being modified by the introduction of new supply chain models as well as funding alternatives.

A more detailed model pertaining to business development is available in Appendix A and will be discussed in the following chapters.

4. Business Development Analysis

4.1 Specific Value Chain – Strategic Partnerships

As mentioned earlier, the technology that is being applied to the model is confidential, but will provide a good example of a product initially entering a niche in the wastewater
remediation market. This particular market could be characterized as being in a fluid phase environment with many technologies attempting to prove their efficacy. The particular target contaminant has been linked to the process of eutrophication whereupon wastewater nutrients, abundant in many municipal and industrial wastewater streams, are discharged into a river system or estuary. Algae and other plant forms thrive on the nutrients and in turn proliferate to such a degree that other sea life is deprived of sunlight. A process also commonly called fish kill. To combat this trend, the EPA has targeted said contaminant for reduction and has posed an upper limit which is a mere fraction of its former allowance. Some regions have gone as far as requiring removal technologies capable of reducing levels to one-tenth of even this proposal. In response to a lack of information in this area, the one particular water district proposed and conducted a trial of technologies capable of these efficiencies. 8-10 companies representing distinct removal technologies were piloted as potential candidates indicating that the industry has yet to establish any type of dominant design.

The technologies are tested in a way that they effectively simulate a utility’s wastewater treatment system. In reference to the water value chain, they will receive their water from municipal and industrial effluents while discharging directly into estuaries. Direct competition is primarily with existing conventional technologies, new bio-driven solutions, and companies with high tech products whose effectiveness in other areas has been gaining public awareness, but who are unsure about how they will perform in this application. Regardless, many have identified the market as large and burgeoning where a technology that emerges ranking highly on a cost/benefit plane will likely see rapid adoption and drive regulatory forces.

Assuming a strong place in the water chain, the initiative must now look towards its product chain and decide how it will penetrate the market. On the supplier side, its product is already manufactured and utilized in another industry where components can be attained quickly and production ramp-up would be fluid. The cost of these components is not known at the time, but large orders would no doubt be welcomed by suppliers. The biggest challenge with most start-ups is settling on the right distribution
strategy. There are two types of strategies in contention, the first being a turnkey solution for utilities. In this model, the start-up company will be involved in the sale, design, build and potentially servicing of the end product. This strategy has its advantages for keeping the company close to the customer and their future needs/recommendations. It also offers the highest profit per sale vs. other alternatives and includes the option of potentially significant recurring revenues through servicing packages. Conversely, the strategy requires a clear operational structure with strong capabilities usually outside of the abilities of a start-up company. This of course is less of an issue with organizations who are already relatively large and have divisions familiar with such projects. Therefore an entrepreneurial endeavor by an established firm may opt for this path.

There is however a hybrid solution whereupon the startup company may access distribution and build solutions through an existing firm with more resources. There are many varieties of strategic partnerships and alliances, one of which is licensing or a black box alternative. In this scenario, the start-up can attain higher profit margins on all activities by reducing the amount of overhead needed for turnkey solutions. They also potentially avoid retaliation with competitors by partnering with them or using their strengths as leverage. The third advantage of a black box scenario is the speed at which the technology can reach a large part of the market geographically. Dangers may arise however if the priorities of the larger organization don’t match those of the smaller. Risks are therefore taken concerning how quickly the product can be introduced to the market and the sale price where there could be a significant loss of operational control.

Lastly, patent protection is a critical aspect when determining sustainability in strategic partnerships. Not only will this aspect be weighted by the partner for points of leverage in other areas of an agreement, but if the patent is not strong enough the risks of imitations will be high. On the other hand, if a strong personal relationship is formed on trust, the larger organization may also be able to provide legal leverage in the future. The proposed product is patent protected on the process of its use, but not on the core technology. This is a point that will require attention, speed to market and strong trusting relationships.
With regard to the water value chain, the technology offers a highly effective process at half the cost of other available products. It is operationally sound, environmentally friendly and can be integrated into existing facilities easily.

4.2 Decision Making Process

During a satellite teleconference on Emerging Treatment Technologies in November 2002, hosted by the American Water Works Association (AWWA) which is the largest water association in the U.S., Black and Veatch proposed a method for decision making among public/private utilities. This same decision making process in many ways is just as applicable for a company’s internal industrial process application, a home owner’s decision to buy a POU or POE system, or even for a regulatory agency to determine what technological solutions are “reasonable”, further evidence of feedback loop activity between technological capabilities and regulatory enforcements. Differences in these applications exist in the type of considerations taken by each party and the weighting of each component in a cost/benefit analysis.

This model offers a representation of methodologies currently utilized in the field. It does not however sufficiently take into account the dynamics of the industry and how they should factor into the decision making process. The end of this section will elaborate on this point, but for now it is still important to understand the current model.

Customers aim their decisions on choosing technologies to be credible, efficient, defensible, cost effective and show consensus. A simplified conceptual model of the process is illustrated in figure 7. Having an intimate knowledge of the customer’s impressions and methods of quantifying them, which may not always be the same, is the strongest method for a company to determine their competitive advantage. Like beauty, competitive advantage is in the eyes of the beholder, or customer, respectively.

The first question asked is "what is the ultimate objective?" For example, perhaps a home owner wants to improve their drinking water aesthetics or a semiconductor plant who has just upgraded their chip capacity needs to increase the ohmic resistance of their process water. The next step is to define what measures are required to meet these objectives successfully. In these examples, they might need to meet the requirements of the Primary Drinking Water Regulation (DWR) or Enhanced Surface Water Treatment Rule (ESWTR) for the home owners, and a reduction of Total Organic Caron (TOC) for the semiconductor plant. Once these fundamental choices are made, the decision process begins to focus on more detailed characteristics of treatment technologies and weighs certain criteria to determine relative importance. These considerations may include the footprint of the system, impact on the environment, safety, noise, effluent quality, or distribution capabilities to name a few. Here the benefit model takes on two levels of criteria, a primary level for overall objectives and a secondary level for additional capabilities possessed by each technology. The first objective must be met yet the second could still provide substantial competitive advantage.

With this definition of objectives and a framework for system attributes, one can now develop a list of alternatives based on available technologies. Scoring now may be subjective such as a 1 to 10 point system, or more objective and based in % removal efficiencies or pounds of sludge produced per year. This information might require more data or research through the use of pilot plant comparisons, demonstration units or full scale facilities already in operation. “My water is different from anyone else’s.” is a perception widely held in the water industry. In some respects is true, and unless a sufficiently sized system is piloted at that specific facility, the best data in the world may still lack ever important credibility. The end result is a quantitative and visual representation of how different technologies stack up for the application. The least they do is help a customer understand the alternatives in more detail and identify a logical method to warrant a system upgrade. This information may also be of use as a bargaining tool for the next stage of the decision making process, the cost model.

More easily quantified, the cost model rests on 4 major components; capital costs, operational costs, product lifetime and the cost of capital or interest rates. These are generally amortized over the life of the system and translated into a cost per year or cost per gallon statistic. Once these costs have been identified and settled, the cost model and benefit model can then be placed into a ratio or cost/gallon/unit benefit, ultimately a cost benefit ratio. In this scenario, the lower the number the better the solution is for society or the customer, assuming there is still enough capital to fund the unit regardless of the benefit. This point cannot be understated and is reflective of the considerations mentioned in Chapter 3’s section on financing. The cost-benefit technique is also the primary tool utilized by the EPA and other regulatory agencies who report to the U.S. Office of Management & Budget (OMB) for “major” projects defined as $100 million in economic impact or greater.

This is a typical example of a decision making process on the water treatment end, but should be noted that other aspects of the water industry such as IT, security and piping
infrastructure also rely on similar cost/benefit analyses. Below is an example of some of the variables considered in a decision making process and the model in chapter 5.

Table 3: Decision Making Profile

<table>
<thead>
<tr>
<th>Category</th>
<th>Technology Value</th>
<th>Unit</th>
<th>Requirement</th>
<th>Additional Performance Weight 0-100%</th>
<th>Weighted Benefit</th>
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</thead>
<tbody>
<tr>
<td>Footprint</td>
<td>70</td>
<td>ft²</td>
<td>&lt;80</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Capacity-Flow Rate</td>
<td>1.2</td>
<td>MGD</td>
<td>1</td>
<td>60</td>
<td>72</td>
</tr>
<tr>
<td>Removal Efficiencies</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.01</td>
<td>mg/L</td>
<td>0.2</td>
<td>80</td>
<td>1600</td>
</tr>
<tr>
<td>Total Coliform</td>
<td>1</td>
<td>1/100ml</td>
<td>10</td>
<td>50</td>
<td>500</td>
</tr>
<tr>
<td>Total Susp. Solids</td>
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<td>mg/L</td>
<td>5</td>
<td>30</td>
<td>250</td>
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<tr>
<td>BOD</td>
<td>10</td>
<td>mg/L</td>
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<td>30</td>
<td>90</td>
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<tr>
<td>Cryptosporidium</td>
<td>1</td>
<td>log</td>
<td>0</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Max Loading (P)</td>
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<td>mg/L</td>
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<td>80</td>
<td>64</td>
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<td>Safety</td>
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<td>%</td>
<td>90</td>
<td>40</td>
<td>0</td>
</tr>
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<td>Environmental Compatibility</td>
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<td>%</td>
<td>90</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Quietness</td>
<td>40</td>
<td>%</td>
<td>30</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Ease of O&amp;M</td>
<td>70</td>
<td>%</td>
<td>50</td>
<td>70</td>
<td>98</td>
</tr>
<tr>
<td>Time to Install</td>
<td>3</td>
<td>months</td>
<td>3</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Time before Completion</td>
<td>5</td>
<td>months</td>
<td>9</td>
<td>70</td>
<td>126</td>
</tr>
<tr>
<td>Ease of Post-Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
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<td></td>
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<td></td>
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<td>2990</td>
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<tr>
<td>10Yr Amortized Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$100K</td>
</tr>
<tr>
<td>Cost/Benefit Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33.44</td>
</tr>
</tbody>
</table>

As mentioned earlier, there are certainly deficiencies in this framework from a decision making perspective. The model only takes “today’s” characteristics into account and does not effectively weigh equally important risks and advancements that are likely to occur over time. This is not only the fault of the utilities, but also of the participating suppliers for not pointing out additional evolutionary competitive advantages. For example, perhaps a particular technology or company has exhibited a faster learning curve than a competitor. Highlighting potential advancement for upgrades in conjunction with a flexible cost structure may offer a long term advantage, even if the current product is less cost effective. Industry evolution with respect to the emergence of dominant
technology also warrants attention as this has a profound effect on regulatory activity, approval, and distribution models.

One way in which the industry does talk about future development is when utilities attempt to pre-empt or predict new regulations. If a utility envisions a regulation taking effect down the road they may be more apt to adopt the best practical technology with this in mind or opt to postpone their decision until a clearer picture emerges. This however is not emphasized in the analytical techniques promoted within the industry.

Further evaluation in a technology should take into account a firm's specific resources for support, sustainability and their ability to recognize complementary relationships with other technologies.

4.3 Impending Competition

What are the existing competitive forces pressing on the water treatment industry and more specifically the targeted market for the technology applied to the model? Currently, large players such as U.S. Filter and conglomerates like Suez dominate the playing field and tend to absorb smaller companies with new technologies to add to their product suite. Luckily, utility operators are all somewhat autonomous and hold fairly un-objective views on new technologies and what is best for their plant. This opens the door for new companies to market their technology and gain access to pilot testing opportunities - as long as the utilities don't incur any costs to run the program. The level of conviction required through extended season to year long pilot tests, word of mouth promotion, certifications and regulatory endorsements to establish credibility in the field is however a bigger challenge for upstarts than it is for large competitors. The industry's "rule of thumb" to be able to prove a technology's claimed performance is through the successful operation of a 1 million gallon per day (MGD) system through multiple seasons, regardless of the eventual size of the system to be sold. Therefore it is very difficult and time consuming to establish a relationship with a municipality without having a leveraged angle or partnership. This is perhaps the largest barrier to entry and is the reason why
many partnerships are formed, even in the R&D and stages of a product. The larger organizations also have the ability to introduce a similar product very quickly through existing distribution channels and access to regulatory agencies as well as the power to drop their price and capitalize on economies of scale.

The availability of potential substitutes for the technology in this case has given buyers, though limited by regulatory requirements, a significant amount of power. It is this reason that much of the buyer's decision making process comes down to the ability to solve the problem and price over other benefits. The biggest long term threat to the proposed technology however is most likely the development and adoption of membranes as the dominant water treatment technology. Though much more exorbitant in price and sensitive to slight changes in water quality, membranes still possess the biggest potential for improvement as large scale systems gather data and experience. Strides in materials science and nanotechnologies are fuelling its development and point towards a promising future. At the present moment, enhanced conventional treatment (ECT) alternatives are leading the pack in initial sales for the targeted contaminant, but common beliefs are that these are short lived and results of regulatory pressure. The stated technology's cost benefit analysis is actually significantly lower than the ECT processes, but has encountered the high initial "willingness to adopt" barrier to entry explained earlier.
5. Model Simulation

5.1 Introduction to the Case Studies (Wastewater – Desalinization Evolution - UVLED)

Three technologies will be analyzed with this model. The primary case, as mentioned, is based on a wastewater purification technology being developed by a new venture. All of the inputs to the model will be based on this technology, market and company’s internal competencies, though many of the variables are generic enough to be utilized in other cases as well. Once a detailed analysis of the dynamics is posed, the remaining technologies will be benchmarked against the findings to; 1) think about how varying technologies in the same industry will proliferate. 2) provide historical verification and a future looking comparison to the primary case.

Membrane or Reverse Osmosis technology in the desalinization market will provide the second case and historical example. This is also an interesting case with regard to many of the issues raised in this paper. A distinguishing factor between the often compared water and oil industries is the fact that water is the most abundant resource on earth. Though desalinization technologies have existed for some time now, none have been even close enough to warrant widespread adoption and full scale production. Water demand and the allure of surrounding oceans for countries such as Saudi Arabia among others have fuelled the development of membranes as a desalinization alternative to distillation. Reverse-osmosis facilities are now taking shape under this pressure in the form of large scale designs. If any design will drive another part of the industry it will be desalinization driving infrastructure and distribution networks. The dynamics of market demand, government incentives and technological development suggest that this will be an interesting application to the model.

The third technology is the most forward looking of the three as it has not yet been developed, ultraviolet light emitting diodes (UVLED). It also completes the breadth of this analysis of which now encompasses a semi-historical case, a present case, and a
forward looking case. LED research has led to the development of white light and infrared commercially available products. Advantages for the technology over incandescent bulbs exist in the form of operational flexibility, heat loss reduction, and especially capital and operational cost reduction. These three attributes could have an enormous disruptive impact on a plethora of industries utilizing ultraviolet light. The water industry is need for low cost disinfection alternatives to the chemical treatments and insight into the potential for UVLED technology may be interesting.

5.2 System Dynamics Model

The model is structurally comprised of an integration between Vensim DSS system dynamics software package and an excel spreadsheet which acts as the brain for the customer's decision making process described in chapter 4. The variables and associated values were formulated through educated assumptions in addition to interviews with industry professionals and are spread over a time period of twenty years. Appendix A illustrates the entire model while appendix II contains the detailing of assumptions and equations as put together by Vensim DSS for reference. Many of the assumptions that appear to hold significant weight in the model will be highlighted here.

The construction of the model consisted of an iterative research process, and evolved to incorporate 6 primary categories, each of which will be described here and in the finding section in more detail. These are: Customer Decisions & Internal Operations (Appendix B); Growth and Technology Development (Appendix C); Adoption (Appendix D); Market Dynamics (Appendix E); and Regulation (Appendix F).

NOTE: It is not the intention of the model to churn out exact forecasts of sales in the future, but to lend insight into the relationships between the variables in terms of dynamics and relative magnitude, therefore the numbers should not be postulated as heavily as the trends.
Customer Decisions and Internal Operations (Appendix B) focuses around an excel spreadsheet decision making model and how it translates the given inputs into a cost-benefit ratio vs. the proposed (from this point on referred to company or technology A) product's most significant competitor's technology (from this point on referred to company or technology B). Each cost-benefit value is then placed into a third ratio, which along with s customer's ability to finance the project, will result in either a sale or a missed opportunity. This model analyzes the competitive advantages of the technology A against technology B which is assumed to be the lead competitor from a cost and benefit perspective. Each cost-benefit ratio however is augmented into Incremental Technological Advancements; Company A's technology is enhanced through the organizational Growth and Technology Development loop, while the competitor's technology is strengthened by market dynamics, which includes the number of competitors and average Incremental Advancement based on membrane technologies as a worst case scenario. The cost assumptions used in the model are illustrated in appendix H, while the benefit assumptions will not be shown for confidentiality reasons, but are modeled after the example in Chapter 4.

Internal Operations represents the company's initiative to finance its first 1 MGD facility. This is considered a "must" and is the trigger mechanism for future sales. The initial sale produces a pulse prompted by the function of capital required and an estimation of the amount of time generally required to raise this money based on past venture capital data. The sales stock and flow structure will not be activated without this input. Afterwards the rest of the model becomes autonomous and this trigger is inactivated.

Growth and Technology Development (Appendix C) happens to be the most interesting segment of the model and focuses on the importance of harmony between growth strategies and technological investment as a function of the technology's attributes and the company's resources. This loop is driven by the proceeds from sales and again is not activated until the first system is sold. Once revenues are realized, this capital is then converted into profit by removing expenses and subsequently split into two potential paths; Company Growth and Investment in R&D. The ratio of these contributions greatly
affects the outcome of sales in the long term. This is mainly due to estimations on slower incremental advancement capabilities for technology A vs. competitive technologies, and the fact that a start-up company with limited resources entering a ready market and a presently significantly superior product, will be limited by its Capacity to Sell Units.

Adoption (Appendix D) analyzes the customer’s Willingness to Adopt technology A and factors back into the rate of sales. This loop has been structured to feed off the number of Operational Units with technology A’s stamp and calculates a percent Willingness to Adopt through a series of weighted categories such as the significance of Regulatory Endorsements and adoption by Iconic Users. All weights are based on assumptions, but the interesting effect provided by this loop is its impact on sales once existing plants reach an age where upgrades are necessary. At this point, competitive technologies have taken greater leaps and closed the competitive cost-benefit gap. The combined effect dampens customer excitement and their Willingness to Adopt. This is an especially potent finding when the rate of upgrades is faster than the rate of sales, leading to a reduction of Operational Plants and Buyer Confidence.

Market Dynamics (Appendix E) focuses on the availability of Potential Sales. This stock is derived from two feeders: 1. Overall demand based on Population Growth and Upgrades needed in the water treatment industry. There is currently a large amount of demand in the market compared to the ability of all competitors to sell systems, evident in an increase in Potential Sales over time instead of depletion. In time Population Growth is expected to slow down where its trend will begin to plateau and eventually decrease, but the current population growth projections used in the model will not allow this to happen for some time. 2. The number of competitors entering the market. As demand increases and the market size expands, more companies will enter the arena with the hope of grabbing a slice of the pie. The market size will be limited however by Market Exit as companies fail or consolidate over time. The market’s affect on technological development is represented by an average percentage of competitive research and development advancement. The total amount of advancement however is diluted by the number of different technologies in the market, i.e. the more technologies
there are, the more fractionated overall R&D spending becomes. The model also incorporates this evolution over time based on historical examples of company concentration in an industry. As consolidation occurs and a dominant design emerges, a higher percentage of research and development can then be focused on fewer technologies and therefore have more impact on their performance before the law of diminishing returns sets in. This calculation takes an assumption that by year 20 approximately 3 technologies will likely be left competing for market share. The number of competitors in the field and their focus of R&D will also effectively tie into the regulatory loop described below.

Regulation (Appendix F) weighs the relationship between Public Awareness of water deficiencies with the rate of technological improvements, ultimately affecting a customer’s Willingness to “Enact change”, or in other words, influence to enter the market for a new plant or upgrade. Consistent with observable trends, the number of Potential Sales in the market is highly dependent on this variable. Generally, with limited funding, waste treatment facilities will not put money towards new systems unless there is sufficient pressure from regulators and incentives to comply. An agency’s enforcement of a rulemaking also depends on technological availabilities that are reasonable according to a cost/benefit analysis. There is an interesting dynamic here that connects company A’s incremental technological advancement with the regulatory proposal and enactment rate. This sends a message that even relatively small incremental advancement in a technology can still have a significant impact on market size vs. market share if the technology is the leader in performance. If a company’s sales and adoption capabilities are limited by market availability vs. its internal capacity to sell units, then this technique can be quite valuable.
5.3 Base Case, Sensitivity Analysis & Findings

Perhaps the most significant actionable variables of the model reside in the Growth and Technological Advancement segment and how they affect other dynamics leading to sales per year and profitability. Growth strategies as a function of the environment will become the focus of this paper and revolve around the allocation of resources towards structural growth vs. research and development. This segment also provides a floor plan for the balance of investment within R&D between incremental and new technologies. The following arguments will show that potential strategic growth opportunities depend on this relationship with respect to a company’s current competencies and influence over regulatory behavior. The points developed in 5.2, the industry analysis, data from industry experts and the system dynamics model, will offer a clearer picture of the current state of the system as it pertains to the company A.

The base case scenario is a good starting point to get a point in time look at the significant elements in the system and to understand when they become active, as well as set the stage for further sensitivity analyses. The set of plots in figure 11 below represent an evolutionary picture of the market and will each be discussed in detail. Placing them together helps create mental links during analysis.

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23 Based on Hamel’s Resource Based View Framework
Figure 19: Modeled Industry Trends

Indexed Competitive Advantage: Function of Industry Tech. Investment

Market Share

System Start-Ups From Sales

Upgrades

Willingness To Adopt

Operational Plants

Potential Sales

Capacity To Sell Units
The trends above are good indicators that this is a technology that initially possesses a noteworthy technological advantage, evident by a 1.5x Indexed Competitive Advantage over its competitor, as well as a significant profit opportunity represented by the growth in potential sales over time. At time zero, the index is based on the standard cost-benefit analysis which again does not include dynamic parameters, even though these elements could weigh heavily on the results. Here,

\[
\text{Indexed Competitive Advantages} = \frac{\text{Cost Benefit Ratio}_{\text{Company A}}}{\text{Competitor Cost Benefit Ratio}}
\]

where a value greater than 1 indicates an advantage. As time progresses however, the model's dynamics do influence this index through technological advancements. As competitors continue to enter the market and membrane or other technologies race down the learning curve, the indexed competitive advantage begins to contract. This effect is also due to the assumed relatively slow incremental advancement characteristic of Company A's technology. Both incremental advancement variables in the model refer to a percent advancement per year in each of the individual cost-benefit values. For example, a one-hundred percent advancement in a technology will half the current value of the technology's cost-benefit ratio.

To understand this further, it is important to clarify one of the assumptions taken with regard to Company A's ability to improve its technology as a function of R&D dollars spent. The following figure is based on compounded information from a company in the water industry with a variety of treatment technologies.
The trend is simply a representation of average investments in R&D and the law of diminishing returns, but being aware of this assumption is important when performing a sensitivity analysis on indexed competitive advantages as a function of technology investment. This will be discussed later in the section.

In the end, as long as the competitive advantage is greater than 1, company A should sell units. Herein lies one of the weaknesses in the model and current decision making processes. As mentioned earlier, the dynamic relationships that are being outlined in this paper are significant factors in competitive sustainability and therefore have a present value risk factor that should certainly sway a decision maker’s opinion. This would be a nice addition to the model going forward.

The other factor indicating high profit potential is the sheer size of the market represented by Potential Sales. Potential sales are ultimately driven by population growth, user willingness to enact change, and the rate of systems sold. Potential Sales is fed by a rate of new opportunities as a function of new potential buyers, i.e. systems that were not
previously in existence (estimated at 2.7 MGD), and new upgrades (estimated at 1 MGD). Population growth over the next 20 years, with its hill-like profile, is a function based on U.S. census reports and drives demand for wastewater services. Though most work being performed today revolves around existing plants and infrastructure, i.e. upgrades, roughly 25% of new jobs have been allocated towards new potential buyers. A relatively high number, this is an attempt to reflect the industry’s progression towards point source treatment.

Along with demand, a utility is pressured to upgrade or build by regulation. These incentives are activated through a utility’s Willingness to Enact Change. As population increases the demand for water treatment and technological advancements take place, the EPA is able to regulate new contaminants or tighten their regulations on existing ones. The latter effect is the dominant trend in today’s regulatory environment and is represented in the model by Regulatory Enactment Rate, where the value at time = 0 is based on today’s rate of approximately one regulation per year, and Regulatory Stringency where:

\[
\text{Regulatory Stringency} = \text{Avg. Percent Tightening} \times \text{Regulatory Enactment Rate}
\]

Tighter effluent requirements and their effect on Willingness to Enact Change is proportional to the number of new regulations proposed, multiplied by an averaged affect that each regulation will have on all contaminants in the industry. The approach is fairly generalized but somewhat representative.

As Willingness to Enact Change increases, a higher percentage of utilities that have water “problems” will actually enter the market for a technological solution, thereby increasing the market size and the number of potential sales. The balancing factor for the stock of Potential Sales is dependent on actual sales by company A and its competitors. The plot of Potential Sales over the 20-year span actually declines after year 14 due to a slowing rate of new opportunities (again assuming population leveling) and just as importantly, the added capacity that industry competitors build over time. In other words, the industry
will see new opportunities slow down and actual sales speed up, there by decreasing the pool of Potential Sales.

**Weighing Growth vs. Technology**

Capacity to sell units is a prime focus in this paper for two reasons. First, the ability of competitors to sell units on a large scale ultimately has a direct impact on market share and competitiveness, but also the number of companies that can or desire to enter the market due to under-capacity. Cumulative efforts in technological development and sustained competitive advantages for firms are directly impacted. Second, we can look at the specific case of company A. When a clear technological advantage is present in a large and partially uninhabited market, current and future profit potential is largely determined by a company’s capacity to sell units. We see this in the model’s projections as the number of System Starts from Sales and Operational Plants are both limited by the company’s Capacity to Sell Units. Note the almost identical correlation between System Starts from Sales and Capacity to Sell Units. At least for the first 10 years of operation, the other dynamics in the model are muted by this extremely limiting factor.

If organizational growth becomes such a critical component in a firm’s early life, then what can be done to promote it? The first of which is simply to invest a higher percentage of ones operating profits into the company vs. large dividends, external investments, or interestingly, technological development. The latter point is somewhat counter intuitive for a company to contemplate. Figure 13 below is a sensitivity analysis of revenues over time as a function of varying the Percentage of Profits invested into R&D and profits invested back into the organization for sales and support, i.e. Company Growth. The legend in the chart identifies the trends as 1 % of profits for R&D and actually represents the percentage of profits allocated for capacity growth. It should be noted that on a percentage measurement (about 25% between plots) differences are significant, yet for the turn-key model, the difference in revenue on whole may not justify the reduction in technology investment, especially in the early years. The point here is that the potential for additional revenue by focusing profits on growth is apparent, but there is still something else that is stunting significant expansion. This is due to the fact
that the ability to increase capacity as a function of % growth in the company is very small for a turn-key approach. In other words, the amount of work and dedication per employee and unit of overhead for each sale is significant, thereby limiting capacity and the growth potential of the firm.

Figure 21:

The second method of increasing capacity is through alternative growth strategies. This model is based on providing turn-key solutions which include design, build and operating services. Forming strategic partnerships and licensing the technology could be an alternative distribution model. Of course with that comes added organizational complexity and reduced profit per sale. Here the model would have to be based on a set of realistic assumptions as in a financial projection. Then the black box and turn-key scenarios could be compared to determine their effect on overall profit, growth and future adoption. The balance concerns the potential profit per unit sold in each scenario and the number of units that can be sold due to capacity and adoption rates. As an example, if a black box model can offer more than 10 times the # of sales, and the sale price is one-
tenth that of a turn-key model, (all other things being equal) it would most likely be a preferred method.

Company A, as with many start-ups is currently financially weak, and is in the process of attaining additional funding to sustain operations. Part of its near term strategy may include partnerships for added distribution networks and potentially equity investments, or raising money through venture capitalists and/or private investors. The potential network effects and perpetual learning offered by a hybrid model (turn-key and black box) could provide the company with a solid start and good growth. Now the focus would turn to sustainability.

The Shake Up
Year 12 however depicts an interesting environment for Company A. In addition to capacity anemia to capture market share (still only 3% at this point) the firm will eventually have to deal with the impact of system aging and upgrades. Upgrade life is averaged at roughly 10 years after start up based on utility expectations. The affect it has on the number of Operational Units at year 12 has an impact on Market Share as well as Willingness to Adopt which begins to level off at this point. The upgrade mechanism and resulting effect suggests that selling a system based on exposure and buyer confidence may not get any easier in the future. In fact it may get harder due to the increased risk of being overtaken by a technologically superior product, evident in an indexed competitive advantage of only 1.2 at year 12 (and still declining). All arrows point to an uncertain future at this point. This period presents itself as a crossroad for the company where it must decide whether or not appropriate effort should be spent to continue targeting the given market with the given technology. In actuality, the company must identify this threat in advance if it is to adapt sufficiently and quickly enough to survive.

Company A may however be able to utilize this 5-7 year window of opportunity, prior to adapting for upgrades, to bring in early cash flow for internal growth and investment in other technologies or research into other applications.
Industry Sensitivities and Other Findings

Overall industrial dynamics also offer interesting insights as companies react to each other in ways that represent competitive escalation. It is important to view how the industry environment evolves and how this augmentation changes the outlook of individual competitors. Again, a good starting point for sensitivity analysis and understanding the dynamics of the industry is in the demand engine of the system. Demand is for the most part driven by population growth which here is represented by yearly growth. After 15 years, population growth is expected to begin declining as global sustainability gains awareness and perhaps people the mortality rate increases. As mentioned earlier, demand is also driven by a key Willingness to Enact Change variable which is defined as a customer’s incentive to upgrade or build a new facility. On one side is society’s demand and on the other is the influence of regulatory incentives. These incentives are driven by the need for solutions as a function of; 1) Demand: As populations grow more, waste is produced and the more precious the commodity of water becomes and 2) the development rate of reasonable technologies that can be applied as solutions. The latter is a function of technological advancements in the industry and is sensitive to R&D allocations as well as competitive entrants, i.e. the total R&D workforce for the industry. For argument’s sake we can look at these drivers as ultimately affecting the market size of the industry. Population growth is a figure based on census trends, and will not be used as a sensitivity tool, but advancements in technology is an element that can vary greatly.

In figure 14 below, three sensitivity trends are depicted showing a base case as well as heightened and emaciated R&D environments and how they affect the rate of potential sales on a yearly basis. “Incremental Advancements from External Technological Advancements” represents the percentage of performance improvements achieved by the competition. This is based on “Competitive Research and Development” and indicates the percentage of a company’s activities invested into R&D. Company A, as the technological leader in this scenario also contributes to combined industry wide technological improvement through its own “% Incremental Advancement”. This factor is dependent on the magnitude of profits allocated back into R&D. In the heightened
case, the assumption states that all companies, both Company A and competitors, invest between 25% and 30% of their profits back into R&D. In the low investment case, the model assumes between 10% and 15% of profits are reintroduced into R&D. This determination of market size is solely a function of technological evolution affects through regulatory and willingness to enact change elements. It is also consistent with current trends in the water industry as the amount of technological research occurring is currently unprecedented, as is the amount of regulatory rulemakings by the EPA. Though the total number of contaminants regulated is actually decreasing, “identification” regulations were established primarily to start the technological engine. Now as technology is ramping up, so is the regulatory activity with regard to stringency. As mentioned earlier, more regulations are being finalized in the last decade than there have been in the previous two. Instead of finding new contaminants (though there are still some and always will be), regulatory action is focused on tightening requirements for currently regulated contaminants to levels that are finally acceptable to the environment and society.

Figure 23:

New Sales Opportunities as a Function of Industry Technology Investment

![Graph showing new sales opportunities as a function of industry technology investment. The graph compares different investment levels: Base: 20-25%, Tech Inv. Low: 10-15%, and Tech Inv. High: 30-35% over time. The x-axis represents time in years, ranging from 0 to 25, while the y-axis represents new opportunities per year, ranging from 350 to 550.]
Interestingly, the High investment case converges and actually dips below that of the base case in year 20. This was an unexpected result, but upon further analysis was determined to be the effect of knocking the technological leader out of contention at year 14, thereby destroying their contribution to continued technological advancement for the industry as a whole. This is an interesting indication of research escalation and collapse, or in other words unknown love-hate relationships between competitors if market size is more profitable than market share.

Representative of an escalation in competitive R&D, the finding’s overall effect initially increases market size through heightened regulatory activity, but ultimately leads to market size destruction by toppling the technological leader. This is evidence of smaller industry gains for all when each company in the “laggard” group aims to capture market share with the strategic intent of overthrowing the leader. The effect has been identified in other industries, especially when buyer confidence sees the leader’s demise as a bad omen, leading towards reduced industrial investment. This is also a statistic to be watched carefully by company A as it poses a direct threat to the company’s own existence in the future if too much dependency relies on this market.

Given these demand variances, the analysis now drives towards company A’s strength in the cost-benefit analysis which is also subject to the same trends in technology investment. Figure 15 represents the indexed competitive advantages of our firm compared to the competition under the same scenarios. It must be noted that these trends are a function of our company’s limited resources in an industry with a slow clock speed and the assumption that this particular technology is already close to its endpoint in performance. The point at which the Indexed Competitive Advantage becomes less than 1 indicates that the company’s ability to sell units utilizing the customer decision making process becomes nullified. This is an extreme case and may not be replicated in reality to this degree, but it still represents the potential threat when R&D escalation rears its ugly head against a short term high performance, but limited long term potential technology.
Again, between year 13 and 14, the indexed competitive advantage of Company A crosses the advantage threshold, thereby taking away all business opportunities. This "creative destruction" slowslows adoption and subsequently degrades the market size, even with continued R&D. For companies that would actually benefit more from market size than market share, this is a detrimental reaction to aggressive competitive and previously conceived benign market beneficial.

Summary for Company A
The strongest advantage that company A has at the present over the current competition is the uniqueness in its technology and its significant cost savings. Though seen as a strong competitive advantage in the present, the ability of this attribute to hold its position is questionable due to an accelerating industry clock speed and higher development rates expected from other technologies. In addition, the current environment’s apparent inability to standardize technologies past their rated life along

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with increasingly active regulatory behavior offers little hope for technological lock-in. The firm will have to adapt its growth strategy to capitalize on its current advantage through strategic partnerships while insuring sustainability through research and development in new technologies and applications vs. incremental performance improvements with its current technology and market. The window for market entry and fairly significant initial revenue generation, created by an increasingly point treatment geared industry could provide funding for other technologies and growth opportunities. With this type of "Judo Strategy" the organization can be flexible enough to avoid the treats of competitive escalation and complexities arising from degrading systems. The combination of long lead times to design and build systems with company A's technology and the increasing clock speed of the industry as a whole offers high potential for disruptive or other dominant technologies to take hold and destroy value.

These strategic partnerships could potentially be focused on gaining distributional resources while offering developmental possibilities to the larger organizations R&D/product suite. Such an arrangement may offer additional resources into the investigation of new applications for the product where the threat of membrane technologies would be less potent or better yet, a scenario where the two could become complementary technologies. This latter point cannot be underemphasized as there is potential for the given technology to improve the performance of membranes as a pretreatment.

An addition to the model, whereupon a more dynamic process of quantifying competitive advantages as a function of industry and technology conditions at each stage in time, would also provide the company with a novel tool for proving sustainable reasons for customer adoption.

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5.4 Case Analysis 2 & 3

The following technologies are promising additions to the water industry. The intent of their investigation and application to the model in a more generic qualitative sense is to relate the lessons learned to alternate technologies. This will provide a sense of efficacy in the model as well as offer insight into the development of these technologies over time. Their development and adoption could have significant impact on water treatment methodologies.

Reverse Osmosis Desalinization

Desalinization offers an interesting dynamic to the mix. As water supplies will inevitably end up relying on ocean sources, its importance in the water industry is obvious. The technological development in this sector is under a transition from solely distillation processes to cogeneration facilities and reverse osmosis membrane technologies. The cost of generating a given volume of water has been quartered in the last 10 years and improvements in efficiencies continue on a very steep learning curve. The impact on regulation and infrastructure development is significant, specifically with regard to the dynamics of distribution models. It is perhaps the only sector in which large capacity facilities and a hub and spoke model may triumph over smaller point source trends given limits on coastline availability to supply non-coastal regions. This model also offers a higher potential for standardization and incremental advancements given the enormous capital costs to build large scale facilities.

The city of San Diego is currently in the finalization process of approving a Reverse Osmosis desalinization facility to service the region. Built in stages, the plant would eventually generate 100 MGD of ocean sourced drinking water to San Diego. The staged progression creates incentives for technological advancements in membrane research, provides flexibility for changing regulations and takes advantage of the rate of improvement currently evident for the technology.

The effect such a model will have on the rest of the industry is more difficult to predict, but will certainly require a high degree of involvement from security technologies and
also introduce a new component in marine management. Technological advancements in this new arena will also help fuel development in cooling systems for power generation and create a closer relationship with energy utilities. Power providers for such large scale systems will undoubtedly become a significant part of the water utility’s value chain. This prediction is already evident in San Diego where the provision of power from a local nuclear plant with reduced rates actually became the deciding factor in taking the 100 MGD proposal to its present state.

**Ultraviolet Light Emitting Diodes**

Ultraviolet (UV) technologies have also taken leaps in the last 20 years. Developments from low pressure Hg lamps towards medium pressure lamps and alternate technologies such as blackbody “broadband” Xenon lamps and pulsed systems have synergized with EPA regulations on disinfection by-products (DBP’s). DBP’s are residual and usually carcinogenic components left in water as a result of chemical disinfection, namely Chlorine. DBP rules have cast somewhat of a bad light on chemical treatments and the industry is attempting to get away from conventional chlorine disinfection techniques. As such, adoption of non-invasive technologies such as ultraviolet disinfection has become an interest in recent years. This represents yet another cross-industry integration that now exists with developments in the lighting industry.

Light Emitting Diodes (LEDs) are becoming more prevalent in applications due to lower production costs, increased efficiencies and lower heat loss. These three benefits would hold significant weight in the OEM industry for water disinfection. Without this target in mind new research in the field has begun expanding the output of LEDs into the UV zone. Though initial applications for such a technology would most likely involve analytical products and electronics, huge potential exist in the water industry. The development could present itself as a disruptive technology by reducing system costs and improving operational efficiency. Lead researchers in the field suggest that it may even offer the potential for the ultimate point source technology on a hand held level, and create enormous benefit to developing regions.
The operational and installation flexibility of such a technology would also lend assistance to terrorist considerations as it could be placed at multiple points along a distribution system, with minimal power consumption and enhanced maintenance friendliness. A leap in UV technology would have a significant impact on the chemical disinfection industry because of its favor amongst regulatory agencies. Ultraviolet disinfection is thought of as a technology whereupon enhanced performance will create incentive for tighter chemical addition regulations.

UVLED’s however should expect competitive retaliation in the form of external technological research and advancement. Similar to the rest of the lighting industry LED’s are seeing heightened competition from incandescent and florescent technologies. Their imitability and low replacement costs offer low risk from the “Upgrade” effect seen in Company A’s case, but also create a high risk potential for similar technologies to flood the market and commoditize the product quite rapidly. Development and adoption of the technology over time will be interesting to observe.

6. Global Sustainability – Corp. Responsibility Revisited

The frequent mentioning of global sustainability and corporate responsibility throughout this paper is an indication of the importance the two play in the growth of the water industry as well as the significance of the industry on these initiatives. Along with agriculture and disease prevention, water has become a primary technologically driven industry in the realm of global sustainability. With this in mind, perhaps no industry can rival its impact on an economy through its pervasiveness in our lives and industry.

In 2000, U.N. Secretary General Kofi Annan announced the necessity to integrate social responsibility with the markets in response to worldwide injustices, deficiencies and globalization. The infiltration of water in almost every industry, both supply and production, offers an incredible potential for the industry to act in this arena. Already, international organizations are acting on social, labor and environmental projects and efficiencies, but there is much more benefit that can be actualized with water. One
method to act is through efficiency by drawing less water, thereby increasing the capacity for the surrounding communities. In some ways this path can be driven by price or other incentives. Another involves a scenario where companies which have advanced purification technologies can potentially provide additional services to the community. Taking this a step further, a capital investment by an organization for a public water system may in many cases provide a better and cheaper source of water for its own production facilities over time. The social benefits that it may have on a region should be reason enough to act, but a financial bottom line approach allows a company, whose sustainability is always in question, further justification to act.

It is the author’s perspective that industry would not only benefit society as a hole, but also capitalize on multiplicative benefits realized through simple human appreciation. The provision of a life sustaining resource can have immeasurable impact on people’s motivations and moral, especially in times/areas where corporate “invasion” is not always regarded well by the surrounding community. Participants in water management and purification entities have enormous opportunity to act in this arena and contribute as drivers for the industry.
7. Conclusion

The water industry has become a pervasive and ubiquitous element in all of our lives, from survival to industry and growth. The system dynamics approach has shown the potential for participants to identify critical industry and cross-industry links, opportunities and risks on a dynamic plane. Growth and technological development act as critical components in any endeavor, but must be evaluated after environmental conditions and internal resources have been sufficiently understood. Furthermore, as stated by an unknown source, “There are the things we know we know, there are the things we know we don’t know, and there are the things we don’t know we don’t know.” The system dynamics exercise also lends insight into the latter category which generally tends to be the largest and most threatening among the three, especially within shifting industries such as water. Strong reinforcing and weak balancing feedback loops in terms of industry growth potential and new technological inclusions highlight the water industry as a dynamic and stimulating environment for new business.
Bibliography


Knoll, Karin, 1995 (SM), A System Dynamics model for the diffusion of a new technology.


Appendix B

Figure 28: Internal Operations & Customer Decision Dynamics

INTERNAL OPERATIONS

Production Cost

Customer’s 10 yr Amortized Capital
From Excel

10 yr Amortized
Costs From Excel

Benefit Rating
From Excel

Indexed Competitive
Advantages - Ratio

Competitor Cost
Benefit Ratio

Capacity to
Supply/Use Units

System Starts
From Sales

10 yr Amortized
Cost Gap

INTERNAL OPERATIONS

TFR TABLE

First Plant Market
Entry Switch

Funding Needed For
Start Up Operations

Total Funding
Required

Time Required to
Raise Capital

Time To Build
First Plant

Funding Needed for
First Installation

Reference Bank
Interest

Bank Interest
Rates

<Input
Modifications>

New Financial
Products

Financing
Alternatives

Other Income

Cash

Federal Subsidies

Available Capital
To Excel

Bank Loans

Expected Revenues

Expected Operating Profits

Average Water
Production

Price per Gallon

Percent of Customer
Revenues as Operating Profit

Desired Profit Margin

AvgSell Price per unit - To Excel

<Interannual Advancements
from External Technological
Developments>

Competitor’s 10 yr Amortized Cost From Excel

Competitors Benefit Rating From Excel

Cost Benefit Ratio

Ratio

<Capacity to
Supply/Use Units>
Appendix C

Figure 29: Growth & Technology Development Dynamics

GROWTH & TECHNOLOGY DEVELOPMENT
Appendix D
Figure 30: Adoption Dynamics
Appendix E

Figure 31: Market Dynamics
Appendix F

Figure 32: Regulation Dynamics

New Upgrades Per Year

Corporate Responsibility Adoption Standards

Existing Plant's Benefit Gap - from excel

Regulatory Stringency

Power of "Best Available Technology"

Lobbying Power

Regulatory Proposal & Enactment Rate

% Tightening per Enactment

New Public Awareness of Needs

Capability of new technologies to reasonably treat hazards

New Technological Capabilities
### Cost Assumptions

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<th>Tech B</th>
<th>Unit</th>
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Appendix H

Percentage of Facilities Subject to Specific Contaminant =
0.2
~ dnn
~ The percentage of facilities that are subject to remove the specified contaminant. Not all discharge into similar locations or have similar problems.

"Existing Plant's Benefit Gap - from excel":=
GET XLS DATA ('Decision Making Model.xls','Values To DSS','1','A7')
~ benefit
~ This is the benefit differential from excel. If it is positive it will not invoke customers to enact change. If it is negative, meaning there are benefit deficiencies with regard to regulation for the existing plant, it will increase customer willingness.

Upgrades = DELAY MATERIAL (System Starts From Sales,"Avg. Time to Upgrade",0,0)
~ Plant/year
~ Existing customer plants needing upgrades due to regs, quality, demand.

Capacity per Entrant =
5+RAMP(1,0,25)
~ Plant/Entrants/year
~ The avg. capacity of each entrant to sell units per year. This is a ramp and assumes that the competitors that remain and new competitors entering the market will be growing or already large.

Rate Increment of 1 Year =
1
~ year
~ This is needed for units adjustment

Competitive Capacity to Sell Units =
Number of Direct Competitors*Capacity per Entrant
~ Plant/year
~ The number of plants competitors are capable of selling.
Customer's 10 yr Amortized Available Capital From Excel:

GET XLS DATA('Decision Making Model.xls', 'Values To DSS', '1', 'A4')
~ $/year
~ available capital to customer

Time To Build First Plant=

1.5
~ year
~ The time to get all permits, design and build system prior to operation

First Plant Market Entry Switch=
STEP(1, Time Required to Raise Capital )
~ dmnl
~ Switch to activate sales.

Company Growth=
((Operating Profits-(Operating Profits*"% of Profits for R&D"))*"%
Growth/Retained $"\n)*100
~ percent/year
~ Growth of company in percent due to profit not spent on R&D

"% of Facilities with Capital"=
0.1
~ dmnl
~ % of areas that need upgrades with available capital to enter the market.

"Avg. Plant size"= 1
~ 1/Plant
~ Average Plant size (odd units to make tab work)

Plant Recognition=
Operational Plants*"Avg. Plant size"
~ dmnl
~ Plant recognition comes with average plant size. The bigger the plants, \\
the more respect they get.

Competitive Research and Development=
0.25
\sim dmnl/Entrants
\sim \text{percentage of incremental advancement per competitor per year.}\backslash
Arbitrarily set at 25\% as a guess for membrane technologies.

\textbf{Lobbying Power=}
\quad 2e+007
\sim \text{people/regulations}
\sim \text{regulatory proposals per person aware through representative lobbying efforts.}

\textbf{Decommissioned Plants=}
\quad \text{"# of Competing Operational Plants"*Ratio of Competitor Decommissions}
\sim \text{Plant/\text{year}}
\sim \text{The number of competing technology plants decommissioned (or again on the \backslash}
\text{market for upgrade) per year based on a 10 year lifecycle.}

\textbf{Rate of Market Entry=}
\quad \text{\text{"Existing Corp. and New Venture Entry per unit Demand"*New Wastewater Processing Needs\backslash}
\quad \quad )}
\sim \text{Entrants/\text{year}}
\sim \text{The rate of new competitors entering the market. minus one fifth \backslash}
\quad \text{(arbitrary) of the existing market of slowing due to saturation.}

\textbf{"\% Incremental Advancement"=}
\quad \text{"\% Incremental Advancement per Dollar RandD TABLE"(RandD Investments\text{Cumulative})}
\sim \text{dmnl}
\sim \text{\% Advancement}

\textbf{"10 yr Amortized Cost Gap"=}
\quad \text{Customer's 10 yr Amortized Available Capital From Excel\text{"10 yr Amortized Costs From Excel"}}
\sim \text{\$/\text{year}}
\sim \text{The amount of capital the customer will have on top of the cost of the \backslash}
\quad \text{system. If this number is negative, they do not have enough money to fund \backslash}
\quad \quad \text{the system.}
"Avg. Capacity per Upgrade"=
1/9.125e+007
≈ Plant/Gallon
≈ The average capacity per upgrade per year

Confidence per Endorsement=
0.05
≈ 1/Plant/year
≈ Arbitrarily set at 5 percent per Endorsement

"Avg. Competitor Life"=
5
≈ year
≈ avg competition life and company failure. Assumed 5 yr expectancy

Ratio of Competitor Decommissions=
1/10
≈ 1/year
≈ ratio of plants decommissioned per year

Confidence per Icon=
0.05
≈ 1/Plant/year
≈ arbitrarily set at 5% per endorsement

Market Exit=
Number of Direct Competitors/"Avg. Competitor Life"
≈ Entrants/year
≈ Needs to take into account growth of giants, dominant designs and curves
\ 
representative of Utterback's work.

Reference Bank Interest=
5
≈ percent
≈ 

"Power of "Best Available Technology""=
0.005
~  dmnl/benefit
~  This will eventually be an output to excel similar to the % tightening rate and will brighten customer willingness to enact change by a percentage. It is arbitrarily set at .5 %.

"# of Competing Operational Plants"= INTEG ( 
  +Rate of Competitor Sales-Decommissioned Plants, 
  1) 
~  Plant 
~  The number of competing plants operating

Tech Confidence TABLE( 
  [(0,0)-(100,100)],(0,1),(1,5),(2,7),(3,8),(5,9),(10,15),(15,30),(20,50),(30,70),(40,80),(60,90),(100,90)) 
~  1/year 
~  % of customer's confidence in teh technology as a function of the total # of plants existing utilizing the technology. First curve is lead users, second is mass acceptance.

"% Growth/Retained $"= 
  0.05/3000000 
~  percent/$ 
~  5 percent growth for every 300k of profits not spent on R&D

"Capacity to Sell Units per % Growth"= 
  0.3 
~  Plant/percent/year 
~  For every % growth of company, its efforts to grow its sales and engineering departments is arbitrarily set at 3 (plants per year per percent growth)

"Capacity to Supply/Sell Units"= INTEG ( 
  Company Growth*"Capacity to Sell Units per % Growth", 
  3) 
~  Plant/year 
~  The company's capacity to sell units with regard to Sales and Engineering capabilities.

"% Tightening per Enactment"=
0.025
~ dmnl/regulations
~ The average percent per year that we can expect required benefits to contract for every regulatory enactment issued. Arbitrarily set at 5%.

Capability of new technologies to reasonably treat hazards = 0.3
~ dmnl
~ An index of the rate of new technology development and their ability to effectively treat a hazard, with respect to effectiveness and lowest detection capabilities. This is arbitrarily set at a solution or regulatory agreement for every 30% advancement in new technologies.

"Existing Corp. and New Venture Entry per unit Demand" = 1e-010
~ Entrants/Gallon
~ Entries per Gallon of new wastewater demand. Assuming 1 entrant for every 1 billion gallons of water demand

Percentage of Demand for New Systems = 0.3 + RAMP (-0.001, 0, 20)
~ dmnl
~ Arbitrarily set at 20%. New systems vs. Upgrades

Number of Direct Competitors = INTEG ( + Rate of Market Entry-Market Exit-Market Exit, 1)
~ Entrants
~ The number of direct competitors currently in the market.

******************************************************************************
Business plan constituents v2
******************************************************************************
10 year span, generating data on a quarterly basis.

Competitor Cost Benefit Ratio = (Competitor's 10 yr Amortized Costs From Excel/Competitors Benefit Rating From Excel) - 0.5*(Competitor's 10 yr Amortized Costs From Excel
Competition Benefit Rating From Excel)

(Incremental Advancements from External Technological Developments)

\[
\begin{align*}
\sim S/\text{year/benefit} \\
\sim \text{Cost Benefit ratio including } \% \text{ changes due to tech advancements. } 100\% \ \text{advancement should reduce cost benefit ratio in half.}
\end{align*}
\]

New Technological Capabilities =

\[
\text{"% Incremental Advancement"}/100 + \text{Incremental Advancements from External Technological Developments}
\]

\[
\begin{align*}
\sim \text{dnnl} \\
\sim \text{Percent Advancements in New Technologies.}
\end{align*}
\]

System Starts From Sales =

\[
\begin{align*}
\text{IF THEN ELSE} \("10 \text{ yr Amortized Cost Gap}\) \geq 0: \text{AND:"Indexed Competitive Advantages - Ratio"} \\
\geq 1: \text{AND: First Plant Market Entry Switch = 1: AND:"Capacity to Supply/Sell Units"} > 0, \text{MIN}\(
\text{(Willingness to Adopt*Potential Sales,"Capacity to Supply/Sell Units" \\
\), 0)}
\sim \text{Plant/year}
\sim \text{The rate of plants sold per year. Answers the question. Is there a positive cost gap between the customer's available capital and the cost of the system? And is there a positive indexed cost-benefit ratio? If so, the rate of sales will be equal to the rate of adoption or willingness to adopt and the potential sales.}
\end{align*}
\]

Time Required to Raise Capital =

\[
\text{(TFR TABLE(Total Funding Required)) / Time To Build First Plant}
\]

\[
\begin{align*}
\sim \text{year} \\
\sim \text{The expected amount of time from "time 0" that it will take to raise enough capital through equity, debt, and partnerships to start company (if needed) in addition to subsidize and build the first installation. (If needed)!!\!\!\!
\end{align*}
\]

New Upgrades Per Year =

\[
\text{(((New Wastewater Processing Needs*(1-Percentage of Demand for New Systems \text{"Avg. Capacity per Upgrade"})))*Percentage of Facility\text{ys Subject to Specific Contaminant}} \\
\sim \text{User Willingness to Enact Change + Upgrades}"% of Facilities with Capital"
\]

85
Plant/year
Average new upgrades externally and internally from customer base.

User Willingness to Enact Change=
Corporate Responsibility Adoption Standards*"Existing Plant's Benefit Gap - from excel"
*(1+Additional Regulatory Stringency)) + "Power of "Best Available Technology"
"Existing Plant's Benefit Gap - from excel"*(1+Additional Regulatory Stringency))

~ dnnl
~ (need to redefine units) This is based on a percentage weighting of the benefit gap due to the power of best avail tech and corp responsibility.

Technological Confidence=
Tech Confidence TABLE(Plant Recognition)
~ 1/year
~ percent customers with confidence in our technology.

Rate of Competitor Sales=
MIN(((Potential Sales/Rate Increment of 1 Year)-System Starts From Sales)*0.8), Competitive Capacity to Sell Units\*0.8)
~ Plant/year
~ rate at which competitors deplete the market. Which ever is the limiting factor (The potential sales per year left over times 80% success rate) or (their capacity to sell units multiplied by a success rate of 80% (this remaining 20% is assumed to be a procrastination factor i.e. things just don't work out)

Operational Plants= INTEG (System Starts From Sales-Upgrades, 0)
~ Plant
~ The total number of operational systems produced by the analyzed company. Initial is 0 until first system is sold.

Competitors Benefit Rating From Excel:=
GET XLS DATA ('Decision Making Model.xls','Values To DSS','1','A6')
~ benefit
Net Benefit rating from Excel

Potential Sales = INTEG ( 
+ Rate of New Opportunities - Rate of Competitor Sales - System Starts From Sales, 100)
- Plant
- The number of potential sales for the company. It does not take into account a feasibility fraction. (maybe want to put one in)

"% of Profits for R&D" =
0.2
- dmnl
- Percentage of Profits dedicated to R&D or process improvements

New Potential Buyers =
(New Wastewater Processing Needs * Percentage of Demand for New Systems * "Avg. Capacity per Plant"
* User Willingness to Enact Change * "% of Facilities with Capital"
- Plant/year
- New plants as potential buyers due to demand and user willingness to enact change due to regulatory drivers.

Incremental Advancements from External Technological Developments =
Competitive Research and Development * (Number of Direct Competitors * (0.1 + RAMP (0.02, 0, 20)))
- dmnl
- Percentage of incremental advancements per competitor per year. multiplied by a percentage ramp ramp because we assume that no more than 10% of the technologies will be the same at the start and this will grow to 50% by year 20.

"Regulatory Proposal & Enactments" =
(New Public Awareness of Needs / Lobbying Power) * (Capability of new technologies to reasonably treat hazards *
(1 + New Technological Capabilities))
- regulations
- This ramp like result is a good one. It says that now most regulatory initiatives will be based on technological advancements. This is
consistent with a slow down in new regulated contaminants and a \
proliferation of regulatory rules for the existing contaminants. Nice.

"% Incremental Advancement per Dollar R&D TABLE"

\[(0,0), (1e+008,40),(0,0),(500000,5),(1e+006,10), (1.5e+006,15), (2e+006,20), (3e+006,26)\]
\[,(4e+006,28),(1e+007,29),(1e+008,30)\]
\[\sim \text{dmn}\]
\[\sim 5\% \text{ incremental reduction in the cost benefits ratio for the} \]
\[\text{initial 500K invested in R&D} \text{. Then a table function. With a 2 year delay}\]
\[\text{for product development.}\]

Buyer Confidence=

\[\text{Regulatory Endorsements*Confidence per Endorsement+Iconic}\]
\[\text{Users*Confidence per Icon+}\]
\[\text{Technological Confidence+Customer Awareness}\]
\[\sim 1/\text{year}\]
\[\sim \text{This Needs lots of work. Each of the inputs have been arbitrarily}\]
\[\text{weighted according to importance.}\]

Cost Benefit Ratio=

\["10 \text{ yr Amortized Costs From Excel"/Benefit Rating From Excel)-0.5*"10 \text{ yr}\]
\[\text{Amortized Costs From Excel"}/\text{Benefit Rating From Excel}*"% \text{ Incremental Advancement"}/100)\]
\[\sim $/\text{year/benefit}\]
\[\sim \text{cost - benefit Ratio including } \% \text{ reduction from tech advancements}\]

Willingness to Adopt=

\[\text{(Buyer Confidence+Public Pressure Effect+Regulatory Delinquency}\]
\[\sim 1/\text{year}\]
\[\sim \text{This is a relative percent willingness scale out of } 100\% \text{. It incorporates}\]
\[\text{Public pressure, the degree of separation between present benefits and}\]
\[\text{expected regulations, buyer confidence in the technology, and the}\]
\[\text{customer's compared to 10yr ammortized costs.}\]

Bank Interest Rates=

\[\text{Reference Bank Interest*Input Modification}\]
\[\sim \text{percent}\]
\[\sim \text{Yearly interest rate. Could be a table function to look at interest }\]
rate's effect over time

Revenues= DELAY FIXED (  
    System Starts From Sales**"Avg.Sell Price per unit - To Excel" , 1, 0)  
    ~ $/year  
    ~ Revenues per year equal to units sold times average unit price. (Still \needs clarification on time period, if any) 12 month delay for accounts \receivable.

Corporate Responsibility Adoption Standards=  
    0.0005  
    ~ dmnl/benefit  
    ~ This is also a catalyst for customers to enact change. It is arbitrarily \set at .005% (I need to think if this is necessary since it is \insignificant. If it can grow over time, it needs to include inputs for \growth.

Additional Regulatory Stringency=  
    "% Tightening per Enactment"**"Regulatory Proposal & Enactments"  
    ~ dmnl  
    ~ The percent tightening of benefit needs (including effluent \charachteristicce) as a function of new regulations and the percent \tightening per reg.

Word of Mouth TABLE(  
    [(0,0)-  
        (100,100),(0,1),(1,5),(5,20),(10,40),(50,95),(100,95)]  
    ~ 1/year  
    ~ This could be expanded to include contact frequency and the amount of \people out there that can be made aware. This should be a table function \of market share where 0-50 it goes up and then down and equal a \percentage \of the market. It should hit 100% before the table function does. M/M/M!

Iconic Users=  
    0.1*(Operational Plants)  
    ~ Plant  
    ~ The number of iconic users for this technology. Iconic user refers to a \customer of clout that others follow. This is arbitrarily set at 10%.
Customer Awareness=
   Word of Mouth TABLE(Market Share)
   ~ 1/year
   ~ The percent of potential customers that are at least aware that the \n     product exists.

Regulatory Endorsements=
   Operational Plants
   ~ Plant
   ~ Regulatory Endorsements from technologies that have proven worth
     through \n     operating systems. (need to figure out how to create a bell curve or \n     leveling along with time and adoption. Arbitrarily set at 1 endorsement \n     per plant)

Public Pressure Effect=
  40
  ~ 1/year
  ~ Rating of 0-100% of public pressure. 100% being unrelenting demand, 0 \n    being no pressure at all.

Regulatory Delinquency=
  30
  ~ 1/year
  ~ Rating of 0-100%. 100% being a regulatory gap of 100% from \n    requirements. \n    0 being already in compliance. (needs to integrate with excel somehow)

Market Share=
   Operational Plants*100/(Operational Plants+Potential Sales+"# of Competing \n   Operational Plants")
   ~ dmnl
   ~ Market share of company as percentage of total potential and existing \n   plants.

"10 yr Amortized Costs From Excel":=
   GET XLS DATA ('Decision Making Model.xls', 'Values To DSS', '1', 'A2')
   ~ $/year
   ~ Payments based on 10 year annual ammortization. From excel.
"Indexed Competitive Advantages - Ratio"=
  Competitor Cost Benefit Ratio/Cost Benefit Ratio
  ~ Dimensionless
  ~ How much better our technology is vs. our competitor. If >1 we win. If <1 they do.

Competitor's 10 yr Amortized Costs From Excel:=
  GET XLS DATA ('Decision Making Model.xls','Values To DSS','1','A3')
  ~ $/year
  ~ Payments based on 10 year annual ammortization. From excel.

"Avg. Capacity per Plant"=
  1/3.65e+008
  ~ Plant/Gallon
  ~ average capacity for a plant per year

Benefit Rating From Excel:=
  GET XLS DATA ('Decision Making Model.xls','Values To DSS','1','A5')
  ~ benefit
  ~ Net Benefit rating from Excel

Operating Profits=
  Revenues*(Desired Profit Margin/100)
  ~ $/year
  ~ Operating profits per year based on a desired profit margin calculated using the system design cost. ($ or $/yr?)

RandD Investments Cumulative= INTEG ( Operating Profits**"% of Profits for R&D", 0)
  ~ $
  ~ Dollars invested into R&D per year. (Total as a stock or on a per year basis?)

New Wastewater Processing Needs=
  ("Muni-Industrial Wastewater Production/capita"/365)*Population Growth
  ~ Gallon/year
  ~ Additional gallons per year needing treatment (need to include reduction
of this number when new plants are being built.) (need to work on units)

"Avg. Time to Upgrade"=
10
~ year
~ Avg. Time before needing to upgrade due to regs. quality or demand

New Public Awareness of Needs=
Population Growth*Media Coverage and Press Releases
~ people
~ People aware of water needs. Function of population and media attention.

"Muni-Industrial Wastewater Production/capita"=
41975
~ Gallon/people
~ Gallon per person per year. Guess of 80 gpd per person of municipl
waste \water + 15 gpd of industrial wastewater. 95 * 365 =

Rate of New Opportunities=
New Potential Buyers+New Upgrades Per Year
~ Plant/year
~ Number of new opportunities: both upgrades and new systems

Population Growth=
2e+008+RAMP( 5e+006 , 0 , 20 )-SMOOTH(RAMP( 1.5e+007, 0, 20),20)
~ people/year
~ Annual Population Growth

Media Coverage and Press Releases=
0.4
~ dmnl*year
~ Percentage of people exposed to major Media announcements regarding
water \shortages, inadequacies, regulations, etc... on a yearly basis

Pulse Quantity=
0
~ Dimensionless*year
The quantity to be added to the delay in the pulse input, as a fraction of the value of Input.

For example, to pulse in a quantity equal to 50% of the current value of input, set to .50.

Noise Amplitude = 0
~ Dimensionless
~ Magnitude of the random input, as a fraction of the base value of the input.

Noise Start Time = 5
~ year
~ Start time for the random input.

Input Modification=
1+STEP(Step Height,Step Time)+
(Pulse Quantity/TIME STEP)*PULSE(Pulse Time,TIME STEP)+
RAMP(Ramp Slope,Ramp Start Time,Ramp End Time)+
Sine Amplitude*SIN(2*3.14159*Time/Sine Period)+
STEP(1,Noise Start Time)*Noise Amplitude*(RANDOM 0 1() - 0.5)
~ Dimensionless

Sine Amplitude=
0.1
~ Dimensionless
~ Amplitude of the sine wave in Input, as a fraction of the base value.

Sine Period=
5
~ year
~ Periodicity of the sine wave in Input.

Ramp End Time=
1e+009
~ year
~ End time for the ramp input.
Pulse Time=
   5
   ~ year
   ~ Time at which the pulse in Input occurs.

Step Time=
   5
   ~ year
   ~ Time for the step input.

Ramp Slope=
   0
   ~ 1/year
   ~ Slope of the ramp input, as a fraction of the base value.

Ramp Start Time=
   5
   ~ year
   ~ Start time for the ramp input.

Step Height=
   0
   ~ Dimensionless
   ~ Height of the step input, as a fraction of the base value.

Percent of Customer Revenues as Operating Profit=
   0.1
   ~ dmnl
   ~ Average percentage of revenues converted to profit or "money in the bank".
   \   For now Rule of thumb = 10%

Average Water Production=
   1e+006
   ~ Gallon
   ~ Average Gallons Per Day produced by utility or other.

Funding Needed for First Installation=
1e+006
~ \text{dmnl}
~ The amount of $ needed to subsidize and build first system.

Price per Gallon =
0.0002
~ \$/Gallon
~ This is the price that the utility can charge per 1000 gallons for \ revenue. Similarly we could look at this as money saved by an industry \ whose purpose is to increase efficiency rather than sell water as a \ product. A penny saved is a penny earned.

Total Funding Required =
Funding Needed for First Installation + Funding Needed For Start Up Operations
~ \text{dmnl}
~ Total funding necessary to start company and build first plant

Other Income =
0
~ \$
~ Exogenous input of cash flow for a water project originating perhaps from \ other activities.

Expected Revenues =
Average Water Production * Price per Gallon * 365
~ \$
~ Price per gallon * average water production * days per year.

\text{TFR TABLE(}
\{(0,0),
(1.5e+007,2),(0,0),(250000,0.5),(500000,2),(750000,3.5),(1e+006,6),(2e+006,9),
(3e+006,12),(4e+006,15),(5e+006,18),(1.5e+007,30),(0,0),(250000,0.042),(5000
00,0.167),
(750000,0.292),(1e+006,0.458),(2e+006,0.917),(3e+006,1.17),(4e+006,1.37),(5e+
006,1.5),(1e+007,1.67),(1.5e+007,1.75)
\}\text{ year}}
Funding Needed For Start Up Operations=
5.75e+006
~ dmnl
~ The amount of $ needed to start company and attain inventory

Expected Operating Profits=
Expected Revenues*Percent of Customer Revenues as Operating Profit
~ $\$
~ Using the rule of thumb for % revenue converted to profits and expected \ revenues this will give us an idea of expected yearly profit as cash \ available for the utility

Cash=
Expected Operating Profits+Other Income
~ $\$
~ Cash on hand from water profits as well as other activities that can be \ used as subsidys for the capital investment.

Desired Profit Margin=
10
~ dmnl
~ percent of total sell price as profit

Available Capital To Excel=
Bank Loans+Cash+Federal Subsidies
~ $\$
~ Total Available Capital for Project

Bank Loans=
100000
~ $\$
~ Year 1 loan

Financing Alternatives=
MIN(Bank Interest Rates, New Financial Products)
~ percent
~ This should eventually be a table function. Optimal Financing Option \ expressed in an annual interest rate
Production Cost=
  100000
  $/Plant
  This is the one time cost for the manufacturer or new business to produce their system. Includes hardware, IT and system's integration. Need to make this a function of Gallons per day peak demand with % redundancy.

Offered Interest Rate to Excel=
  Financing Alternatives
  percent
  this needs to be a min or more complex method of choosing financing options for interest rates and capital investment choices.

"Avg.Sell Price per unit - To Excel"=
  Production Cost+(Production Cost*Desired Profit Margin/100)
  $/Plant
  Sell price to customer with % margin mark-up for profit.

Federal Subsidies=
  0
  $  Money Alloted by the Government to Aid in Development

New Financial Products=
  1.2
  percent
  Expressed as interest rate. This needs further clarification on the benefits of various options other than interest rate

*****************************************************************************
  .Control
*****************************************************************************
  Simulation Control Parameters

FINAL TIME = 20
  year
  The final time for the simulation.
INITIAL TIME = 0
~ year
~ The initial time for the simulation.

SAVEPER =
TIME STEP
~ year [0,?]~ The frequency with which output is stored.

TIME STEP = 1
~ year [0,?]~ The time step for the simulation.