Overcoming Organization Barriers to Adopting Sustainable Business Practices

By
Mark P. Chew
M.S. Electrical Engineering and Computer Science, University of California, Berkeley, 2004
B.S. Electrical Engineering and Computer Science, University of California, Berkeley, 2002

Submitted to the MIT Sloan School of Management
and the Department of Chemical Engineering
in partial fulfillment of the requirements for the degrees of

Master of Business Administration
and
Master of Science in Chemical Engineering

In conjunction with the Leaders for Global Operations at the
Massachusetts Institute of Technology
June, 2010

Signature of Author ______________________
MIT Sloan School of Management, Chemical Engineering
May 7, 2010

Certified by ______________________
Roberto Fernandez, Thesis Supervisor
William F. Pounds Professor of Organizational Studies, MIT Sloan School of Management

Certified by ______________________
David Hardt, Thesis Supervisor
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering, Engineering Systems, MIT

Certified by ______________________
Gregory J. McRae, Thesis Reader
Hoyt C. Hottel Professor of Chemical Engineering, MIT

Accepted by ______________________
Charles Cooney, Graduate Committee Chairman
Department of Chemical Engineering

Accepted by ______________________
Debbie Berechman, Executive Director of Masters Program
MIT Sloan School of Management

Overcoming Organization Barriers to Adopting Sustainable Business Practices

By
Mark P. Chew
Submitted to the MIT Sloan School of Management and Department of Chemical Engineering on May 7, 2010 in partial fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Chemical Engineering

Abstract

Companies of all sizes are now looking for ways to reduce their energy use and carbon emissions, motivated by the desire to save money, improve public relations, and prepare for a possible carbon tax. From a technical perspective, reducing energy use and reducing carbon emissions represent opportunities to save on operating costs. However, the largest barriers to adopting better energy practices are often organizational, rather than technical. This work shows how organizational structure can hinder efforts to improve energy performance and recommends ways to overcome these barriers.

Thesis Supervisor: Roberto Fernandez
William F. Pounds Professor of Organizational Studies, MIT Sloan School of Management

Thesis Supervisor: David Hardt
Ralph E. and Eloise F. Cross Professor of Mechanical Engineering, Engineering Systems, MIT

Thesis Reader: Gregory J. McRae
Hoyt C. Hottel Professor of Chemical Engineering, MIT

This page is intentionally left blank

Acknowledgements

*The author wishes to acknowledge the
Leaders for Global Operations Program at MIT
for its support of this work.*

*He would also like to thank Mark Faulk, James Hunter,
Daryle McGunigale, Jack Holt, Scott Pozza, Dick Johnston,
and the Facilities Engineering and Energy Department
at Raytheon Company.*

*Finally, he would like to thank his wife, Catherine
for her insight, inspiration, and loving support.*

This page is intentionally left blank

Table of Contents

List of Figures

List of Tables

1 Importance of Sustainability to Businesses

1.1 Pressure to Reduce Energy and Emissions

Sustainability has recently become an important consideration for businesses in a wide range of industries, stemming from the scientific evidence for global warming, the rising cost of energy, and impending emissions legislation.[1] Broadly defined, sustainability describes the extent to which human activities can continue in present patterns of behavior. Measures of sustainability can apply to food consumption and natural resource consumption, but are most commonly applied to the atmospheric emissions and energy usage caused by human activity. This work focuses on reducing energy use and decreasing greenhouse gas emissions because these aspects of improving sustainability can have the most impact on both climate change and an organization's financial performance.

As world population continues to increase rapidly at the start of the 21st century, effects on the Earth's natural resources caused by human activity have become evident.[2] Large numbers of people in the developing world are also adopting Western lifestyles, further straining limited supplies of fresh water, arable land, food, and energy. In recent years, it has become evident that to sustain population growth and the adoption of Western lifestyles, humans must decrease the volume of natural resources they consume and reduce the associated emissions.

Besides benefiting the environment, improving a company's sustainability practices can also significantly reduce its operating costs. In the United States, the industrial and commercial sectors account for 65% of energy consumption, compared to 35% in the residential sector.[3] Improving the sustainability practices of the nation's businesses therefore represents a major opportunity to reduce the nation's total energy usage and levels of greenhouse gas emissions. Using Raytheon as an example, this work examines the organizational barriers to adopting more sustainable practices and explores ways for leadership to move past these barriers.

1.2 Problem Statement: Acting on Sustainability Initiatives

Improving sustainability practices represents an opportunity for companies to save costs, reduce environmental risk, and differentiate their products in the marketplace. Faced with the desire to decrease energy consumption and to increase the use of renewable energy,[4] corporate leaders set sustainability goals and form energy groups, usually within their facilities divisions. This tends to have a moderate effect on a company's sustainability initiatives because engineers and managers can argue for sustainability projects by invoking an executive's goals: "Vice-President Smith really wants us to reduce our energy usage."

---

[1] K.O. Packard, F.L. Reinhardt, "What Every Executive Needs to Know About Global Warming", Harvard Business Review; Jul/Aug2000, Vol. 78 Issue 4, p105-113.
[2] W.M. Adams "The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century." Report of the IUCN Renowned Thinkers Meeting, 29–31 January, 2006.
[3] McKinsey & Company, "Unlocking Energy Efficiency in the U.S. Economy", July 2009. http://www.mckinsey.com/clientservice/electricpowernaturalgas/US_energy_efficiency/
[4] Renewable energy is energy generated from natural resources that are naturally replenished, including sunlight, wind, rain, tides, and geothermal heat.

1.2.1 Observation: Sustainability Initiatives are Often Not Implemented

Sustainability opportunities easiest to seize are those that require little capital investment and have almost immediate payback. For example, a building can be programmed to reduce air flow during off-peak hours, resulting in immediate energy savings with no invested capital. Similar minimal-investment opportunities such as adjusting temperature set points can be accomplished by one engineer within a single day of work.

Once the easiest opportunities for conservation have been exhausted, achieving further conservation goals generally requires larger investments of time and money.[5] For example, purchasing more energy-efficient humidifiers carries an up-front cost but results in savings in the long run. Organizations that invest capital generously to save energy and operating costs are later able to free up money to invest in further savings opportunities.

In practice, however, energy-saving opportunities commonly receive lower priority compared to other projects in a facilities division,[6] in general receiving less funding and fewer human resources. Research documents that financially viable sustainability projects are commonly ignored or postponed.[7] The lost savings resulting from this practice make it more difficult to invest in further energy-saving opportunities, resulting in higher energy usage and costs in the long run.

1.2.2 Effect of the Organization in Accomplishing Sustainability Initiatives

This work examines the proposition that the main barrier to accomplishing sustainability projects is not technological, but organizational. Furthermore, we identify areas of leverage whereby upper management can make an organization more effective in is sustainability initiatives, based on academic frameworks and observations of the facilities division at Raytheon Space and Airborne Systems (SAS) in El Segundo, CA. The implication is that an executive team that aims to improve the sustainability of its organization's operations should consider the flow of project initiatives within the organization and design the organization to allow a large volume of sustainability ideas to be reviewed and funded.

1.3 Raytheon Company

Raytheon Company is a major American defense contractor specializing in defense systems and defense electronics manufacturing. Founded in 1922 in Cambridge, Massachusetts, Raytheon is the world's largest producer of guided missiles and obtains 90% of its revenues from defense contracts.[8] Raytheon is also known for its corporate stewardship, regularly donating large amounts of money to math and science education and philanthropy.

1.3.1 Sustainability at Raytheon

Because of its extensive operations and manufacturing activities, energy consumption represents a sizeable part of Raytheon's operational costs. In 2002, executives set the ambitious goal of reducing greenhouse gas (GHG) emissions by 33% by 2009, normalized to revenue and

---

[5] McKinsey & Co. "Unlocking Energy Efficiency in the U.S. Economy", July 2009.
[6] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.
[7] S. DeCanio, "Barriers within firms to energy-efficient investments", *Energy Policy* Volume 21, Issue 9, September 1993, pp. 906-914.
[8] M. Jarman, "Missile maker hopes to diversify, create technology for peacetime", The Arizona Republic Sept. 30, 2007.

adjusted for inflation. In response, facilities engineers and maintenance personnel found several opportunities to save energy that required minimal capital investment and offered almost immediate payback. Raytheon exceeded the initial goal by achieving a reduction of 38% in GHG emissions by the end of 2008.[9] Further projects to reduce energy usage and GHG emissions are also in progress.

1.3.2 Facilities Division at Raytheon: Background

As with most other large companies, the facilities division at Raytheon is responsible for sustainability initiatives. This includes improving energy efficiency, increasing the use of renewable energy sources, conserving water, and encouraging sustainable behavior among employees. This work draws on examples from Raytheon's facilities division to illustrate typical sustainability practices in large organizations.

The main objective of the facilities division is to keep the facility running, with minimal impact to the customer – revenue generating programs within the company.[10] Therefore, when a failure in any part of the facility causes work to stop or laboratories to fall out of specification, fixing the problem becomes the highest priority for the facilities division. Besides keeping the plant running, the facilities division's secondary objective is to meet customer requirements for facility improvements on time and at minimal cost. Individual project managers and engineers are rewarded for meeting customer specifications at minimal cost, but they incur minimal penalties when projects result in low productivity and high maintenance costs. This sometimes leads to decisions that minimize cost in the short-run, while increasing maintenance costs in the long-run.

Raytheon's facilities division is widely seen as a cost center both by employees inside and outside the division. As such, facilities managers, engineers, and technicians experience constant pressure to lower costs and justify expenditures. A small fraction of the facilities budget is allocated to infrastructure improvements, but there are consistently more feasible infrastructure-improvement projects than funding available. Like other divisions, the facilities division can ask corporate for additional funding. Utility costs are an expense in the facilities division budget, but savings from energy improvements do not fully accrue to the facilities division because projected energy cost is one of the factors used to determine the facilities budget at the corporate level.[11]

The group primarily responsible for sustainability at Raytheon is commonly referred to as "the energy group" because of its emphasis on energy efficiency. The energy group is part of the facilities division because a major part of improving energy efficiency involves upgrading facilities equipment such as air handler units, temperature control, and humidity control. However, a tension still exists between the mission of the facilities division and the goals of the energy group. A large fraction of the proposed sustainability projects save money, reduce energy usage, and reduce GHG emissions but are not driven by a specific customer. As a customer-driven organization, the facilities division as a whole tends to give lower priority to such projects. A prevalent attitude toward sustainability projects is, "If we have survived up to now without this particular improvement, it cannot be critical now, so we should keep focusing on customer service." Although the energy group has successfully executed several energy saving

[9] 2008 Raytheon Corporate Responsibility Report, p. 17.
[10] Based on interview with director of facilities at Raytheon Space and Airborne Systems (SAS) in El Segundo, CA.
[11] Based on interview with finance specialist at Raytheon.

initiatives and has several more in process, the list of viable energy projects yet to be done continues to grow.

1.4 Structure of Discussion

This work is structured as follows:

Chapter 1 introduces sustainability, the difficulty of accomplishing sustainability projects in organizations, and provides background on sustainability at Raytheon.

Chapter 2 identifies the most common methods of renewable energy generation, including the advantages and disadvantages of each.

Chapter 3 discusses practical issues related to implementing fuel cell and solar on-site generation. These are the two methods that Raytheon is pursuing in El Segundo.

Chapter **Error! Reference source not found.** discusses practical issues related to implementing fuel cell and solar on-site generation. These are the two methods that Raytheon is pursuing in El Segundo.

Chapter 5 discusses the importance of investing in sustainability, presenting the consequences and dynamics of under-investing.

Chapter 6 presents two models of how capital allocation happens within organizations. Sections 6.2 and 6.3 describe Joseph Bower's 1970 work – a prescription of the resource allocation process as primarily determined by a company's structural context, rather than simply financial considerations.

Chapter 7 presents case studies of sustainability initiatives within Raytheon and applies resource allocation theory presented in chapter 6 to analyzing the fate of each potential project.

Chapter 8 concludes with recommendations for improving sustainability practice in an organization generalized implications of this work.

2 On-site Energy Generation Methods

Chapters 2 and **Error! Reference source not found.** discuss technical details of on-site energy generation and energy-efficient building improvements as background for the discussion of organizational barriers to sustainability projects which begins in chapter 5.

Chapter 2 summarizes the characteristics of the most common methods for on-site energy generation. Generating electricity on-site rather than buying from utilities is attractive for several reasons, including the rising cost of energy, emissions regulations, and public relations.

2.1 Wind

Wind energy was harnessed by humans early in recorded history, and has recently become the world's fastest-growing renewable energy source.[12] Winds are caused by uneven heating of the atmosphere by the sun and the rotation of the earth, and this flow can be captured as mechanical energy. This mechanical energy can then be used to do work such as grinding grain or pumping water; it can also be converted to electricity.

2.1.1 Advantages of Wind Energy

Wind energy is a renewable, clean energy source. It does not require depleting natural resources such as coal, oil, or gas, and its use does not involve emissions of greenhouse gases or other pollutants. In the United States, wind energy is abundant, especially in the Midwest, and it can cost as little as $0.04 to $0.06 per kilowatt-hour (kWh), depending on the wind resource, the financing, and the project size.[13]

Because wind turbines can be built in rural areas using only a small fraction of the land, ranchers and farmers can utilize wind power in remote locations without major disturbances to their activities. Additionally, when energy is generated in a more distributed manner (rather than from centralized plants), the cost and losses associated with long-distance transmission are avoided.

2.1.2 Disadvantages of Wind Energy

Wind energy must compete with conventional energy sources such as coal and natural gas on a cost basis. Although wind energy can be cost-competitive with conventional sources in certain locations, it generally requires a higher level of initial investment. Favorable wind sites are usually located far from the urban centers where the energy is needed – either offshore where the surface of the earth is smoother or in rural areas. **Figure 2-1** and **Figure 2-2** show the availability of wind resources in the United States and California.

---

[12] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program: http://www1.eere.energy.gov/windandhydro/wind_history.html

[13] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program: http://www1.eere.energy.gov/windandhydro/wind_ad.html

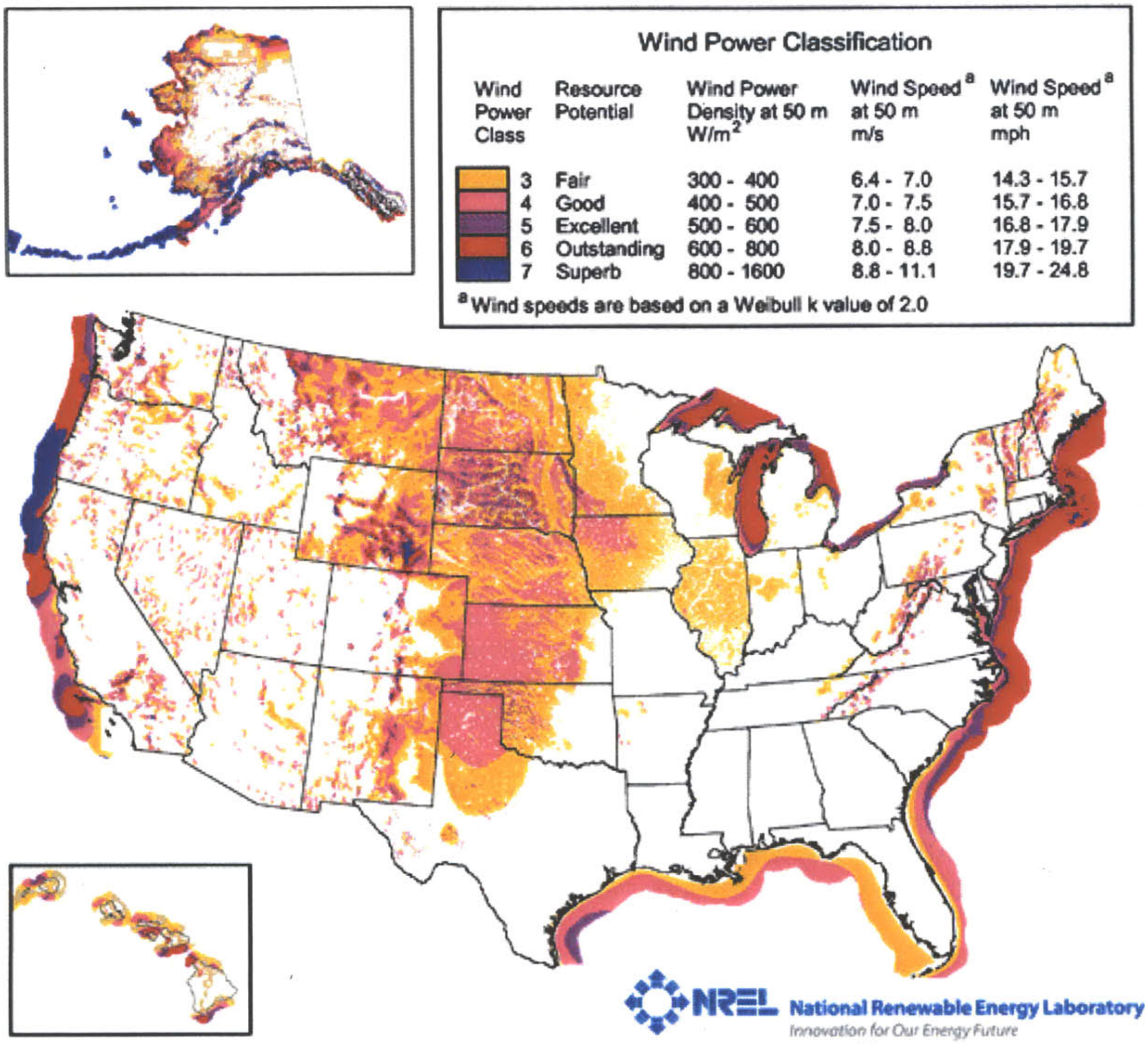


Figure 2-1: Wind Resources in the United States[14]

[14] National Renewable Energy Laboratory: http://www.nrel.gov/wind/resource_assessment.html

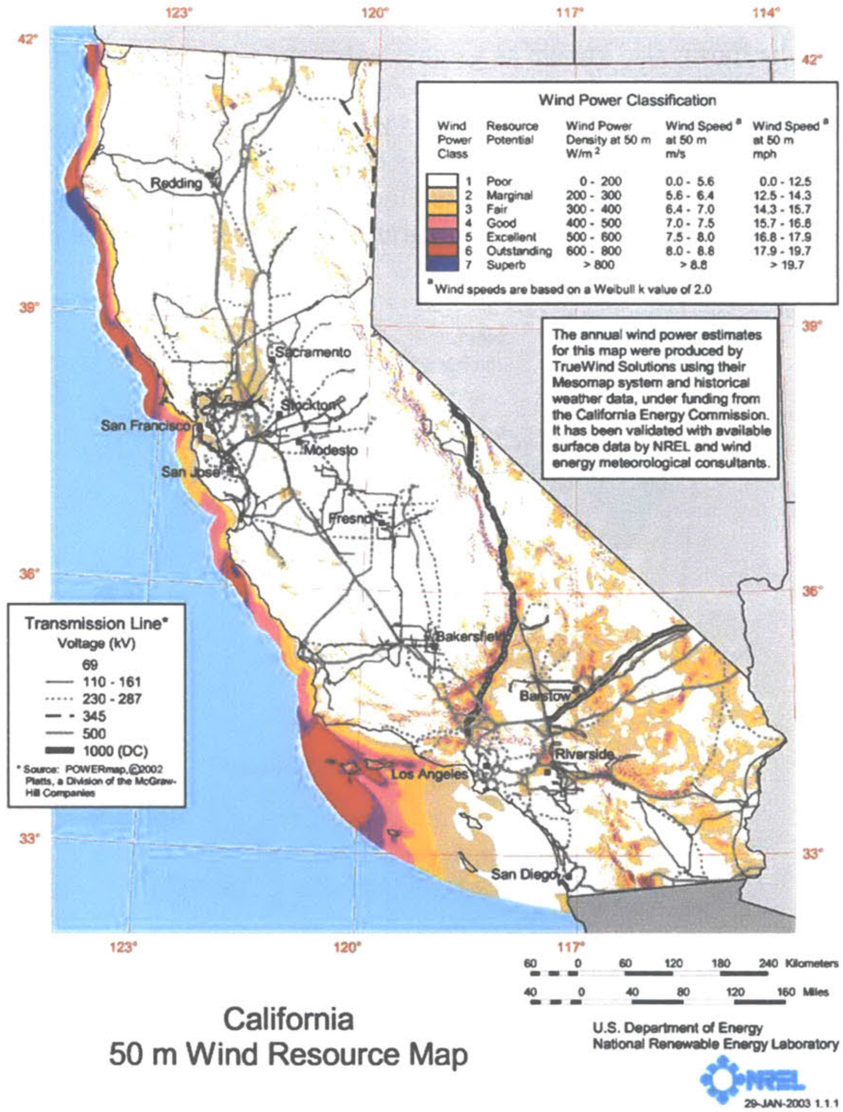


Figure 2-2: Wind Resources in the California[15]

Since wind is intermittent, it often does not coincide with electricity demand. Therefore, wind energy can be used to offset the use of coal and natural gas, but additional storage technologies are necessary for wind to represent a larger fraction of energy generation. Wind can account for up to 10% of a utility's energy portfolio before intermittency becomes an issue.[16]

In urban areas, zoning requirements also can be a major obstacle in installing a wind energy system, and wind energy systems remain uncommon in urban areas.

---

[15] National Renewable Energy Laboratory: http://www.nrel.gov/wind/resource_assessment.html
[16] American Wind Energy Association: http://www.awea.org/faq/wwt_potential.html

2.2 Geothermal

Heat from the Earth, also known as geothermal energy, is accessed by drilling water or steam wells. Historically, this energy has been used for heating, but more recently it has also been used to drive generators to create electricity. Early geothermal plants were located at sites where hot water is naturally available, but more recent geothermal plants have incorporated techniques in which water is injected into the ground to absorb heat, then pumped back to the surface where the heat can be extracted.[17] A diagram of a typical geothermal power plant is shown in **Figure 2-3**.

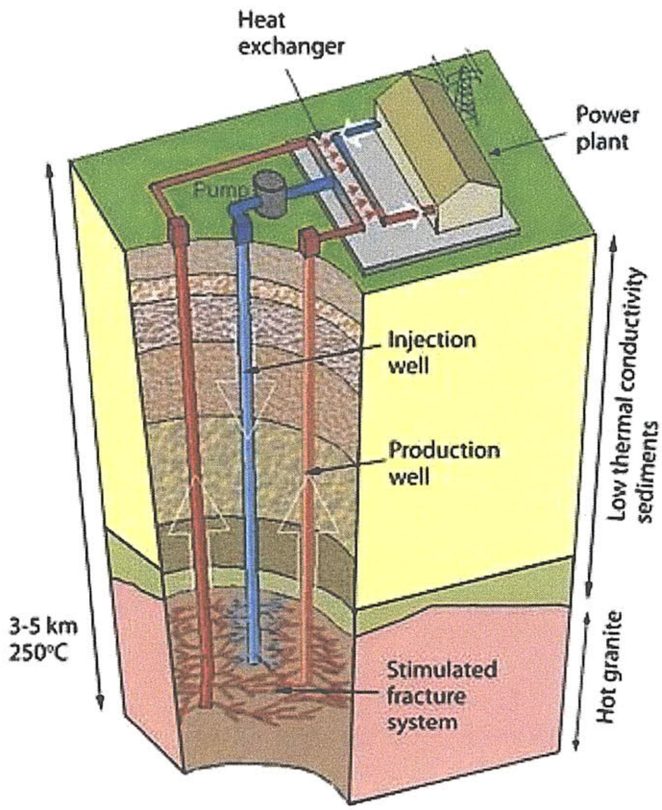


Figure 2-3: Cutaway of typical geothermal power plant[18]

2.2.1 Advantages of Geothermal Energy

Geothermal energy is renewable because it taps the almost unlimited heat generated by the Earth's core. As such, geothermal energy can be extracted with minimal emission of greenhouse gases, and this energy is available 24 hours per day, 365 days per year. Geothermal plants built today would produce energy at approximately $0.05 per kWh – significantly lower than the cost of electricity in many areas.[19] Geothermal plants also require relatively little area

[17] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Geothermal Technologies Program: http://www1.eere.energy.gov/geothermal/history.html
[18] Geothermal Energy Investing. Courtesy of Siemens.
[19] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Geothermal Technologies Program: http://www1.eere.energy.gov/geothermal/faqs.html

on the Earth's surface, compared to wind and solar plants generating the same amount of renewable power.

2.2.2 Disadvantages of Geothermal Energy

Geothermal energy is most economical in locations that provide access to hydrothermal resources – reservoirs of steam or hot water. These tend to be located in tectonically active regions.[20] In the United States, these favorable sites are primarily in the Western states, Alaska, and Hawaii.[19] In other locations, extracting geothermal energy requires drilling miles beneath the surface and using water injection and pumps, adding to the cost of a new plant. Geothermal plants cost $2,500 to $5,000 per kW of electrical capacity to build, and require an additional $0.01 to $0.03 per kWh in operating and maintenance costs.[19] Recent geothermal projects in Basel, Switzerland and near Anderson Springs in Northern California have raised suspicions that deep drilling destabilizes the rock, causing earthquakes.[21] Because of the high initial costs and technical expertise necessary of geothermal energy, the vast majority of geothermal projects in the United States have been done by companies specializing in energy industry, rather than organizations seeking to offset their carbon footprint.[22]

2.3 Fuel Cells

A fuel cell is an electrochemical device that uses atmospheric oxygen and a gaseous fuel, usually hydrogen, to produce direct current (DC) electricity. Unlike combustion engines which convert the chemical energy in fuel to heat, then to mechanical energy, and finally to electrical energy, electrochemical reactions convert the chemical energy in fuel directly to electrical energy. This results in a significantly higher efficiency of conversion. Water vapor, rather than carbon dioxide is the main exhaust from a fuel cell device, but during the reforming process to create the hydrogen fuel for fuel cells, carbon dioxide is still emitted. A diagram of a typical fuel cell is shown in **Figure 2-4**.

---

[20] I. Fridleifsson, R. Bertani, E. Huenges, J. Lund, A. Ragnarsson, L. Rybach (2008-02-11). O. Hohmeyer and T. Trittin. ed (pdf). "The possible role and contribution of geothermal energy to the mitigation of climate change." Luebeck, Germany. pp. 59-80. http://iga.igg.cnr.it/documenti/IGA/Fridleifsson_et_al_IPCC_Geothermal_paper_2008.pdf. Retrieved on 2009-04-06.

[21] The Ne w York Times (June 23, 2009). "Deep in Bedrock, Clean Energy and Quake Fears", James Glanz.

[22] Geothermal Energy Association (August 2008). http://www.geo-energy.org/information/plants.asp

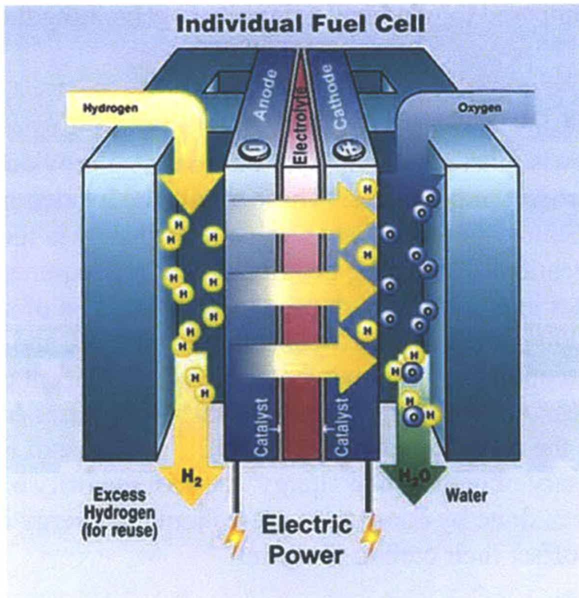


Figure 2-4: Schematic of Typical Fuel Cell[23]

2.3.1 Advantages of Energy from Fuel Cells

Because of their direct conversion from chemical to electrical energy, fuel cells are much more efficient than combustion generators that create electricity from burning coal, natural gas, and other fuels. Estimates vary widely because of differences in assumptions, but fuel cells are generally 30-90% more efficient at producing electricity from fuel than combustion engines.[24] The main action in fuel cells occurs across a membrane with no moving parts, making fuel cells quieter and easier to maintain. If hydrogen gas is used as the fuel, a fuel cell will emit water vapor as a main byproduct and very low levels of other harmful pollutants, while generating high-quality, reliable electricity.

2.3.2 Disadvantages of Energy from Fuel Cells

Fuel cells represent a major advance in carbon emissions per unit electricity generated, but operating fuel cells still involves significant carbon emissions. Although using hydrogen as the input fuel would prevent CO_2 emissions during operation, creating the hydrogen fuel is an emissions-intensive process. Presently, the most feasible way to create hydrogen fuel is generated from natural gas. During this process, the carbon atoms in the natural gas are released into the atmosphere as CO_2. Including the process of forming the hydrogen fuel, using a fuel cell system would reduce carbon emissions by about 30%, compared to the present rate of emissions from California's grid. (see **Table 3-3**)

Using biogas instead of natural gas would further reduce the CO_2 emissions from fuel cell operation, increasing benefit to the company through incentives. In California, companies can pay for methane to be processed and fed into the natural gas pipeline at its source. For example, methane from a hog farm's waste would enter the atmosphere if it were left alone. If this

[23] Joint Service Pollution Prevention and Sustainability Technical Library.
[24] "Face Off: Internal Combustion Engine versus the Hydrogen Fuel Cell", F.Igot, Montgomery College Student Journal of Science & Mathematics, Volume 1, September 2002.

methane is processed and put into the natural gas pipeline, the same amount of natural gas can be used at a different location, theoretically resulting in zero total net emissions.

2.4 Photovoltaics

A photovoltaic (PV) cell converts the energy in incident sunlight into electricity, releasing no GHG during operation. Presently, commercially available PV devices are made of crystalline silicon, polycrystalline silicon, or thin films of semiconducting materials. Despite the high cost of PV devices relative to other alternate energy-generation methods, much attention has been given to developing PV technology because of the abundance of sunlight that hits the earth – about 6000 times the amount of energy consumed by humans.[25]

Incident sunlight on photovoltaic cells causes positive and negative carriers to split at the junction barrier within the cell. These carriers can be harnessed as useful energy before they recombine, as shown in **Figure 2-5**.

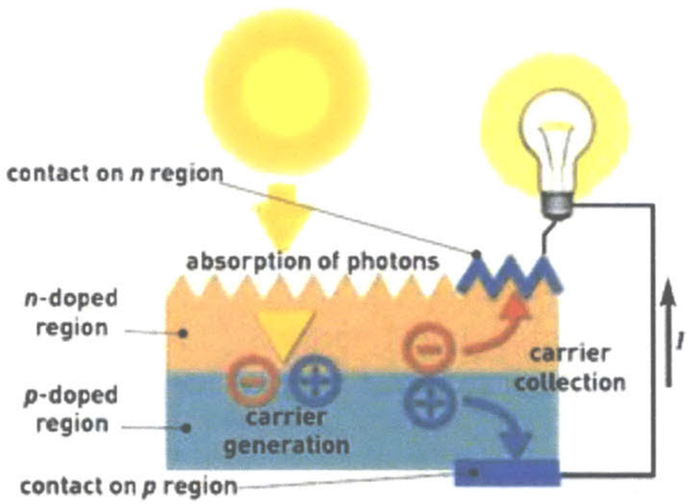


Figure 2-5: Schematic of Typical PV Cell[26]

The availability of solar resources varies by geography, depending on latitude, altitude, and weather patterns. **Figure 2-6** shows the availability of solar resources in the continental United States.

[25] Global Science Forum Conference on Scientific Challenges of Energy Research, Paris, May 17-18, 2006. "Energy at the Crossroads", Vaclav Smil.
[26] Courtesy of Belaj Technology.

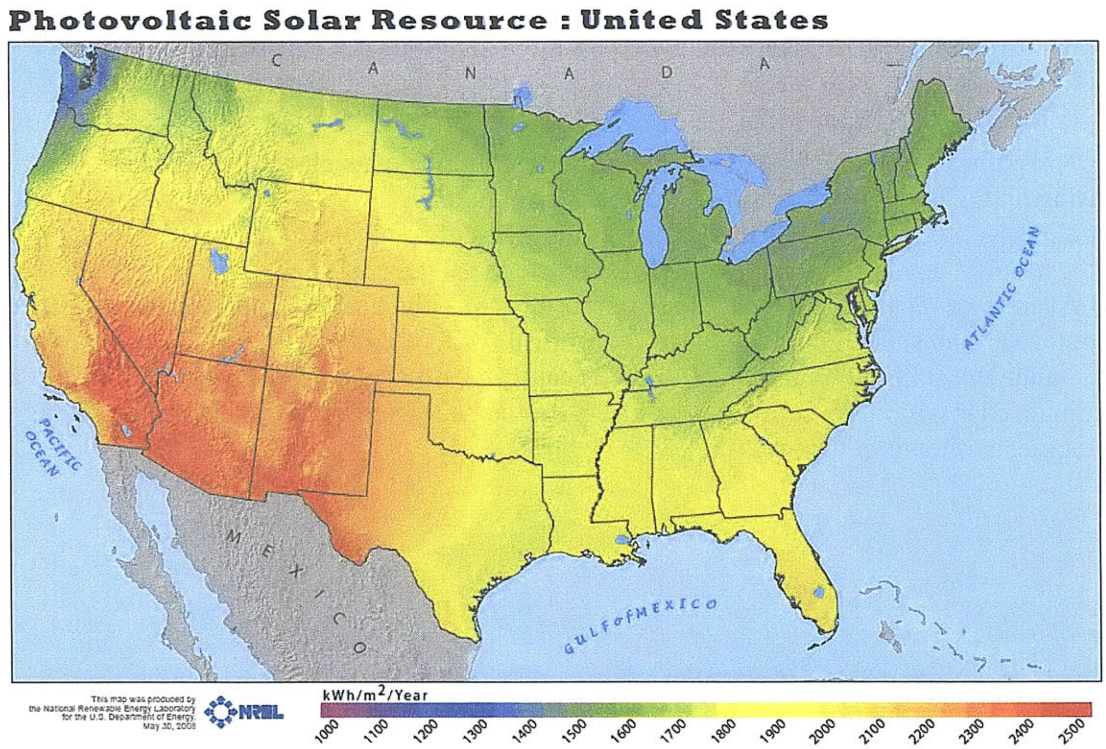


Figure 2-6: Availability of Photovoltaic Resources in the United States[27]

2.4.1 Advantages of Photovoltaic Energy

Besides requiring no fuel and releasing no greenhouse gases during operation, a PV installation has three other distinct advantages. First, the energy usage by most companies peaks during the day, which coincides with the peak production of a PV system. This reduces the company's peak load on the grid and lowers the amount of energy bought from the grid when it is most expensive. Second, the cost of electricity has been steadily increasing over several years and is expected to continue increasing with the price of coal and natural gas. Because they do not require the purchase of fuel, PV systems also act as a hedge against rising utility costs. Third, PV systems have no moving parts and therefore entail minimal cost and effort to maintain.

An additional advantage of PV systems is their public relations value to a company: solar power is widely understood by the public, and installing a PV system represents a high-visibility way for a company to associate itself with environmental stewardship and sustainability.

2.4.2 Disadvantages of Photovoltaic Energy

Like wind energy, PV energy has only intermittent availability. Time of year, time of day, and weather all impact the power output of a PV system, so solar power must be either combined with a storage system or with other energy sources to provide continuous power. Companies that invest in PV can also make this problem transparent through net metering – an arrangement where unused power generated is sold to the public electrical grid.

---

[27] Modified from Solar Energy Industries Association, "US Solar Industry Year in Review 2008". http://www.seia.org/cs/about_solar_energy

Presently, the biggest disadvantage of PV energy is its high initial cost, relative to other options for renewable energy generation. This cost has decreased in recent years because of the learning curve, improved manufacturing, and technical advances; government incentives have also increased the economic attractiveness of PV systems.

3 Case Study: On-site Generation in El Segundo, CA

Raytheon Space and Airborne Systems (SAS), headquartered in El Segundo, CA, is looking to continue its leadership in energy conservation and sustainability. From 2002 to 2008, it reduced energy usage by 33% adjusted for revenue and inflation[28] and continues to seek ways to reduce the GHG emissions from its operations. To this end, Raytheon is considering reducing the electricity it buys from the grid by installing fuel cells and photovoltaic cells to generate electricity on-site.

Wind was eliminated because of zoning issues and the availability of wind in El Segundo. (see **Figure 2-2**) Geothermal was eliminated because of high up-front cost, lack of other non-energy companies choosing geothermal on-site generation, and legal issues with disturbing the widely-used groundwater supply in the South Bay Basin.[29]

This section focuses on fuel cells and photovoltaics (PV), examining severalconsiderations in Raytheon's decision-making process and generalizes the conclusions for the benefit of other companies considering investments in on-site generation.

3.1 Common Considerations for On-site Generation Projects

3.1.1 Capital Expenditure

Recent government incentives have made on-site generation technologies financially attractive to many companies. However, even if a proposal for on-site generation of electricity meets a company's internal requirements for investment, it still may not be funded because of the limited availability of capital for investment.

Entering a power purchase agreement (PPA) is an attractive method for a company to avoid this roadblock in completing an on-site generation project. Under a PPA, the fuel cell or PV system is installed on the purchasing company's site, but owned, fueled, and maintained by the supplier or a third party. The third party sells energy to the purchasing company at a predetermined rate.

Such an arrangement helps the purchasing company because the owner of the system is incentivized to maintain it at peak efficiency for the life of the agreement. Moreover, entering a PPA gives the purchasing company more certainty about its future utility expenses. PPAs usually last between 10 and 20 years, after which the purchasing company can extend the agreement, purchase the unit, or have it removed. Before entering a PPA contract, a company should perform the background and legal due diligence necessary to protect itself in the unlikely event that either the supplier or financer default. Because it is difficult to get the large amount of capital needed in Raytheon's facilities group, only projects financed by PPAs are being considered for on-site electrical generation.

Several states have recently passed laws requiring companies to generate a certain percentage of their electricity from renewable sources.[30] This has increased the importance of renewable energy credits (RECs): tradable environmental commodities that represent proof of 1

[28] Raytheon Corporate Responsibility Report 2008, pp. 17-19.
[29] Water Replenishment District of Southern California, Replenishment Operations http://www.wrd.org/engineering/groundwater-los-angeles.php?url_proj=replenishment-operations
[30] California requires 33% renewable by 2020 and New York requires 24% renewable by 2013. For a complete list, see http://www.dsireusa.org/

MWh of renewably generated electricity.[31] Since RECs enable companies to demonstrate their compliance with renewable generation requirements, a company that enters a PPA should not overlook the importance of REC possession in the terms of the contract.

3.1.2 Water Consumption

As demand for water resources increases in many parts of the United States, a company must consider water as it evaluates possible actions to achieve its environmental goals. Moreover, the price of water has been increasing in recent years. In El Segundo, Raytheon's cost per gallon of water increased every year from 2004 to 2009, with a total increase of 64% during that period.[32]

Technology	gallons/kWh
Nuclear[33]	0.62
Coal[33]	0.49
Oil[33]	0.43
Combined Cycle Gas[33]	0.25
Wind[34]	0.001
Solar[35]	0.030
Fuel Cell[36]	0 to 0.096

Table 3-1: Water Consumption of Energy Sources

Table 3-1 compares the water consumption of common energy generation technologies in gallons per kWh. Both wind and solar generators require water for cleaning purposes only. By contrast, some fuel cells require water for the process whereby hydrogen is reformed from the methane in natural gas. A company considering on-site fuel cell generation should ensure that the water requirements of the system are acceptable for a given location.

3.1.3 Overloading

With any on-site generation project, attention should be given to the possibility of generating more power than needed. For on-site generation projects which aim to offset a small fraction of electrical usage and demonstrate the viability of a technology, it is sufficient to compare generation capacity to historical usage patterns to preclude the possibility of overloading.

---

[31] Renewable energy is energy generated from natural resources that are naturally replenished, including sunlight, wind, rain, tides, and geothermal heat.
[32] Based on data for El Segundo South Campus, found in BUD files, 2004 through 2009.
[33] American Wind Energy Association: http://www.awea.org/faq/wwt_environment.html
[34] American Wind Energy Association estimate, based on data obtained in personal communication with Brian Roach, Fluidyne Corp., December 13, 1996. Assumes 250-kW turbine operating at .25 capacity factor, with blades washed four times annually.
[35] Meridian Corp., "Energy System Emissions and Materials Requirements," U.S. Department of Energy, Washington, DC. 1989, p. 23.
[36] Based on specification data tables from Fuel Cell Energy and UTC Power.

For projects that aim to offset 20% or more of a site's electrical usage, either a storage technology or a net metering arrangement is necessary to prevent overloading.[37]

3.2 Considerations for Fuel Cells

3.2.1 Combined Heat and Power (CHP)

Heat can be recovered from fuel-burning electricity generators and recycled; this is true of coal-burning plants, gas turbines, and some fuel cells. Utilities often use this heat to drive secondary steam turbines, but on-site generators can reclaim a larger percentage of the waste heat by configuring a generator in a combined heat and power (CHP) configuration. In such a configuration, the waste heat replaces the need to burn additional natural gas for heating water.

Because of their higher operating temperature, a larger percentage of waste heat can be reclaimed with molten carbonate fuel cells (MCFC) or solid oxide fuel cells (SOFC). SOFC generators in a CHP configuration with energy efficiencies of up to 90% have been demonstrated,[38] but this efficiency level is only achieved if demand exists for both the electricity and recovered heat. By contrast, highest efficiency achieved to date with a combined cycle gas turbine is 60%.[39]

3.2.2 Types of Fuel Cells

Polymer electrolyte membrane (PEM) cells are most commonly used in fuel cell vehicles because of their low operating temperature and fast start-up time. For stationary power generation, PEM fuel cells are less favorable because of their low efficiency and difficult-to-recover waste heat, relative to other types of fuel cells.

Alkaline fuel cells are mostly used in controlled aerospace and underwater applications because they are easily poisoned by small amounts of carbon dioxide.[40]

Worldwide, the vast majority of stationary fuel cell installations have been PAFC installed by UTC power, or MCFC installed by Fuel Cell Energy.[41] Other companies have developed techniques to overcome the manufacturing and reliability barriers associated with SOFC, and as of the summer of 2009, these products have become commercially available as well.

SOFC has the highest potential efficiency and shows great promise in power generators for buildings but is presently the least mature technology listed. SOFC has the highest theoretical efficiency of any of the technologies (60-70%) and can use both hydrogen and methane fuel. Because SOFC operates at a very high temperature, manufacturing and reliability issues are the biggest barrier that must be overcome.

Raytheon has selected SOFC products, despite the risk of dealing with a new technology, because of the efficiency benefits and an early-adopter price. One-MW units will be installed at five different sites because this is the capacity level that maximizes its incentives and tax credits

---

[37] Net metering is an arrangement with a site's local utility company, where excess electricity generated is sold back to the grid. Such an arrangement lowers a site's electrical costs because it only pays for the net electricity used.
[38] Siemens Fossil Power Generation; http://w1.siemens.com/responsibility/en/environment/portfolio/fossil_power_generation.htm
[39] In a combined cycle gas turbine, efficiency is increased by using waste heat to drive a downstream steam turbine.
[40] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; Hydrogen, Fuel Cells & Infrastructure Technologies Program: http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html
[41] Fuel Cell Installation Database, http://www.fuelcells.org/db/

in California. Since this is a pilot project, the most important objective is to show that renewable generation saves money. We believe Raytheon should instead choose a vendor and technology that will deliver cost savings at minimal risk, waiting for later years to invest in more risky technologies. A summary of five different types of fuel cell technologies is shown in **Table 3-2**.

Fuel Cell	Electrolyte	Operating Temperature (°C)	Efficiency[42]
Polymer Electrolyte / Membrane (PEM)	Electrolyte Solid organic polymer poly-perfluorosulfonic acid	60-100	30-50%
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100	60%
Phosphoric Acid (PAFC)	Liquid phosphoric acid soaked in a matrix	175-200	40%
Molten Carbonate (MCFC)	Liquid solution of lithium, sodium and/or potassium carbonates, soaked in a matrix	600-1000	50%
Solid Oxide (SOFC)	Sold zirconium oxide with a small amount of ytrria added	600-1000	55-60%

Table 3-2: Comparison of Five Common Fuel Cell Technologies[43]

3.2.3 Fuel

Although fuel cells are widely seen as a source of clean energy, stationary fuel cells for industrial generation still cause non-negligible emissions. The process of producing electricity from hydrogen fuel does not release carbon dioxide, but 95% of today's hydrogen fuel is produced from natural gas in a reforming process that does release carbon dioxide.[44]

Table 3-3 shows a comparison of emission levels from stationary generator technologies in CHP configuration, including emissions levels associated with electricity purchased from the grid.[45] "eGRID" refers to the baseline case in California – the amount of pollutant generated per kWh if the electricity is bought from California's grid. A combined cycle gas turbine (CCGT) is a turbine that uses both the mechanical energy from the turbine and the waste heat to generate

[42] In system configuration.

[43] J.M. Deutch and R.K. Lester (2008), Massachusetts Institute of Technology. "Applications of Technology in Energy and the Environment"

[44] National Hydrogen Association, Hydrogen Production Overview Fact Sheet. http://www.hydrogenassociation.org/general/factSheet_production.pdf

[45] eGRID factor describes the emissions level per MWh electricity production and varies by region. Figures are published by the U.S. Environmental Protection Agency (EPA).

electricity, improving efficiency. CCGTs are usually installed on-site. The conventional diesel engine is also listed in this table to show that switching to fuel cells will result in a modest reduction in greenhouse gas emissions, per kWh generated.

Application	CO_2 (g/kWh)	CH_4 (g/kWh)	NO_x (g/kWh)	SO_x (g/kWh)
eGRID factor in California	328	13.7	3.7	0.241
CCGT & gas boiler	270	0.20	0.31	0.007
Diesel Engine	315	0.08	4.4	0.68
Phosphoric Acid Fuel Cell CHP	218	0.15	0.027	0.006
Solid Oxide Fuel Cell CHP	218	0.15	0.021	0.005

Table 3-3: Comparison of on-site generation emissions assuming CHP configuration[46,47]
NHMC: non-methane hydrocarbon; PM: particulate matter
Emissions are expressed per unit of useful energy (recoverable heat and electricity)

3.2.4 Maintenance

With no moving parts, fuel cells are very reliable, and some commercially available systems have statistical uptimes of greater than 95%.[48] High-temperature fuel cell technologies require the fuel cell core to be replaced approximately every five years; this represents the largest maintenance commitment for a new installation. Major fuel cell suppliers also offer remote monitoring services and maintenance personnel in major urban areas.

To minimize the burden on the facilities maintenance group, Raytheon is only considering contracts for fuel cell systems that also include all maintenance work.

3.2.5 Start Up

Because molten carbonate and solid oxide fuel cells operate at high temperatures, their startup time from cold to maximum efficiency can be up to ten days.[48] For this reason, these technologies should be operated 24 hours per day. In general, fuel cells are best used on a continuous basis to offset a company's constant baseline usage, rather than peaks in usage.

Fuel cell technologies that operate at cooler temperatures such as PEM, PAFC, and AFC tend to have lower efficiencies in a CHP configuration, but their start up time is much lower – on the order of minutes. These technologies are therefore more favorable in applications with highly variable loads, such as automobiles.[49]

[46] U.S. Environmental Protection Agency, eGRIDweb, http://cfpub.epa.gov/egridweb/ghg.cfm
[47] Fuel Cell Technology Handbook, CRC Press, 2003; p. 12-14, Table 12.3.
[48] Based on discussions with representatives of Fuel Cell Energy and UTC Power.
[49] Car Design Online, http://www.cardesignonline.com/technology/fuelcell.php

3.3 *Considerations for Photovoltaics*

3.3.1 Roof vs. Parking Canopy

PV installations are generally less expensive when installed on commercial rooftops, compared to parking canopies. This is mainly because parking canopy installations require a foundation and additional materials for the structure, while rooftop installations can rest on a roof with fewer fasteners.

Because PV systems have an expected life of 20 or more years[50], a facility should install PV systems only on new roofs to ensure that the roof does not need to be replaced during the system's lifetime. In most cases, facilities managers will find it easier to get approval for a parking canopy PV system than for both a new roof and a rooftop PV system. Additionally, certain buildings require frequent reconfigurations that involve modifications in the rooftop layout; rooftop PV systems are also less attractive in such situations.

Since the El Segundo site has a roof that is both old and frequently reconfigured, Raytheon is only considering a parking canopy PV installation.

3.3.2 Types of Photovoltaic Cells

Most PV systems presently installed contain single-crystal silicon.[51] The manufacturing process for single-crystal PV cells is similar to that for microelectronics: an ingot of pure, crystalline silicon is cut into wafers and then patterned. Although the process of manufacturing silicon in a single crystal is intensive and more expensive than the other PV technologies, single crystal PV cells have the highest performance among silicon-based PV technologies.

Polycrystalline silicon (polysilicon) PV systems are primarily manufactured in two ways: cast polysilicon and string ribbon silicon. Cast polysilicon is manufactured by casting molten silicon into a large block, cooling, and sawing the block into thin wafers that are made into PV cells. String polysilicon is manufactured by drawing small strips of crystalline silicon out of a molten form, eliminating the sawing process. Polysilicon PV cells contain small grains of crystalline silicon, and have lower efficiency than single-crystal PV cells because the grain boundaries create significant conversion loss.

Amorphous silicon PV cells are made by depositing silicon on surfaces such as glass, plastic, or metal. This allows the manufacture of PV cells on curved and flexible surfaces. Besides the versatility advantage, amorphous silicon PV cells can also be manufactured at very low cost. Because amorphous silicon does not have a regular atomic structure, it has the lowest conversion efficiency among the common types of PV technologies.

Group III-V technologies such as gallium arsenide have received considerable research attention because they can respond to a large range of solar energy. Because they require rare and expensive materials, to date III-V PV technologies have only been deployed in specialized areas such as space applications.

Raytheon should invest in the PV technology with a risk-reward tradeoff that best matches the company's goals. Since this initial on-site generation project is a pilot project, total electricity generated, reduced emissions, cost saved, and perceived reliability will all factor into the approval of future PV investments. Although initial PV projects will involve single-crystal

---

[50] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; Solar Technologies Program: http://apps1.eere.energy.gov/solar/cfm/faqs/third_level.cfm/name=Photovoltaics/cat=The%20Basics

[51] Polar Power Inc. http://www.polarpowerinc.com/info/operation20/operation23.htm

silicon, Raytheon should design flexibility into its PV mounting structures so future technological advances can be easily incorporated in the system. A summary of the most common types of PV cells available is shown in **Table 3-4**.

Type of PV	Efficiency	Manufacturing	Description
Single-crystal silicon	15-18%	Made from crystalline silicon wafers	More expensive to produce but cost-effective due to higher efficiency
Polycrystal silicon	12-14%	No crystalline wafers	Less expensive and less efficient than single-crystal silicon PV cells
Amorphous silicon (thin film)	5-6%	Made by depositing silicon as a film on different materials	Cheap to manufacture, mechanically flexible, low conversion efficiency
Group III-V Technologies	>25%	Contain group III and V elements from periodic table (eg. gallium arsenide)	Efficient because bandgap can be engineered, expensive because materials are rare

Table 3-4: Comparison of PV Technologies[52]

3.3.3 Nameplate Capacity versus Actual Generation

The capacity factor of a power generator is the ratio of the actual output power to the output if operated at nameplate capacity the full time. Unlike commercially available fuel cells which generally produce power at 95% of nameplate capacity on average,[48] commercially available PV systems produce significantly less power than their nameplates suggest, depending on weather, season, and latitude. Within the continental United States, capacity factor for PV generators can range from 12-15% in Massachusetts[53] to 19% in Arizona.[54]

The availability of solar power varies by geography; it is mostly a function of latitude and altitude, as shown in **Figure 2-6**.

3.4 Evaluating Proposals for On-site Generation

To properly evaluate the value of fuel cell or solar PPAs, a company must understand the rate structure by which it is charged for electricity. PPA providers commonly estimate the marginal cost of electricity (in $/kWh) by taking the total cost of electricity and dividing by the total number of kWh used over a year. Such an approach is overly simplistic because it does not account for variations in rate based on the time of day and because it usually does not accurately estimate the cost of electricity avoided.

---

[52] Massachusetts Technology Collaborative, Renewable Energy Trust. "Types of Panels" http://www.masstech.org/cleanenergy/solar_info/types.htm

[53] Renewable Energy Research Laboratory, University of Massachusetts at Amherst. "Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow?" http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_2a_Capacity_Factor.pdf.

[54] Treehugger. "Solar Versus Wind Power: Which Has The Most Stable Power Output?". John Laumer, June 2008. http://www.treehugger.com/files/2008/03/solar-versus-wind-power.php.

The calculator shown in Appendix A addresses these issues. This tool compares the cost of a solar PPA to the cost of continuing to generate electricity from the grid over a 20-year period. The user enters assumptions including rate escalations, initial price, and capacity factor, and the calculator compares the cash flows of the two different options. Total cash flows over a 10-year period and a 20-year period are summed, and the calculator indicates that a set of assumptions favor the solar PPA by changing from red to green.

Appendix B goes deeper in breaking up the charge structure in a given year. By differentiating between fixed charges, demand charges (peak kW), and consumption charges (total kWh), this sheet accurately calculates the financial savings from saving each kWh. Additionally, it estimates solar generation as a function of time of day. This allows the company to determine the true value of energy generated on-site and therefore what it is willing to pay.

An analogous calculator can also be implemented for fuel cell PPAs, as was done at Raytheon. In the long run, we believe PV will be more successful because it requires no fuel and therefore emits minimal carbon. However, until PV technologies reach the right cost, fuel cells will deliver more emissions reductions and cost savings, per amount invested.

4 Energy Efficiency

4.1 The Case for Energy Efficiency

In July 2009, McKinsey and Company released a report[55], which examined in detail the potential of greater efficiency in the use of energy. The report found that by 2020, the United States could reduce its annual energy consumption by 23 percent compared to a business-as-usual (BAU)[56] projection by deploying an array of NPV-positive efficiency measures. These measures in total would save 9.1 quadrillion BTUs of end-use energy[57] or 18.4 quadrillion BTUs in primary energy.

Figure 4-1 shows the breakdown of energy usage in the United States. The McKinsey Report found that excluding transportation, the potential in end-use efficiency improvements can be divided up into residential (35%), commercial (25%), industrial (40%). The implication is that a broad approach is needed to make significant, nation-wide improvements in energy efficiency; focusing on a single sector will be insufficient.

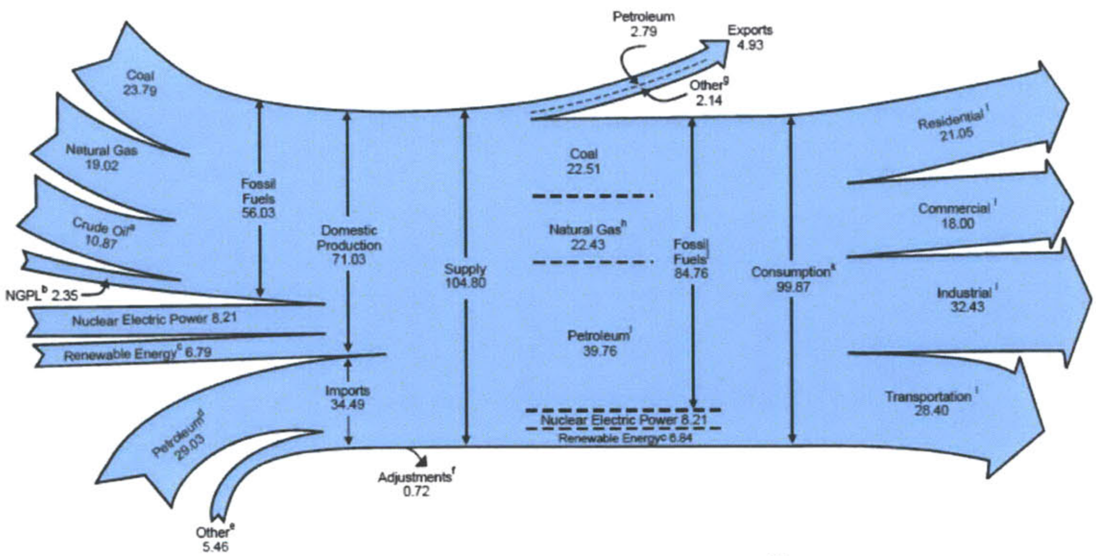


Figure 4-1: US Energy Flow, 2006 [58]

Efficiency represents an emissions-free energy resource because from an emissions point of view, a significant improvement in efficiency is equivalent to finding a large emissions-free source of energy. Captured at full potential, taking opportunities to improve efficiency across the US economy into would reduce emissions by 1.1 gigatons CO_2e, relative to BAU

[55] "Unlocking Energy Efficiency in the U.S. Economy", McKinsey and Company, July, 2009.

[56] McKinsey's business-as-usual projection is taken from the Energy Information Administration's *Annual Energy Outlook, 2008*, and focuses on the 81 percent of non-transportation energy with end-uses they could attribute.

[57] End-use energy is consumed in residential, business or industrial settings, providing light, heating, cooling, and power for electrical devices. Primary energy is energy in its original form (eg. coal, natural gas, or oil), and only a fraction of the primary energy in its original source can be delivered for end-use.

[58] Courtesy of John Deutch

projections.[59] Moreover, McKinsey found that several proposed efficiency improvements are NPV-positive, meaning they represent good business investments as well. This is illustrated in **Figure 4-2**.

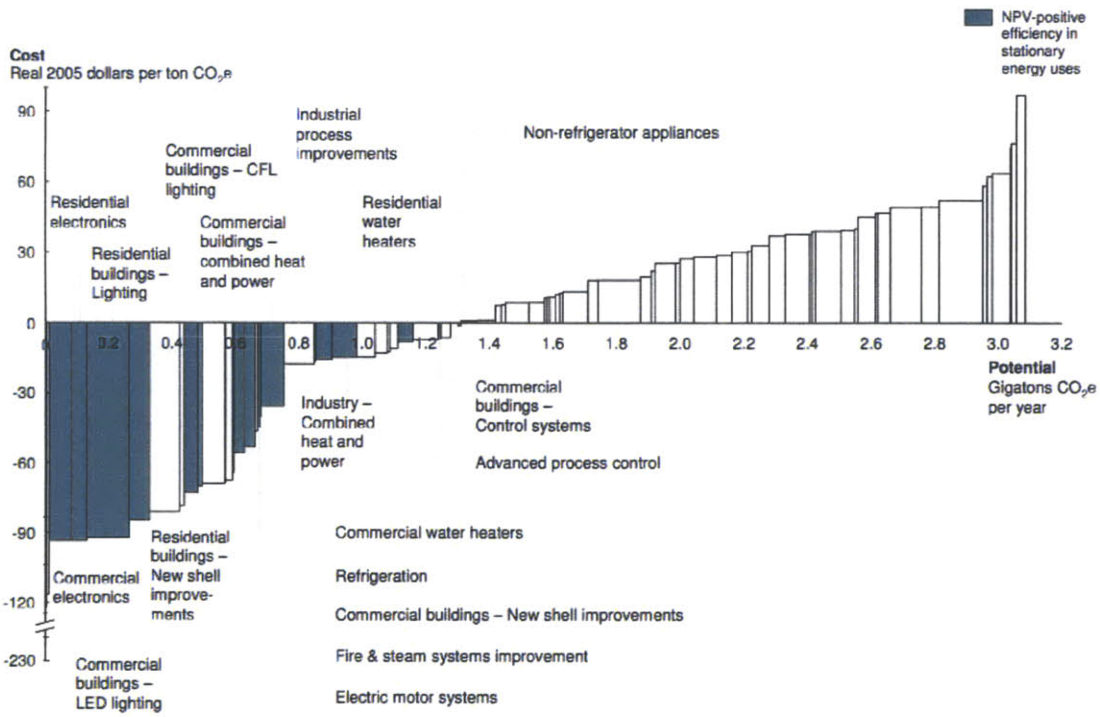


Figure 4-2: GHG abatement potential compared with dollar cost per ton CO_2 [55]

4.2 Energy Efficient Commercial Buildings

4.2.1 Heating, Ventilation, and Air Conditioning (HVAC)

Heating, ventilation, and air conditioning (HVAC) accounts for approximately 40% of the energy use in commercial buildings.[60] The energy needed for HVAC can be reduced in each of the following ways:

Lowering heating and cooling loads: Small improvements such as insulation, energy-efficient windows, and appropriate roofs can significantly reduce the energy needed to keep a commercial building at a comfortable temperature. Additionally, using energy-efficient lighting and appliances also reduces the amount of heat that must be removed, further reducing the energy needed for HVAC.

Optimizing heating and cooling systems: Besides choosing the correct size of HVAC equipment, optimizing a heating or cooling system involves ensuring employees' comfort, while minimizing the energy used. The system's behavior temperature, humidity, and ventilation level must be observed in response to common events and parts of the system

[59] "Unlocking Energy Efficiency in the U.S. Economy", McKinsey and Company, July, 2009, p. 3.
[60] Businees.gov – official business link to the US government.
http://www.business.gov/manage/green-business/energy-efficiency/upgrades/hvac.html

must be modified in response. For example, a main lobby will experience large, fast changes in the number of people and therefore HVAC needed over the course of a day. The system should be set to respond to sensor data more slowly than other rooms to minimize the chance of wasting energy on an overshoot.

Installing advanced control systems: Advanced control systems have capabilities such as controlling multiple zones and sensing carbon dioxide. The former allows the company to save energy on heating or cooling unused spaces, and the latter allows the HVAC system to adjust fan power and the amount of conditioned air it pumps into a room, depending on the occupancy. Although advanced systems require regular maintenance to ensure they are working properly, the benefits in energy typically greatly outweigh the small installation and maintenance costs.

Improving Maintenance: Energy efficiency improves when air filters are regularly replaced, machinery is tuned-up, and evaporator and condenser coils are kept clean. Inspecting ducts, insulation, and valves regularly and replacing parts when necessary also helps maximize efficiency under a given set of equipment and weather conditions. Good maintenance requires an organization that proactively seeks out problems, as opposed to firefighting, and this is discussed in more detail in chapter 5.

4.2.2 Lighting

Lighting accounts for 20-50% of a commercial building's energy use, depending on the type of business.[61] Reducing lighting costs involves both installing more energy-efficient light fixtures and providing better controls. By switching from incandescent to compact fluorescent lighting, a business can save 75% in energy, and moving to light-emitting diodes (LEDs) can save even more. However, the cost of LEDs is presently prohibitive in most cases at present.

Improving lighting controls allows lighting to be turned off when not needed. To improve controls, a commercial building can install occupancy sensors, daylight sensors, and lights with multiple brightness levels. Taking advantage of daylight is also a comfort-enhancing and energy-saving option. Although improvements to a building's lighting are usually a low-priority and distributed task, significant energy savings can often result from a system-wide lighting overhaul.

4.2.3 Plug Loads

Plug loads include any electrical device plugged into a wall. Like lighting, plug loads can be reduced by installing either more efficient appliances and by controlling appliances to only consume energy when needed. For typical commercial spaces, computers, monitors, space heaters, and refrigerators commonly are the most energy-consuming plug loads. Reducing energy consumed by plug loads is often difficult because it largely involves replacing many individual pieces of equipment and changing employees' personal habits. When marketed correctly with the right incentives, however, campaigns to reduce plug loads can be extremely effective. We believe that as a manufacturing company, Raytheon should first focus on reducing energy in its manufacturing facilities because this represents the lowest-hanging fruit. Although energy use in manufacturing facilities must be analyzed on a case-by-case basis, the same

[61] Businees.gov – official business link to the US government. http://www.business.gov/manage/green-business/energy-efficiency/upgrades/lighting.html

principles apply: reducing system usage, reducing the load of individual pieces of equipment, and automatically turning off unused equipment.

4.3 Enabling Energy Efficiency

Raytheon's energy use is typical for a large company with both office space and manufacturing facilities. Although numerous NPV-positive opportunities exist for investment in energy efficiency, major barriers that exist include:

1. the upfront capital investment required to realize savings over a lifetime of several years
2. being spread over millions of locations and billions of devices, making energy efficiency a low priority for most individuals and businesses
3. the difficulty of measuring and verifying energy not consumed

The dynamics of these barriers are discussed in chapter 5.

5 Reinvestment as a Cycle

This chapter compares the consequences of generous investments and meager investments in energy efficiency. Starting from a system dynamic model initially built to understand investing in an organization's capabilities, an analogous model is built to provide insight into investment decisions and to explain the observation that positive-NPV sustainability projects are commonly ignored or postponed.[62] The short-term and long-term dynamics of decision-making on sustainability projects are also discussed.

5.1 Feedback Loops in Organizations – Background

In practice, divisions of large organizations are given yearly budgets which they are tasked to invest in the way their leaders see fit. Although division leaders commonly lobby executives for more funds, division leaders typically end up with insufficient capital to fund all available positive-NPV projects.

The facilities division is usually the part of a large company tasked with achieving the company's sustainability goals. When a facilities division avoids investment in projects with reasonable payback times because of insufficient capital, the company will later lose savings opportunities, making it increasingly difficult over time to free up capital for further investment for achieving sustainability goals. Similarly, generous investment in sustainability projects results in savings over time, which can be further reinvested in new sustainability projects.

The positive-feedback dynamic of avoiding or committing to investments is discussed in a different context by Nelson Repenning and John Sterman of MIT's Sloan School of Management.[65] Focusing on implementing process improvements rather than capital expenditures, they ask the question, "If process improvements clearly make organizations more effective in the long run, why do so many organizations fail to implement improved processes?" We will first examine their model and its implications before applying it to sustainability investments.

It should be noted that another constraint to accomplishing sustainability projects is the availability of staff. This issue is not discussed in this work because the availability of capital has a much greater effect on a facilities division's ability to accomplish sustainability projects. As one manager in Raytheon's facilities division explained, the availability of staff is only a second-order problem because if money is available but not staff, the company can always hire outside contractors.

5.1.1 System Dynamic: "Better-before-Worse"

Repenning and Sterman's basic system dynamic model for investing in an organization's capability is explained, beginning in **Figure 5-1**.[63] In this system, the performance gap represents the difference between the desired level and the actual level of an organization's performance. Time can be spent in two ways: on working or improving. Increasing the organization's time spent working – for example working more overtime hours – directly

[62] S. DeCanio, "Barriers within firms to energy-efficient investments", *Energy Policy* Volume 21, Issue 9, September 1993, pp. 906-914.
[63] Adapted from: N. Repenning and J. Sterman (2001). "Nobody Ever Gets Credit for Fixing Problems that Never Happened: Creating and Sustaining Process Improvement." *California Management Review*. Vol. 43, No. 4. 64-88.

increases the organization's actual performance, decreasing the performance gap, but this is only true as long as the increased effort is sustained. By contrast, time spent on improvement increases the organization's capability level, but the effect of time spent improving only shows after a delay. Over time, however, increases in capability will increase actual performance and decrease the performance gap, even if time spent working stays the same. Because time is a finite resource, increasing the time spent working will necessarily decrease the time spent on improvement. This effect will be addressed as we further develop this model.

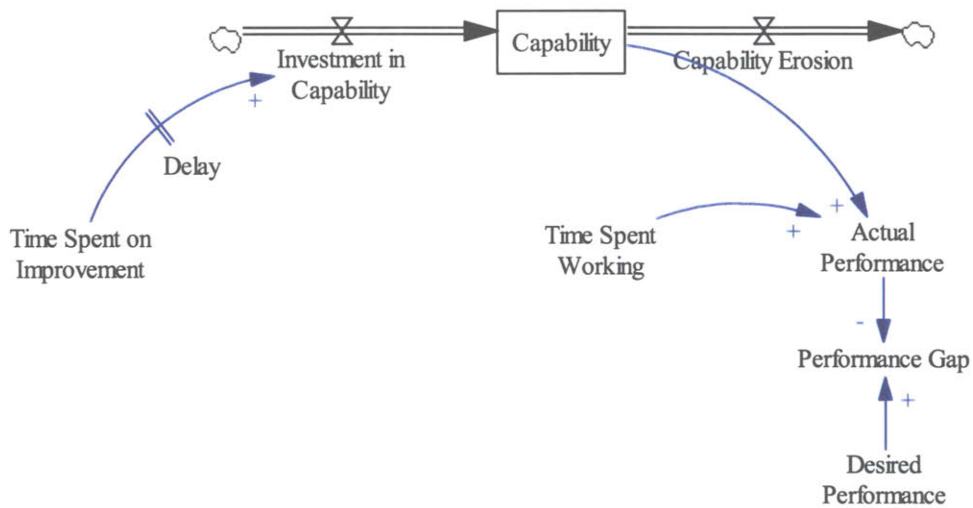


Figure 5-1: The Performance Gap

When faced with a performance gap, one option available to managers is to increase pressure to do work. This is shown in **Figure 5-2**. In response to an increase in the performance gap, managers can increase pressure and thereby close the performance gap through the "work harder" loop. Under this stabilizing loop, the pressure applied by managers effectively keeps the performance gap at an acceptable level. Once the performance gap is sufficiently small, managers will tend to reduce the pressure until the next crisis.

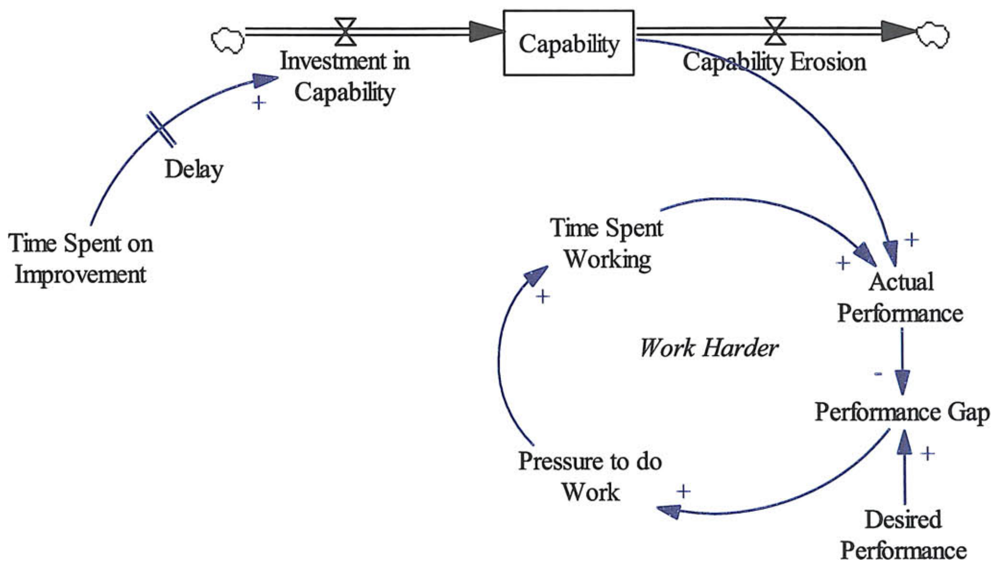


Figure 5-2: Work Harder Loop

The second option available to managers when faced with a performance gap is increasing pressure to improve capability, shown in **Figure 5-3**. Improving capability includes investing in training, launching improvement programs, and creating efficient process for standard work. Collectively, these actions are part of the "work smarter" loop.

Although everyone knows it is better to work smarter than to work harder, several motivations cause managers to favor the *work harder* loop. Working overtime (working harder) is sometimes the appropriate response to crises that arise, and managers ideally will bring their organizations back to the *work smarter* loop when a crisis passes. However, this usually does not happen in practice for several reasons. First, the *work smarter* loop includes delays, and spending time on an immediate performance improvement often looks more attractive than investing time in a difficult-to-quantify future benefit. The tendency of individuals to choose a smaller, immediate benefit over a larger, delayed benefit is well-documented.[64] Second, more uncertainty is associated with investments in capability, largely because of time.

It is not surprising when managers operate in the *work harder* loop in response to crises. When a product defect is discovered, managers are more likely to push for overtime until the problem is fixed than to send their employees to training in quality manufacturing. Theoretically, managers should invest in working smarter once the crisis has passed, but in practice, it is common to find managers who operate in the *work harder* loop as standard procedure.[63]

[64] S. Covey, *The Seven Habits of Highly Effective People*, New York, 1989.

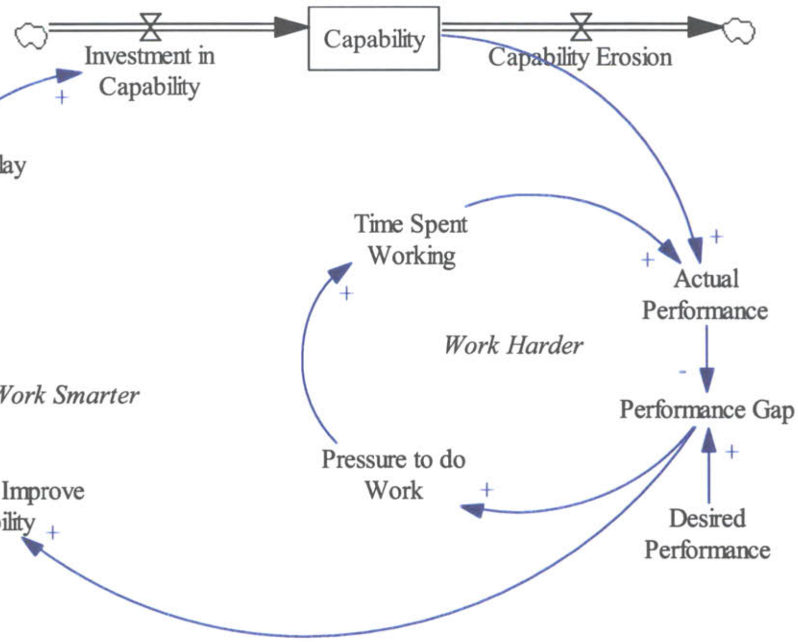


Figure 5-3: Work Smarter Loop

The final paths in this model represent shortcuts taken, as shown in **Figure 5-4**. In response to pressure to do work, employees tend to take shortcuts such as neglecting documentation, scheduled maintenance, or due diligence. By decreasing time spent on improvement in the short run, time spent working increases, yielding an immediate improvement in performance. But this patter also casues the organization's capability to decrease over time, leading to worse performance in the long run. By contrast, the *work smarter* loop causes the capability to rise over time.

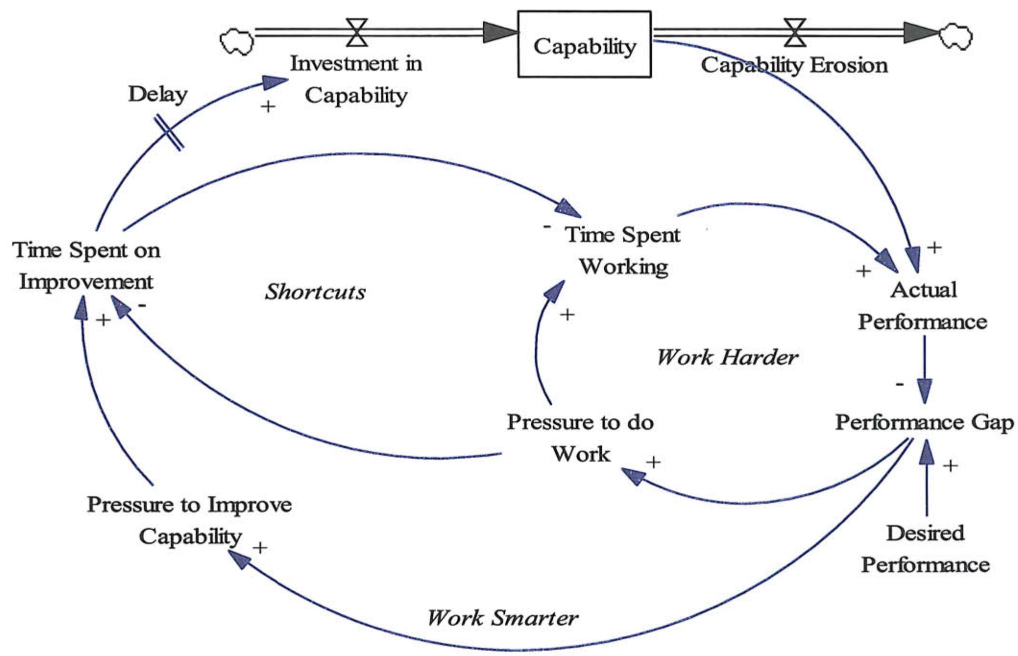


Figure 5-4: The Shortcuts Loop

An important point about the *work harder* and *work smarter* loops is that both are self-reinforcing and therefore likely to become permanent. An organization characterized by the *work harder* loop will find itself continuing to work harder in the future because it has neglected to invest in capability. This state is commonly called "firefighting." By contrast, an organization characterized by the *work smarter* loop will spend less time in the future working to achieve the same results, and therefore will have more time in to further invest in improvement, continuing the *work smarter* loop.

Discipline is required for managers to keep an organization in the *work smarter* loop. The absence of delay between action and result in the *work harder* loop creates a continual temptation for managers, and it has been observed that the length of this delay impacts managers' ability to maintain the necessary discipline.[65]

Figure 5-5 shows how a hypothetical process reacts to working harder versus working smarter. When an organization starts working harder, time spent on improving decreases immediately but capability does not. Actual performance improves in the short run, but eventually decreases, creating a "better-before-worse" situation. When an organization starts working smarter, time spent improving increases immediately, but capability does not immediately follow. Actual performance drops immediately but eventually improves beyond the starting point, creating a "worse-before-better" situation.

[65] N. Repenning and J. Sterman (2002). "Capability Traps and Self-Confirming Attribution Errors in the Dynamics of Process Improvement." *Administrative Science Quarterly.* 47, 265-295.

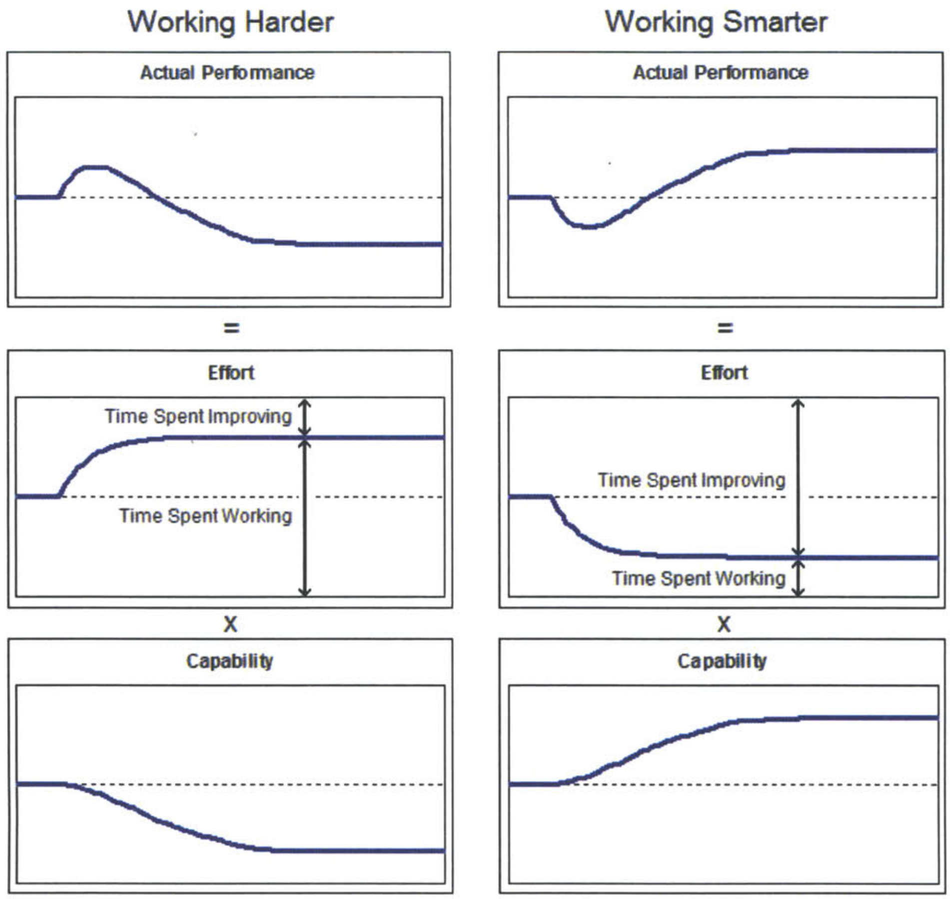


Figure 5-5: Simulations of Working Harder and Working Smarter Strategies
Actual Performance = Effort × Capability

This analysis suggests that managers must accept a temporary performance decrease to realize a sustained performance gain in the future. In other words, an investment is required to get into the *work smarter* loop, and the constant pressure for immediate results prevents organizations from investing in capability, keeping them in the *work harder* loop.

Therefore, there are two ways for organizations to get into the *work smarter* loop: create a surge of productivity (usually in the form of temporary workers) or temporarily stop taking on new projects. In either case, management should expect declines in performance before the system begins to realize the benefits of increased capability.

5.1.2 Fundamental Attribution Error

Upon observing that their workers respond to increased pressure by improving output, managers are likely to attribute the initial low performance to the characteristics and character of their workers, rather than to the system in which the managers failed to invest in building up capability. This attribution of problems to individuals rather than to the system is widely observed in the field of psychology and so common that it has been given a term: "fundamental attribution error."[66]

A manager who believes that workers' laziness is to blame for the performance gap will respond applying constant pressure. Ironically, this behavior leads to more firefighting, keeping the organization in the *work harder* loop.

When a manager does invest in improving his organization's capability, he is unlikely to understand the full benefit of his investment. This is largely because of the amount of time between action and result and the difficulty of measuring the benefit of improving capability. This leads the manager to make a better-before-worse tradeoff in which in which the small, transient benefit happens quickly and is easy to assess, while the negative, long-term consequence happens with a delay and is difficult to characterize.[67] The literature on human decision-making in such circumstances presents the conclusion that humans do not learn to manage such systems well.[68]

5.2 "Worse-before-better" dynamic applied to Capital Investment

5.2.1 The Reinvested Savings Loop

An organization with goals in energy conservation and sustainability should expect to invest capital to improve the efficiency of its facilities and systems. As discussed earlier, investments can include both on-site generation technologies and energy-saving improvements. A strong business case can be made for certain energy-related investments based on returns-on-investment, but energy projects with good business cases often are not implemented.[69] Based on employee interviews, one of the main reasons this happens at Raytheon is the lack of capital available for new projects.

Similar to the capability system, the way an organization allocates its capital affects its operating mode over time. An analogous system dynamic is shown in **Figure 5-6**. This describes the relationship between capital available and organization's investments in energy-efficient equipment such as direct digital controls (DDC), ventilation system optimization, and modern chillers. Like the capability system, this system also has key stock whose value is affected by past decisions and also affects the future behavior of the system: the energy-efficiency of the organization's equipment. In the energy-investment system, it is capital that works smarter or harder for the organization, rather than employees.

[66] S. Plous, *The Psychology of Judgement and Decision-Making*. New York, NY: McGraw-Hill, 1993.
[67] N. Repenning, "Firefighting". The Journal of Product Innovation Management 18 (2001) 285–300.
[68] J. Sterman, "Learning in and about complex systems". System Dynamics Review 1994; 10(3): 291–332.
[69] L. Weber, "Some reflections on barriers to the efficient use of energy". *Energy Policy* Volume 25, Issue 10, August 1997, 833-835.

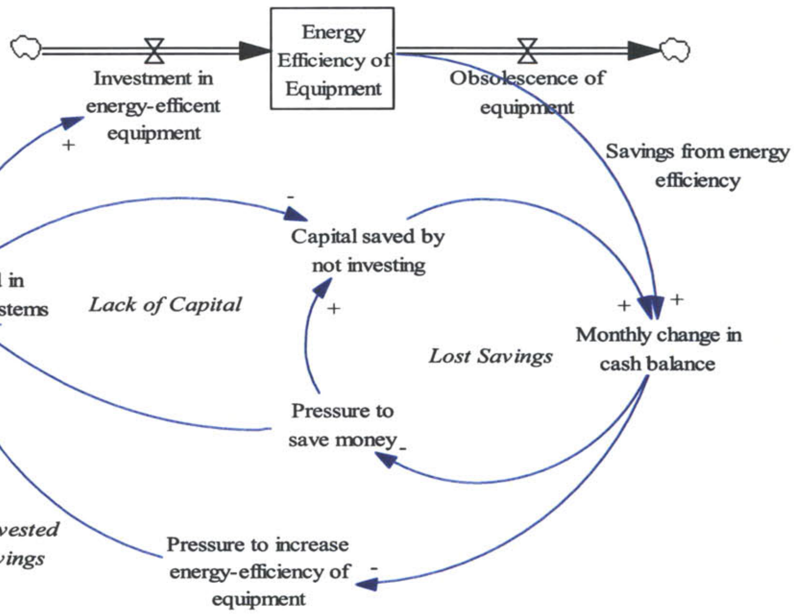


Figure 5-6: Analogous System Dynamic in Capital Budgeting for Facilities

The capital budgeting system also has two possible loops, and the loop in which an organization normally operates is largely depends on managers' accumulated decision-making. In the *lost savings* loop, the organization saves capital in the short run by not investing in new energy-efficient equipment. In this loop, equipment gradually becomes obsolete, and the organization fails to realize savings on energy purchases each month. This increases the pressure to save money, encouraging more short-term saving, and keeping the organization in the *lost savings* loop.

By contrast, the *reinvested savings* loop the energy efficiency of an organization's equipment over time. Over time, the savings result in a more positive monthly cash flow which can be reinvested in further equipment.

Like the capability system, the capital budgeting system is also self-reinforcing: organizations tend to get stuck in one loop or the other. Additionally, to move from the *lost savings* loop to the *reinvested savings* loop, an organization must create a temporary surge in the form of injected capital to break the loop. A management team committed to breaking out of the *lost savings* cycle must also be prepared to accept a temporary decrease in performance – in cash balance rather than employee performance.

5.2.2 Implications

The most important implication of this model is that a facilities division given insufficient capital to invest in sustainability-related improvements will perpetually remain in the *lost savings* loop. A corporate executive who wishes to change this dynamic should therefore supply the facilities division with a one-time injection of capital to allow it to break into the *reinvested savings* loop. According to this model, the astute facilities division leader should convince the company's appropriations committee that even if no capital is available, a certain amount should be borrowed because the operating in the *reinvested savings* loop would represent the payback to the company.

A corollary to the main implication of this model is that managers will not commit to getting out of the *lost savings* loop if they are evaluated based on short-run measures such as how much capital they spend during a particular time frame.

Another insight from the system dynamic model is that the likely consequence of restraining the budget of the facilities division. A budget cut to the facilities division would probably not result in major immediate consequences, since the leaders of the facilities division would first cut preventative maintenance. The capital budgeting committee is likely to use the lack of immediate consequences to confirm its previously held belief: that facilities is a cost center should be wasting less of the company's money. This fundamental attribution error could lead the capital budgeting committee to further cuts to the facilities division budget, plunging it further into the *lost savings* loop.

According to the model, the path for facilities division to move from the lost savings loop into the reinvested savings loop is to infuse capital. The following chapter provides a framework for thinking about the capital allocation process within an organization.

6 The Capital Allocation Process

6.1 Net Present Value (NPV) Model of Resource Allocation

6.1.1 Basics of NPV

Net present value (NPV) is the common method taught in business schools, describing how companies should evaluate possible investments. In the introduction of their popular text *The Capital Budgeting Decision*[70], Harold Bierman and Seymour Smidt offer the following theoretically correct approach to capital budgeting decisions:

> Essentially, the procedure consists of a choice of a rate of discount representing the time value of money, and the application of this rate of discount to future cash flows to compute their new present values. The sum of all the present values associated with an investment (including immediate outlays) is the net present value of the investment. Those investments with the highest present value should be chosen.[71]

To mitigate risk, companies institute a minimum rate of return, below which a potential project would not receive funding; this minimum rate is often referred to as the "hurdle rate." In the NPV model of capital budgeting, all of a company's investment opportunities can theoretically be ranked by NPV. Funding is awarded to the highest ranked of these opportunities until capital is no longer available. In some companies, it may even make sense to borrow money to fund more NPV projects when accounting for interest expense, the payback still clears the hurdle rate.

6.1.2 Problems with the NPV Model

The NPV model has two major shortcomings. First, it assumes that for budgeting purposes a project can be usefully summarized and compared based on a few quantitative measures. In reality, risk associated with each proposed project is difficult to compare, and the perceived trustworthiness of the manager making the proposal also influences budgeting decisions.

Second, the NPV model assumes that the choice among project alternatives is the most important step in the capital budgeting process – that this stage determines whether projects will be funded or postponed indefinitely. This does not account for the commonly observed phenomenon where NPV-positive projects "fall through the cracks." Joseph Bower's model of the capital allocation process is presented in the next section and addresses these observations of the resource allocation process.

[70] H. Bierman and S. Smidt, *The Capital Budgeting Decision – Economic Analysis of Investment Projects*, 9th edition. Routledge, 2006.

[71] Bierman and Smidt, p. 1.

6.2 Bower Model of Resource Allocation

6.2.1 Organizational View of Resource Allocation

In his influential book, *Managing the Resource Allocation Process*[72], Joseph Bower models the capital allocation process with an emphasis on organizational dynamics. Although he considers the NPV method to be theoretically correct[73], the problem is that this method does not fully describe the process of resource allocation in today's large organizations, from initial idea to final approval. Bower prescribes a framework for understanding the process of resource allocation initiatives within an organization and from this framework recommends ways for high-level managers to improve the process.[74]

6.2.2 Disconnects between Financial and Project Planning

Bower defines "large companies" as those in which budgeting decisions and project goals are defined by different groups. Splitting the tasks of financial planning and project planning causes a disconnect where budgeting goals must be aligned with specific project goals in an ongoing process. Moreover, large companies have multiple groups generating project proposals, leading to competition for funding.

In such a system, it is insufficient to view the company as a monolithic whole, with a single set of interests. Instead, a more accurate model recognizes that the sub-units of large companies will have some interests that are either incidental to or in conflict with the interests of the corporation as a whole. The process by which these different interests are resolved is described by the Bower model.

6.2.3 Three Levels of a Large Company

Bower divides the structure of large companies into three general levels: corporate, middle-management, and operating:

The corporate level is mostly concerned with the company's financial state, focusing on metrics such as return-on-investment and quarterly earnings per share. Long-run problems and goals are also dealt with mostly at the corporate level.

The middle-management level acts as an intermediary between the corporate and operating levels, helping translate between the goals and metrics of each. In practice, managers at this level inform the corporate level of necessary operating details and guide efforts at the operating level based on corporate direction.

The operating level is where strategic ideas are first developed. The focus at this level is on metrics such as market share, manufacturing yield, and margin. Because specialized knowledge is necessary to function at the operating level, employees here usually have only basic knowledge about corporate goals and metrics.

The most important observation from this distinction of organizational levels is that a disconnect exists between the corporate level and the operating level. Because different metrics are used to evaluate performance, a project that looks obviously good at the operating level may be rejected at the corporate level. Similarly, a change in technology or in the business

---

[72] J. Bower, *Managing the Resource Allocation Process*. Harvard Business School Press, Boston, MA, 1986.

[73] Bower, p. 7.

[74] Bower uses the term "resource allocation", rather than "capital allocation", so the former is used in the discussion of his work.

environment may also lead to unrealistic expectations at the corporate level because of the lack of specialized knowledge. This tension is the basis for the Bower model of the resource allocation process, as commonly observed. The following section outlines Bower's description of a typical project as it moves through the organization.

6.3 The Bower Model: Steps in the Investment Process

6.3.1 Step 1: Discrepancy

The first step in the investment process occurs when a discrepancy is observed between the company's goals and the capability of its existing facilities. This observation is usually made at the operating level, based on metrics indicating that performance is inconsistent or will soon be inconsistent with business demands.[75] "Costs are too high," "quality is inadequate," and "sales exceed capacity" are examples of discrepancy observations.

Applied to sustainability projects, discrepancy observations often occur when an employee observes a gap between an organization's present energy use and the feasible alternatives available. It should be noted that discrepancy observations happen constantly, and only a fraction of these end up making it to the next step. There are a wide range of possible reasons that employees who make discrepancy observations do not communicate their observations, including apathy, busyness, and discouragement with previously rejected ideas.

6.3.2 Step 2: Definition

In response to an observed discrepancy, employees at the business level propose a project to correct the discrepancy. The definition step is the process by which the technical and economic characteristics of a proposed project are determined. Project definition occurs primarily at the operating level, where engineers, maintenance personnel, and managers use their specialized knowledge to define the scope, costs, and benefits of the proposed project.

Bower emphasizes that the definition of investment projects is strongly influenced by the structure of the organization. Employees at all levels have an idea of "what the organization wants of me," based on both explicit communications (job descriptions, metrics) and implicit observations (rewards). This informs how they should present a project and which aspects will be of most concern to managers and executives.

6.3.3 Step 3: Impetus

Impetus is the force that moves a defined project toward funding. This part of the resource allocation process is primarily political and depends on the extent of a middle-manager's willingness to sponsor a project at higher levels in the organization.

After evaluating a project's technical and economic merits, a manager either decides to back the project proposal or does nothing. Based on his perception of what the organization wants from him, the manager calculates the project's effect on his reputation – both if it succeeds and if it fails – because each time he gives impetus to a project, the manager puts his reputation for good judgment on the line. This is a significant risk because a manager's reputation for judgment is extremely important to his standing in the organization. It affects the extent to which his superiors will defer to his judgment and the likelihood of his subordinates receiving

[75] Bower, 50.

funding to implement their ideas. In short, a mid-level manager gives impetus to a project when based on the rules he perceives, he believes it will be in his best interest to do so.

6.3.4 Step 4: Approval

In most organizations, the middle-manager fills out a form explaining the benefits, cost, and risks of the request. The request is sometimes reviewed cursorily but sometimes thoroughly, depending on the capital requested and the record of the requesting manager. Usually, requests for large amounts of capital or those promising a low rate of return are discussed the most intensely.

From his data, Bower observes little change in project definition at this stage. In addition, appropriations requests that that make it to this level are also likely to be approved. Bower attributes this to the fact that corporate-level executives must trust the judgment of specialized managers because in a large corporation, it is impossible for them to understand the intricacies of each business unit. Additionally, middle-managers quickly learn to predict whether a project will receive funding and tend to only present those likely to be approved, since their rate of successfully receiving funding for projects is strongly tied to their reputation.

6.4 Comparison between NPV and Bower Process

The flow of a single resource allocation initiative is shown below in both the NPV model (**Figure 6-1**) and the Bower model (**Figure 6-2**). In the NPV model, discrepancies are observed either at the operating level or the middle-management level – usually the operating level. Discrepancies lead to project definitions, which are then evaluated at the corporate level. Executives at the corporate level either fund the project or reject it, based on NPV and cash available.

In contrast to the NPV model, the Bower model includes path where a project is either not acted upon or is postponed indefinitely. This model accurately captures the observation that many noticed discrepancies are not defined into possible projects[76] and most defined projects that do not receive funding fail because they do not receive impetus at the middle-management level – not because they are rejected at the corporate level.

[76] Based on interviews with maintenance group at Raytheon.

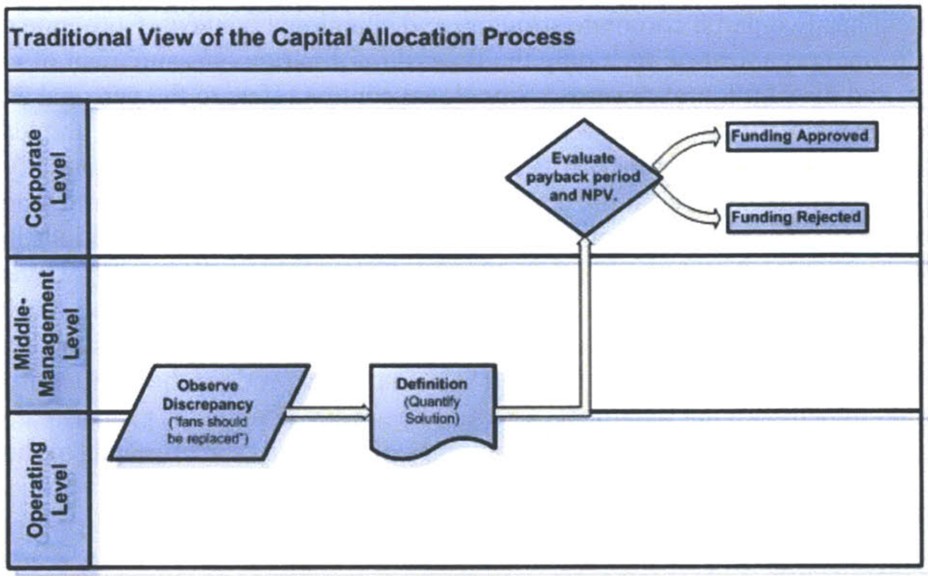


Figure 6-1: Traditional NPV Model of the Capital Allocation Process

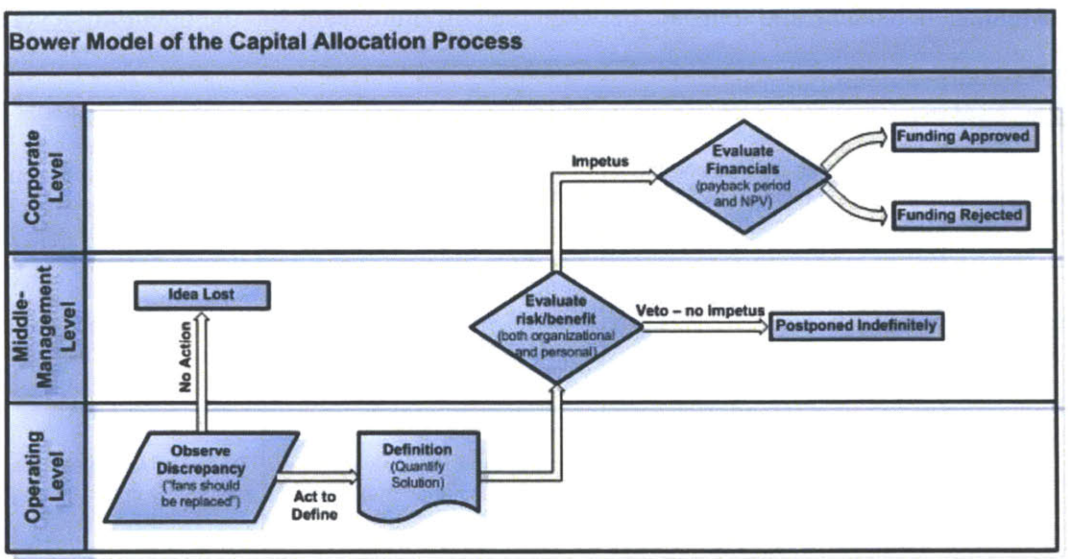


Figure 6-2: Traditional Model of the Capital Allocation Process

6.5 Structural Context Shapes Strategy

6.5.1 Structural Context

In his discussion, Bower focuses on definition, impetus, and context as the most important processes in the resource allocation process. (The definition and impetus are phases in the allocation process, explained in sections 6.3.2 and 6.3.3.) Context, by contrast is not a phase in the process but a set of forces that influences definition and impetus.

Context has two parts: corporate structure and situational context. Corporate structure refers to the formal organization including the flow of information, measurement of performance, and distribution of rewards. Situational context refers to the personal and historical forces at work in a situation. The Bower model focuses on corporate structure and leaves out situational context because the latter is difficult to generalize and study systematically.

Structure-setting happens at the corporate level when the executive team recognizes that unsatisfactory performance of product-market sub-units is because of imperfections in organizational structure. In large companies, the executive team has little control over the definition and integrating parts of the resource allocation process because of the specialized knowledge needed in these stages. Therefore, the corporate level should focus on creating the structural context within the company that will systematically produce the desired project definitions and impetus-giving judgment. Creating the desired context is primarily dependent on accurately measuring and rewarding the performance of employees at all stages of the process.

6.5.2 Summary of the Bower Model: Three Processes

The three processes at work in an organization are summarized in **Table 6-1**. This table represents the ongoing forces affecting the resource allocation process, rather than following a single project, as in **Figure 6-1** and **Figure 6-2**. The columns of **Table 6-1** represent the three processes that most affect corporate resource allocation: definition, impetus, and structural context. The rows represent the three general levels of an organization. For all three processes, middle managers balance and translate between the corporate level and the operating level.

Forces at Work	Definition of Content	Impetus for Commitment	Structural Context
Corporate Level	**Set** and communicate corporate mission and financial goals	**Commit** funds/resources	**Design** organizational structure, **measure** performance, **create** incentives (Structural context is initiated at the corporate level.)
Middle-Manager Level	**Translate** between corporate and business-unit thinking	**Sponsor** projects that fit, slow projects that don't, compete for resources (Impetus primairy occurs at the middle-manager level.)	**Interpret** and adopt structural designs to business-unit needs
Operating Level	**Propose** new investments and strategy (Definition primarily occurs at the operating level.)	**Champion** proposals for new business and capability	**Respond** to rules of the game, as set by upper management

Table 6-1: Summary of Three Forces in the Bower Model[77]

The traditional view of corporate structure is that structure should be aligned to serve strategy.[78] However, Bower emphasizes the importance of considering managers' sensitivity to the company's structural context. For example, if excess capacity is considered evidence of poor judgment, a manager will likely wait until the risk of excess capacity is minimal before

[77] Adapted from J. Bower and C. Gilbert, *From Resource Allocation to Strategy*, Oxford University Press, New York, 2005, p. 34.
[78] Alfred Chandler, *Strategy and Structure*. MIT Press, 1990.

approving a capacity-expansion project. By contrast, when an organization rewards managers who have sponsored novel but unprofitable projects, managers will give impetus to more creative project definitions. As precedents are set and resources are committed, the organization's norms and future options are solidified. In short, structure shapes strategy.

6.5.3 Application to Sustainability Projects

When the Bower model is applied to sustainability projects, it predicts that while some favorable projects will survive through the system and receive funding, several other favorable projects will be stopped – commonly at the impetus stage. The following chapter will examine the extent to which this is true in Raytheon's facilities division.

7 Case Studies: Sustainability Initiatives at Raytheon

7.1 Introduction to Case Studies

7.1.1 Breakdown of Facilities Projects by Type

The wide range of projects assigned to a company's facilities division can be classified into four categories, as shown in **Table 7-1**:

	Customer-Driven	Internally Driven (by Facilities)
Urgent	**Priority 1**	**Priorty 3**
Not Urgent	**Priorty 2**	**Priority 4**

Table 7-1: Classification of Facilities Division Projects

Urgent customer-driven projects (priority 1), such as repairing a pipe explosion or restoring a lab that falls out of specification, are given highest priority because of the immediate impact to business programs. The impact of equipment failures can be measured in lost productive hours, and customers whose operations have been limited exert pressure on the facilities division in response. Although urgent projects are often considered random events, their frequency can be reduced by proper preventative maintenance.

Non-urgent customer projects (priority 2), have a smaller immediate impact on the company's day-to-day operations. These include renovations necessary for new product programs and preventative maintenance of existing equipment. Raytheon's the facilities division has the largest volume of projects in this category, but these projects are usually interrupted when urgent projects arise.

Internally driven projects are urgent (priority 3) when the window of opportunity to complete them is limited. At Raytheon, the most common example of an urgent, internally driven project is replacing the HVAC system in an area being renovated. The facilities division benefits from HVAC improvements because of savings in maintenance and energy, but customers usually do not require HVAC improvements. A non-customer-driven project is urgent when its only realistic chance of being implemented is to be attached to an existing project before its deadline.

Internally driven projects are non-urgent (priority 4) when they do not face a hard deadline. Energy-efficiency projects usually fall into this category because customers have minimal concern about energy consumption and because no compelling deadline exists for their completion. Improving the efficiency with which hot water is distributed through a plant is one example of an internally-driven, non-urgent project.

It should be noted that as an organization that is primarily judged on its customer service, a facilities division will consistently prioritize customer desires ahead of internally-generated goals. This is reflected in the order of priorities shown in **Table 7-1**. Additionally, parts of the same project sometimes fall into different priority levels. For example, a customer might specify for a new lab to be built (priority 2) and the energy team may want to add additional features to the project to improve maintainability and decrease energy usage (priority 4).

7.1.2 Methodology and Format of Case Studies Presented

The remainder of this chapter presents case studies of energy initiatives at Raytheon, including both projects that received funding and those that failed to receive funding. Priority 1 and priority 2 projects are not presented as examples because their funding comes from customers. Organizational dynamics within the facilities division therefore have minimal effect on whether these projects are completed.

Projects are selected to be representative of the facilities group's range of tasks. Sustainability projects represent a large fraction of those selected to emphasize the contrast between receiving funding and being denied funding.

For each case study, we describe the initial state of the facility, provide details of the project proposal, follow the sequence of events, and discuss the outcome in light of the models previously presented. **Table 7-2** shows a summary of the case studies presented. In this table, the number "Priority" column refers to **Table 7-1**, and indicates the priority of the facilities-driven portion of the project – not the entire project.

Case	Project	Priority	Result
1	Data Closet	3	Funded by Customer
2	Laboratory Air Temperature	3	Funded by Customer
3	HVAC Modification	3	Funded by Customer
4	Laboratory Renovation	3	Uncertain - in Negotiation
5	Systems Overhaul in Small Building	4	Funded by Facilities
6	Solid-State Frequency Converters	4	Funded by Facilities
7	Parking Lot Lighting	4	Postponed - not Funded
8	Fan Scheme in Large Building	4	Postponed - not Funded
9	DDC in buildings	4	Postponed - not Funded
10	Major Systems Overhaul	4	Uncertain - in Negotiation

Table 7-2: Summary of Case Studies Presented
Numbers in "Priority" column refer to **Table 7-1**.

7.2 Data Closet for Core Weapons Program (Case #1)

7.2.1 Proposal Description

A weapons program initiated a request for facilities to build a data closet in its workspace – an improvement necessary for the program's next development stage. Due the urgency of this project, initial design work was completed in three days. The initial proposal required 600 cubic feet per minute (cfm) of cool air to cool the data closet, which was to be diverted from an adjacent room which was initially receiving 2050 cfm of cool air at all times.

Another engineer proposed a more energy-efficient system: varying the fan speed of the air handler serving the entire area, to reduce the volume of cool air flow when not needed. Since this modification would have changed the initial assumption of 2050 cfm being constantly available, it would have required a modification of the initial design.

7.2.2 Sequence of Events

Because of a miscommunication, no immediate action was taken because no one in facilities initially assumed responsibility. Faced with the threat of having their progress stopped, the program escalated their request to the VP level, and design work soon commenced. Fortunately for facilities, the program delayed its initial deadline by two weeks for internal reasons, allowing the energy efficiency changes to be incorporated in the design.

7.2.3 Discussion

Because of its urgent nature, this project would have likely gone forward without the energy improvements, had it not been for the delayed deadline. This is an example of the pattern in the facilities division of prioritizing customer requirements and deadlines higher than internally generated requirements – in this case the internal requirement was energy efficiency. As a customer-driven project, funding did not present a barrier and the energy-efficiency part of the project was incorporated with minimal political effort.

7.3 Laboratory Air Temperature (Case #2)

7.3.1 Initial State

The laboratory in a small building had been frequently falling out of specification – usually because humidity was too high. Because its air conditioning units were starting to fail, it was difficult to control both the lab's temperature and humidity. In addition, the equipment could not be controlled electronically, so it was operating at full-power 24 hours per day. The lab had a laser requiring 9 MW of power for cooling during its 15 minute-windows of operation each day. The ability to adjust the ventilation and cooling levels therefore presented a huge opportunity for energy savings.

7.3.2 Proposal Description

An overhaul of the building's ventilation system was proposed. This included rebuilding the air conditioning units, new air handler units (AHUs), DDCs, cog belts, and replacing variable frequency drives (VFDs). Electronic control valves were also to be installed. With the exception of the air conditioning units, the proposed equipment was primarily intended to improve energy efficiency – not customer service.

7.3.3 Sequence of Events

A consultant whose specialty was programming controls put together the project description. An engineering manager and an infrastructure manager both drove this project, giving it sufficient impetus to receiving funding. Because the project was partially customer-driven, obtaining funding was not a major problem. Fans are now significantly slowed at night, resulting in a decrease in energy usage of approximately 90%.

7.3.4 Discussion

Because this project was partially customer driven and partially facilities-driven, it was more likely to be successful than if it had been purely facilities. In fact, the vast majority of the energy efficiency projects that Raytheon's facilities group has accomplished have been of this nature: energy-efficient additions to existing customer-driven projects. Energy-saving opportunities that are added to customer projects only require a small additional amount of effort and funding. They are therefore more likely to be funded than stand-alone energy projects that often must meet higher standards to be approved.[79]

Raytheon's energy group has been highly effective in identifying energy-saving opportunities in existing projects, often funding them with customers' money, and following up with utility companies to receive incentive money for the efforts.[80]

7.4 Modification of Existing HVAC System (Case #3)

7.4.1 Initial State

A weapons program was having difficulty controlling the temperature and humidity in one of its anechoic chambers. Because of government specifications of testing conditions for weapons, the chamber had to be fixed to ensure compliance during testing. At the time of the proposal, minimal test time was being performed, so the project was not urgent from the customer's point of view.

7.4.2 Proposal Description

An engineer designed a modification that included replacing control valves for hot water, coils for the air filter, and replacing the steam humidifier with an adiabatic humidifier. The new equipment was expected to improve temperature and humidity control, and the adiabatic humidifier was chosen to improve energy performance.[81]

7.4.3 Sequence of Events and Discussion

Usually, customer-driven projects are routed through an account manager and a planner before they are assigned to engineers. This project followed a non-traditional route in that the customer directly sent e-mail to an engineering manager, who in turn assigned it to an engineer. As a non-urgent project, the engineer allowed himself to be interrupted as he worked on this project, but still finished it in a reasonable time. Since the project was customer-funded, even the energy-efficiency portion was accomplished and approved without formal definition, impetus, and financial evaluation steps.

---

[79] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.

[80] Southern California Edison (SCE) and several other utility companies offer rebates to provide incentives for customers' energy-saving projects. This benefits SCE because decreased demand allows them to avoid spending capital on increases in generating capacity.

[81] An adiabatic humidifier works by producing a fine and uniform fog from supply water. By contrast, a steam humidifier uses electricity to boil and evaporate water. Steam humidifiers require significantly more energy, and the excess heat they generate must also be removed from the room by the HVAC system, further increasing energy consumption.

7.5 Laboratory Renovation (Case #4)

7.5.1 Initial State and Proposal Description

A project to renovate a basement lab was initiated by a customer who wanted to modernize the lab space. Previously, the space had been used as a lab for electronics and chemicals, so constant-velocity fans were used to move supply air and exhaust air. Humidity was also kept high to minimize the risk of sparks leading to fires.

The new plan envisioned the lab space mostly as a computer area with some testing equipment. Part of the design included energy efficiency improvements, most notably to replace the seven steam humidifiers with two adiabatic humidifiers and to change ventilation ducting so that air did not have to circulate at high volumes at all times. The energy-efficiency part of the project was expected to cost $370,000 and was expected to save $325,000 and 2.3 million kWh annually – 1.8% of Raytheon's total energy usage in El Segundo.

7.5.2 Sequence of Events

Having not budgeted money for energy conservation on this project, the customer was reluctant to assume the extra cost of the energy improvements. An engineering manager in facilities pushed hard for the energy improvements to be included in the project, but a standoff ensued.

7.5.3 Discussion

This is an example of misaligned incentives leading to poor overall system performance. Since facilities, rather than the customer, pays for energy, the customer has no financial incentive to commit extra cash to energy conservation. Facilities, however, has a very small budget for energy projects, and therefore must convince the customer to assume the costs. The result is a standoff and the risk that the energy improvements are never implemented. Given that the energy improvements would be a favorable investment, this misalignment of incentives can cause a result that overall is unfavorable to Raytheon.

7.6 Complete Systems Overhaul in Small Building (Case #5)

7.6.1 Initial State

One of El Segundo's smaller buildings had long been identified as consuming significantly more energy than others, for its size. This building was constructed at a time when energy was inexpensive enough not to be a major consideration, and inefficient ventilation and cooling systems were originally installed.

7.6.2 Proposal Description

The proposal was to completely replace the old equipment. Chilled water was to replace latent cooling, which is much less efficient and is less effective in controlling humidity. Direct digital controls (DDC) were to replace pneumatic controls so that data could be centralized, processed, and result in a system-level response. Old mechanical systems were to be replaced with efficient new ones. Additionally, controls were programmed to shut down certain areas of the building during nights and weekends. Because of the major changes, a large drop in energy usage was expected from this project.

7.6.3 Sequence of Events

The opportunities to improve energy performance were identified by building managers, maintenance staff, and facilities engineers in this project. The energy manager was able to put significant impetus behind this upgrade, even without a detailed project definition because the existing equipment was already past its expected life and therefore due for an upgrade anyway. As such, capital for the project came from the equipment replacement budget, and it was not difficult to secure. Once implemented, the project resulted in a 60% reduction in energy usage – a major improvement.

7.6.4 Discussion

This project is typical of energy-efficiency projects in that action was delayed until a large energy savings was possible. Although the project was not customer-driven, the definition contained a significant enough improvement in energy performance that it presented an opportunity for improvement so favorable that the facilities director would be "too good to pass up." In general, energy-efficiency projects receive greater impetus when existing equipment is performing poorly or is scheduled for replacement. For an organization just starting its drive for improved sustainability, replacing older facilities equipment is a favorable place to start. Improving controls to shut down equipment when not needed also represents a high-leverage, low-cost opportunity with minimal organizational barriers. About half of the 60% reduction was attributed to improved controls and the other half was attributed to improved equipment.[82]

7.7 Solid-State Frequency Converters (Case #6)

7.7.1 Initial State

Raytheon uses several pieces of special test equipment that requires a 400 Hz electrical power supply, rather than the standard 60 Hz. For decades, a set of six mechanical motor generators was used to convert the 60 Hz electrical supply to a 400 Hz electrical output. Because the test equipment was only used sporadically, the 400 Hz output was only needed 6% of the time during the year. However, the motors were constantly running, drawing a yearly total of 70,000 kWh when in use and 430,000 kWh when idle. The 430,000 kWh used when idle represents a waste of 84% of the total energy used by the motor generators during idle periods.

7.7.2 Proposal Description

A proposal was made to replace the six motor generators with four solid-state frequency converters. With no moving parts, the frequency converters used significantly less energy when idle and were also much easier to maintain. With efficiencies of 87.5%, the frequency converters were expected to use 9.3 kWh per year when in use and 4.6 kWh per year when idle – an energy savings of 98.5% and about 1% of the total yearly energy usage in El Segundo.

7.7.3 Sequence of Events

This project was identified and defined by an electrical engineer who had been working on a smaller project where he also replaced motor generators with frequency converters. When he realized the magnitude of energy savings possible through this kind of replacement, he looked for other motor generator installations to replace. Once he defined the approximate cost and

[82] Based on an interview with a building controls expert who worked on this project.

energy savings of the project, the engineer brought it to his supervisor, who immediately took the proposal to the facilities director to ask for funding. The funds were granted, and work on the project began immediately.

7.7.4 Discussion

It is rare to find opportunities for energy savings of this magnitude, so the engineer was deserving of the credit he received for proposing this project. Although the magnitude of the project was an anomaly, the process by which it was discovered, defined, and funded exactly fits Bower's description: the engineer noticed the discrepancy and defined the project, he presented it to his manager who provided impetus, and after a financial evaluation, funding was approved. Although the project was not customer driven, the financials presented in the definition were so compelling that it was elevated to the "too good to pass up" level.

The importance of non-managers in innovating and improving a process, as in this case, is well-documented.[83] By consistently funding and rewarding sustainability ideas generated at the engineer and technician levels, the management of a facilities division can encourage discrepancy observations to be consistently documented as project descriptions to which managers can confidently provide impetus.

7.8 Parking Lot Lighting (Case #7)

7.8.1 Initial State

The parking lot lighting for one of Raytheon's El Segundo campuses was last replaced over 30 years ago. Lights are mounted in a grid, and each structure is 35 feet tall. The present setup is designed to minimize the number of lighting fixtures, and as a result, each fixture must be tall and must light a large area. This lighting setup uses excessive energy because of inefficient light bulbs and because the height of the fixtures uses more energy to achieve the required level of lighting at the ground level.

7.8.2 Proposal Description

A maintenance engineer proposed a more energy-efficient design that calls for shorter fixtures, more energy-efficient light bulbs, and a setup that spreads light more effectively over the surface of the parking lot. If implemented, the new system would consume 205,000 kWh of electricity per year, compared to 826,000 kWh previously – a 75% reduction resulting in an annual savings of $119,000. Accounting for materials, labor, disposal, and rebates, the up-front cost would have been $353,000, implying a reasonable payback period of three years.

7.8.3 Sequence of Events

The electrical engineer who did the definition work for this idea first created a presentation that included a cash flow analysis and an argument that this investment would also improve safety. This was presented to an engineering manager, who appeared supportive initially. Two months after the presentation, nothing had happened. When the engineer followed up with the manager, he was told that the payback had been analyzed and the proposal did not make financial sense to pursue at that time. The plans for the project were preserved, but no action was planned.

[83] S.J. Spear, "Learning to Lead at Toyota", Harvard Business Review, May 2004.

7.8.4 Discussion

In this case, the project definition clearly shows that the project is NPV-positive with a three-year payback period, so the traditional model predicts that the project would have been funded. Consistent with the Bower model, the engineer defines the scope of the project considering both energy goals and financial goals. The proposal emphasizes improved safety, quantifies the improved energy performance, and shows that the project is also financially feasible.

According to the facilities director's explanation during an interview, this project was not funded because the large capital commitment required was not available. The director did offer that a crisis situation would probably provide enough impetus for this project to be funded (such as a rusted light fixture falling on the division president's car). This implies that the company possesses capital for projects like this, but only provides it to projects of high enough priority. As a project not driven by customer needs, this project is still on the "to do" list.

It is also possible that the engineering manager withheld impetus because: (1) he assessed the project would probably be rejected because of its large capital requirement, (2) he was reluctant to take on new work because he was already overloaded, or (3) he was reluctant to encroach on what he considered to be another manager's territory. It should be noted that the above is speculation and represents another possible explanation for the result of this project proposal, under the Bower model.

7.9 Fan Scheme in Large Office/Lab Building (Case #8)

7.9.1 Initial State

A large, multi-level building in El Segundo containing for both office space and lab space uses significantly more energy for ventilation than comparably sized buildings in similar geographies. This is largely because of a poorly designed fan system.

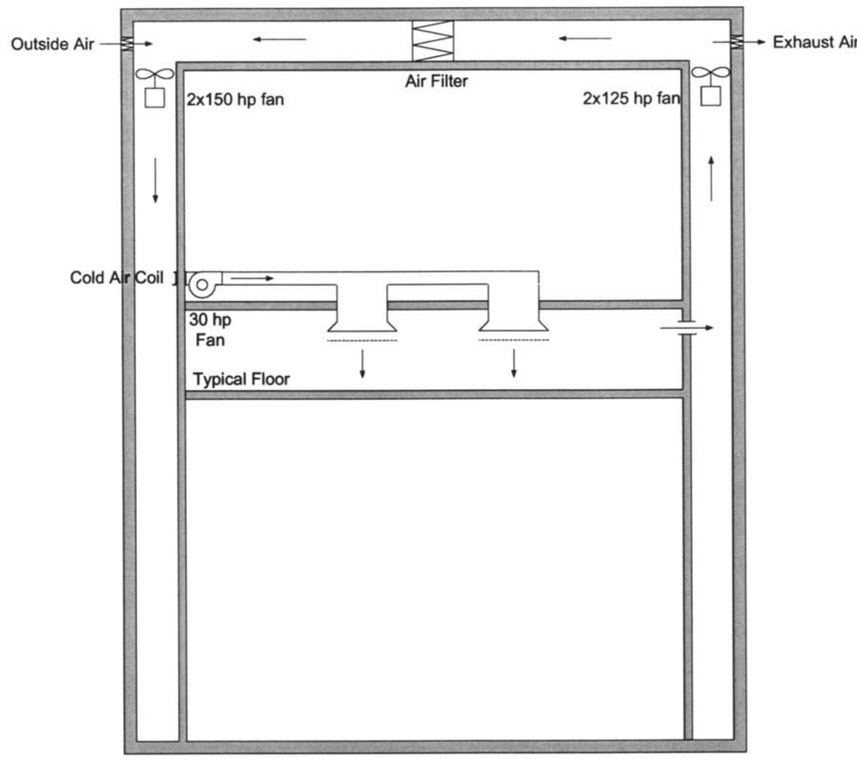


Figure 7-1: Extremely Inefficient Ventilation System in Building Z
(Side View of Building)

A diagram of the inefficient system in building Z is shown in **Figure 7-1**. As air is circulated through each floor, Building Z's system pumps air from the exhaust shaft (right side) up to the top of the building and then back down an intake shaft (left side) before pumping it back through each floor. This setup wastes large amounts of energy for two reasons. First, 80% of the exhaust air can be re-circulated through the floor space, so it is unnecessary to pump it to the top of the building and then back down again. Second, the speed of the large fans cannot be controlled, so they collectively require 450 hp (335 kW), 24 hours per day. This translates into approximately $35,000 per month in additional energy expenses.

7.9.2 Proposal Description

A much more efficient ventilation system is shown in **Figure 7-2**. A single 50 hp provides fresh outside air to all floors, and 80% of the exhaust air from each floor is mixed with the fresh air and pumped back into the same floor. This design avoids the unnecessary action of pumping air to the top of the building and then back down to each floor. Therefore, the large fans are normally turned off, except for during a smoke purge,[84] saving 335 kW.

---

[84] Smoke purge is a system capability needed during a fire. The ventilation system must remove smoke from a burning floor without the smoke contaminating other floors.

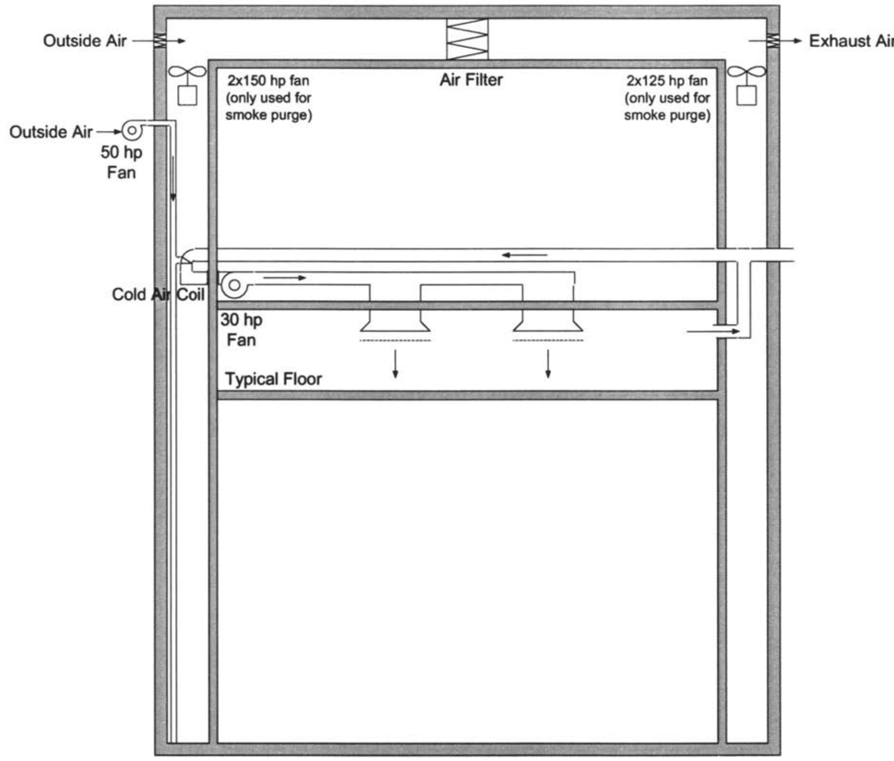


Figure 7-2: Normal Ventilation System
(Side View of Building)

7.9.3 Sequence of Events

A consultant specializing in controls programming first noticed this improvement opportunity. The consultant presented the idea to an engineering manager who asked a mechanical engineer to do a feasibility study. The engineer found the project to be extremely favorable, with an up-front cost of $150,000 to $200,000 and a payback period of four to six months.

The project was then presented to the building manager responsible for Building Z. At the time, the facilities team was working on a separate project in Building Z. Because they were under significant time pressure, the building manager decided that the team's focus should be on meeting their deadline and that this project should be considered a separate project. Two years later this project had not yet been started.

7.9.4 Discussion

This project is an example of a facilities-driven energy project being neglected because an urgent, customer-driven project took precedence. The observed discrepancy was effectively passed to an engineer, whose definition work showed the project to be highly favorable from a corporate point of view. However, impetus was lacking because the building manager was preoccupied with meeting a customer deadline, and the project ended up being delayed.

From an upper-management point of view, this project is one that clearly should be done, based on its short payback period. From the Bower model, when a middle-level manager does not give impetus to such a project, the decision most likely has its basis in the company's structural context. In this case, the structural context values customer service and meeting the deadline, so the opportunity to improve energy efficiency with very short payback period was dropped.

7.10 Direct Digital Control (Case #9)

7.10.1 Initial State

The majority of the temperature sensors in Raytheon's El Segundo buildings are based on pneumatic sensors, which were popular in buildings built during the 1980's. In pneumatic devices, temperature fluctuations in the room cause an actuation response (usually a torque), and this response is used to control valves to vary the volume of hot air or cold air entering the room. Pneumatic sensors are usually configured in a negative feedback loop to stabilize the temperature of a room. A sample pneumatic device is shown **Figure 7-3**.

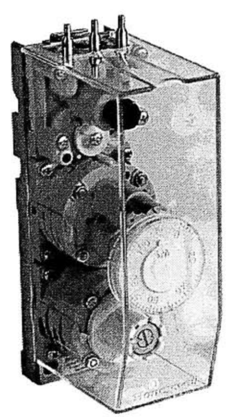


Figure 7-3: Typical Pneumatic Temperature Sensor[85]

There are three main problems with pneumatic sensors. First, because of their mechanical nature, the set point drifts over time. This leads to inaccurate temperature regulation: a room set to 72°F could stabilize at 75°F because of a drift in the sensor's set point. Second, pneumatic sensors can only be configured in simple mechanical feedback loops, confining temperature control loops to controlling local areas. This can result in adjacent areas receiving excessively heating and excessive cooling – a waste of energy. Third, they cannot be easily programmed, so optimizing their set point based on time of day or day of the week is almost impossible.

7.10.2 Proposal Description

Several years ago, a maintenance manager proposed to replace all pneumatic sensors in one particular building with direct digital control (DDC). The sensors would be wired into a central area where the data could be aggregated, allowing complex controls of different zones on each floor. The DDC sensors would have cost approximately $1500 per zone, compared to $500 per zone for pneumatic sensors.

[85] Courtesy of Honeywell International.

7.10.3 Sequence of Events

Upon presenting this to his supervisor, the maintenance manager was told, "You have not proved to me that DDC results in energy savings." However, it is common knowledge to individuals in the facilities and maintenance field that DDC is far favorable to pneumatic control. The maintenance manager was frustrated that his supervisor's lack of technical understanding was hindering energy efficiency improvements, but did not further pursue the matter.

7.10.4 Discussion

This is an example of a priority-four project not receiving impetus. Although the maintenance manager's explanation of his supervisor's reaction was that the supervisor lacked technical knowledge, it is also possible that the supervisor lost interest in trying to understand, once he realized this project was not for a specific customer. Moreover, if customers had complained about difficulty controlling the temperature, this may have motivated the supervisor more to understand the technology. In this case, it would have been a priority-two project.

7.11 Major Systems Overhaul for Energy Improvement (Case #10)

7.11.1 Initial State

One group of older buildings in El Segundo has been identified as problematic for several reasons. Customer satisfaction was low because temperature controls were poor and because average tenant improvements cost twice as much and took twice as long to finish, compared to comparable projects in other buildings. The buildings also had inefficient ventilation systems and mostly pneumatic controls.

7.11.2 Proposal Description

These problems were widely recognized among maintenance personnel, but it was an engineering manager who proposed a major overhaul of the buildings' interior. The manager planned to compile as complete a list as possible of all the improvements that could be made and have a contractor calculate the cost and energy savings of each possible improvement. The eventual plan was to fund as many financially sensible projects as possible on a rolling basis.

7.11.3 Sequence of Events

As the first step, an intern set up a meeting with the experts on this building. Representatives from maintenance, building management, project management, and energy were invited to this meeting because all were seen as stakeholders. The invited individuals were considered stakeholders because they would all have an easier time doing their jobs if the overhaul happened.

As part of the invitation, the intern asked the experts to provide their wish list of building improvements. Despite having one week to put together their list and several reminders from the intern, only one out of the fourteen individuals responded with wish lists. During the meeting, this one wish list was discussed, and eight additional ideas were presented verbally and added to the list of improvement opportunities.

Before the end of the intern's time at Raytheon, he attempted to transition the project and find a champion for it. Between a different engineering manager and a facilities manager, there was reluctance to become the project champion, and the engineering manager who initially proposed the project had to step in and assign the task.

7.11.4 Discussion

The purpose of the initial meeting for this project was to better define the project. As such, it was fitting that most of the individuals invited to the meeting were from the operating level. Given that they were all stakeholders, already with well-formed ideas of how to improve the buildings, it was surprising that the response was so poor.

The best explanation for this behavior is the organizational structure – that somehow idea generation is not an activity that individuals perceive to be highly valued or rewarded by the organization. This is consistent with the attitude towards the workload expressed by a maintenance manager who said he really would like to have fuel cells and PV arrays, but that he was just too busy to maintain an additional piece of equipment. Given that several ideas were presented verbally during the meeting, the lack of response also suggests that individuals did not highly value being credited for originating energy-saving ideas, possibly because such credit had been misdirected or simply not given in the past. Similarly, individuals' lack of desire to champion this project, despite the fact that its completion would make their jobs easier in the long run, suggests that improving energy performance is not perceived to be a highly valued or rewarded by the organization.

7.12 General Observations from Case Studies

The above case studies represent both Raytheon's effectiveness in accomplishing sustainability projects as well as some opportunities for improvement. The list of projects in **Table 7-1** also suggests a few generalizations of interest to other organizations experiencing organizational barriers to accomplishing sustainability projects. These are discussed in the following section. Most notably, the observations are consistent with the Bower model which predicts that impetus, not financial evaluation is the stage where most viable projects are dropped.

7.12.1 Facilities projects tied to existing customer projects are often funded by customers and given more impetus

Cases one through three are examples of how impetus is more easily given to projects that incorporate facilities-motivated features in existing projects for two reasons. First, the facilities division must meet customer deadlines such as design completion, reviews, and job walks, so making additions to existing projects is more urgent. Second, the high likelihood that the additional features would be funded by customers is seen as an opportunity to improve maintainability and energy performance without cutting into the facilities budget. Although customers are not always willing to pay for facilities-generated features (eg. case four), the likelihood of obtaining funding from customers is seen as higher than the likelihood of obtaining funding from facilities. Additionally, the Bower model also predicts that in a structural context driven by customers and their deadlines will de-prioritize internally-generated, non-urgent projects. This prediction is also consistent with observation.

7.12.2 Priority-four projects need to reach the "slam dunk" level to be assured of impetus and funding

Cases five and six are examples of proposals so favorable that when presented with the numbers, decision-makers felt the right decision was obvious. Projects seven through nine were also favorable, but did not reach the "slam dunk" level and did not receive adequate impetus or funding. The observation that energy projects must meet a very high standard to be funded has also been documented in publications[86]. A very strong case is required for priority-four projects to be funded and staffed because the facilities division is driven by customer demand.

7.12.3 Availability of capital can be a major barrier to impetus

The best example of capital being a barrier is case eight (Fan Scheme in Large Building), where a project with a four to six month payback period is not funded because of the high up-front cost. At Raytheon, one employee referred to an energy project by saying, "at $1 million, there's no way it's going to happen – even if the payback were less than one year." Manufactures of on-site generation technologies have recognized this problem and addressed it by offering PPAs as an alternative. (See section 3.1.1 for more on PPAs.) Large, stable organizations like Raytheon generally have strong enough credit to borrow money to for funding high-return projects, but this does not usually happen in reality.

[86] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.

8 Conclusion

Based on the discussion presented, this chapter draws specific courses of action and considerations for managers who seek to improve their organization's sustainability practices. Recommendations are labeled "A" through "E", and their relevance to non-funded projects is shown in **Table 8-1** which is an expansion of **Table 7-2**.

Section	Project	Priority	Result	Relevant Recommendations
1	Data Closet	3	Funded by Customer	-
2	Laboratory Air Temperature	3	Funded by Customer	-
3	HVAC Modification	3	Funded by Customer	-
4	Laboratory Renovation	3	Uncertain - in Negotiation	-
5	Systems Overhaul in Small Building	4	Funded by Facilities	-
6	Solid-State Frequency Converters	4	Funded by Facilities	-
7	Parking Lot Lighting	4	Postponed - not Funded	A,B,E
8	Fan Scheme in Large Building	4	Postponed - not Funded	A,B,C
9	DDC in buildings	4	Postponed - not Funded	B,C,(A)
10	Major Systems Overhaul	4	Uncertain - in Negotiation	D,(B)

Table 8-1: Summary of Case Studies Presented - Expanded

8.1 Recommendations

8.1.1 Recognize Situations that Require Upper-Management Intervention (Recommendation A)

The Bower model presents a picture of facilities improvement largely initiated by operating-level employees. While this pattern ensures a wide selection of potential projects, the bottom-up model for innovation has been observed to fail in situations where (1) innovative forces must prevail over pressure from powerful customers, (2) disinvestment is the appropriate course of action, and (3) politics in middle-management hinders the forward progress of the organization.[87] Moreover, the bottom-up approach to innovation has been observed to result in an excessive focus on incremental improvements when major directional changes are sometimes necessary.[88]

If management is not satisfied with the rate of sustainability improvement in the organization, drastic action may be necessary to change course. Intervention would have

[87] D.N. Sull, "When the Bottom-up Resource Allocation Process Fails", *From Resource Allocation to Strategy*, Oxford University Press, 2007. pp. 94-95.
[88] C.M. Christensen, *The Innovator's Dilemma*. Harvard Business Press, 1997.

increased the likelihood of funding the parking lot lighting (case 7) and large fan scheme (case 8) projects, because the availability of capital was a major barrier on these.

8.1.2 Create a Separate Division for Sustainability (Recommendation B)

One drastic action for upper management to consider is to create a separate division whose main goal is to identify and execute sustainability projects. Creating a separate sustainability division is one way to relieve the external pressures from customers that can render sustainability projects as lower priority. Such a division could work closely with the existing facilities division, but would have sustainability as its main mission, rather than customer service. In such a division, advocacy for sustainability projects would be the primary responsibility of middle-management, and mid-level managers would be more inclined to give impetus and less inclined to judge sustainability projects as not worth the political risk.

The parking lot lighting (case 7), large fan scheme (case 8), and DDC (case 9) projects would have benefitted from a separate sustainability division because their low priority level within the existing facilities division was a major factor in their being delayed indefinitely.

8.1.3 Create a Clear Process and Criteria for Evaluating Sustainability Proposals (Recommendation C)

The Bower model and the case studies from Raytheon suggest that potential sustainability projects often fail at the impetus stage, before financial evaluations can be made by upper management. By creating a systematic process that clarifies how to best propose a project to improve sustainability, management can encourage proposal generation by giving idea-generators more confidence that their ideas will be accepted. Moreover, communicating criteria used by management will help employees at all levels to create better project definitions, increasing the rate or successfully funded projects.

A clear set of criteria for evaluating sustainability proposals would have increased the likelihood of success for the large fan scheme (case 8) and DDC in buildings (case 9) projects because evaluating these projects based on a clear set of criteria would have clearly revealed their favorability.

8.1.4 Establish a Pattern of Rewarding Successful Energy Improvement Ideas (Recommendation D)

Most employees in an organization have a primary responsibility besides defining energy-efficiency projects, so just knowing that conservation is a good thing to do is often not enough motivation for them to take the initiative to define projects or provide the necessary impetus. When employees are publicly rewarded for their successful sustainability projects, employees are motivated to generate their own ideas in the future.[89] Additionally, when upper management can share the process by which an employee proposed a successful project, it provides a clearer blueprint in other employees' minds for moving their own ideas from discrepancy observation to receiving funding.

Having a pattern of rewarding successful energy ideas would have increased the responsiveness and incentive of stakeholders in the major systems overhaul project (case 10) and therefore made the sharing of ideas more efficient.

---

[89] Raytheon has consistently recognized energy achievements as well as contributions of individuals in the energy group, and its leadership deserves recognition for this effort.

8.1.5 Consider Sustainability Projects against other Investment Options (Recommendation E)

Sustainability projects should be viewed as investment options, rather than as expenses, since reducing energy costs can help the bottom line as much as a new product. For example, it is reasonable for executives to decide between investing cash in physical plant upgrades and launching into a new consumer market.

Sustainability projects are commonly funded from the facilities budget, which from the corporate point of view is a cost of doing business. Therefore, the instinct of decision-makers is to minimize expenditures, rather than to invest in opportunities that offer the maximum return. Treating sustainability projects as investment options is both appropriate from a financial perspective and favorable to sustainability initiatives. This perspective has been documented in academic literature on business and the environment.[90]

With a three-year payback period, the parking lot lighting project (case 7) would likely have been above the line and therefore funded if it had been compared with other investment options at the corporate level.

8.2 Implications

The significant organizational barriers that hinder sustainability projects have implications for several groups. The upper management of a large organization must recognize that goal-setting and mandates will have only a modest effect on the organization's ability to accomplish sustainability projects. They should therefore adjust the structural context to be as conducive as possible to these projects. Manufacturers of energy-efficient plant equipment and on-site generation products should adjust their strategy to minimize barriers within the organizations of potential customers. Finally, policy makers should recognize that price is not the only barrier to the adoption of more sustainable business practices. Besides providing financial incentives for organizations to adopt sustainability measures, policy makers should also consider government recognition and opportunities for publicity as means to encourage desired behavior in organizations.

---

[90] F.L. Reinhardt, "Bringing the Environment Down to Earth", Harvard Business Review. Jul-Aug 1999; 77(4), pp. 149-157.

9 Bibliography

[1] K.O. Packard, F.L. Reinhardt, "What Every Executive Needs to Know About Global Warming", Harvard Business Review; Jul/Aug2000, Vol. 78 Issue 4, p105-113.

[2] W.M. Adams "The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century." Report of the IUCN Renowned Thinkers Meeting, 29–31 January, 2006.

[3] McKinsey & Company, "Unlocking Energy Efficiency in the U.S. Economy", July 2009. http://www.mckinsey.com/clientservice/electricpowernaturalgas/US_energy_efficiency/

[4] McKinsey & Co. "Unlocking Energy Efficiency in the U.S. Economy", July 2009.

[5] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.

[6] S. DeCanio, "Barriers within firms to energy-efficient investments", *Energy Policy* Volume 21, Issue 9, September 1993, pp. 906-914.

[7] M. Jarman, "Missile maker hopes to diversify, create technology for peacetime", The Arizona Republic, Sept. 30, 2007.

[8] 2008 Raytheon Corporate Responsibility Report, p. 17.

[9] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program: http://www1.eere.energy.gov/windandhydro/wind_history.html

[10] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program: http://www1.eere.energy.gov/windandhydro/wind_ad.html

[11] National Renewable Energy Laboratory: http://www.nrel.gov/wind/resource_assessment.html

[12] National Renewable Energy Laboratory: http://www.nrel.gov/wind/resource_assessment.html

[13] American Wind Energy Association: http://www.awea.org/faq/wwt_potential.html

[14] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Geothermal Technologies Program: http://www1.eere.energy.gov/geothermal/history.html

[15] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Geothermal Technologies Program: http://www1.eere.energy.gov/geothermal/faqs.html

[16] I. Fridleifsson, R. Bertani, E. Huenges, J. Lund, A. Ragnarsson, L. Rybach (2008-02-11). O. Hohmeyer and T. Trittin. ed (pdf). "The possible role and contribution of geothermal energy to the mitigation of climate change." Luebeck, Germany. pp. 59-80. http://iga.igg.cnr.it/documenti/IGA/Fridleifsson_et_al_IPCC_Geothermal_paper_2008.pdf. Retrieved on 2009-04-06.

[17] The New York Times (June 23, 2009). "Deep in Bedrock, Clean Energy and Quake Fears", James Glanz.

[18] Geothermal Energy Association (August 2008). http://www.geo-energy.org/information/plants.asp

[19] Joint Service Pollution Prevention and Sustainability Technical Library.

[20] "Face Off: Internal Combustion Engine versus the Hydrogen Fuel Cell", F.Igot, Montgomery College Student Journal of Science & Mathematics, Volume 1, September 2002.

[21] Global Science Forum Conference on Scientific Challenges of Energy Research, Paris, May 17-18, 2006. "Energy at the Crossroads", Vaclav Smil.

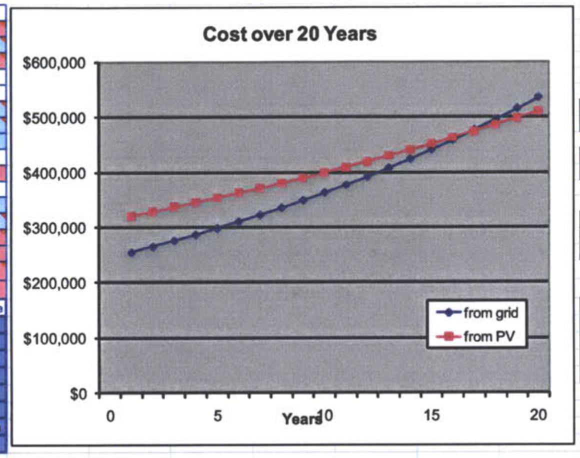
[22] Belaj Technology.
[23] Solar Energy Industries Association, "US Solar Industry Year in Review 2008". http://www.seia.org/cs/about_solar_energy
[24] Raytheon Corporate Responsibility Report 2008, pp. 17-19.
[25] Water Replenishment District of Southern California, Replenishment Operations http://www.wrd.org/engineering/groundwater-los-angeles.php?url_proj=replenishment-operations
[26] http://www.dsireusa.org/
[27] El Segundo South Campus, found in BUD files, 2004 through 2009.
[28] American Wind Energy Association: http://www.awea.org/faq/wwt_environment.html
[29] Meridian Corp., "Energy System Emissions and Materials Requirements," U.S. Department of Energy, Washington, DC. 1989, p. 23.
[30] Siemens Fossil Power Generation; http://w1.siemens.com/responsibility/en/environment/portfolio/fossil_power_generation.htm
[31] J.M. Deutch and R.K. Lester (2008), Massachusetts Institute of Technology. "Applications of Technology in Energy and the Environment"
[32] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; Hydrogen, Fuel Cells & Infrastructure Technologies Program: http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html
[33] Fuel Cell Installation Database, http://www.fuelcells.org/db/
[34] National Hydrogen Association, Hydrogen Production Overview Fact Sheet. http://www.hydrogenassociation.org/general/factSheet_production.pdf
[35] U.S. Environmental Protection Agency (EPA).
[36] U.S. Environmental Protection Agency, eGRIDweb, http://cfpub.epa.gov/egridweb/ghg.cfm
[37] Fuel Cell Technology Handbook, CRC Press, 2003; p. 12-14, Table 12.3.
[38] Car Design Online, http://www.cardesignonline.com/technology/fuelcell.php
[39] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; Solar Technologies Program: http://apps1.eere.energy.gov/solar/cfm/faqs/third_level.cfm/name=Photovoltaics/cat=The%20Basics
[40] Massachusetts Technology Collaborative, Renewable Energy Trust. "Types of Panels" http://www.masstech.org/cleanenergy/solar_info/types.htm
[41] Polar Power Inc. http://www.polarpowerinc.com/info/operation20/operation23.htm
[42] Renewable Energy Research Laboratory, University of Massachusetts at Amherst. "Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow?" http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_2a_Capacity_Factor.pdf.
[43] Treehugger. "Solar Versus Wind Power: Which Has The Most Stable Power Output?". John Laumer, June 2008. http://www.treehugger.com/files/2008/03/solar-versus-wind-power.php.
[44] "Unlocking Energy Efficiency in the U.S. Economy", McKinsey and Company, July, 2009.
[45] Businees.gov – official business link to the US government. http://www.business.gov/manage/green-business/energy-efficiency/upgrades/lighting.html
[46] S. DeCanio, "Barriers within firms to energy-efficient investments", *Energy Policy* Volume 21, Issue 9, September 1993, pp. 906-914.

[47] Adapted from: N. Repenning and J. Sterman (2001). "Nobody Ever Gets Credit for Fixing Problems that Never Happened: Creating and Sustaining Process Improvement." *California Management Review.* Vol. 43, No. 4. 64-88.
[48] S. Covey, *The Seven Habits of Highly Effective People*, New York, 1989.
[49] N. Repenning and J. Sterman (2002). "Capability Traps and Self-Confirming Attribution Errors in the Dynamics of Process Improvement." *Administrative Science Quarterly.* 47, 265-295.
[50] S. Plous, *The Psychology of Judgement and Decision-Making.* New York, NY: McGraw-Hill, 1993.
[51] N. Repenning, "Firefighting". The Journal of Product Innovation Management 18 (2001) 285–300.
[52] J. Sterman, "Learning in and about complex systems". System Dynamics Review 1994; 10(3): 291–332.
[53] L. Weber, "Some reflections on barriers to the efficient use of energy". *Energy Policy* Volume 25, Issue 10, August 1997, 833-835.
[54] H. Bierman and S. Smidt, *The Capital Budgeting Decision – Economic Analysis of Investment Projects*, 9th edition. Routledge, 2006.
[55] J. Bower, *Managing the Resource Allocation Process.* Harvard Business School Press, Boston, MA, 1986.
[56] J. Bower and C. Gilbert, *From Resource Allocation to Strategy*, Oxford University Press, New York, 2005, p. 34.
[57] Alfred Chandler, *Strategy and Structure.* MIT Press, 1990.
[58] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.
[59] S.J. Spear, "Learning to Lead at Toyota", Harvard Business Review, May 2004.
[60] S.L. Kulakowski, "Large Organizations' Investments in Energy-efficient Building Retrofits", Energy Analysis Department, E.O. Lawrence Berkeley National Laboratory, UC Berkeley 1999.
[61] D.N. Sull, "When the Bottom-up Resource Allocation Process Fails", *From Resource Allocation to Strategy*, Oxford University Press, 2007. pp. 94-95.
[62] C.M. Christensen, *The Innovator's Dilemma.* Harvard Business Press, 1997.
[63] Raytheon has consistently recognized energy achievements as well as contributions of individuals in the energy group, and its leadership deserves recognition for this effort.
[64] F.L. Reinhardt, "Bringing the Environment Down to Earth", Harvard Business Review. Jul-Aug 1999; 77(4), pp. 149-157.

10 Appendix A

Cash flow comparison over 20 years

Variables (input yellow cells))	Value
Rate of Increase - Grid Electricity	4.5%
Rate of Increase - PV Electricity	3.0%
Size of Installation (kW nameplate)	1200
PV annual hours of operation	1840.86
PV kWh per year	2,209,032
Capacity Factor	21%
Sunlight Factor	100%
Peak Load Avoided by PV (kW)	100
Marginal Cost of Demand ($/kW)	$2.74
Present cost of electricity	$0.135
(1st year)	$0.115
($/kWh)	$0.145
Degradation rate of PV	0.5%
Usage in all El Segundo (million kWh)	126
Discount rate (includes inflation)	7%
eGRID factor CO_2 (lb/MWh)	724.12
Annual decrease in energy use	1%
KEY	Fixed Value
2008 El Segundo - GHG from electricity	41,386
Metric ton =	2,204.60
eGrid CA =	724.12
MMBTU/MWH=	3.412
MMBTU RATE =	$11.12
GHG = (MWH * eGrid) / Metric Ton	
1 mmBtu =	10 Therms
NG mmBTU * 53.06/ 1000 = GHG	



345 megawatthours per day
345,205 kilowatthours per day

PV below grid = favorable for PV

Red when $ amount is negative; Green when

-$418,325	NPV (in year 0 dollars, over 2(
-$593,440	Dollars Saved (not adjusted fo
-$382,235	NPV (in year 0 dollars, over 1(
-$527,179	Dollars Saved (not adjusted fo

	RECs needed	RECs Year 1
20%	25200	2209
33%	41580	

KEY

(purple)	From Kevin S
(blue)	Data Supplied by PPA Provid
(yellow)	From Billing Statements
(white)	White=calculated by formula
(pink)	Need Data from Raytheon

	Year	0	1	2	3	4	5	6	7	8	9
Total electricity used (million kWh)		126	124.7	123.5	122.3	121.0	119.8	118.6	117.4	116.3	115.1
Total Paid for Electricity ($)		$17,010,000	$17,597,696	$18,205,696	$18,834,703	$19,485,442	$20,158,664	$20,855,145	$21,575,691	$22,321,131	$23,092,326
Cost of Grid Electricity ($/kWh)		$0.135	$0.141	$0.147	$0.154	$0.161	$0.168	$0.176	$0.184	$0.192	$0.201
Avg Marginal Cost of grid electricity ($/kWh)			$0.115	$0.121	$0.126	$0.132	$0.138	$0.144	$0.150	$0.157	$0.164
Marginal Cost of PV electricity generated ($/kWh)			$0.145	$0.149	$0.154	$0.158	$0.163	$0.168	$0.173	$0.178	$0.184
Marginal Cost of PV demand avoided ($/kWh)		$2.74	$2.820	$2.904	$2.991	$3.081	$3.173	$3.269	$3.367	$3.468	$3.572
Demand Avoided (kW)		100.0	99.5	99.0	98.5	98.0	97.5	97.0	96.6	96.1	95.6
PV Electricity generated (million kWh/yr)			2.21	2.20	2.19	2.18	2.17	2.15	2.14	2.13	2.12
Cost of Grid Electricity Displaced ($)			$255,064	$265,205	$275,749	$286,712	$298,112	$309,965	$322,289	$335,103	$348,427
Cost of PV Electricity Generated ($)			$320,310	$328,269	$336,427	$344,787	$353,355	$362,136	$371,135	$380,358	$389,810
Saving due to having PV			**-$65,246**	**-$63,065**	**-$60,678**	**-$58,075**	**-$55,243**	**-$52,171**	**-$48,846**	**-$45,255**	**-$41,383**
Savings as % of total electric bill			-0.37%	-0.35%	-0.32%	-0.30%	-0.27%	-0.25%	-0.23%	-0.20%	-0.18%
Discount rate in year 0		1.00	1.07	1.14	1.23	1.31	1.40	1.50	1.61	1.72	1.84
Saving due to PV in year 0 dollars		$0	-$60,978	-$55,083	-$49,531	-$44,305	-$39,388	-$34,764	-$30,419	-$26,339	-$22,510
RECs generated (1 REC=1MWh renewable)			2209	2197	2186	2176	2165	2154	2143	2132	2122
CO_2 emissions avoided (metric tons)			725.58	721.95	718.34	714.75	711.17	707.62	704.08	700.56	697.06

	Year		11	12	13	14	15	16	17	18	19
Total electricity used (million kWh)			112.8	111.7	110.6	109.5	108.4	107.3	106.2	105.1	104.1
Total Paid for Electricity ($)			$24,715,571	$25,569,494	$26,452,920	$27,366,868	$28,312,394	$29,290,587	$30,302,577	$31,349,531	$32,432,657
Cost of Grid Electricity ($/kWh)			$0.219	$0.229	$0.239	$0.250	$0.261	$0.273	$0.285	$0.298	$0.312
Avg Marginal Cost of grid Electricity ($/kWh)			$0.179	$0.187	$0.196	$0.204	$0.214	$0.223	$0.233	$0.244	$0.255
Marginal Cost of PV electricity generated ($/kWh)			$0.195	$0.201	$0.207	$0.213	$0.219	$0.226	$0.233	$0.240	$0.247
Marginal Cost of PV demand avoided ($/kWh)			$3.789	$3.903	$4.020	$4.141	$4.265	$4.393	$4.525	$4.660	$4.800
Demand Avoided (kW)			94.6	94.2	93.7	93.2	92.8	92.3	91.8	91.4	90.9
PV Electricity generated (million kWh/yr)			2.10	2.09	2.08	2.07	2.06	2.05	2.04	2.03	2.02
Cost of Grid Electricity Displaced ($)			$376,685	$391,662	$407,235	$423,427	$440,263	$457,768	$475,970	$494,896	$514,574
Cost of PV Electricity Generated ($)			$409,424	$419,598	$430,025	$440,711	$451,663	$462,887	$474,389	$486,178	$498,259
Saving due to having PV			**-$32,739**	**-$27,936**	**-$22,790**	**-$17,284**	**-$11,400**	**-$5,118**	**$1,581**	**$8,718**	**$16,314**
Savings as % of total electric bill			-0.13%	-0.11%	-0.09%	-0.06%	-0.04%	-0.02%	0.01%	0.03%	0.05%
Discount rate in year 0			2.10	2.25	2.41	2.58	2.76	2.95	3.16	3.38	3.62
Saving due to PV in year 0 dollars			-$15,554	-$12,404	-$9,457	-$6,703	-$4,132	-$1,734	$500	$2,579	$4,511
RECs generated (1 REC=1MWh renewable)			2101	2090	2080	2069	2059	2049	2038	2028	2018

11 Appendix B

Breakdown of electrical costs for one year, based on consumption, demand, and fixed charges.

Avoided Cost Calculator

green=savings		
	$245,347	Total Avoided Cost
	$0.116	Avoided cost per kWh - check vs. Solar!B9
	2,109,762	Year 1 Solar Production (kWh)

PPA Rates	$0.130	
ESP Rates	$2.74	$/kW
	$0.1153	$/kWh
	$0.0189	
	$0.1342	average $/kWh

Key Values	
$8,863,760	Ending Bill
$8,618,413	Starting Utility Bill
2,109,762	Solar production (kWh)
66,033,900	Starting kWh used
$274,269	Cost of solar power

Key:

(orange)	Important Results
(purple)	From Kevin S
(blue)	Data Supplied by PPA Provider
(yellow)	From Billing Statements
(white)	White=calculated by formula
(pink)	Need Data from Raytheon

	Actual
Pilot	$0
Shell	$4,850,563
SCE	$2,772,491
Solar	$0
	$7,623,054

% added cost - total el
% added cost - solar only

Starting Utility Consumption (kWh)

Month	On-Peak	Part-Peak	Off-Peak	Total
Jan		2,171,376	3,234,276	5,405,652
Feb		2,213,748	3,176,640	5,390,388
Mar		2,328,912	3,044,808	5,373,720
Apr		2,292,336	3,393,756	5,686,092
May		2,065,176	2,873,772	4,938,948
	102,024	142,596	295,128	539,748
Jun	1,109,664	1,553,400	2,810,988	5,474,052
Jul	1,089,864	1,526,976	3,289,572	5,906,412
Aug	1,105,632	1,543,536	2,940,984	5,590,152
Sep	1,050,084	1,461,816	2,677,428	5,189,328
		116,136	83,196	199,332
Oct		2,459,664	3,475,188	5,934,852
Nov		2,170,620	3,220,812	5,391,432
Dec		1,823,760	3,190,032	5,013,792
Total	4,457,268	23,870,052	37,706,580	66,033,900

Solar Production Year 1 (kWh) - based on SCE's TOU-8-BU schedule

Month	On-Peak	Part-Peak	Off-Peak	Total		
Jan		77,246	32,979	110,225	$14,329	53
Feb		64,505	47,007	111,512	$14,497	105
Mar		114,076	54,643	168,719	$21,933	159
Apr		134,688	76,121	210,809	$27,405	181
May		139,601	91,826	231,427		190
					$30,086	204
Jun	96,578	71,374	90,563	258,515	$33,607	201
Jul	94,896	74,029	86,930	255,855	$33,261	183
Aug	77,831	65,778	97,383	240,992	$31,329	143
Sep	47,793	47,836	63,665	159,294		125
					$20,708	94
Oct		85,553	44,836	130,389	$16,951	73
Nov		76,132	47,862	123,994	$16,119	
Dec		75,739	32,292	108,031	$14,044	
Total	317,098	1,026,557	766,107	2,109,762	$274,269	

Ending Utility Consumption (kWh)

Month	On-Peak	Part-Peak	Off-Peak	Total
Jan	0	2,094,130	3,201,297	5,295,427
Feb	0	2,149,243	3,129,633	5,278,876
Mar	0	2,214,836	2,990,165	5,205,001
Apr	0	2,157,648	3,317,635	5,475,283
May	0	1,925,575	2,781,946	4,707,521
	102,024	142,596	295,128	539,748
Jun	1,013,086	1,482,026	2,720,425	5,215,537
Jul	994,968	1,452,947	3,202,642	5,650,557
Aug	1,027,801	1,477,758	2,843,601	5,349,160
Sep	1,002,291	1,413,980	2,613,763	5,030,034
	0	116,136	83,196	199,332
Oct	0	2,374,111	3,430,352	5,804,463
Nov	0	2,094,488	3,172,950	5,267,438
Dec	0	1,748,021	3,157,740	4,905,761
Total	4,140,170	22,843,495	36,940,473	63,924,138

Starting Utility Demand (kW)

Month	On-Peak	Part-Peak	Off-Peak	kVar
Jan		8,784	7,920	5184
Feb		9,360	8,784	5616
Mar		9,216	8,208	5616
Apr		9,648	8,496	5616
May		9,648	8,928	5616
	8,784	8,784	8,064	
Jun	9,648	9,648	8,784	5,616
Jul	9,360	9,648	8,496	5,472
Aug	9,648	9,648	8,496	5,328
Sep	9,504	9,504	8,496	5,616
		9,648	8,352	
Oct		9,648	8,352	5,184
Nov		9,072	8,640	5,040
Dec		8,496	7,776	4,896

Demand Reduction due to Solar Year 1 (kW)

Month	On-Peak	Part-Peak	Off-Peak
Jan		50	0
Feb		50	0
Mar		50	0
Apr		50	0
May		50	0
		50	0
Jun	100	50	0
Jul	100	50	0
Aug	100	50	0
Sep	100	50	0
		50	0
Oct		50	0
Nov		50	0
Dec		50	0
Total	400	700	0

Net Utility Demand (kW)

Month	On-Peak	Part-Peak	Off-Peak
Jan	0	8,734	7,920
Feb	0	9,310	8,784
Mar	0	9,166	8,208
Apr	0	9,598	8,496
May	0	9,598	8,928
	8,784	8,734	8,064
Jun	9,548	9,598	8,784
Jul	9,260	9,598	8,496
Aug	9,548	9,598	8,496
Sep	9,404	9,454	8,496
	0	9,598	8,352
Oct	0	9,598	8,352
Nov	0	9,022	8,640
Dec	0	8,446	7,776
	Total	46,544	130,052

SCE	Demand Deliver	On-Peak	Part-Peak	Off-Peak	Direct Access	kVar
Jan	$2.48		$0.00793	$0.00793	$0.027	$0.20
Feb	$2.49		$0.00793	$0.00793	$0.027	$0.20
Mar	$2.68		$0.00795	$0.00795	$0.027	$0.20
Apr	$2.80		$0.00815	$0.00815	$0.027	$0.20
May	$2.80		$0.00817	$0.00817	$0.027	$0.20
	$2.80	$0.00812	$0.00812	$0.00812		
Jun	$2.80	$0.00812	$0.00812	$0.00812	$0.027	$0.20
Jul	$2.80	$0.00812	$0.00812	$0.00812	$0.027	$0.20
Aug	$2.80	$0.00812	$0.00812	$0.00812	$0.027	$0.20
Sep	$2.80	$0.00812	$0.00812	$0.00812	$0.027	$0.20
			$0.00812	$0.00812		
Oct	$2.80		$0.00812	$0.00812	$0.027	$0.20
Nov	$2.80		$0.00812	$0.00812	$0.027	$0.20
Dec	$2.80		$0.00812	$0.00812	$0.027	$0.20

Starting Utility Bill

Month	SCE Usage	SCE Demand	kVar	Other	Subtotal SCE	UUT	SCE Total
Jan	$188,819	$21,784	$1,037	$4,568	$216,209	$6,486	$222,695
Feb	$188,286	$23,300	$1,123	$4,629	$217,338	$6,520	$223,858
Mar	$187,812	$24,699	$1,123	$4,649	$218,283	$6,548	$224,832
Apr	$199,866	$27,014	$1,123	$4,901	$232,905	$6,987	$239,892
May	$192,659	$27,014	$1,123	$4,976	$225,773	$6,773	$232,546
Jun	$192,249	$27,014	$1,123	$5,866	$226,252	$6,788	$233,040
Jul	$207,433	$27,014	$1,094	$3,616	$239,158	$7,175	$246,332
Aug	$196,326	$27,014	$1,066	$4,313	$228,719	$6,862	$235,580
Sep	$189,250	$27,014	$1,123	$6,220	$223,608	$6,708	$230,316
Oct	$208,432	$27,014	$1,037	$928	$237,411	$7,122	$244,533
Nov	$189,347	$25,402	$1,008	$4,852	$220,609	$6,618	$227,227
Dec	$176,084	$23,789	$979	$4,622	$205,475	$6,164	$211,639
Total	$2,316,563	$308,075	$12,960	$54,141	$2,691,739	$80,752	$2,772,491

Actual to SENA	Diff	SENA ($/kWh)	SENA ($)	Pilot($/kWh)	Pilot ($)
$407,972.39	$57,956.42	$0.065	$350,015.97	$0.01245	$67,289.18
$381,423.35	$32,395.73	$0.065	$349,027.62	$0.01245	$67,099.18
$400,942.53	$52,994.16	$0.065	$347,948.37	$0.01245	$66,891.70
$367,883.79	$26,718.27	$0.060	$341,165.52	$0.01245	$70,780.08
$373,883.90	$45,162.14	$0.060	$328,721.76	$0.01245	$68,198.43
$383,287.67	$54,844.55	$0.060	$328,443.12	$0.01245	$68,140.62
$452,546.45	$5,135.74	$0.076	$447,410.71	$0.01245	$73,522.61
$436,853.33	$13,399.32	$0.076	$423,454.01	$0.01245	$69,585.83
$438,244.48	$30,053.49	$0.076	$408,191.00	$0.01245	$67,077.67
$420,732.23	$26,064.57	$0.067	$394,667.66	$0.01245	$73,876.63
$434,540.63	$76,010.40	$0.067	$358,530.23	$0.01245	$67,112.17
$352,251.86	$18,834.69	$0.067	$333,417.17	$0.01245	$62,411.34
$4,850,563	$439,569.48		$4,410,993		$821,985

Pilot Invoice (	Pilot ISO	Totals		
$66,280.85	$13,592.08	$696,948.10		66280.85
$77,197.74	$23,994.17	$682,479.56		77197.74
$79,750.46	$27,433.60	$705,524.56		79750.46
$116,631.24	$62,913.60	$724,406.67		116631.24
$123,943.10	$66,612.27	$730,372.89		123943.1
$126,987.37	$0.00	$743,315.04		126987.37
$92,693.39	$29,015.14	$791,572.33		92693.39
$100,978.69	$39,975.84	$773,412.26		100978.69
$103,028.31	$42,375.28	$771,588.69		103028.31
$89,318.59	$30,057.70	$754,584.32		89318.59
$98,189.73	$39,977.90	$759,957.69		98189.73
$96,516.86	$42,773.66	$660,407.74		96516.86
	$418,721	$8,863,760	Total 2008 ESS E	