COST BENEFIT ANALYSIS OF POTENTIAL ENERGY CONSERVATION PROGRAM AT OKLAHOMA STATE UNIVERSITY

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NOMENCLATURE

CBA	Cost–benefit analysis
Dth	Decatherm (measurement unit for heat; 1,000,000 BTU)
EIU	Eastern Illinois University
EPA	Environmental Protection Agency
ESCO	Energy service company
EPC	Energy Performance Contract
HVAC	Heating, ventilation, and air conditioning system
IRR	Internal Rate of Return
LEED	Leadership in Energy and Environmental Design (Green Building Rating System)
NPV	Net Present Value
OSU	Oklahoma State University
ROI	Return on Investment
UB	State University of New York at Buffalo
UBC	University of British Columbia
U.S.	United States of America
WTP	Willingness to Pay
WTA	Willingness to accept compensation

CHAPTER I

INTRODUCTION

Oil boycotts in 1970s and resulting shocks for economy and everyday life put the energy conservation firmly in the minds of millions of Americans, or so it seemed. In the last three decades significant progress has been made in discovering the ways to effectively conserve energy and still enjoy the same comfort levels as before. However, after the energy crises ended and days of cheap energy returned, energy conservation slipped from a mind of general public and officials. Only in the 1990s we have witnessed the slow resurgence of it, this time because of environmental problems connected with extraction, and production of electricity.

Universities have followed a similar path. Most of the Universities began thinking and investing in energy conservation in 1970s, only to return to ‘sloppy habits’ in the 1980s (Fickes, M., 2002). While there are many examples of Universities that were successful in keeping their energy conservation programs active (and that now count their annual savings in millions), there are also many universities where with passing of 1970s energy crises, their interest in energy management and conservation passed also. By doing so they have missed an opportunity to improve energy efficiency and thus improve the environment while enjoying significant financial benefits.

Financial benefits are only a part of the overall benefits that such Universities are missing. Byproducts of energy generation (air pollution, global warming, water pollution, land disturbance, etc) are the cause of numerous environmental and human health problems.

Universities as centers of education and research should try to move away from a narrow, short-term point of view and embrace the concept of sustainability that requires that our actions should not only be economically, but also environmentally and socially sound. Such a view also has a significant education role by serving as a model to the students. Energy conservation programs are one such action, not only do they help reduce environmental and social problems associated with energy production and consumption, but they also make perfect business sense.

Concentrating on a case study of Oklahoma State University, this study will show that by committing to a comprehensive energy conservation program, Universities can improve their financial and environmental performance at the same time.

In the last couple of years OSU has experienced a financial crisis: on one hand costs are increasing (and utility costs are part of it), while on the other the state support is dwindling. The administration has reacted with multiple tuition and fees increases on one hand and by cutting costs on another. I believe that the financial crisis would be even greater if not for the efforts this University in general, but especially Physical Plant have been making in order to conserve energy. Measures varied from posting signs reminding people to turn the lights off to campus-wide lightning retrofit and modernization and expansion of building control management systems. All those measures have resulted in significant energy savings and while in the last 5 years a couple of new buildings were added to the campus, overall energy consumption has stayed almost flat. Most of those measures have made the university a safer and more comfortable place to work and learn. There is also much more that can be done to enable this university to conserve energy, while at the same time keeping or even increasing the comfort levels.

Without strong support of senior administration, the Physical Plant personal cannot utilize the full extent of cost-savings opportunities. The University officials may not be fully aware of potential benefits of developing such systems, and consequently, given the tight budgets are very reluctant to commit to something that might prove to be very costly.

A benefit-cost analysis of an energy management system may help to dispel such reservations. Such analysis can present the full potential of such system, and show if an energy conservation project can benefit the triple bottom line: economic, social and environmental.

This thesis will be effort to conduct and present a model for such economic analysis.

CHAPTER II

ENERGY MANAGEMENT AND ENERGY CONSERVATION

2.1 Introduction

Energy conservation programs, that burst forcefully on the scene with the oil crises of 1970s, only to be significantly scaled down after 1985 collapse of oil prices, are again enjoying a renaissance. The renaissance is driven partly by environmental concerns, but also because new energy efficiency technologies developed in the 1990s have enabled the significant cost savings (Haugland, T., 1996).

Even though they were not always supported, the conservation and efficiency programs have been very successful. As result of such programs total primary energy use per capita in the United States in 2000 was almost identical to that of 1973. Over the same 27-year period, gross domestic product per capita increased 74%. In 2000, consumers and businesses spent over $600 billion for total energy use in the United States. Had the nation not dramatically reduced its energy intensity over the previous 27 years, they would have spent at least $430 billion more on energy purchases in 2000 (Nadel, S. and Geller, H., 2001).

Turner and Capehart (2001) conclude that energy managers have proven time and time again, that energy management is cost effective. Furthermore, energy management is vital to national security, environmental welfare, and economic productivity.

However, even though the United States is much more energy-efficient today than it was 25 years ago, there is still enormous potential for additional cost-effective energy savings (Nadel, S. and Geller, H., 2001). Energy conservation measures have been promoted as a win-win option, meaning that appropriate conservation measures will both benefit the environment and provide energy consumers and society with a net economic gain. The win-win proposition draws its scientific basis from a large number of engineering studies showing that energy consumption can profitably be reduced by 20% or more (Haugland, T., 1996). The U.S. Department of Energy estimates that increasing energy efficiency throughout the economy could cut national energy use by 10% or more in 2010 and approximately 20% in 2020, with net economic benefits for consumers and businesses (Nadel, S. and Geller, H., 2001).

Everybody, on all levels starting from government or society as whole down to a single individual can benefit from conserving energy. Somewhere in the middle of this pyramid of users we find the user of interest for this thesis: “Universities that represent microcosms of society, and as such consume vast amounts of resources” (UBC Campus Sustainability Office, 2004).

The reason for this particular interest is that Universities, as research and education centers of the world, are responsible for countless achievements. They’ve saved millions of lives through medical advances, raised living standards, and nurtured healthy communities. But universities must take some responsibility for the more disturbing aspects of their achievements. To a certain degree, they contribute to and support attitudes that have built a foundation for the western world’s consumptive lifestyle—a lifestyle that is responsible for majority of environmental problems we are faced with today. So, universities need to set positive social, environmental, and economic examples for their societies to follow (UBC Campus Sustainability Office, 2003b).

The case for energy management and conservation is especially strong in recent years for public universities. State and federal budgets are running at a deficit and so the state universities are faced with choice either to increase the tuitions and fees or make cuts and eventually lower the quality of service. While struggling to make more out of less the question is, will the universities rely mainly on multiple tuition increases or will they look for creative ways to provide the same or better services at lower cost? Energy management is one such area that produces dramatic savings without decreasing user comfort (Zeloznicki, S., 2000).

Energy conservation on campus saves state tax dollars and mitigates the numerous adverse environmental and social impacts associated with energy production and consumption. These impacts include air pollution, acid rain and global warming, oil spills and water pollution, loss of wilderness areas, construction of new power plants, foreign energy dependence and the risk of international conflict over energy supplies. (UB Green, 2002)

In addition to energy savings, other benefits of more energy-efficient campuses include increased productivity, positive cash flow, healthier indoor air quality, improved lighting, more comfortable working and learning conditions, and a contribution to a cleaner environment (Dickerman, R. N., 2002).

A common excuse for universities not committing to greening activities in general, or more narrowly to energy conservation are financial constraints. While universities are, indeed faced with many financial constraints, Allen A. S. (1999) argues that other barriers are more important in constraining the universities to fully utilize the energy conservation opportunities. Such barriers are:

- Institutional/organizational – *lack of communication*, *lack of advocacy* and the *lack of a leader / fixer*.
- Financial – *lack of allocation of resources*, not simply “financial”.
- Cultural – amounts to a *lack of education*. and
- Educational – *lack of a modus for education.*

Another, more detailed and operational list of the main barriers before the energy management differentiates between managerial and technical barriers (BEE, 2003):

Managerial:

- Energy management is side-lined as a technical specialty.
- There is insufficient interest and driving force from above.
- There is little incentive for departmental managers and general staff to save energy.
- Lack of senior management commitment.
- Senior management unaware of potential savings.
- Higher priority given to "more important" issues.
- It is seen as an overhead cost.
- Energy is consumed by a large number of users.
- Users are unaware of energy use and costs.

Technical:

- Getting accurate data on time is a key problem.
- Monitoring and targeting is not integrated with financial accounting.

- Output is not reported to either users or senior managers in a form they can readily understand and use.
- Users have no information on how to make saving.

Even though each university is unique, and energy conservation programs have to be tailored to University's specific needs, Allen A. S. (1999) lists the following characteristics as shared by most of successful energy conservation initiatives at Universities: an institutionalized leader, involving faculty and students (in research and implementation), advocacy, educating the campus community, the need for seed monies to start projects (and paying for the projects with savings, or appropriate allocation or resources), community involvement (competitions and building conservation contacts) and changing of both large (infrastructure) and small (building scheduling) processes. To this I will add the support of the senior administration at Universities. It is essential, especially for new initiatives to have full support from administration starting with policy developing, then by ensuring enough resources are devoted to conservation programs, and, equally important, by setting the tone by actually following the recommended policy in everyday work, in other words serve as example for the staff, faculty and students. One of the goals for this study is to devise such system of energy management at Universities that will overcome above-mentioned barriers and allow full utilization of the benefits of energy conservation

2.2 Energy Conservation in Practice

The economics of campus environmental initiatives in higher education are well documented: National Wildlife Federation's *Green Investment, Green Return* report (Eagan, D. J., Keniry, J., 1998) showcased the 23 campus conservation projects (transportation, energy, water, recycling, composting, dining services) with combined annual savings of $16,755,500 with energy conservation projects accounting for more than $11.5 million of this amount. Investing in campus greening projects and especially in energy conservation projects is an economic, environmental, and educational investment with good financial returns.

Table 2.1. Annual revenues and savings for several campus energy conservation projects

Energy Conservation Project	Annual Revenues and Savings
Saving Energy at SUNY-Buffalo	$9,068,000
Retrofits at Elizabethtown College	$247,000
Energy Reduction at Brevard Comm. College	$2,067,000
Laboratory Renovations at Brown University	$15,500
Better Lights in Dorms at Dartmouth	$75,000
Solar Panels at Georgetown	$45,000
Total	**11,517,500**

Source: Eagan, D. J., and Keniry, J. (1998)

2.2.1 University of Arizona

The University of Arizona (PERC, 1995) is a small ‘city’ of 50,000 with a utility bill of over $15 million a year. One million dollars have been saved annually since the school adopted conservation projects three years ago, despite an increase in electricity use by 15.8 percent and campus growth by 17.7 percent over the past five years. The campus’s computerized energy management system shuts down many air handlers on weekends and holidays. Many rooms are also installed with movement-sensitive light switches that automatically shut off after fifteen minutes of no movement. The University of Arizona’s Student Union and Residence Life also encourage energy conservation through separate metering. A contest held by Residence Life rewarded the most energy-conserving hall a television set and thus created an added incentive for residence halls to reduce energy use.

2.2.2 State University of New York at Buffalo

Annual Energy Consumption in 2001-2002 (UB Green, 2003):

- Electricity -- 204,000,000 kWh.
- Natural Gas -- 480,000 mcf.
- Coal -- 1,700 tons.

This amount of energy is equivalent to an annual consumption for nearly 50,000 households. Campus energy consumption is responsible for the following estimated annual energy-related air pollution emissions:

- 500 tons of acid rain-producing sulfur dioxide.

- 700 tons of acid rain and smog-producing nitrogen oxides.
- 200,000 tons of global warming enhancing carbon dioxide.

It would take 40 square miles of trees (the same area as the City of Buffalo) to "fix" or remove the carbon in 200,000 tons of carbon dioxide out of the atmosphere.

These numbers might be 40 to 50 percent higher if not for campus energy conservation efforts. Since the late 1970, UB has implemented hundreds of energy conservation measures and projects, which have produced annual energy savings of over $9 million in avoided energy costs and cumulative savings in excess of $60 million.

These projects have included (UB Green, 2003):

- Lighting retrofits.
- Building shell insulation and window improvements.
- Heating and cooling system upgrades.
- Energy efficient motors and variable speed drives for fans and pumps.
- Enhanced computer controls to regulate heating, ventilating, and air conditioning equipment.
- Heat recovery.
- Conversion of electric space and water heating to natural gas.
- Reduced operating hours of all energy-consuming equipment.

In 1998 UB won the Association of Energy Engineers "Energy Project of the Year" Award for a 1994-1997 $17 million comprehensive demand side management project, which has reduced UB North Campus energy consumption by $3 million annually and produced many other campus benefits.

2.2.3 Eastern Illinois University

Eastern Illinois University (Fickes, M., 2002) estimates that it has avoided several million dollars in utility costs through the past six to 10 years. More importantly, EIU hopes to improve its utility cost performance substantially through the next 10 years and to begin pumping at least a portion of those cost savings into EIU budgets serving the school's core educational missions.

EIU structured their early efforts around a series of no-cost initiatives (such as education programs about importance of saving energy aimed at students, faculty and staff, and review of maintenance practices) and low-cost initiatives (such as replacing incandescent bulbs in all desk lamps with screw-in fluorescent lamps; installing sensors on 115 soda machines that turn the machines off when no one is around; installing showerheads that reduced water flow from 5 gallons per minute to 2.5 gallons per minute). Low cost programs had total investment costs of around $55,000 and have resulted in savings of over $270,000.

Through performance contract, EIU also enlisted the help of one energy service company (ESCO). The ESCO recommended a series of energy efficiency upgrades, which were carried out using the $3.4 million in bond funding. The upgrades included the installation of T-8 fluorescent lamps with electronic ballasts, compact fluorescent lighting, variable air volume controls, variable speed fan drives, and building automation systems related to HVAC. The ESCO guaranteed that this work would save a minimum of $553,000 annually, enough to pay off the bonds as well as the debt service. EIU found that the actual savings have exceeded the performance guarantee in each of the contract years.

2.2.4 University of British Columbia

Since 1999 UBC has established the necessary institutional framework for energy conservation and other greening programs at the University by developing sustainability policies, strategic plans and forming a Sustainability office to implement them. With a population of more than 50,000 students, residents, staff, and faculty living and working on the campus, UBC annually consumes (UBC Campus Sustainability Office, 2002):

- 146 million kWh of electricity. and
- 836 million pounds of steam.

In 2002, UBC spent $18.2 million for electricity, gas, steam, water and sewer.

UBC has also established 2010 Energy Conservation Target of 30 percent reduction in energy use intensity (measured as energy use per square meter in GJ/m^2). This goal will be partly achieved by implementation of ELECTrek and ECOTrek projects, and partly by building new institutional buildings to the LEED Silver benchmark (a 50 percent reduction over existing energy intensity) (UBC Campus Sustainability Office, 2004)

The ELECTrek Project was completed last year. It involved a lighting upgrade in 41 major campus buildings. It is estimated that this upgrade will result in an 11 million kWh of electricity savings annually. Capital costs are in the order of $4 million of Canadian dollars, and will be paid back from the resulting energy savings.

The ECOTrek Project represents the largest energy conservation project at a Canadian University. This three year project (will be completed by the end of this year) was financed through an Energy Performance Contract (EPC). An EPC is a unique business arrangement where an Energy Service Company guarantees that the energy savings will pay off the capital costs over the term of the contract. UBC feels the EPC is the best vehicle to lower energy usage while minimizing financial risk (UBC Campus Sustainability Office, 2002).

The ECOTrek Project will involve work in 80 large buildings, and numerous smaller buildings, totaling over 6.7 million square feet over a three-year period.

Total project costs will range from $35 million to $40 million Canadian dollars, with a 10-year simple payback (UBC Campus Sustainability Office, 2003a). Through physical upgrades and retrofits, the project is committed to annually:

- Generate savings of up to $3 million.
- Improve comfort for building occupants.
- Reduce energy use in core buildings on campus by 30 percent.
- Reduce CO_2 emissions by 30,000 tons.
- Reduce water-use in core facilities by 45 percent.

2.3 Benefits of Green Buildings

As we have seen in the last example, the University of British Columbia expects to achieve its 30 percent energy reduction target. UBC will achieve this partly from committing to green building design. UBC has realized that an inefficiently designed new building is either a great retrofit candidate or an energy headache for the next 50 or 100 years. Although retrofitting buildings to improve efficiency makes sense, the retrofit is costly and time consuming. New buildings should be, instead, designed right and energy efficient in the first place so that the need for retrofitting can be minimized (Simpson W., 2003).

The state of California established the Sustainable Building Task Force, which commissioned a report to assess the costs and financial benefits of constructing green buildings in California. Based on a review of the construction costs of 33 green buildings in the United States, the report (published in October 2003) found that a minimal upfront investment of about 2 percent of construction costs typically yields life cycle savings of over 10 times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of at least $1 million over the life of the building, assumed conservatively to be 20 years (Kats, G., et. al., 2003).

In addition to the significant financial and environmental benefits of lower energy and water use, there are compelling additional benefits, including:

Significantly reduced operating costs — operating costs for green buildings can be less than half those in conventionally designed buildings.

Improved indoor air and light quality saves money and benefits the health, morale, and productivity of employees (UBC Campus Sustainability Office, 2002).

These benefits, such as energy savings, should be looked at through a life cycle cost methodology, not just evaluated in terms of upfront costs. From a life cycle savings standpoint, savings resulting from investment in sustainable design and construction dramatically exceed any additional upfront costs (Kats, G., et. al., 2003).

CHAPTER III

COST-BENEFIT ANALYSIS

3.1 Introduction

Cost–benefit analysis (CBA) is the applied tool of welfare economics that has started out as an attempt to more systematically incorporate economic information in public investment decisions involving water resources. CBA is used for project evaluation and regulatory review (Navrud, S., and Pruckner, G. J., 1997). The idea of this economic accounting originated in 1848 with Jules Dupuit, a French engineer. But the practical development of CBA came as a result of the requirement provided by the Federal Navigation Act of 1936. This act required that the U.S. Corps of Engineers carry out projects for the improvement of the waterway system when the total benefits of a project to whomsoever they accrue exceed the costs of that project. Thus, the Corps of Engineers had created systematic methods for measuring such benefits and costs. It wasn't until about twenty years later in the 1950's that economists tried to provide a rigorous, consistent set of methods for measuring benefits and costs and deciding whether a project is worthwhile. Some technical issues of CBA, like choice of discount rate, have not been wholly resolved even now but the fundamentals are well established (Watkins, T., 2002). Cost-benefit analysis may be viewed at three levels (Gilpin, A. 1999):

1. A financial statement of the costs and benefits of a private investment, the findings indicating the expected returns on capital invested.
2. An assessment that takes into account external costs and benefits that may be ignored by the private investor but be of high importance to local community.
3. A broad assessment of the implications for the economy as a whole.

Cost-benefit analysis imposes an accounting framework that prescribes classes of benefits and costs to consider, means to measure them, and approaches for aggregating them. It measures the economic efficiency of the proposed policy or project. When all else is equal more efficient projects should be chosen over less efficient ones (Bjornstad, D., 2003)

3.2 Characteristics and Principles of Cost-benefit Analysis

Strengths of Cost-Benefit Analysis (Kopp, R.J., et. al., 1997):

- **Transparency**: The results of a well-executed CBA can be clearly linked to the assumptions, theory, methods, and procedures used in it.
- **Ignorance Revelation**: CBA requires information regarding the effects that a policy can have on social welfare and provides the analyst with a template for collecting and organizing that information. The template character of CBA permits the decision-maker to determine the adequacy of the information collected and see important information is missing.
- **Comparability**: CBA attempts to capture in a single index all the features of a policy decision that affect the well-being of society. The single-metric approach permits the comparison of policies that affect different attributes of well-being

> differently, that is, it permits the decision-maker to compare "apples" and "oranges" on the basis of a single attribute (the index of social welfare) common to both.

Critics of CBA usually raise questions about the assumption that individual well-being can be characterized in terms of preference satisfaction, the assumption that aggregate social well-being can be expressed as an aggregation (usually just a simple summation) of individual social welfare, and the empirical problems encountered in quantifying economic value (especially of environmental benefits) and aggregating measures of individual welfare.

Principles of Cost Benefit Analysis (Watkins, T., 2002):

- There must be a common unit of measurement.
- CBA valuations should represent consumers or producers valuations as revealed by their actual behavior.
- Benefits are usually measured by market choices.
- Gross benefit of an increase in consumption is an area under the demand curve.
- Some measurements of benefits require the valuation of human life.
- The analysis of a project should involve a with versus without comparison.
- Cost-benefit analysis involves a particular study area.
- Double counting of benefits or costs must be avoided.

A properly constructed cost-benefit analysis will attempt to measure the change in economic welfare associated with all costs and all benefits uniquely generated by a project. Bjornstad, D., (2003) has categorized the benefits into one of the following three categories:

1. Marketed Benefits and Costs

Marketed benefits, also referred to as private benefits, are measured as the sum of willingness to pay by consumers for the new quantity of product produced by the project being evaluated. The private costs associated with the project, unlike the benefits, are typically measured at market prices.

2. Non-Marketed Direct Benefits and Costs

A large number of natural and environmental resources are consumed directly, but are not purchased in markets. Examples include fishing in a mountain stream, enjoying a panoramic view, living in a community or neighborhood with clean (or dirty) air, or working in an occupation that provides opportunities to enjoy increased (or decreased) health. A statistical tool called hedonic analysis can be used to estimate these wage differentials. In other cases, a travel cost approach is used to infer willingness to pay for an environmental amenity

3. Non-Marketed Indirect Benefits and Costs

Non-marketed indirect benefits and costs arise not because of direct use of a resource, but rather because individuals place value on the "existence" of the resources. For example, many people have never seen the redwood forests, but have willingness to pay to see them preserved. The most commonly applied approach is contingent valuation analysis wherein a hypothetical, or "contingent," choice is made that is designed to reveal an individual's willingness to pay.

3.3 Analyzing Benefits

At its roots, benefits analysis develops monetary values to inform the policy making process. These values are important because they allow decision makers to directly compare costs and benefits using the same measure (i.e., dollars).

Economists define benefits by focusing on measures of individual satisfaction or well-being, referred to as measures of welfare or utility. Economic theory assumes that individuals can maintain the same level of utility while trading-off different "bundles" of goods, services, and money. The tradeoffs individuals make reveal information about the value they place on these goods and services.

The willingness to trade off compensation for goods or services can be measured either as *willingness to pay* (WTP) or as *willingness to accept compensation* (WTA). Economists generally express WTP and WTA in monetary terms (EPA, 2000).

3.3.1 Energy Conservation Paradigm vs. Economics Paradigm

Different methodologies are used in economics paradigm and energy conservation paradigm for measuring the benefits of energy conservation programs at social level.

In energy conservation paradigm costs and benefits are measured in terms of saving energy, using technology cost data. The benefits of energy conservation programs are defined as energy costs saved. The dollar value of energy saved is calculated as the present value of the reduction in energy costs (Sutherland, R. J., 2000).

On the other hand as it was explained earlier, in standard cost benefit framework benefits from projects are defined as the value that consumers would place on a project, and they are measured as the sum of willingness to pay by consumers for energy saving programs. Energy costs saved is the measure of benefits of energy conservation programs; this benefit is estimated as the present value of future reductions in energy costs. The willingness to pay for an improved market outcome, such as environmental quality, is the standard economics measure of benefits (Sutherland, R. J., 2000).

3.4 Key Technical Considerations:

3.4.1 Cost-Benefit Analysis and Discounting

Any project that is considered for implementation, be it private investment or new public policy will generate costs and benefits over period of time, with often costs occurring right at the beginning of the project and benefits following later, sometimes even years later. This represents a problem for cost-benefit analysis since value of today's dollar is not the same as value of one dollar ten years from now. Cost-benefit analysis deals with this problem by discounting costs and benefits in each future time period and summing them to arrive at a present value (Bjornstad, D., 2003).

Time discounting is accomplished by multiplying the future values of a policy's effects by discount factors that reflect both the amount of time between the present and the point at which these events occur and the degree to which current consumption is more highly valued than future consumption (EPA, 2000).

While the concept of discounting is fairly simple, the choice of the discount rate is one of the most contentious and controversial aspects of cost-benefit analysis (Bjornstad, D., 2003). Discounting can substantially affect the present value of net benefits estimates for public policies when there is a significant difference in the timing of costs and benefits. For example, if the costs of a policy are incurred today, they are not discounted at all. But if the benefits will occur 30 years from now, the present value of the benefits, and, hence, the net present value of the policy's effects depends critically on the discount rate used (EPA, 2000). In any case, higher interest rates will lead to fewer projects having positive net present values than lower ones (Bjornstad, D., 2003).

The question of discount rate choice is still open so that in the final analysis the choice of a rate is fairly arbitrary (EPA, 2000) representing the analyst's beliefs and assumptions. Analysts performing cost-benefit analysis of public policy in the U.S. have to follow the White House's Office of Management and Budget guidance on discounting that currently recommends discounting using a rate of seven percent, an estimate of the average real pre-tax rate of return generated by private sector investments (and performing sensitivity analysis with discount rate of 5 and 9 percent), while based on historical rates of return on relatively risk-free investments, adjusted for taxes and inflation, a consumption rate of interest is measured at two to three percent (EPA, 2000).

3.4.2 Dealing with Uncertainty

There is uncertainty in every variable estimated, including the most important categories of costs and benefits. For these reasons, it is important that a cost-benefit analysis does not present a single number as the sole estimate of net present values. Rather sensitivity analysis should be conducted to illustrate how the results change with different analytical choices and with variation in the uncertain levels of key costs and benefits (Bjornstad, D., 2003).

Sensitivity analysis is a method for analyzing uncertainty by changing input variables and observing the sensitivity of the result. For example, if a positive present value is calculated for a range of discount rates, the analyst can conclude that uncertainty over which discount rate to use does not factor heavily in the analysis (Bjornstad, D., 2003).

3.4.3 Methods of Valuation of the Project

Once estimates of benefits and costs associated with a project have been identified and estimated, they must be analyzed to determine the value of the project. This value is derived from the net benefits, expressed usually in monetary terms, the project is expected to generate in the future. The goal of the evaluation process is to ensure that, from a number of alternative choices, the project or set of projects chosen generates the greatest economic value to society (Bjornstad, D., 2003).

Any chosen method should meet the following criteria (Bjornstad, D., 2003):

- Incorporate the value of time.
- Reflect all future cost-benefit flows.
- Incorporate risk into the calculation of the value.

The Simple and Discounted Payback method simply calculates how many periods into the future it takes for a project to repay the initial investment. Since the costs and benefits continue to occur even after the investment is repaid this method fails to account for all cost and benefit flows. Further, the simple payback method does not take into consideration the time value of money. Finally, risk of investment is not considered (Bjornstad, D., 2003).

The Internal Rate of Return (IRR) is a method for determining value that does not depend on the determination of a discount rate and that expresses value in terms of a percentage. Essentially, the method requires the calculation of a discount rate such that the present value of costs minus the present value of benefits equals zero.

To calculate the IRR it is necessary to find the discount rate that would equate the initial investment with the future cost-benefit flows. To determine whether or not project C is a winner, the calculated IRR must be compared to a minimum acceptable rate of return that should reflect the time value of money, risk, etc. (for example at Penn State, an approximately 7 percent rate of return is expected on long-term investments) (Pearce, J. M., and Uhl, C. F., 2003).

The problem with IRR is that any project that has relatively large positive cost-benefit flows early in its life will generate a relatively large IRR. This means that the ranking of projects will depend as much on their relative size and the timing of their cost-benefit flows as it will on the actual cost-benefit flows, while the ranking of projects should only depend on actual flows (Bjornstad, D., 2003).

The Net Present Value method accounts for the time value of money through discounting. It also considers all of the expected future cost-benefit flows. Further, the discount rate can be adjusted on a project-by-project basis to reflect the inherent risk of each. It yields one value that is easily interpreted. If the value is positive, the project yields benefits that exceed its costs. If the value is negative, costs exceed benefits (Sometimes benefits and costs are discounted separately and placed in ratio form. In this case, a benefit-cost ratio greater than one implies that the net present value is positive) (Bjornstad, D., 2003).

From economic perspective the way to improve the probability of implementation of large-scale conservation measures is to shift from simple payback method, which is commonly used for project evaluation, to life cycle evaluation.

Even though the project might be unlikely to be implemented if it has a longer payback, life cycle analysis may show that it still makes excellent financial sense —given its projected savings over the life of the equipment being installed as well as its quantifiable maintenance savings, capital improvement, and other benefits (Simpson W., 2001).

While not as easy to calculate as the payback method, NPV is computationally easier than the IRR. Finally, NPV provides a simple basis upon which to accept or reject projects and to compare across projects (Bjornstad, D., 2003). Because of its advantages Net Present Value is used in cost-benefit analysis to measure project's cost and benefits.

In formal terms, the net present value of a projected current and future benefits and costs is found by multiplying the benefits and costs in each year by a time dependent weight, d_t, and adding all of the weighted values as follows (EPA, 2000):

$NPV = NB_0 + d_1NB_1 + d_2NB_2 + ... + d_nNB_n$

NBt is the net difference between benefits and costs (Bt-Ct) that accrue at the end of period, t, and the discounting weights are given by:

$d_t = 1/(1+r)^t$

where r is the discount rate and n is the final period in the future in which the policy's effects are felt.

To account for inflation, either real or nominal values may be used, as long as they are used consistently. In other words, nominal costs and benefits require nominal discount rates, and real costs and benefits require real discount rates. Moreover, same discount rate has to be used for both benefits and costs (EPA, 2000).

3.5 Measuring the Externalities in Energy Production

Producing energy and at universities the major part of this is in the form of electricity, places costs on society. Some of costs are reflected in price that is charged to consumers, but some costs, especially those resulting from the undesirable effects on the environment and human health, are considered ‘externalities’. Even though they cause economic loses (like health problems), there are not usually reflected in the market price. External costs (or benefits) result from unintended byproduct of an economic activity that accrue to someone other than the parties involved in the activity. Most of these externalities result from combustion of fossil fuels, which accounts for nearly 70 percent of the total electricity generated in the United States (EIA**,** 1995).

Externalities attributable to electric power generation have been classified by EIA **(**1995) in the following categories:

- **Air pollutants** including sulfur dioxide, nitrogen oxides, particulates, and heavy metals with impacts on human health, flora and fauna, building materials, and on other social assets like recreation and visibility;
- **Greenhouse gases** including carbon dioxide, methane, and chlorofluorocarbons suspected of contributing to global climate change and thus to potential impacts on agriculture and human health;

• **Water use and water quality** affected by electricity production, principally through thermal pollution or hydroelectric projects that affect aquatic populations;

• **Land use values** affected by power plant sitings and by waste disposal including solid, liquid, and nuclear wastes.

Upstream externalities for coal include costs of acid mine drainage and from unreclaimed surface mine. Oil and natural gas externalities involve issues associated with drilling, pipelines, and spills. Downstream externalities are associated with landfills/ ash disposal, climate change (or global warming potential), acid rain, transmission lines (electromagnetic fields), and siting of power plant.

According to neo-classical welfare economics, external costs have to be internalized, i.e. added to the price of electricity, to achieve a full picture of the consumption of scarce resources (Voss, A., 2001). In the last decade, especially, there have been a number of studies trying to fully measure the external costs of energy production. The effects of energy occur at all stages of the fuel cycle: production, refining/processing, transformation and conversion, transportation and distribution and consumer usage/disposal. The impact is dependent on the source of energy and its respective usage. Since the studies have used different methodologies and assumptions their results vary greatly (see Table 3.1. for examples of studies measuring externalities caused by coal fuel chain)

The most extensive study on determining the monetary value of energy production external costs are conducted in the European Union under a project titled ExternE. ExternE started in early 1990’s as joint EU-USA program, but after the results of the first phase were published in 1995, US government consequently decided to withdraw its support. The project has continued to be solely supported by EU for over a decade now.

Table 3.1 Summary of impacts and damage costs for coal fuel chain

Study	Occupational Fatalities	Public Health	Occupational Health	Environment	Global Warming	Study Total
	Impacts (deaths per TWh)	Damage costs (in milli-Euro per kWh)				
Ottinger et. al 1991						22-55
Pearce et al 1992		0.05		0.005	0.04	0.14
Pearce et al 1995						0.11
Friedrich & Voss 1993		0.01-0.07		0.013-0.015		0.02-0.09
Ball 1994	0.04-0.14					
ORNL/RFF 1994		0.01-0.64	0.08	0-0.1	nq[1]	0.7-1.4
Rowe et. al 1996		3 to5		0.1	nq	3-5
ExternE 1995	0.13-0.23	4 to 13	1 to 2	0.2 to 0.8	10 to 18[2]	16-34
Rabl et al 1996		5 to 14	nq	0.02	15	20 to 29
ExternE 1999		10 to 50		0.5 to 2	10 to 50	20 to 100

Source: Wilson, R., et al (1999); 1) nq = not quantified; 2) at 0% discount rate

The ExternE estimates external costs resulting from different forms of electricity production (fossil, nuclear and renewable) for 15 European countries. The project has proven that the cost of producing electricity from coal or oil would double and the cost of electricity production from gas would increase by 30 percent if external costs such as damage to the environment and to health were taken into account. It is estimated that these costs amount up to 1-2 percent of the European Union's Gross Domestic Product (GDP), not including the cost of global warming. (ExternE , 2004).

The ExternE data (table 3.2) illustrate that the external costs of electricity generation differ greatly, depending on fuel choice, technology and location. Such external-cost estimates can then be added to market price as an estimate of full social costs of energy production. This full price estimate can then be used in cost-benefit-analysis of energy conservation programs. In such an analysis the costs to establish energy conservation measures that will result in lower energy consumption and contribute to reduction of a certain environmental burden are compared with the benefits, i.e. damage avoided due to this reduction (European Commission, 2003).

Table 3.2. External cost figures for electricity production in the EU for existing technologies (1) (in Euro cents per kWh)

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

Source: European Commission (2003); 1) sub-total of quantifiable externalities (such as global warming, human health, occupational health, material damage); AT- Austria; BE-Belgium; DE – Germany; DK – Denmark; ES – Spain; FI – Finland; FR – France; GR – Greece; IE – Ireland; IT- Italy; NL – Netherlands; NO – Norway; PT – Portugal; SE – Sweden; UK – United Kingdom

CHAPTER IV

METHODOLOGY

Before a proposed energy management program is accepted it has to overcome, what usually turns out to be a major challenge, preconceived skepticism of decision makers toward such programs. The barriers decision-makers are most likely to rise, which makes it hard to, or even impossible to implement energy management programs can be summarized as (ENERGY STAR, 2002):

1. Lack of money.
2. Lack of time or personnel to design and plan the projects because of other, higher priorities.
3. Lack of internal expertise to implement the projects.

While the other two concerns are very important and can stall the energy management program if they are lacking, if first concern about the lack of money is successfully addressed, then priorities can be rearranged and existing staff can be trained if needed, or an energy manager can be hired to lead the program.

Regarding the concern decision-makers might have about lack of money, some of the questions and challenges they commonly raise are (ENERGY STAR, 2002):

- If it is not in this year's budget, it simply has to wait.
- Equipment improvements must be paid from the capital budget.

- Paying lower interest (by floating bonds) or no interest (by delaying the project and planning it into future budgets) saves more money and, therefore, is in the best interest of our organization.
- Taxes or fees will have to be increased to pay for these improvements.
- Performance contracting with an energy service provider (ESP) is expensive and unreliable.
- Tax-exempt lease-purchase agreements don't lend themselves to energy projects and are expensive alternative funding solutions.

The best way to address such concerns is to present the benefits (and costs) of energy management programs in a clear and consistent way. Cost-benefit analysis is one such method that can accomplish this.

Before performing the cost-benefit analysis of a potential energy management program for OSU, the attempt will be made to first establish the baseline by researching and then evaluating the present practices and accomplishments in the field of energy management at Oklahoma State University.

The next step would be to develop the potential energy management program. Such a proposal should be as detailed as possible, given the constraint that every university is a unique case. What functions great in one university, might not be very useful for another. In developing such program, experiences and lessons learned at other universities will be combined with an evaluation of the present practices at OSU. The result, hopefully, will be an outline of the energy management program that will be acceptable to decision-makers at the University.

The main part of this thesis, the analysis of such potential program will follow. The cost-benefit analysis will be conducted for period 2005-2015. I have chosen this period because it allows enough time for energy management program to be established and to start achieving cost savings, but is not too long to be seen as too distant in the future. One of the major steps in cost-benefit analysis will be to identify all the costs and benefits of such program, and then to evaluate and quantify them.

The issue with cost and benefits of any project is that direct costs and benefits that are valued at market can, by their very nature, be quantified, whereas the social and environmental costs and benefits are generally seen as external costs. Since OSU is a public educational and research institution, and as such should have broader perspective than private enterprise, my intention is to include, as much as possible, the social and environmental costs- and benefits into my analysis. In order to do so, such costs will be quantified using data from a EU project, ExterneE, which researched external costs of electricity production and consumption for a wide range of technologies.

Summary of the steps discussed:

1. Establish the baseline – through interviews with responsible personnel from Physical Plant and through the data available
2. Investigate the needed changes – especially with regard to support of the administration and university policies
3. Develop a potential energy management program for OSU for next 10 years.
4. Perform an initial cost-benefit analysis. One analysis will estimate actual dollar expenditures for OSU and a second will be for society, which will include benefits and costs external to the OSU budget.

Following above steps I will test the following working hypotheses:

1. That campus wide energy conservation projects and broader energy management systems represent an untapped area for savings at Oklahoma State University.
2. Such programs are valuable and are economically, environmentally, and socially sound to implement and support.
3. The net present value of energy management projects is positive to both OSU and to society. That is the benefits of proposed energy conservation program and energy managements system are higher then the costs of running such programs.

CHAPTER V

FINDINGS

5.1 Energy Management Practices at Oklahoma State University

5.1.1 Oklahoma State University: An Overview

Oklahoma State University is a comprehensive, land-grant research university that comprises OSU-Stillwater, OSU-Tulsa, OSU-Oklahoma City, OSU-Okmulgee, and the OSU Center for Health Sciences in Tulsa. Total student population is more that 30,500 students. The largest campus and the focus of this study is in Stillwater where 21,604 students enrolled in Fall 2003. The Stillwater campus encompasses 840 acres and more than 200 permanent buildings.

The Physical Plant is responsible for energy management at Oklahoma State University's Stillwater campus. In the Physical Plant's new Strategic Plan (OSU, 2003), energy conservation is considered one of the objectives in the effort to promote effective utilization of facilities and financial assets. It is to be established through:

- Lower utility consumption through energy management.
- Continued vigorous pursuing of on-going lighting fixture upgrades.
- Increased use of state-of-the-art building control technologies and metering.
- Seeking better energy savings cooperation from campus community through enhanced communications.

5.1.2 State of Energy Management Practice at Oklahoma State University[1]

The University does not have an Energy Manager or Energy Management Office. Energy management is part of responsibilities of different departments, mainly Engineering & Utilities Services and Maintenance & Operations departments in the Physical Plant.

The University Policy on Energy Management accepted in February 1983 is outdated, and after reviewing the current state of energy management practice at OSU it is safe to conclude that most of its requirements are not followed in the practice.

The University wide policy stating the minimum acceptable payback or return on investment is not published, thus decisions on attractiveness of energy conservation projects might not be consistent over time.

An energy audit has not been conducted in recent years. The latest audit performed in early 1990s covered only lighting, so the benchmark situation is hard to establish.

OSU gets majority of its electricity from Oklahoma Gas and Electric Company (OG&E), and this amount ranges 9 – 13.5 million kW/h per month. OG&E energy comes from a mixture of coal and natural gas power plants (60 percent coal, and 40 percent natural gas). Since Fall 2003, the University has been purchasing 139,900 kWh per month of energy produced by wind turbines from OGE (about 1.3 percent of OSU total electricity use). The price is 2 cents above the base rate, but there is no fuel cost adjustment, so the final price is little more than 1 cent over the price of electricity produced by coal or natural gas.

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[1] The information in this chapter is based on internal data from Physical Plant obtained through personal communication with Jeff Stewart, director of Engineering and Utilities, Ted Maxwell, Electrical foreman and Daniel Ferguson, Building Systems Group foreman

About 8-9 percent of the Campus electricity comes from the OSU Power Plant that uses natural gas for fuel and produces approx. 1 mil kW/h per month. The University uses natural gas for producing steam, chilled water and heating. Natural gas is used for cooking and space heating, and hot water generation in some areas of campus.

After adding the natural gas used at OSU power plant the total percentage of fossil fuel used for production of electricity for OSU is: 45 percent natural gas and 55 percent coal.

Table 5.1 Energy consumption at Oklahoma State University in the last five fiscal years

Fiscal year	1999	2000	2001	2002	2003
Electricity					
OG&E (kWh)	123,765,990	125,068,800	131,347,200	130,752,000	123,686,400
OSU Power Plant	12,502,700	11,719,900	11,719,900	11,820,800	12,323,267
Total (kWh)	136,268,690	136,788,700	143,067,100	142,572,800	136,009,667
Cost	$5,969,533	$6,951,787	$7,815,118	$7,412,956	$6,424,873
Unit Cost	$0.044	$0.051	$0.055	$0.052	$0.047
Heating Steam	**-**	**-**	**-**	**-**	
Cons (1000 lb)	340,482	330,053	380,902	337,109	322,731
Cost	$1,236,477	$1,075,839	$2,212,237	$2,346,867	$2,370,249
Unit Cost	$3.632	$3.260	$5.808	$6.962	$7.344
Heating Nat. Gas	-	-	-	-	-
Cons (Dth)	159,155	147,141	161,654	150,664	152,605
Cost	$482,037	$538,783	$1,217,403	$767,896	$774,055
Unit Cost	$3.029	$3.662	$7.531	$5.097	$5.072
Chilled Water	-	-	-	-	-
Cons (Ton-Hr)	38,425,223	37,369,779	38,057,707	38,733,479	35,980,587
Cost	$3,253,706	$4,468,166	$5,021,099	$4,900,179	$4,050,548
Unit Cost	$0.085	$0.120	$0.132	$0.127	$0.113
Total Cost	**$10,941,753**	**$13,034,575**	**$16,265,857**	**$15,427,898**	**$13,619,725**

Source: adapted from Stewart, J. (2004)

The cost of energy, especially the price of natural gas rose sharply 3 years ago, and this is the main reason for an increase of almost of 60 percent in energy costs between 1999 and 2001. In response, the Director of Utilities developed a new energy plan, but it was never accepted as official policy (Stewart, J., 2001).

During the last five years the University was expanding in size, so the absolute energy consumption and cost numbers are not the best way to describe the trend. Given the square footage for electricity, chilled water and steam it is possible to calculate the cost per square foot for whole campus. However, not every building on campus uses the central system for heating and cooling, and the University's electricity distribution system extends to area west of campus to include some of the buildings that are university property. This results in a different square footage for each form of energy.

Table 5.2 Energy consumption at Oklahoma State University per square feet

Fiscal year	1999	2000	2001	2002	2003
Electricity					
Total (kWh)	136,268,690	136,788,700	143,067,100	142,572,800	136,009,667
Square footage	7,491,032	7,728,419	7,818,488	8,615,588	8,785,411
KWh/sq-ft	18.19	17.70	18.47	16.55	15.48
Unit Cost	$0.044	$0.051	$0.055	$0.052	$0.047
$/sq-ft	$0.80	$0.90	$1.01	$0.86	$0.73
Heating Steam	-	-	-	-	
Cons (1000 lb)	340,482	330,053	380,902	337,109	322,731
Square footage	5,848,143	5,906,695	5,906,695	6,203,889	6,203,889
1000 lb/sq-ft	0.0582	0.0559	0.0645	0.0543	0.0520
Unit Cost	$3.632	$3.260	$5.808	$6.962	$7.344
$/sq-ft	$0.21	$0.18	$0.37	$0.38	$0.38
Chilled Water	-	-	-	-	-
mmBTU*	483,375	463,109	473,830	485,017	429,430
Square footage	5,528,876	5,598,652	6,126,638	6,604,234	6,609,832
mmbtu/sq-ft	0.0874	0.0827	0.0773	0.0734	0.0650
Unit Cost	$6.73	$9.65	$10.60	$10.10	$9.43
$/sq-ft	$0.59	$0.80	$0.82	$0.74	$0.61
Total cost/sq-ft	**$1.60**	**$1.88**	**$2.20**	**$1.98**	**$1.72**

Source: modified from Stewart, J. (2004); *mmBTU = 1,000,000 BTU

As it can be expected, the energy cost per square foot hit a peak in 2001, and has been dropping in the last two fiscal years, due mostly to lower energy prices, but also in part because of the energy efficiency programs being implemented at physical plant in the last couple of years. Those projects are going to be discussed in following pages.

Table 5.3 Annual energy costs per student at Oklahoma State University

Academic Year	Total Energy Cost ($)	Number of students	Cost per student (nominal $)
1998-1999	10,941,753	19,521	561
1999-2000	13,034,575	19,724	661
2000-2001	16,265,857	19,860	819
2001-2002	15,427,898	20,272	761
2002-2003	13,619,725	21,149	644

Source: calculated by author

Electricity generation is a source of air pollution resulting from burning fossil fuels used to produce energy. The following formulas and factors, modified from Woodroof, E. A (2001) were used to estimate the reduction in emission per kWh per year:

CO_2: kWh/yr * emission factor * 0.45359 * 0.001= tons/yr

SO_2: kWh/yr * emission factor * 0.000001 = tons/yr

NO_x: kWh/yr * emission factor * 0.000001 = tons/yr

Table 5.4 Approximate emissions from electricity generation at Oklahoma State University

Fiscal Year	CO_2 (tons/yr)	SO_2 (tons/yr)	NOx (tons/yr)
1999	105,077	300	341
2000	105,478	301	342
2001	110,319	315	358
2002	109,938	314	356
2003	104,877	299	340
Average	**107,138**	**306**	**347**

Source: calculated by author

As shown in table 5.4, OSU is responsible for average annual emissions of 107,138 tons of CO_2, 306 tons of SO_2, and 347 tons of NOx (not including emissions from natural gas burned at campus for steam, chilled water or heating). To calculate these emissions, aggregate data for EPA region 6 were used. Because of this, the results are only approximations and serve as an illustration.

Table 5.5 Natural Gas use at Oklahoma State University in Dth*

Fiscal Year	Power Plant (steam, chilled water, electricity)	Heating	Total
1999	726,946	159,155	886,101
2000	669,150	147,141	816,291
2001	769,043	161,654	930,697
2002	660,289	150,664	810,953
2003	701,164	152,605	853,769

Source: Stewart, J., 2004; *Dth = Decatherm (1,000,000 BTU)

Energy consumption is billed to the University for the Academic Buildings, but income generating buildings like the Student Union, Residential Life, Wellness Center, Food service, Athletics department, and others pay the bills individually. Since the academic departments are not billed individually, there is no direct incentive for them to conserve the energy.

The Building Control Management System invested over $2 million in the last 5 years for upgrades. Most of the campus with the exception of the Athletics, which have independent operations, is under its control. Future plans include a) unification of two software systems, b) integration of the lighting system within the Building Control

System, c) further increase in the safety and comfort of building users, and d) more efficient use of buildings.

The University Policy on Energy Management requires the heating season temperature in buildings to be 68° F and the cooling season temperature 78° F, but in practice because of comfort, the heating season temperature is usually set to 70°-72° F and the cooling season temperatures are usually set 72°-73° F.

Normally, air-conditioning is turned on after May first and is turned off after October first each year. Heating is provided from November through March each year. The exact day on which air-conditioning/heating will be started and stopped is dependent upon need and weather conditions.

The problem with the old heating, ventilation, and air conditioning (HVAC) systems is usually one large unit covers an entire floor of a building, and is regulated from one place. This means the whole floor needs to be cooled or heated to accommodate one or two persons (high per occupant costs, late at night and during weekends). New buildings and major renovations include state-of-the-art HVAC systems which are more energy efficient.

The old chiller plant has capacity of 12,000 tons. In 2000, a new, more efficient chiller plant was finished. The West Chilled Water Plant provides 4,000 additional tons of cooling capacity to handle campus loads. The facility will eventually have 16,000 tons of capacity. A cost-benefit analysis was not used to justify the project.

This year the Physical Plant will start with an upgrade on steam boiler controls (steam is used to heat campus, drive the power plant turbines and one chiller). This will enable more efficient use and a precise control, resulting in less gas will be used to produce the same amount of steam, and thus emissions and costs will be lower.

Lighting represents the major part of electricity usage. The Physical Plant started retrofitting T-12 fluorescent lamps with T-8 fluorescent lamps (T-8 fluorescent lamps are smaller, more energy efficient, have a longer life, and require less maintenance). Also T-8 lamps use electronic ballast so there is no heating from magnetic ballasts as was the case for the T-12 lamps. The retrofit project started three years ago, but there are over 600,000 lights[2] on this campus. If the University continues to finance this project at the rate of $200,000-$300,000 per year, the retrofit will not be completed before 2014. Up to April this year more than 16 percent of general university buildings have been retrofitted. The total cost of project is estimated to be around $3.5 million.

Measurements at OSU (Maxwell, T., 2004) have shown that T-8 lamps require 25 to 30 percent less electricity than the T-12 lamps. This estimate assumes 12 hours of use per day, and 5 days per week. Savings will increase if the lights are used longer that assumed. This is especially case with bathrooms and hallways, where lights are rarely turned off. In addition the electronic ballasts used with T-8 lamps have much smaller heat output compared with magnetic ballast used with T-12 lamps. Consequently, the buildings retrofitted with T-8 lamps use less energy for cooling. Even though, the T-8 lamps are more expensive than T-12 lamps, the payback is slightly over 3 years at OSU. One of the major advantages of T-8 lamps is that they have considerable longer life and better light output. The T-12 lamp loses 40 percent of light output after 3 years, but T-8 lamp loses only about 5 percent of light output after 5 years. Since the T-12's average life is 2.5

[2] this is an estimate based on estimated 8 mil sq-ft floor area, which multiplied with standard of 3 watt per square foot and divided by 40 watts per bulb gives above number (Maxwell, T, 2004)

years, and the T-8's average life is 5 years, maintenance and relamping costs are cut in half. The cost of labor to replace each lamp varies from $1.00 (when entire building is relamped at one time) to $5.00 (when only one lamp is changed). Changing all 600,000 lights on campus from T-12 to T-8 lamps will save between $1.2 and $6 million in maintenance costs over the 10-year period.

The Physical Plant is finishing a retrofit of EXIT signs from 14 W fluorescent lights to 2.2 W light-emitting diode (LED). LED lamps use about 80 percent less energy, have a life of 25-30 years, so maintenance and energy costs are minimal. The University apartments are retrofitted from incandescent to compact fluorescent on regular maintenance intervals when occupants leave the apartments.

Table 5.6 University buildings where the retrofit to T-8 lamps have been completed

	FY 2001	FY2002	FY2003	FY2004 (till March)
1	Whitehurst (not finished)	Life Science East	Library (3rd floor)	Morrill
2	Public Info Office	Life Science West		Gundersen
3	South Murray	Library (4th floor)		Architecture
4	North Murray	Physical Science I		Civil Engineering
5	Human Environ Sci	Physical Science II		Engineering South
6	Math Science			Engineering North
7				Cordell North
8				Cordell South
9				Business Build
10				Physical Plant Adm.

Source: Maxwell, T. (2004)

For a couple of years now, at the beginning of each semester 1 full-time employee and 2 part-time students go around campus and turn off the lights. At the beginning of the program, the University had $100,000 per year in savings.

The Physical Plant does not install halogen lamps, but they are allowed for personal use. However, the halogen lamps use a lot of energy (200-300 W) and present a fire hazard, but this has not yet been officially recognized at OSU.

The average computer systems use a lot of energy, first directly as electrical power (average of 150 W/h) and indirectly because of waste heat produced, additional energy is needed for cooling of computer labs. While most computers have activated energy savings option for monitors, there is no policy for turning off computers in offices and in computer labs over night or when not in use.

5.2 Economic Analysis of Potential Energy Management Program

5.2.1 Introduction

The Energy Management Programs have direct costs that are easy to calculate, but for the benefits the situation is slightly different. Net benefits of the energy management programs can only be assessed through evaluating a string of projects and activities performed or initiated by the energy manager. Each of those projects have their direct and indirect costs and benefits, and by performing analysis on each of them and then adding the net present values of the projects it is possible to indirectly assess the net contribution of the energy manager and the energy management program and thus answer the concern about lucrativeness of such program. Direct benefits will be calculated as a cost savings, while other benefits such as improved comfort, and productivity will be noted but not monetary expressed.

Examples of benefits of the energy management program are:

- The savings of energy costs over the ones that would have been incurred in a ‘do nothing’ situation
- Increased occupant comfort and productivity - improved indoor air and light quality benefits the health, morale, and productivity of faculty and students.
- Improved productivity with more efficient use of labor and skills.
- Environmental improvements (reduced greenhouse gases and other emissions, reduced use of nonrenewable natural resources) and other social benefits of cleaner air
- Through awareness and education programs, change of students’ attitudes towards energy conservation. Hopefully, the important result would be that a portion of students will implement them in their personal life after graduation
- Benefits for nation in conservation of limited resources and increased energy security.
- Benefits for the Earth in reduction of greenhouse gases and as a contribution to sustainable development

Evaluate Energy management programs for the period of the next ten years (2004-2014). This particular period was chosen to give enough time for energy management program to mature and establish itself as major contributor to cost savings with numerous initiatives and projects, but not too long to be considered irrelevant by today’s decision-makers.

It would be impossible to realistically recognize and evaluate all the projects and initiatives the energy manager might implement during this period. In the following pages I will attempt to evaluate only a handful of projects that will serve as an illustration and a template for future analysis.

As always when dealing with the future, uncertainty is inherent. The analysis will be based on a combination of past data, experience from other case studies and a number of assumptions. To account for such uncertainty a sensitivity analysis will be performed. A number of discount rates will be used to account for uncertainty: 3, 5, 7, and 9 percent. The five percent discount rate is the medium one and will be used as major rate.

5.2.2 External Costs of Energy Consumption

The reasoning behind including the social costs in cost of electricity is two-fold: the University is an educational institution, and as such it should educate the students about the consequences of the energy production and consumption and the real costs that society bears as a result. The second reason is that this University is a state institution and as such is ultimately responsible for its action, to the taxpayers and the wider community. The reduced consumption of electricity produced by the burning of fossil fuels and increased consumption of ‘renewable’ energy results significant reduction of social costs of energy production and consumption. Benefits of cleaner air can be felt across the society due to lower rate of illnesses, higher productivity, better quality of life, healthier environment, healthier food, and so on. The ultimate beneficiaries are the taxpayers and their families that the University is accountable to.

However, the current state of practice is such that not all social and environmental costs of energy consumption are included into the price of electricity. So, an attempt has been made to include estimation of external costs of electricity production and use, by using the ExternE data (see pages 28-29).

In order to simplify the calculations it has been assumed that for the next ten years the Euro will be on average exactly equal to the US dollar. External costs added to the electricity rate were conservatively chosen by taking the lower end data from table 3.2: $0.01 per kWh for natural gas and $0.03 for coal. Since OSU gets 45 percent of its electricity from a natural gas and 55 percent from coal, the total external costs added to the electricity rate are $0.021/kWh. In the period of 1999-2003 the average electricity rate (including the fuel adjustment cost and OSU power plant production) has been $0.050 per kWh, which with the addition of external costs totals $0.071/kWh. With inclusion of the environmental cost of using energy from fossil fuels, the rate equals the rate for the renewable wind energy. The wind energy when compared with energy derived from fossil fuel has negligible environmental and social costs (see table 3.2), so one of the goals in the next ten-year period should be to increase the percent of electricity from wind energy in order to lower the external social and environmental costs. However, in the analysis, both rates (with and without external costs) will be used in order to analyze the attractiveness of projects by conventional standards.

Table 5.7 Electricity cost for OSU in the last 5 fiscal years with inclusion of social cost

Fiscal Year	Total (kwh)	Cost ($)	Cost ($ per kWh)	Externality ($ per kWh)	Full Cost ($ per kWh)	Full Electricity Cost ($)
1999	136,268,690	5,969,533	0.044	0.021	0.065	8,831,175.49
2000	136,788,700	6,951,787	0.051	0.021	0.072	9,824,349.70
2001	143,067,100	7,815,118	0.055	0.021	0.076	10,819,527.10
2002	142,572,800	7,412,956	0.052	0.021	0.073	10,406,984.80
2003	136,009,667	6,424,873	0.047	0.021	0.068	9,281,076.01
Average	**138,941,391**	**6,914,853**	**0.050**	**0.021**	**0.071**	**9,832,622.62**

Source: calculations by author

5.2.3 Costs of an Energy Management Program

In this section only the direct cost and opportunity costs of people directly involved with energy management will be assed. Costs of changing attitudes and behavior are not assessed. Costs of individual projects are not assessed either.

The major group of costs will be borne by an energy manager. The position of the energy manager could be filled either by reorganization i.e. not increasing existing payroll costs or by creating a new position. In either case the energy manager position should be a full-time position in order to ensure continuity and constant focus on energy conservation at the University.

For the purposes of this analysis, it was assumed the position of energy manager will be filled by adding an energy manager to existing organization structure, thus increasing the Physical Plant’s payroll and office running costs.

Costs of the energy management program:

- The salary for energy manager would be, according to Jeff Stewart (2004) in the range of $45,000 to $60,000 per year plus benefits that presently are 38 percent on top of the salary. This makes total annual cost from $62,100 to $82,800.
- Overhead cost of running the office (PC, furniture, paper, telephone, copying, printing, heating, cooling etc.) are estimated to be in range of $7,000-$10,000 per year.
- Opportunity costs of energy management. While these costs will not result in direct net increase in payroll for the University, they represent the costs of time that members of the energy committee and action group could have been used to work on different issues.

Table 5.8 The work-hours associated with the energy management program

Action	Hours
Energy Committee 1st year 10 meetings (2-hour), 15 members	300
Energy Action group 1st year 10 meetings (2 hour), 5 members	100
Other tasks not included in specific projects (annual)	100
TOTAL hours in 1st year	**500**
Energy Committee 2-10 years 5, meetings, 15 members	150
Energy Action group 2-10 years 10 meetings, 5 members	100
Other tasks not included in specific projects (annual)	100
TOTAL annual hours in 2-10 year	**350**
TOTAL hours 1-10 years	**3650**

Source: calculations by author

If we assume the constant cost per one hour is $40, the opportunity labor cost associated with the development and implementation of EMS program for 2004-2014 is $146,000.

The summary of the energy management cost calculations for period 2005-2014 is presented in table 5.9. The table shows how the cost of having the energy manager on the payroll and an active energy committee and action group change when the different percentage of the annual salary increase is applied. The costs presented are discounted to present value. The number of discount rates, including 0 percent rate, have been used to examine how the discount factor influences the result (see Appendix C for more detailed analysis)

Table 5.9. Summary of energy management cost calculations for period 2005-2014

Annual salary increase:	0%	2%	4%
Discount rate:	-	-	-
0%	$1,074,000	$1,165,933	$1,268,191
3%	$916,851	$990,919	$1,073,074
5%	$830,396	$894,900	$966,313
7%	$755,726	$812,153	$874,504
9%	$690,910	$740,482	$795,156

Source: calculations by author

Before trying to assess the cost-effectiveness of the energy management program by examining some of the potential projects the energy manager might find valuable to implement, it would be useful to actually attempt to calculate the total energy cost for the University for the next ten years for the ‘do nothing’ case and then compare with the cost of energy management and see what is the minimum percentage the energy manager needs to reduce energy cost in order for savings to pay for the program cost.

Two of assumptions have been made for this calculation. First it is assumed that the University will not increase its size over the next ten years and that real energy costs will also be constant. If energy prices do rise, the returns from energy savings investments will be more favorable.

Table 5.10. Summary of total energy cost calculations for OSU for period 2005-2014

Annual change in price:	-4%	-2%	0%	2%	4%
Discount rate:	$	$	$	$	$
0%	116,118,415	126,749,905	138,579,620	151,740,818	166,380,176
3%	100,035,101	108,652,269	118,211,227	128,814,842	140,576,227
5%	91,131,565	98,666,348	107,007,509	116,242,049	126,465,565
7%	83,403,867	90,021,570	97,332,526	105,410,602	114,336,901
9%	76,663,046	82,500,179	88,935,657	96,032,427	103,859,554

Source: calculations by author

For the period 1999-2003 average energy cost was $13,857,962. Starting from there in the table 5.10 result of cost calculations is presented. The same discount rate has been used as in the previous table and the annual change in energy cost of -4 percent up to +4 percent has been also used. This negative change, or decrease in energy cost can come from deduction in actual consumption or from energy price decrease. Obviously, only actual consumption reduction has multiple advantages since it not only lowers the costs for the University, but also lowers the environment and human health costs.

The results in table 5.9 and table 5.10 allow us to calculate the cost of energy management as the percentage of total energy cost in period 2005-2014. The results of such comparison show that the cost of energy management represents only between 0.64

and 1.1 percent of the total energy cost. Even in the 'worst' case examined here, where the annual salary increase is 4 percent and annual energy bill decreases 4 percent the energy management represents only 1.1 percent of total costs. Table 5.11 has the percentages for 0 percent discount rate. The results for different discount rates vary slightly from the ones below.

Table 5.11. Energy Management as percentage of total energy cost in period 2005-2014 with 0 percent discount rate

Annual salary increase:	0%	2%	4%
Annual change in energy price	%	%	%
-4%	0.92	1.00	1.09
-2%	0.84	0.92	1.00
0%	0.77	0.84	0.91
2%	0.70	0.77	0.83
4%	0.64	0.70	0.76

Source: calculations by author

The question that needs to be answered next is "would the energy management program led by an energy manager in the next ten years be able to achieve such savings so that energy management program be cost-effective?" Out of so-called no cost and low cost activities the most important one would be the education program. During the next ten years, if taken seriously, raising awareness among staff, faculty, administration and especially students about energy issues combined with concrete 'how to' steps should result in behavior changes that can save at least one percent out of total energy cost, above the costs of such programs.

According to numerous examples, some of which were presented earlier (see chapter 2.2.), efficient energy management program is responsible for much higher percentage of energy savings. According to Turner and Capehart (2001) the typical savings through energy management are:

- Low Cost activities first year or two: 5 to 15 percent.
- Moderate cost, significant effort, three to five years: 15 to 30 percent.
- Long-term potential, higher cost, more engineering: 30 to 50 percent.

Those numbers show other energy management programs have been cost-effective even when not counting the environmental and health benefits of more efficient energy use.

5.2.4 Lighting Retrofit

From 2001 on, the Physical Plant's Electrical shop has been retrofitting the T-12 fluorescent lamps that use magnetic ballasts with more efficient T-8 lamps and electronic ballasts. If the University continues to finance the project with the $200,000 to $300,000 per year, the retrofit is planned to continue until 2014.

As part of the analysis of the present and planned projects, the energy manager should perform economic analysis of lightning retrofit in order to determine if the present practice is indeed the most cost-saving course of action that could be taken.

In the buildings where the retrofit is finished the achieved savings in lighting energy were in the range of 25 to 30 percent. Because of lower heat output of the electronic ballasts, compared with old magnetic ones, the lighting retrofit should lower the cooling requirements during the summer, but also slightly increase heating requirements during the winter. However, due to a deficiency in usable data for cooling and heating loads, the analysis will be conducted only for lighting savings. Additional benefits not taken into account include the significant savings in maintenance and relamping costs due to longer life of T-8 lamps and the fact that because of better light output it is possible to replace four T-12 lamps with three T-8 lamps without reducing the light level.

Lighting on average makes about 20 percent of electricity use in the United States (MnTAP, 2004), but universities like OSU where air conditioning is done through use of steam and chilled water generated by burning natural gas, lightning likely has a higher share of total electricity use. For the purposes of analysis the following numbers have been used: 27.5 percent lighting savings; lighting 30 percent of total electricity consumption and as result total electricity savings due to retrofit are estimated at 8.25 percent. Average electricity cost, without 'external' costs, for period 1999-2003 was $6,914,853.40 so the maximum savings from retrofit are $570,475.41.

The goal of analysis was to first find the Net Present Value (NPV) of retrofit if it is continued as planned, and then to compare it with the NPV of possibility that the University takes the loan or issues the bond in FY 2005 for $2,500,000 to pay for retrofit. The bonds are to be paid over 7 or 10 years with interest rate conservatively determined at 5 percent. Also, the calculation have been made for the case that the University decides to wait for better discount rate and raises bonds in FY 2008 with 3 percent interest rate. Besides the Net Present Value, the Internal Rate of Return on investment was calculated in order to get the discount rate that would have the value of the NPV to be equal to zero.

While retrofit has started in 2001 and has already generated the savings for the purpose of this analysis it is regarded as a separate project and is not considered. Several assumptions have been made in order to calculate the electricity savings. Average electricity cost for the last five years is taken to be average annual consumption for the next ten years. Resulting maximum savings of $570,475.41 or 8.25 percent of total electricity cost can be achieved only after the project has been finished. For the budget option the retrofit is estimated to be finished in 2014, so that would be the first year when the maximum savings will be achieved. Since the annual budget is estimated to be the same every year the savings from retrofit are also estimated to rise by 10 percent of the maximum savings in the next 10 years. For the bond issue of $2,500,000 the project is estimated to be implemented over two years so that in the first year 50 percent of the maximum savings is achieved and starting with the second year maximum savings are regularly achieved.

Bond payments are calculated using the MS Excel PMT function that calculates the payment for a loan based on constant payments and a constant NPV function that returns the present value of investment based on discount rate and a series of future payments and income.

The summary of results is presented in table 5.12 (Appendix D has more detailed analysis). As can be seen from the table the Net Present Value for OSU of all project alternatives, given the above-mentioned assumptions, is positive, but significant variations exist between the amounts of NPV for each alternative.

Table 5.12. Net Present Values of lighting retrofit

Discount rate	0%	3%	5%	7%	9%	IRR
Financing	$	$	$	$	$	%
Budget	637,615	425,404	315,743	225,887	152,104	15
Bonds issued in 2005 (paid over 10 years)	2,181,902	1,827,590	1,633,405	1,466,238	1,321,640	640
Bonds issued in 2005 (paid over 7 years)	2,395,170	1,897,550	1,633,405	1,411,763	1,224,945	98
Bonds issued in 2008 (paid over 7 years)	626,858	459,924	370,729	295,607	232,139	22

Source: calculations by author

The Net Present Value of financing the retrofit through annual budget contributions is the lowest. If instead, the University decides to use external funds like loans or bonds to cover the cost of retrofit, the project will be implemented much faster and consequently full savings could be utilized 9 years earlier then in the present case. The major benefit from such approach is that while the annual payment on a loan or bond with 5 percent interest would be $323,761 (for 10 years) or $432,050 (for 7 years), but with the estimated savings of $570,475, the financial obligations can be covered completely from the savings in operational budget without using the capital budget. There is no significant difference between payment plan over ten years or seven years, but if the University believes that assumed interest rate of 5 percent is too high and decides to wait for a couple of years until the interest rates fall to 3 percent, the maximum savings is going to be achieved later and consequently the Net Present Values are going to be significantly lower. The difference between NPVs for bonds raised in 2005 with interest rate of 5 percent and NPVs for the bonds raised in 2008 with 3 percent interest rate, illustrates the opportunity cost of savings lost while waiting for better interest rate.

If we include the 'external' costs into the calculation the average five-year cost of electricity becomes $9,832,622. By changing this amount, with all other variables unchanged, the maximum social benefits from lighting retrofit are $811,191, and consequently the social Net Present Value of the lighting retrofit increases significantly. In the table 5.13 comparisons of NPVs for OSU with social NPVs are presented (with 3 and 5 percent discount rate).

Table 5.13 Net Present Values of lighting retrofit with social cost

Discount rate	3%		5%		IRR
Financing	NPV for OSU ($)	Social NPV ($)	NPV for OSU ($)	Social NPV ($)	Including Social Costs (%)
Budget	425,404	**1,504,749**	315,744	**1,263,533**	42
Bonds issued in 2005 (paid over 10 years)	1,827,590	**3,764,094**	1,633,405	**3,377,523**	Indefinite
Bonds issued in 2005 (paid over 7 years)	1,897,550	**3,834,053**	1,633,405	**3,377,523**	1433
Bonds issued in 2008 (paid over 7 years)	459,924	**1,935,143**	370,729	**1,673,213**	63

Source: calculations by author

5.2.5 Vending Miser

Vending Miser is a very good example of a low cost project that an energy manager should pursue. Vending MI$ER, produced by Bayview Tech LLC, is an occupancy-based energy saving device. It reduces energy consumption by an average of 46 percent, translating into savings of $150 or more per year per machine, while maintaining the temperature of the vended product so the sales don't go down (Bayview, 2003). Vending Miser achieves this by using infrared motion sensor so that it powers down a vending machine when the area surrounding it is unoccupied and automatically powers up the vending machine when the area is reoccupied. Additionally, it monitors the ambient temperature while the vending machine is powered down. Using this information, it also automatically powers up the vending machine at appropriate intervals, *independent of occupancy*, to ensure that the vended product stays cold. Vending Miser reduces the maintenance costs and extends the life of the vending machine by significantly reducing the number of compressor cycles that are run (Bayview, 2003).

The Vending Miser has a five-year warranty. For this analysis, the assumption is made that after five years, the misers are completely replaced. From personal experience of the author, it is possible to install on average 6 vending misers per hour (including travel time). Analysis is performed for 150 vending machines. All other data needed for this analysis were taken from a model develop by Bayview Tech (see Appendix E for detailed analysis).

Total project cost is $27,100, and it would generate 54 percent savings in electricity consumption for vending machines and that would translate to annual savings of $14,040 (with rate of $0.05/kWh). The project has simple payback period of 23 months and the internal rate of return on investment of 101 percent for the next ten years. A summary of Net Present Values for OSU and social NPVs is presented in table 5.14

Table 5.14. Net Present Values of Vending Miser project

Discount rate	0%	3%	5%	7%	9%
NPV for OSU ($)	86,174	70,735	62,361	55,208	49,066
Social NPV ($)	145,130	121,026	107,886	96,616	86,902

Source: calculations by author

Net Present Values for the OSU are positive for all discount rates that were used, and it indicates that this project is cost-effective and should be implemented. Of course social benefits that include the benefits from reduced environmental and human health problems are even higher.

5.2.6. Computer use

Personal Computers, like lighting, represent a significant portion of campus energy consumption. Simpson W. (2001) calculated that a typical 150-watt personal computer system (CPU, monitor, and printer) uses 1,314 kilowatt-hours of electricity a year if left on continuously. To generate that much electricity, it takes the energy equivalent of more than 1,000 pounds of coal or 100 gallons of oil.

Enabling energy savings options on an Energy Star certified computers saves energy since such computers use fewer than 30 watts per hour when idle. Shutting off monitors and computers when not in use further increases savings, both in electricity and in cooling, since the unused computers will not be producing excess heat (PERC, 1995).

The energy manager, when addressing the issue of computer energy use could select two of different low or no cost approaches, one for computer labs, and one for private computers in offices, student rooms, etc. In cooperation with IT services and individual departments, the best policy for most labs could be that before the end of lab's operating time to request that students turn off the computers and lab assistants to turn off the computers nobody was using. In the labs open 24 hours a day it might still be appropriate to turn off all unused computers during the night and to put stickers on each computer asking students to turn them off when finished with their work. The energy manager could address the private computers energy use through awareness raising programs, by asking each student to install or enable energy management options on computers, cooperate with each department IT person so to make sure the energy management options are enabled and in use in computers in offices, and finally to remind people through flyers, stickers, etc. to turn off computers at the end of the workday or during the night.

In order to attempt to calculate the potential energy and costs savings that could be achieved through better practice we need to first estimate the total number of computers and separate them in different categories of use. However, Sheldon, M. (2004) from IT division at Oklahoma State University, said that since each department has their own inventory records and student personal computers are not recorded it would be almost impossible to know exactly the total number of computers on campus. However, the number can be estimated to be approximately 13,000 since that is the number of connected devices on the OSU network. For the purposes of calculating the potential savings it is estimated that there is 3,000 public computers in the computer labs and 10,000 private computers.

The detailed calculations for potential savings in electricity (reduced cooling costs are not considered) can be found in appendix F. In performing the calculations it was assumed that a standard computer runs at 150 watts when in use, and 30W when idle, given that the energy savings option is enabled. The electricity rate is 5 cents/kWh. If all 13,000 computers are left on 24 hours without enabling the energy savings options on computers it would result in annual electricity costs of $855,000. If we contrast this worst-case scenario with best-case scenario where energy savings option is enabled and average private computer is assumed to be on only for 8 hours a day in a seven day week, but used only for 4 hours and public computers are assumed to be on 16 hours a day and not used for 8 of those hours the cost for electricity drop to only $210,000 per year, a drop of $643,000!

However, since most public computers and at least some private computers have the energy savings option enabled, actual electricity costs are lower. The more realistic scenario representing the current state of practice would be to assume public computers are on for 24 hours, but idle for 12 hours on average, and private computers on for 24 hours and used for 8 hours, idle for 16 hours. In this case the electricity cost is much lower at $425,000. However, the costs could be still lowered significantly by 50 percent by strictly adhering to this more realistic-scenario. Savings of $214,620 dollars per year or over 20 million dollars in next ten years (given constant electricity rate of $0.05 per kWh and no discount rate) is not something that should be overlooked. Even if the best-case policies are not strictly followed, the savings should be substantial enough to justify the implementations of such measures.

When calculating the total social cost of electricity use, the potential savings from the more realistic scenario are around $300,000 per year! Of course, since the turned off computers do not produce waste heat, savings would be greater if we counted the net savings left after we contrast savings from reduced cooling costs during the cooling season with increased heating costs during the winter. Because the cooling season is longer than heating, savings from reduced need for cooling are assumed to be higher then increased costs from additional heating (Woodroof, E.A, 2001).

5.2.7 Costs and Benefits of Billing Each Building

The current state of practice is that buildings that generate a profit like the Student Union, Athletics, Residential Life, and others are billed individually for their energy use. For those buildings energy use is metered and billed accordingly. For the so-called general university buildings (academic part of the University), the energy cost is provided through the general University fund. Not all buildings have individual meters or they may have meters for electricity and chilled water, but not for steam, and vice versa.

The difficulty of measuring actual building consumption presents an obstacle for energy management. Accurate measurements help the energy manager and Physical Plant to identify problem areas and large energy users. The energy manager and other Physical Plant managers could devise detailed conservation strategies for the main energy users for each building category since those buildings have potential for greatest energy savings. Accurate measurements also enable the energy manager to measure the success of the energy conservation projects, by monitoring the changes in energy use for each building.

The data can be used, also, to further motivate the building users by publicly recognizing and awarding them for their efforts in energy conservation. Such measurements of the buildings energy consumption enable the energy manager to establish annual energy conservation competition among dormitories. Such competitions, that include the prizes and public recognition for the winners, are very good promotional tool for the energy manager to use to get cooperation from student population for the energy conservation measures. The actual savings from such competitions should not be expected to be great, especially in the first year, but nevertheless it could mark the beginning of the change in attitudes. For example, the Yale University had the most recent competition among dormitories. The competition that lasted for four weeks during the months of March and April 2004 resulted in less than 2.5 percent of savings in electricity use (Downing, T., 2004). Obviously, the savings are not big, but if we consider that it was the first such competition and that it was during the time when students are traditionally preoccupied with term projects and finals the results are not surprising. Probably the best time for such competitions would be in the middle of the fall semester. The added advantage is that the freshmen student population is then right from the very beginning of their college life exposed and educated about the energy conservation measures.

Another reason for metering the energy use for each building is that since colleges and departments are not directly billed for their energy use, there is no direct incentive for saving energy. It is human nature that if not charged directly for energy consumption we tend to factor the energy cost to be zero. This means that from users point of view there is no real difference between ‘saving’ and ‘wasting’ energy. The main question would be, “why should departments and individuals put all the effort”, a very real cost from users point of view, in saving energy since their effort will not be recognized and all the benefits will go to somebody else, in this case the University in general (very indirect benefit).

One way to address this would be to charge each building individually for the energy it consumes. Benefits of such a system would be that each college and department would be responsible for its energy use. If they see it is possible to save money on energy and then use the part of savings for things like better equipment, offices, visiting scholars, additional faculty members, and others that will help improve the quality of education and research, they will be much more willing to put an effort and mind toward energy conservation. In other words, direct billing should help the energy manager in changing attitudes towards energy conservation and getting wider support for projects. However, a part of the savings achieved in departments by implementing the energy management projects initiated by the energy manager and Physical Plant, should be designated for further energy conservation programs, so that it can develop and explore all savings opportunities.

However, the metering and direct billing each building has its costs also: metering the energy consumption of each building has the initial implementation costs but also increased maintenance costs due to the need for meter calibration and part replacement, and higher administration costs due to increased complexity of system. Metering should then be seen firstly as an enabling infrastructure, more than a cost saving measure (Downing, T, 2004) If the overall goal is to be energy efficient and not waste energy then metering, while by itself will not save money enables Physical plant to measure how much energy is saved and where and how to improve the savings levels.

5.2.8 Costs and Benefits of Changing the Temperature Settings

Because of the difference between the 1983 energy management policy that required summer temperatures to be as high as 78° F and winter temperatures as low as 68° F, and the current practice where the temperature is held around the 71°-73° F in the winter and 72°-73° F during the summer, there should be a review and a possible adjustment of temperature set points in cooling and heating seasons. Since in residential homes 3 percent of the energy can be saved during winter by lowering thermostat 1° F, and during summer 5 percent of the energy used by air conditioner can be saved by raising the thermostat by 1° F (Phillips Petroleum 1990), the energy manager with the Building Control group should study possibility of changing the temperature settings without lowering the comfort of building users, given that the users are dressed in accordance to the season and outside temperature.

If we assume that the above percentage savings for residential homes are applicable to the University, the savings that can be achieved are clear. However, the personal costs of the temperature being too low or too high are also very real, but harder to measure. A temperature that is set to high or to low for the season will result in increased discomfort and reduced productivity of building users, which defeats the purpose of energy management. The purpose of energy management is, as stated earlier, to explore and exploit the energy conservation opportunities without reducing the comfort of the occupants. It is clear that there is a limited window of opportunity for energy savings regarding temperature settings.

On the other hand, the concerns with overcooling or overheating the buildings are valid. If the users do not feel there is direct connection between how they use energy and the costs of energy use, there is possibility that they would require the temperature settings that result in increased comfort, even if it for example, means they can wear only T-shirts during the winter. However, if the departments and colleges are charged directly for the energy they use the question becomes: would the users be more willing to accept temperatures to be set a little higher for the summer and lower for the winter, if they see the direct link between saving energy and benefits they receive? The answer to this question requires careful research outside the scope of this study, and the question for the time being will have to stay unresolved.

5.2.9 Occupancy Sensors in Restrooms

Occupancy sensors have a potential to significantly reduce the electricity use by shutting off lights when area is unoccupied for a designated period of time. It should be noted that with reduced lightning usage, the light fixtures produce less heat (Kaya, D., 2003). However, in calculations presented here only the energy saved from lighting use reduction has been calculated, due to lack of data about the air-conditioning loads. Maniccia, D. et al. (2000) conducted an occupancy monitoring study, using buildings in 24 states owned and occupied by active participants in the EPA’s Green Lights Program. The study participants included profit, not-for profit, service and manufacturing companies, healthcare organizations, primary and secondary education institutions, and local, state, and federal government entities. The study evaluated energy use before and after occupancy sensors were installed with time-delays of 5-, 10-, 15-, or 20- minutes in restrooms, break rooms, classrooms, conference rooms, and private offices.

The average percentage of time restrooms were occupied was 20 percent, but lights were on for 24 hours per day. The study showed that restrooms have the highest overall potential for energy savings (between 47 and 60 percent). However, those percentages do not consider maintenance costs. When occupancy sensors are added, the lamp life decreases because lamp-switching frequency increases and therefore relamping costs increase too. The study showed that using occupancy sensors will slightly increase relamping costs, but despite the increase, the occupancy sensors can significantly reduce annual energy costs. When these two parameters are combined, the overall annual cost savings for restrooms were from 45 to 40 percent depending on time delay. So, the study clearly showed that despite increased relamping costs and decreased lamp life due to frequent switching, installing occupancy sensors saves lighting energy and reduces overall costs (Maniccia, D. et al., 2000).

Since the Maniccia, D. et al. (2000) showed that highest savings can be achieved in restrooms, the analysis of costs and benefits of installing the occupancy sensors in restrooms at OSU will be made.

The following assumptions were used:

- Lights in restrooms are on 24 hours a day, but are occupied for only 20 percent of that time.
- OSU has 200 buildings and each building has on average 5 restrooms: total is 1000 restrooms at the University.

- Valid concerns can be raised about lights turning off while people are still using the restrooms. Such concerns can be addressed by properly adjusting the time delay (the time between when sensor has detected the last motion and when the lights actually go off). Time delay of 15 minutes should provide enough assurance to users.
- 50 percent average cost savings (only lighting) with time delay of 15 minutes. For the same time delay with inclusion of increased maintenance costs the savings decline to 42 percent (Maniccia, D. et al., 2000). An alternative would be to duplicate the study for OSU and then use the real data.
- The cost of an occupancy sensor is $120 (Maxwell, T., 2004) with one year warranty.
- Labor cost $21 per hour (Maxwell, T., 2004).
- Implementation time: 3 hours per sensor (sensor installation, conduit and by-pass installation so if the sensor fails light can still be turned on).
- 3 light fixtures per restroom on average with 144 W per fixture.
- Electricity rate is constant at $0.05 per kilowatt hour.
- 1 occupancy sensor per restroom.
- Average life of sensor 4 years.

To calculate the simple payback for investment the calculations from Woodroof, (2001) were adapted for this particular situation:

1. Total KWh consumption before the occupancy sensors are installed.

KWh =

= (# restrooms)(#fixtures/restroom)(input watts/fixture)(1 kW/1000 W)(Total annual operating hours)

= (1000 restrooms)(3 fixtures/restroom)(144 watts/fixture)(1 kW/1000 W)(8760 hours/year)

= 3,784,320 kWh/year

2. Total Annual Dollar costs prior to installation of occupancy sensors ($/year)

= (kWh/year) (kWh cost)

= (3,784,320 kWh/year)($0.05/kWh)

= $189,216/ year

3. Total Annual Dollar savings if occupancy sensors are installed ($/year)

= (total $/year)(% cost savings)

= ($189,216/ year)(0.50)

= $94,608 / year

4. Implementation Cost

= (# Occupancy sensors needed)[(cost of occupancy sensor)+(installation time/room)(labor cost)]

= (1000)[($120)+(3 hour/sensor)($21/hour)]

= $183,000

6. Simple Payback

= (Implementation cost)/(Total Annual Dollar Savings)

= ($183,000)/($94,608 / year)

= 1.94 years

The installation of occupancy sensors, given that the above assumptions hold true, seems to have relatively low simple payback of 2 years. However, if only couple of assumptions are not correct (like number of fixtures per restroom, watts per fixture, or installation time) the payback period doubles to 4 years. Whether this would still be an acceptable payback, depends on the occupancy sensors average life, and the established policy at OSU.

The simple benefit-cost analysis was made by using the same assumptions as above, with exemption that average cost savings were only 42 percent instead of 50 percent to account for increased lamp maintenance costs (see appendix G). The calculated Net Present Values are positive for all discount rates used and Internal Rates of Return were 56 percent for OSU and 151 percent socially (see table 5.15), thus the project should be implemented. However, this analysis is very sensitive to changes in assumptions. Changing the average number of fixtures in restrooms from 3 to 2 with all other assumptions equal, would result in negative NPV. This sensitivity to changing assumptions requires careful evaluation of underlying assumptions. Further data gathering and study is needed.

Table 5.15 Net Present Values for bathroom occupancy sensors

Discount rate	0%	3%	5%	7%	9%	IRR
NPV for OSU	$245,707	$202,120	$178,017	$157,125	$138,930	56%
Social NPV	$579,484	$486,838	$435,751	$391,556	$353,137	151%

Source: calculations by author

5.2.10 Cost-benefit Ratio of the Energy Management program

In order to justify the need for the energy management program at the University, the overall costs and benefits have to be estimated. The costs of the energy management program can be easily calculated. Calculating benefits, on the other hand, requires double-step process. First, for each project the energy manager wants to implement, the costs and benefits have to be calculated. Second, the 'excess' benefits in the projects that have positive Net Present Values are added together and divided by overall costs of the energy management program. If this benefit-cost ration has a value equal or greater than 1 then the project is worthwhile. As a general rule, projects that benefit the University or any other entity should be implemented. Even though only three of a number of possible energy conservation projects have been presented, the benefit-cost ratio will be calculated for illustrative purposes.

Table 5.16 Summary of the energy management costs and benefits

Project Name	NPVs for OSU ($)	Social NPVs ($)
Energy Management Costs with 2 percent annual salary increase	(894,900)	(894,900)
Lightning retrofit (bonds issued in 2005 and paid over 10 years)	1,633,405	3,377,523
Vending Miser	62,361	107,886
Occupancy sensors	130,407	435,751
Total Benefits	1,826,173	3,921,160
Benefit-cost ratio	**2.04**	**4.38**

Source: calculations by author

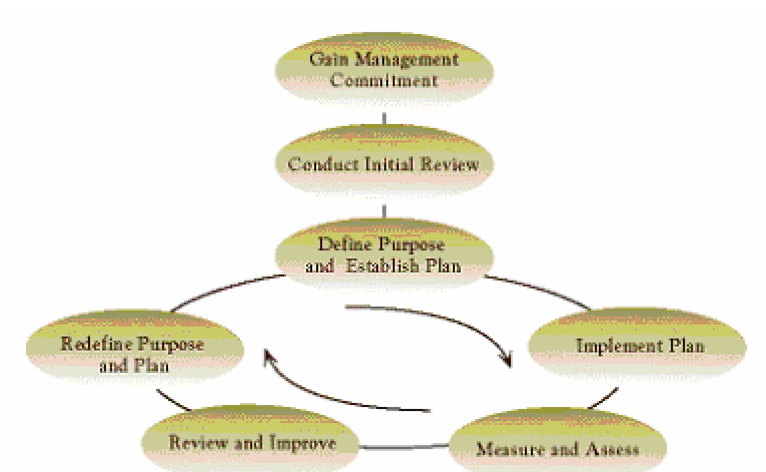
In such calculations the costs and benefits have to be calculated using the same discount rate. Results will be calculated using the discount rate of 5 percent, the mid-range rate used in previous calculations. Given that all the assumptions made during the calculation of costs and benefits hold, the results presented in the table 5.16 clearly indicate that the energy management program has positive benefit-costs ratio, even after considering only three potential projects.

CHAPTER VI

ENERGY MANAGEMENT PROGRAM: A PROPOSAL

One of the proven strategies for successful energy management is to design it around a continuous improvement strategy for management systems, (Energy Star, 2002). The continuous improvement model with its "plan, do, check, act" parts sees energy management as a continuous process that is regularly reviewed and improved. It enables energy management with the flexibility to adapt and respond efficiently to changing environments. This allows the University to utilize the energy conservation opportunities to the maximum.

Figure 6.1 Continuous improvement model



Source: Biggs, R. B., Nestel, G.K. (1996)

According to the continuous improvement model, BEE, (2003), and Mashburn W. H, (2001) the vital components of successful energy management are:

- Senior administration support.
- Energy policy, and strategy and implementation plan.
- Technical expertise for analyzing and implementing energy savings options.
- Effective monitoring system.
- Reporting and program reviews.

6.1 Administrative Support

If an energy management program is to reach its full potential and be taken seriously at all levels in the University, the support and active involvement of a university president and/or vice-presidents is a necessity (Simpson W., 2001).

One of the first steps senior administrators should do to show their support is to publish an energy policy. Another is to empower those given responsibility for implementing the energy management program (BEE, 2003). The evidence of administrative commitment will be seen in the level of support given to the committee and the manager. Having senior administration representative(s) participate in energy committee meetings or in other energy related activities could do this. Also, when valuing the energy conservations projects, OSU should apply exactly the same criteria as it applies for other investments. Of course real evidence of Administration's support is in the resources, such as manpower, and budget designated for energy management.

6.2 Energy Policy

Energy policy acts both as (BEE, 2003):

- A public expression of university's commitment to energy conservation and environmental protection, and
- A working document to guide and provide continuity to energy management practices.

OSU's Energy Management policy has been unchanged for 21 years. Since most of its requirements are not followed any more, it is possible to conclude that such policy on energy management actually represents a barrier to energy conservation.

One of the first steps in energy management at OSU should be to completely rewrite it and publish a new Energy Management Policy, either as part of Environmental Management Policy or as an independent policy. In any case the energy policy should include concrete, measurable goals. For example by 2015 OSU will consume 30 percent less energy per square foot than it did in 2004, and at least 10 percent of the energy used will come from renewable sources. Increasing the percent of renewable or 'green' energy will lower the environmental and human health cost (by-products of fossil fuel consumption) the University is responsible for. Furthermore, wind energy and especially geothermal energy (used for heating and cooling the buildings) are already competitive with more conventional sources of energy. Even though such goals may be ambitious, they are not unreasonable or unachievable. The additional cost of wind energy is less than the estimated externality cost of energy from coal and natural gas.

Green building practices besides benefiting the environment have been demonstrated to be very cost-effective (see Kats, G., et. al., 2003), so the Energy Policy should commit the University to incorporate green building practices in design of all new buildings and major renovations, possibly even seeking LEED green building ratings (see appendix I for proposed policies dealing with energy at OSU).

6.3 Energy Manager

In the initial stages of establishing an energy management system, the only thing more important than strong support from senior administration is the selection of the energy manager. Mashburn W. H (2001) states "every successful program has had this one thing in common – one person who is a shaker and mover that makes things happen. The program is then built around this person. Such person can then win over an initially skeptic administration."

Walter Simpson (2003), energy officer at SUNY Buffalo, recommends that the energy officer be a free agent who develops both large and small energy conservation projects, spearheads awareness efforts, and provides overall leadership to the energy program. The energy officer should be technically trained and competent. But he or she should also be an able manager, organizer, educator, and catalyst.

This is because while technical skills are a prerequisite in improving the energy efficiency, energy management is only partly technical and involves a combination of both managerial and technical skills. Managerial skills include bringing about awareness and motivating people at all levels, changing the structure and procedure, monitoring the energy consumption, and setting targets or norms. Both organizational and people changes are required (BEE, 2003).

For the energy management program to be successful, the energy manager has to involve everyone at the Physical Plant and in the whole university. Developing a working organizational structure may be the most important thing an energy manager can do (Mashburn W. H, 2001).

6.4 Energy Conservation Committee

An Energy committee is the core of the energy management program. It serves not only to supplement the skills of the energy manager (Mashburn W. H, 2001), but also as main body for communication and sharing of ideas throughout the University. The way to achieve this is to have representatives from the Physical plant, senior administration, key departments, faculty, staff and students, thus combining all the major constituencies of the University. The main criteria for the membership should be an interest in energy conservation. Other key ingredients listed by Walter Simpson (2001) include regular meetings, some form of institutional memory, and a subcommittee organization. To be effective, the committee will need to look wherever it wants in its quest to identify both problems and solutions. No area should be “off-limits.” For this the key is strong administrative support.

The Energy committee should set both long-term goals and annual goals. It should also prepare a plan of activities and a system for documenting and following the progress in achieving those goals.

The total skills needed for the committee, including the energy manager may be defined as follows (Mashburn W. H, 2001):

- Have enough technical knowledge within the group to either understand the technology used by the organization, or be trainable in that technology.
- Have knowledge of potential new technology that may be applicable to the program.
- Have planning skills that will help establish the organizational structure, plan energy surveys, determine educational needs, and develop a strategic energy management plan.
- Understand the economic evaluation system used by the organization, particularly payback and life cycle cost analysis.
- Have good communication and motivational skills since energy management involves everyone within the organization.

6.5 Energy Conservation Action Group

While the Energy Committee is dealing with strategies, education, and outreach, the Energy Action Group enables the Physical Plant staff to efficiently coordinate everyday tasks related to energy management programs. An Action group will translate the goals and objectives into an energy management action plan. Such a plan should hold answers to questions like: What needs to be done? Who will do it? When it will be carried out and completed? What resources are required? What financial resources are to be budgeted? (BEE, 2003)

6.6 Energy Audit

The Energy audit is one of the first tasks to be performed after the decision has been made to establish an effective energy management program. A campus wide energy audit is a detailed analysis of the current state of energy use & management. More importantly, the audit identifies possible areas for improvement and recommends the future steps for energy management. It is easy to see that an energy audit represents the key for decision-making and planning and a more efficient way of managing energy (BEE, 2003 and Capehart, B.L, Spiller, MB, 2001).

According to Capehart and Spiller (2001) the typical audit process would start by collecting and analyzing the University's past record of energy consumption and costs. An analysis should determine how the University uses and possibly wastes energy. Energy Conservation Opportunities (ECO) are then identified and assessed in term of their costs and benefits, and then they are ranked according to their cost-effectiveness. An final part of the energy audit is an Action plan that details the implementation plan for ECO's so that the actual process of saving energy and money can start.

The University could use graduate and undergraduate students from industrial engineering and management, civil and environmental engineering, and environmental science departments to perform an energy audit under supervision of the energy manager and the energy committee. The advantages of such an approach are multiple: students can perform audit for no or small compensation, and the training and experience fit the University's core function as an education institution. The audit represents very valuable practical experience for students, and can be performed as part of special course so students receive a grade. The energy audit should be performed every 3-4 years to establish new reference point. A comparison with results from previous audits can compare what was planned and what was actually achieved, and thus identify problem areas and needed improvements.

6.7 Energy Education and Outreach

A major part of the energy manager's job will be energy education and outreach to the whole university population. Mashburn W. H (2001) concludes that raising the energy education level throughout the organization can have big dividends. The program will operate more effectively if management understands the complexities of energy, and particularly the potential for economic benefit. The energy committee members will be more effective if they are able to prioritize energy conservation measures, and be aware of the latest technology. The quality and quantity of staff suggestions will improve significantly with training.

It is important the program raise the awareness among students of the importance of energy conservation and efficient use. It is also important to offer the opportunity for students to take an active role in energy management as part of energy committee or as energy audit team members.

One of the best ways to promote an energy conservation program is to publicize it. Some of the ways to do it are (BEE, 2003):

- Signs and posters raising awareness of the importance of energy efficiency cost control, and environmental conservation be displayed in the classrooms and offices.
- Progress charts showing targets and achievements.
- Energy conservation stickers on light switches and thermostats.
- Information on bulletin boards (at each building publish the energy cost for that building).
- Articles in the O'Colly and other OSU publications.
- Publish achievements in energy management outside the organization, for example taking part in EPA's Energy Star program or in National Wildlife Federation's Campus ecology program.
- Recognize the extraordinary individuals, and departments for their effort to conserve energy.
- Institute energy conservation competition among dormitories. Have awards for the winning dorm and for the best coordinator.
- Publicize current trends in energy use per student.

6.8 Investments and savings

In the first couple of years while the energy management program is still a novelty at the University, it would be good to concentrate on highly visible projects that attract attention to the issue, but have low cost to medium cost, and do not require a lot of new expertise and technical knowledge that OSU does not already have.

Important exceptions to this concentration on low and no cost activities should be made for existing projects. When the cost of delaying an energy conservation project substantially reduces its benefits, measures should be taken to speed its implementation. The cost of delaying a project should always be taken into account because delaying the project implementation also delays the point at which energy savings can begin (ENERGY STAR, 2002).

An example of an existing project that should definitely be implemented more rapidly than the planned 10 years is the lighting retrofit. If the University decides to issue bonds to finance the project so it can be finished in one or two years instead of ten, savings from this program will be so high that they can pay for bond payments without using the capital investment funds. This makes for a great advantage of energy efficiency equipment from other capital equipment. Because the dollars saved by installing energy efficient equipment can be used to pay for its financing, this equipment can be installed without having to increase operating costs or use precious capital budget dollars (ENERGY STAR, 2002).

In the first years of the program, University could assign a proportion of energy savings back to energy management budget to be used for paying for additional conservation projects. The reasoning behind this request is that after usually after implementation of low to medium energy savings projects, the University is going to make considerable savings at little cost, except for the funding needed for energy manager (BEE, 2003). If part of these easily achieved savings are not returned to energy manager's budget, then his/her access to self-generated investment funds to support future activities will be lost. And later in the program, it is likely to be much harder for the energy manager to make savings without significant investment. So the main benefit is on the independence and longevity of the energy management program (BEE, 2003).

One way to avoid hitting the wall after the program has matured and exploited the easier, less costly savings opportunities, is for the University to consider going into long term, 5-10 year performance contract with Energy Service Companies (ESCO).

According to Turner, and Capehart (2001) ESCOs provide the auditing, energy and economic analysis, capital and monitoring to help other organizations reduce their energy consumption and reduce their expenditures for energy services. By guaranteeing and sharing the savings from improved energy efficiency and improved productivity, both groups benefit and prosper.

Under a performance contract, the ESCO insures that the actual energy savings will match the projected savings, and the contract identifies the procedures by which these savings will be measured and verified. In a Guaranteed Savings Agreement the ESCO or an insurance company, who agrees to reimburse the sponsoring organization for any shortfalls, guarantees performance of the equipment (ENERGY STAR, 2002). By doing this, performance contracting through an ESCO transfers the technology and management risks away from the end-user to the ESCO. Additional benefit is that universities get the energy conservation programs in place by paying for it out of guaranteed savings, not from capital expenditures. Performance contracts are treated as an operating expense, not capital.

CHAPTER VII

CONCLUSIONS

Energy conservation first entered the minds of people during the oil crisis in the 1970s is once again becoming important issue in debate concerning the energy policy. On the national level main benefits of energy conservation are the reduced reliance on imports of fossil fuel, and a healthier environment. On the local level universities are also finding that they can do the ‘right’ thing, i.e. conserve energy for betterment of community, while enjoying significant savings without sacrificing comfort and productivity of students and faculty members.

By using the Oklahoma State University’s main campus as case study, the steps that should be made in order to establish a successful energy management program were explored. The economic analysis of costs and benefits of such potential program was then performed. The analysis showed that energy management costs over the next ten years would be less than 1 percent of total energy cost in the same period. The experiences of institutions described in Green Investment, Green Report by the National Wildlife Federation and throughout this study, that have energy management programs in place have shown that the significant energy costs savings can be achieved during the ten-year period. While each situation is different, those experiences suggest that energy management programs are highly beneficial for the universities.

An attempt has been made to include the social and environmental costs of energy production, distribution and consumption. Those costs only partly cover the costs of electrical generation on the environment and health of the end users. The approximation of full ‘external’ costs is added directly to the unit price of electricity. It has resulted in increase in the energy costs, and consequently the increase of benefits of energy conservation. However, an accounting for full environmental costs is not mandated by law or regulation. Ignoring the ‘external’ costs might seem more reasonable, but the University, which, by its very nature of educating students and performing research concerned about betterment of the future, should apply the long term, sustainability driven approach in all its operations. Such an approach would require the University, which is also public institution to be concerned about the present and future state of community and its individual members.

There are numerous ways for this University to incorporate the sustainability and social responsibility into its policies and actions. Incorporating the ‘external’, ‘social’ or ‘environmental’ costs of energy consumptions into economic analysis and supporting even the conservation projects that are profitable only when full costs are considered, is a way the University would make a first major step on the road towards sustainability. Calculations for the energy management project showed that direct costs of salary of energy manager and work-hours of committee members directly involved in energy management program could be easily calculated. The benefits of energy management program are not as easily calculated, but it was shown that savings from adoption of only three minor projects would more than cover the costs.

In order to justify the establishment of proposed energy management program and creation of position of energy manager as program leader, the benefits and costs analysis of each energy management project have to be performed. The sum of discounted benefits of all individual projects is then to be divided by the discounted sum of energy management costs in order to get a benefit cost ratio. The estimated benefit-cost ratio is above 2.0, thus it would be safe to conclude that the energy management program would be successful and beneficial for the University.

If taken individually, projects listed in Appendix B and presented throughout this study can be more or less easy implemented through existing management structure without creating new management position. However, exploiting all possible projects in order to achieve maximum savings would, most definitely, require the constant attention, vigilance and enthusiasm that cannot be achieved by adding yet another responsibility to existing Physical Plant personnel. Constant focus and effort on finding new and exploring existing energy conservation opportunities can be achieved only through the full-time position of an energy manager and energy management program that has public support of Senior Administration. The main points of such potential Energy management Program headed with Energy Manager are as follows:

1. Development of new university policies as basis of Energy Management:
    a. Energy Management Policy – completely updated and expanded with concrete goals and objectives (example: in 2015, 30 percent less energy consumption per square foot, 10 percent energy to come from renewable sources (wind, geothermal and solar).

   b. Green Building Policy – University's commitment for designing all new buildings and major renovations by following LEED green building rating requirements.

2. Establishment of Energy Manager Position to coordinate and lead all energy management activities.
3. Revitalization of the Energy Conservation Committee to steer the program and provide access and input from all part of the University. The Committee should include representatives from Physical Plant, Administration, faculty, staff, and students.
4. Formation of an Energy Conservation Action Group as an inter-Physical Plant group that coordinates all everyday activities related to energy management.
5. The Energy Manager should document and regularly publicize achievements.
6. Perform an energy audit every 2 to 3 years to get a detailed analysis of current state of energy use and management, and to specifically identify possible areas available for improvement and recommend the future steps. Graduate and undergraduate students should conduct it as part of special practicum or capstone course.
7. Set annual, easy to track quantifiable goals. Prepare detailed plan of activities, and system for documenting and following the program.
8. An important part of the program is raising the awareness of energy issues among students, but also to offer an opportunity for students to learn by taking an active role in energy management as end users and as members of energy committee or as energy audit team members.
9. Educate administration, faculty, and staff about the conservation opportunities.

10. For the first 3-4 years, the Energy Management Program should concentrate on low-cost to medium-cost investments, and high cost investments with high returns that have paybacks (or ROI) in short/medium range and that do not require a lot of new outside expertise and technical knowledge.
11. Senior Administration and OSU Regents should accept that part of the savings made as result of energy conservation activities are reinvested in additional energy conservation programs in order to enable energy manager to develop projects that are still lucrative, but have longer paybacks. Without reinvesting part of savings back into conservation projects the energy management program would be, after certain point, limited in its success and the University would loose an opportunity to maximize the savings.
12. After the program has matured and exploited all low cost conservation opportunities, the University should consider partnering with Energy Service Company (ESCO) into 7 to 10 year long performance contract. Benefit of such contracts is that universities get the energy conservation projects in place without out-of pocket money (through bonds or tax-exempt lease purchases), but pay the rates through savings achieved for duration of contract, after the contract have been fulfilled university keeps whole savings. (ESCO usually guarantee the minimum level of annual savings).

7.1 Limitations of the Study

An important limiting factor in this study has been the lack of established baseline data. In order to develop and calculate the examples, number of assumptions had to be made.

The results of such calculations are, therefore, sensitive to the validity of assumptions and their changing nature.

Due to lack of data, the cost and benefit calculations did not include the savings in cooling and heating that are by-products of presented energy conservation projects. Most of the calculations did not include the savings from lower operation and maintenance costs achieved through implementation of conservation programs. If those savings were included the Net Present Value of the project would be even higher. This is likely to be solved only when full energy audit is performed.

The size of the University campus was assumed to be fixed. However the University will probably expand significantly in both size and number of buildings in the next ten years in order to accommodate the expected increase in number of students.

Most calculations use a fixed price for electricity or energy. However these values are subject to change over time. The estimates of external costs of electricity production were taken from the European Union's project ExternE, since no comparable study in US was found. The only attempt to account for possible differences in effects, regulations and technologies used was to use low value of the ExternE cost for calculations in this study. While the social costs of using electricity were estimated, the social costs of producing steam and chilled water by burning natural gas were not estimated due to lack of data. Of course, the underlying limitation was the extent of creative capabilities and expertise of study author.

7.2 Recommendations for the Future Study

There is a pressing need to calculate costs of changing the attitudes and behaviors of energy users at Oklahoma State University, in order to get a complete list of all the costs and benefits of the energy management program. Since the energy management program will only be successful if the students, faculty, and staff accept the changes, the study is needed in order to identify the changes that are acceptable to users, the ones that are not, and the reasoning behind the both. This data can be used then to help the energy manager design an effective energy management program. Such a program can only be developed after the baseline has been established though the energy audit. At Oklahoma State University, an energy audit has not been conducted for at least 15 years, so there is a great need for one. The costs and benefits have to be calculated for a number of other energy management projects, some of which are listed in appendix B, in order to get the total costs and benefits of the proposed energy management system. The costs and benefits should, also, be calculated on per student basis where appropriate. The results of these calculations and all other accomplishments should be promoted in the University and also through professional organizations like the National Wildlife Federation's Campus Ecology Program.

The further study is needed to calculate the costs and benefits of developing a comprehensive environmental management system for Oklahoma State University. Such a comprehensive management system would encompass, not only the energy management, but also solid waste management, hazardous waste management, water management, recycling, purchasing policies, landscaping, and other greening initiatives.

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Appendix A – University Policies on Energy Management

1. Existing Energy Management policy at OSU (OSU, 1983)

POLICY

1.01 Space conditioning and lighting shall be set so as not to interfere with a person's productivity. Those levels have been determined and are specified below.

1.02 Obviously, it is impossible to maintain equal temperatures in all rooms, but none of the temperatures should fall outside the specified range. If they do, the Building Energy Representative should call Physical Plant to have the situation remedied.

PROCEDURE

Space Temperatures

2.01 Space temperatures in University buildings will be maintained at 68°F minimum during the heating season and 78°F maximum during the cooling season. Heating and cooling systems within each building will be adjusted by Physical Plant employees if winter temperatures for any space drop below 68°F and if summer space temperatures exceed 78°F for any given space. This means that all space should consistently fall within this range. If not, please call your Building Energy Representative.

2.02 Computing and research equipment may require special conditioning. Contact the Energy Management Coordinator for details. The University Library shall be maintained to keep relative humidity between 45% and 55%.

2.03 During official University holidays (and the weekend either immediately following or preceding the holiday) building temperatures shall be allowed to drop to 55°F, during the heating season or rise to 85°F, during the cooling season. Special consideration will be given to environmentally critical areas.

2.04 The heating or cooling systems will be turned on each morning early enough to allow buildings to reach proper temperature by 8:00 a.m. on regular working days.

2.05 Certain auxiliary enterprise buildings, such as the Student Union and single student housing, are operated on a self-sustaining basis, i.e., revenues from operations must cover costs. Consequently, we do not control their temperatures. They are set by the management of that building.

Determination of Room Temperature

2.06 Reasonable accuracy will be maintained. Tampering with the thermostats will not be permitted. Temperatures and relative humidity may be measured directly as an option.

2.07 Room temperature may be determined by a thermometer within 24 inches of the thermostat, or average readings of thermometer 24 inches from center of each external wall and at the center of room, or with no external walls at the center of the room. (All measurements taken at thermostat height.)

2.08 For the situation of multiple rooms with one thermostat, the temperature will be measured in the room with the thermostat or any other room in the zone if it is the room with highest temperature when cooling or the room with lowest temperature when heating.

Portable Electric Heaters

2.09 Portable electric heaters or any other energy consuming warming devices are not to be used without approval from the Energy Conservation Committee or the Energy Management Coordinator. Approval may be obtained for reasons similar to the following examples:

(a) A person required to work overtime during a period when the building's heat is to be set back (holidays, weekends, etc.) may use auxiliary heat.

(b) Documented medical needs (see paragraph 2.18).

2.10 Unauthorized heating devices may be confiscated. Fuel burning devices are not to be used. These devices are prohibited by local and state fire codes.

2.11 Window Air Conditioners - Additional window air conditioners will not be installed in University buildings. Existing window air conditioners will be phased out as soon as possible. Exceptions to this policy must be approved in advance by the Energy Management Coordinator or Energy Conservation Committee.

2.12 Ventilation - Windows should not be open when buildings are being heated or cooled.

2.13 Blinds/Shades - Close blinds and shades on sunlit windows during the cooling season (east windows during morning hours and west windows during the afternoon). Close east blinds at night to reduce morning heat gain. During the heating season, close blinds and shades at night to reduce heat loss.

2.14 Lighting - Lights should be turned off in any unoccupied space.

2.15 Domestic Hot Water - No hot water will be supplied to lavatories in public restrooms. Hot water supplied to laboratory sinks, custodial sinks, etc., will be heated no higher than 105`F. Higher temperatures will be allowed for special requirements such as dish and glass washers, sterilizers, etc.

2.16 Auxiliary Fans - Ventilating or free standing fans may be used at any time to increase comfort levels within a space.

2.17 Classroom Scheduling - Scheduling of space shall first utilize all available areas normally conditioned as a part of a larger area. After all such areas have been filled, new zones may be opened and conditioned for use as required. Special needs requiring specific facilities will be accommodated.

2.18 Medical Exemptions - The use of low wattage, thermostatically controlled, electric heated floor mats for persons with documented medical needs will be allowed. Authorization for use must be obtained from the Energy Conservation Committee or the Energy Management Coordinator.

Approved by Energy Conservation Committee: January 1983

Approved by Executive Group: February 7, 1983

2. Proposed polices[3]

Oklahoma State University Energy Policy

Oklahoma State University is committed to continually improving its performance in energy management in all areas of operation. Oklahoma State University is pursuing increased energy conservation, which will result in both cost savings and decrease in environmental impacts associated with energy production and consumption.

The University will:

Create and maintain Energy Management program to enable on-going progress in the energy efficient operation of our campuses.

Adhere to principles of green building design for all new construction and major renovations.

Purchase only energy efficient equipment, consistent with performance and durability.

Maintain or establish energy conservation and efficiency as priorities in facilities maintenance and operation.

Consistently implement University heating and air conditioning policies.

Identify and implement in-house energy conservation projects paid for out of University operations budgets.

Evaluate prospective energy conservation and efficiency capital improvement projects on the basis of life cycle cost-benefit analysis.

[3] Proposed policies presented here are based on policies of SUNY at Buffalo, Yale University, University of British Columbia, and OSU Energy Management Policy

Explore methods for redirecting some portion of energy conservation dollar savings to fund additional conservation measures.

Utilize creative funding mechanisms and energy service companies to accelerate action on larger energy conservation and efficiency projects, which can pay for themselves.

Continue efforts to raise energy awareness on campus.

Minimize SO_X, NO_X and CO_2 emissions from campus fossil fuel burning equipment.

Explore and act on opportunities to purchase clean, renewable power.

Provide support for clean energy research on campus.

Provide support for community-based clean energy initiatives.

Our campus energy goals will be to:

1. Reduce campus energy consumption per square foot by an 30% by the year 2015
2. Use at least 10% of renewable energy by the year 2015.

Energy Management Program Implementation:

The Energy Management Program shall be administered through Physical Plant.

The Energy Manager reporting directly to the Associate Vice President for Physical Plant, and working with all sectors in the University is responsible for carrying out the Energy Management Program.

The Energy Manger will establish Energy Committee with representatives from administration, faculty, students and staff. Energy Committee purpose is to help develop strategic plans, advise the Energy Manager on the operation of the Energy Management

Program, provide assistance on specific tasks when needed, and act as a strong voice in support of energy conservation measures.

The Energy Manger will establish Energy Task Group with relevant Physical Plant personnel as members. The purpose of Energy Task Group is to coordinate the implementation of energy management program among various Physical Plant departments.

Energy Manager shall provide for energy training and awareness programs at all levels of the University.

Energy Manager shall keep the Associate Vice President advised of all efforts to increase energy efficiency at University.

Energy committee and senior administration will perform regular annual reviews of Energy Management Program as part of University's commitment to continual improvement expressed in this policy. It is the responsibility of Energy Manager to prepare the required reports for such review.

Heating and Air Conditioning Policy

The heating or cooling systems will be turned on each morning early enough to allow buildings to reach proper temperature by 8:00 a.m. on regular working days

Heating or cooling for academic program purposes will be provided on weekends and off-hours as needed. The Action Desk should receive requests for off-hour/holiday heating by 12:00pm of the proceeding business day.

The Physical Plant will utilize the most energy efficient means of supplying heat for the approved off-hour/holiday requests.

Due to an inability to precisely control temperatures, it may be the case that some spaces may be warmer than others. In those situations, Physical Plant will permit the use of portable space heaters.

Portable electric heaters not authorized by Physical Plant will be confiscated.

Ventilation - Windows should not be open when buildings are being heated or cooled Ventilating or freestanding fans may be used at any time to increase comfort levels within a space.

OSU Standards for Space Heating and Cooling

	Summer Occupied	Summer Unoccupied	Winter Occupied	Winter Unoccupied	Winter Recess	Relative Humidity
Dormitory	73-76° F	HVAC-Off Temp. up to 80 ° F	70-73° F	65-68° F night setback	60° F T-setback	N/A
Classroom	73-76° F	HVAC-Off Temp. up to 80 ° F	70-73° F	65° F night setback	60° F T-setback	N/A
Offices	73-76° F	HVAC-Off Temp. up to 80 ° F	70-73° F	65° F night setback	60° F T-setback	N/A
Laboratory As req'd	73-76° F	78-80° F night setback	70-73° F	65° F night setback	60° F T-setback	50% RH
Library	73-76° F	N/A	70-73° F	N/A	N/A	45-55% RH
Book stacks	70° F	70° F	68° F	68° F	68° F	50% RH
Dinning Halls, etc.	73-76° F	HVAC-Off Temp. up to 80 ° F	70-73° F	65° F night setback	60° F T-setback	N/A

Halogen Lamps

The OSU energy management program actively discourages the use of halogen Torchiere-type floor lamps. These lamps draw 200-300 watts of electrical power, many times that of conventional incandescent or overhead fluorescent lighting. Moreover, due the temperature of the halogen bulb, halogen fixtures pose a fire risk. They are illegal in all campus buildings.

Computer policy

Leaving a 150-watt computer operating continuously for one year uses an amount of energy equivalent to a 1,000 pounds of coal or over 100 gallons of oil. That translates into a lot of pollution, health and environmental costs. Furthermore, it costs the University over $75 a year per computer in electricity and additional cooling costs.

Office use

University asks everybody to help lower the energy consumption by not leaving computers on continuously. To save energy, enable power management features so your computer saves energy when on. And please turn off your computer at the end of working day and over weekends.

Computer Lab Use

On all computers power management features have to be enabled. In addition in computer labs that are not operating 24/7, computers must be turned off before closing. In computer labs that are operating 24/7 will, after determining the use during the night and weekends, designate the optimal number of computers to be turned off during the times of low use (nights and weekends).

Appendix B - Examples of Low to Medium Cost Projects

- Energy Audit.
- Computer operations and green computing policy (Activating Energy Star features on electrical equipment, turning them off when not needed).
- Develop equipment energy efficiency purchasing standards.
- Review of heating and cooling season temperature settings.
- Review of building HVAC and fan schedules, review of night setback.
- Instituting temperature setbacks during breaks, if needed.
- Synchronizing heating and cooling systems so that they do not run simultaneously in the same room.
- Ban of halogen lamps.
- Outreach Program Promoting Energy Efficiency: develop OSU’s energy conservation website, establish cooperation on conservation with staff within the Physical Plant, with student groups, with faculty and staff and with outside organizations.
- Initiate inter-dormitory or inter-building competitions for energy efficiency.
- Develop Energy conservation practices for residence halls and student apartments.
- Offer incentives for students to buy Energy Star appliances for their dorm rooms.
- Improve heating and insulation system of dormitory rooms.

- Install motion and daylight sensors in campus bathrooms, classrooms, and offices and possibly even hallways (saves 25-50% of electricity, up to 75% in bathrooms, not counting lower cooling load).
- Replace all regular showerheads with low-flow aerated showerheads. Low-flow showerheads cut water use up to 50%, and thus lower the cost of heating the water.
- Vending Mi$er – energy saving device for vending machines that, if installed would save OSU over $14,000 a year in electricity (not counting lower cooling cost during summer) with simple payback in less than two years.
- Spectrally Selective Window Film – by enhancing the ability of existing glass to significantly reduce solar heat gain during the summer, and by insulating against heat loss by as much as 15 percent it helps save the energy all year round, all without darkening building interiors or changing a building's aesthetic appearance. Film can be applied on the interior of existing glass window thus significantly lowering the installation labor costs.
- Green design for new construction and major renovations, also at least one person at Physical Plant LEED certified, thus eliminating charges to the projects by outside consultants.
- Incorporate passive solar design in the construction of new buildings, use geothermal for HVAC systems.

Appendix C – Calculations of Cost of Energy Management Program

Cost of Energy Management Program

Discount Rate 5%
Cost per hour is $40
Annual Salary Increase 4%

Year	EM salary + benefits	Office costs	EC meetings	EAG meetings	Other hours	Annual costs	Discount factor	Discounted costs
2005	$82,800	$10,000	$12,000	$4,000	$4,000	$112,800	0.95238	$107,429
2006	$86,112	$10,000	$6,240	$4,160	$4,160	$110,672	0.90703	$100,383
2007	$89,556	$10,000	$6,490	$4,326	$4,326	$114,699	0.86384	$99,081
2008	$93,139	$10,000	$6,749	$4,499	$4,499	$118,887	0.82270	$97,808
2009	$96,864	$10,000	$7,019	$4,679	$4,679	$123,242	0.78353	$96,564
2010	$100,739	$10,000	$7,300	$4,867	$4,867	$127,772	0.74622	$95,345
2011	$104,768	$10,000	$7,592	$5,061	$5,061	$132,483	0.71068	$94,153
2012	$108,959	$10,000	$7,896	$5,264	$5,264	$137,382	0.67684	$92,986
2013	$113,318	$10,000	$8,211	$5,474	$5,474	$142,477	0.64461	$91,842
2014	$117,850	$10,000	$8,540	$5,693	$5,693	$147,777	0.61391	$90,722
Total						**$1,268,191**		**$966,313**

Total Energy Cost for Oklahoma State University, Stillwater			
Annual change	4%		
Discount Rate	5%		
	Total Energy cost	Discount factor	Discounted Energy cost
2005	$13,857,962	0.95238	$13,198,059
2006	$14,412,280	0.90703	$13,072,363
2007	$14,988,772	0.86384	$12,947,865
2008	$15,588,323	0.82270	$12,824,552
2009	$16,211,855	0.78353	$12,702,413
2010	$16,860,330	0.74622	$12,581,438
2011	$17,534,743	0.71068	$12,461,614
2012	$18,236,133	0.67684	$12,342,932
2013	$18,965,578	0.64461	$12,225,381
2014	$19,724,201	0.61391	$12,108,948
Total	**$166,380,176**		**$126,465,565**

Appendix D – Calculations of Net Present Value for Lighting Retrofit

Lighting retrofit

Lighting savings (25%-30%)			27.50%	
Lighting % of Electricity			30.00%	
Total electricity savings			8.25%	
Average El. cost 1999-2003			$6,914,853.40	
Max annual electricity savings			$570,475.41	
Annual budget 2005-2014			$250,000	
Discount Rate	5%			
			IRR	**15%**
			NPV for OSU	**$315,743.74**
	Fiscal year	Available budget cost	Annual Savings	Savings - costs
1	2005	$250,000.00	$57,047.54	($192,952)
2	2006	$250,000.00	$114,095.08	($135,905)
3	2007	$250,000.00	$171,142.62	($78,857)
4	2008	$250,000.00	$228,190.16	($21,810)
5	2009	$250,000.00	$285,237.70	$35,238
6	2010	$250,000.00	$342,285.24	$92,285
7	2011	$250,000.00	$399,332.78	$149,333
8	2012	$250,000.00	$456,380.32	$206,380
9	2013	$250,000.00	$513,427.86	$263,428
10	2014	$250,000.00	$570,475.41	$320,475
		$2,500,000.00	$3,137,614.73	$637,615

Lighting retrofit				
Lighting savings (25%-30%)		27.50%		
Lighting % of Electricity		30.00%		
Total electricity savings (%)		8.25%		
Average El. cost 1999-2003		$6,914,853.40		
Max annual electricity savings		$570,475.41		
Annual budget 2005-2014		$250,000		
Bond or loan raised 2005		$2,500,000		
Implementation 2 years: 50% in 2005, 100% in 2006				
Discount Rate		5%		
Interest Rate		5.0%		
			IRR	**640%**
Paid over 10 years			**NPV for OSU**	**$1,633,404.91**
Fiscal year		Bond payments	Annual Savings	Savings - payments
1	2005	($323,761.44)	$285,237.70	($38,524)
2	2006	($323,761.44)	$570,475.41	$246,714
3	2007	($323,761.44)	$570,475.41	$246,714
4	2008	($323,761.44)	$570,475.41	$246,714
5	2009	($323,761.44)	$570,475.41	$246,714
6	2010	($323,761.44)	$570,475.41	$246,714
7	2011	($323,761.44)	$570,475.41	$246,714
8	2012	($323,761.44)	$570,475.41	$246,714
9	2013	($323,761.44)	$570,475.41	$246,714
10	2014	($323,761.44)	$570,475.41	$246,714
		($3,237,614.37)	$5,419,516.35	$2,181,902

Lighting retrofit

Lighting savings (25%-30%)		27.50%		
Lighting % of Electricity		30.00%		
% Electricity savings		8.25%		
Average El. cost 1999-2003		$6,914,853.40		
Max annual electricity savings		$570,475.41		
Annual budget 2005-2014		$250,000		
Bond or loan raised 2005		$2,000,000.00		
Implementation 2 years: 50% in 2005, 100% in 2006				
Discount Rate		5%		
Interest Rate		5.0%		
			IRR	**98%**
Paid over 7 years			**NPV for OSU**	**$1,633,404.91**
	Fiscal year	Bond payments	Annual Savings	Savings - costs
1	2005	($432,049.55)	$285,237.70	($146,812)
2	2006	($432,049.55)	$570,475.41	$138,426
3	2007	($432,049.55)	$570,475.41	$138,426
4	2008	($432,049.55)	$570,475.41	$138,426
5	2009	($432,049.55)	$570,475.41	$138,426
6	2010	($432,049.55)	$570,475.41	$138,426
7	2011	($432,049.55)	$570,475.41	$138,426
8	2012	$0.00	$570,475.41	$570,475
9	2013	$0.00	$570,475.41	$570,475
10	2014	$0.00	$570,475.41	$570,475
		($3,024,346.82)	$5,419,516.35	$2,395,170

Lighting retrofit	Bond raised 2008			
Lighting savings (25%-30%)		27.50%		
Lighting % of Electricity		30.00%		
% electricity savings		8.25%		
Average El. cost 1999-2003		$6,914,853.40		
Max annual electricity savings		$570,475.41		
Annual budget 2005-2007		$250,000		
Bond or loan raised 2008		$1,750,000.00		
Discount Rate		5%		
Interest Rate		3.0%		
Implementation 2 years: 50% in 2008, 100% in 2009				
			IRR	**22%**
Paid over 7 years			**NPV for OSU**	**$370,729**
Fiscal year		Budget + bond payments	Annual Savings	Savings - costs
1	2005	($250,000.00)	$57,047.54	($192,952)
2	2006	($250,000.00)	$114,095.08	($135,905)
3	2007	($250,000.00)	$171,142.62	($78,857)
4	2008	($280,886.12)	$484,904.09	$204,018
5	2009	($432,049.55)	$570,475.41	$138,426
6	2010	($432,049.55)	$570,475.41	$138,426
7	2011	($432,049.55)	$570,475.41	$138,426
8	2012	($432,049.55)	$570,475.41	$138,426
9	2013	($432,049.55)	$570,475.41	$138,426
10	2014	($432,049.55)	$570,475.41	$138,426
		($3,623,183.40)	$4,250,041.77	$626,858

Appendix E – Vending Miser[4]

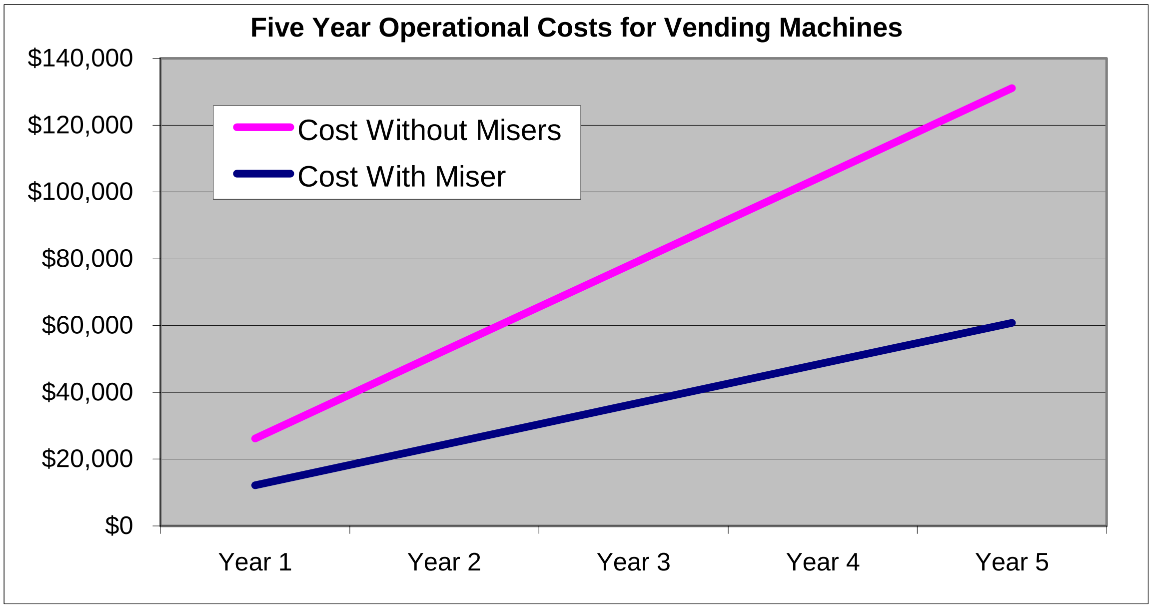
Cold Drink and Snack Vending Machine Energy Conservation Project	
Input Variables	
Energy Costs ($0.000 per kwh)	$0.05
Facility Occupied Hours per Week	60
Number of Cold Drink Vending Machines	150
Power Requirements of Cold Drink Machine (avg. watts)	400
Vending Miser Sale Price (for cold drink machines)	$179.00

Savings Analysis	Cold Drink Machines	
	Before	After
Cost of Operation	$26,208	$12,168
kWh	524,160	243,360
% Energy Savings		54%

Project Summary		
Present KWh	Projected kWH	kWh savings per year
524,160	243,360	280,800
Present Cost	Projected Cost	Annual Savings
$26,208.00	$12,168.00	$14,040.00
Total Project Cost	Payback (months)	
$26,850.00	22.9	

Five Year Savings on 150 Machines =	$70,200.00
Five Year Return on Investment =	161%

[4] Analysis performed by using the model developed by Bayview Technologies Inc. Spreadsheet can be downloaded from http://www.bayviewtech.com/energy/downloads/IntegratedVMSMAnalysis.xls



Source Data for Generating Chart

	Year 1	Year 2	Year 3	Year 4	Year 5
Cost With Miser	$12,168	$24,336	$36,504	$48,672	$60,840
Cost Without Misers	$26,208	$52,416	$78,624	$104,832	$131,040
Total Number of machines	150				

Vending miser

Input Variables

Energy Costs per kWh	$0.05
Facility Occupied Hours per Week	60
Number of Cold Drink Vending Machines	150
Power Requirements of Cold Drink Machine	400
Vending Miser Sale Price	$179.00

Total Miser Energy Usage for 150 vending machines	53kW hrs	Average time for installation	5 min
Vending miser electricity cost	$2.65	Travel time	5 min
Present Total Energy Usage	524,160kW hrs	Total installation	10 min
Projected Total Energy Usage	243,360kW hrs	Installed per hour	6
		Total hours	25
		Hourly wage	$10.00

IRR 101%

NPV for OSU $62,360.73

Year	Vending miser	Installation cost	Vending miser electricity cost	Annual costs	Annual Savings	B-C	Discount factor 5%	Net annual benefits
2005	$26,850	$250	$2.65	$27,102.65	$14,040	($13,063)	0.95238	($12,441)
2006			$2.65	$2.65	$14,040	$14,037	0.90703	$12,732
2007			$2.65	$2.65	$14,040	$14,037	0.86384	$12,126
2008			$2.65	$2.65	$14,040	$14,037	0.82270	$11,549
2009			$2.65	$2.65	$14,040	$14,037	0.78353	$10,999
2010	$26,850	$250	$2.65	$27,102.65	$14,040	($13,063)	0.74622	($9,748)
2011			$2.65	$2.65	$14,040	$14,037	0.71068	$9,976
2012			$2.65	$2.65	$14,040	$14,037	0.67684	$9,501
2013			$2.65	$2.65	$14,040	$14,037	0.64461	$9,049
2014			$2.65	$2.65	$14,040	$14,037	0.61391	$8,618
						$86,174		$62,361

Appendix F – Computer Use

Direct Costs

Computer in use	0.15kW/h		
Computer idle	0.03kW/h		
Price per kWh	$0.050		
Public computers	3,000		
Private (office and students)	10,000		
Total number of computer	13,000		
	Cost/yr. (1 computer)	Cost/yr. Total	Savings/yr.
Private Computer, on 24 hours per day	$65.70	$657,000.00	--
Private Computer, on 24 hours asleep 16 hrs	$30.66	$306,600.00	$350,400.00
Private computer, on 8 hours per day	$21.90	$219,000.00	$87,600.00
Private Computer, on 8 hrs, asleep 4 hrs	$13.14	$131,400.00	$87,600.00
Max savings for private PC			**$525,600.00**
Public Computer, on 24 hours per day	$65.70	$197,100.00	--
Public Computer, on 24 hrs, asleep 12 hrs	$39.42	$118,260.00	$78,840.00
Public Computer, on 16 hrs, asleep 8 hrs	$26.28	$78,840.00	$39,420.00
Max savings for public PC			**$118,260.00**
Maximum costs and savings		**$854,100.00**	**$643,860.00**

Including Social Costs

Computer in use	0.15kW/h			
Computer idle	0.03kW/h			
Price per kWh	$0.071			
Public computers	3,000			
Private (office and students)	10,000			
Total number of computer	13,000			
		Cost/yr. (1 computer)	Cost/yr. Total	Savings/yr.
Private Computer, on 24 hours per day		$93.29	$932,940.00	--
Private Computer, on 24 hours asleep 16 hrs		$43.54	$435,372.00	$497,568.00
Private computer, on 8 hours per day		$31.10	$310,980.00	$124,392.00
Private Computer, on 8 hrs, asleep 4 hrs		$18.66	$186,588.00	$124,392.00
Max savings for private PC				**$746,352.00**
Public Computer, on 24 hours per day		$93.29	$279,882.00	--
Public Computer, on 24 hrs, asleep 12 hrs		$55.98	$167,929.20	$111,952.80
Public Computer, on 16 hrs, asleep 8 hrs		$37.32	$111,952.80	$55,976.40
Max savings for public PC				**$167,929.20**
Maximum costs and savings			**$1,212,822.00**	**$914,281.20**

Appendix G – Occupancy Sensors in Restrooms

Occupancy sensors in bathrooms

Assumptions:		
Lights in use	8760	hr/yr
Number of restrooms	1000	
Cost of sensor	$120.00	
Labor cost for 3 hours	$83.00	
Present electricity cost/yr	$189,216	per year
Total Annual cost savings	42%	(lighting + maintenance)
Sensor average life	4	years
Electricity rate	$0.05	per kWh
Discount rate	5%	

NPV for OSU $130,407.08

Year	Fiscal year	Occupancy sensors cost	Implementation costs	Total costs	Projected cost savings/yr	Benefit-Cost
1	2005	$120,000	$83,000	$203,000	$79,471	($123,529)
2	2006			$0	$79,471	$79,471
3	2007			$0	$79,471	$79,471
4	2008			$0	$79,471	$79,471
5	2009	$120,000	$83,000	$203,000	$79,471	($123,529)
6	2010			$0	$79,471	$79,471
7	2011			$0	$79,471	$79,471
8	2012			$0	$79,471	$79,471
9	2013	$120,000	$83,000	$203,000	$79,471	($123,529)
10	2014			$0	$79,471	$79,471
						$185,707

VITA

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Master of Science

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