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2008 Fall ENGR333 Project Final Report

2008 Fall ENGR333

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Calvin Energy Efficiency Fund

ENGINEERING 333

2008

Final Technical Report

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Background

The Calvin College Engineering 333 class of 2008 was challenged with the question, "What would it take to implement an energy efficiency fund at Calvin?" Before addressing this question, another had to be asked: "What is an energy efficiency fund?" An energy efficiency fund is a revolving fund which takes seed money from donations, tuition, or grants and invests it into projects that save energy. Energy cost savings from the projects are routed back to the fund to help it grow and enable it to finance future projects. In order to begin this, the senior engineering students began organizing and analyzing the feasibility of carrying this out on Calvin's campus.

Introduction

The *Calvin College Statement on Sustainability* states that it is the college's intent to "challenge all of us to lead lives of meaning and purpose in a relationship to the physical world, lives that promote healing and reconciliation among all elements of the creation." As members of Calvin College's Engineering 333 class, students undertook this task, focusing specifically on Calvin's statement that they "continually investigate new technologies for improved energy systems and more efficient use of energy resources." This class investigated the possibility that a revolving energy fund, the Calvin Energy Efficiency Fund, or CEEF, could be introduced to the campus community.

Description

The purpose of the Calvin Energy Efficiency Fund is to pursue our calling to be stewards of God's creation by implementing a process through which Calvin's Campus can promote and realize a goal of energy stewardship and accommodate renewable and sustainable energy- and costs-saving projects.

To achieve this purpose the semester long project was broken down into the tasks of analyzing specific projects which could be implemented on campus and be the catalyst to start the CEEF, determine the financial savings which could be garnered from these projects and institute policies which would build the CEEF into Calvin's organizational structure and ensure the long term sustainability of the fund. The projects analyzed are as follows:

- Upgraded light bulb and fixture replacement
- Motion Sensors as lighting control
- Light Harvesting to reduce artificial lighting use in Hekman Library
- Additional airlock on Chapel doors
- Solar water heating on the roof the Venema Aquatic Center
- Implement software to remote shut down computers after hours
- Tunnels to re-route the HVAC system and disconnect the dated Knollcrest boilers
- Window replacement in Commons Dining Hall
- Additional shut-off times for unnecessary residence hall lighting

These projects are representative of the plethora of potential savings projects which can be implemented all over Calvin's campus and provide the college savings which can be routed into the CEEF. All individual project reports and results are shown in Appendices C-K.

The financial structure of the CEEF is critical to account for all savings determined by the analysis of these projects. Financial projections for the fund were created for the first 50 years and including only the nine proposed projects. These analyses took into account the uncertainties associated with each project. Three separate cases, an optimistic, nominal and pessimistic, were analyzed to determine how the CEEF would react to changing financial climates and unavoidable financial improbabilities (Figure 1).

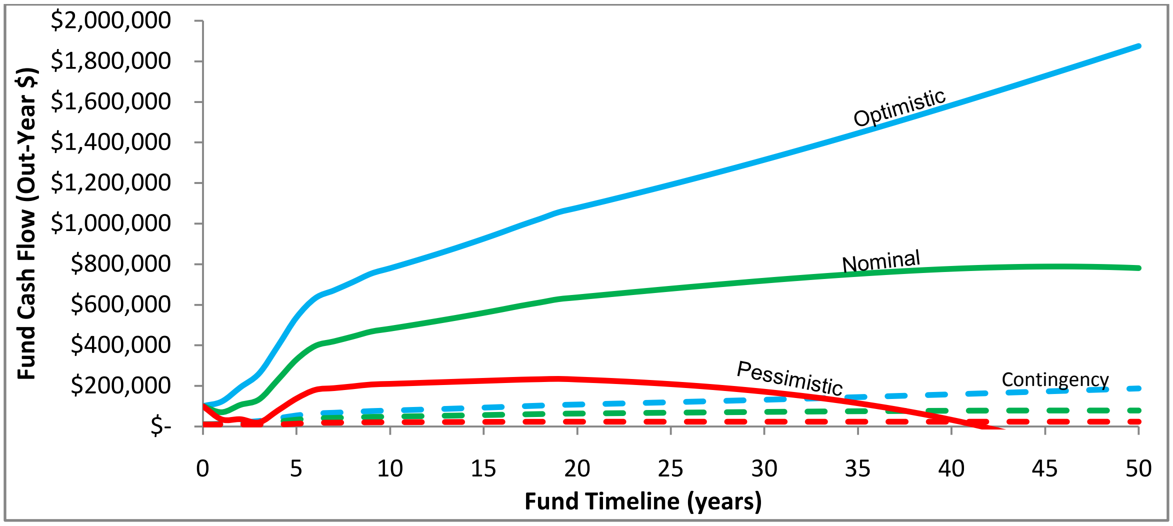


Figure 1: **Cash Flow Diagram**

The CEEF policies established a system which ensures that savings from proposed projects are properly accounted for and approved by Calvin's current policies. This system also monitors the maintenance of past projects and their continued benefit to the Calvin community. The CEEF structure was organized into three parts: proposed projects, financial analysis, and Calvin integrated policies.

Results

The purpose of this proposal is to document the feasibility study for implementation of CEEF at Calvin College. Major tasks included the following: accurately accounting for energy savings; developing a financial system to translate these energy savings to cost-savings projections; and ensuring that the fund is equipped with an infrastructure that it could operate around.

The proposed CEEF management structure includes a board, intern, and club. The board will consist of representatives from the Calvin community, such as members from appropriate college departments, physical plant, and student leadership. A student intern will be responsible for financial analysis of proposed projects and liaison between the club and board. The club will be a student organization dedicated to researching and analyzing potential projects. Full documentation of CEEF Policies is shown in Appendix A.

The financial analyses show that a seed amount of $100,000, will provide enough initial capital to implement 7 of the 9 proposed projects. Furthermore, even with the most pessimistic economic and energy saving conditions the fund continues to grow and earn financial savings until the projects are handed off to Calvin, as shown in Figure 1. A complete financial analysis of all projects and the fund balance are shown in Appendix B.

Conclusion

The results of this semester long project show that a Calvin Energy Efficiency Fund is not only feasible, but also a unique opportunity for Calvin to act as stewards of God's creation. In order for implementation and growth of this fund, there must be dedication from Calvin leaders, both in the student and faculty bodies. The Calvin Energy Efficiency Fund is a step toward bettering Calvin's efforts for creation care and fiscal responsibility. The future project savings and raised awareness for sustainability, brought from this fund, are in the hands of the Calvin community and its willingness to respond to our call to action.

Appendix A

CEEF Policies

Introduction

In order for a sustainable Calvin Energy Efficiency Fund, there requires a structure of policies which allows flexibility for the decision-makers and provides guidance to ensure growth and continuance of CEEF. The policies described in this document are designed to provide the framework for the CEEF which integrates with the college governance structure and culture.

Description

The organization of the CEEF is separated into five sections: Fund Management, Project Types and Requirements, Project Life Cycle, CEEF Costs Responsibilities and Fund Allocation Criteria. These sections encompass how projects will be implemented, who will be in charge of pursuing projects and how the fund will renew itself. Full documentation of the policies is shown in Appendix A1.

The major problem with implementing this type of fund is ensuring that future participants will have a structure within to work so that projects will continue and new ones are generated. To accomplish this, three entities were created as a part of the CEEF to ensure that it continues to grow and new projects are created. The first is the CEEF Board. This is the body which makes the final decisions for project approval and provides a representative voice of the rest of the school. To accomplish this, the board is comprised of a diverse group from physical plant staff, student senate representatives and Calvin's financial department. The second position is the CEEF club. This will be a part of student organizations who will conduct the necessary analysis, both technical and financial, and will be instructed by a CEEF intern and by their faculty advisor, the sustainability coordinator. The CEEF intern will be a paid position and will act as a liaison between the CEEF board and club. They will be responsible for organizing the duties assigned to the club and will present the final calculations and analyses performed by the club to the board.

The type of projects which the CEEF board, club and intern will analyze are separated into two categories; blue and green projects. Blue projects are short term energy efficiency and fossil fuel reducing projects which provide cost savings payback to the CEEF within 10 years. Green projects are carbon reducing and renewable energy promoting ventures including long term energy efficiency projects. These projects also include ideas which might promote CEEF and sustainability initiatives to the Calvin community. It is important that all projects do not conflict with current Calvin policies concerning community and culture. The project structure ensures that none of these projects fully expend the CEEF project account.

All projects which are to be approved must flow through the required project proposal life cycle. A project can be proposed by anyone via the project proposal form (Appendix A2). Once the proposal form has been filled out the idea goes through an initial project review where the CEEF Intern reviews the project and evaluates how it would fit in accordance with CEEF policies and either continues with the project or rejects it. If it is approved the intern will continue by assigning analysis responsibilities to the CEEF club who will document all their findings. After the analysis is completed a final project review is presented by the intern to the CEEF board where the project will have a final rejection or approval. From there the project will be implemented through the proper department (i.e. physical plant). After the project is implemented and active it will be retired after its payback period is completed. This entire cycle will be tracked by the CEEF intern and monitored to ensure that the project is being maintained and cost savings are being monitored.

It is also important to distinguish what exactly the responsibilities of the CEEF will be. In the initial development of the CEEF it was realized that there could be some projects which may coincide with projects already being implemented by other Calvin organizations. In these cases, only the costs directly associated with the area of the project which is related to energy efficiency should be paid through the CEEF fund. CEEF will only be required to pay the incremental costs which are above and beyond what already being implemented by Calvin College. These incremental costs may include labor or materials required to complete the energy efficiency project. There are also some other indirect costs such as the CEEF intern and the contingency fund which will be covered by CEEF.

The final area covered by CEEF policies is how the funds will be allocated within CEEF. There are four major areas where CEEF money will be designated. The project allocation will be allocated so that approximately 80% will be designated to blue projects and 20% will be allocated to green projects. The intern wages will also be covered by CEEF in accordance with Calvin's wage structure and the rest will be designated for the contingency fund. The contingency fund will always be 10% of the maximum CEEF balance and shall not drop below that amount.

Results

The policies designed for the CEEF are not intended to cover every situation which the club, intern or board may encounter. The goals of these policies were to create an infrastructure about which the fund and can operate and continue to build. As the next stages of implementation begin, including incorporation of the fund into current Calvin accounting, project initiation, and selection of board members and an intern, additional policies and more specific policies will need to be drafted to ensure the CEEF continues. It can be said, however, that a revolving fund such as the CEEF can be effectively managed and implemented at Calvin College.

Conclusion

The CEEF policies are designed to correspond with the current Calvin community and culture. They are set up to promote awareness of the fund and energy efficiency in general. In order for these policies to be effective there must be precise collaboration between the CEEF intern, club and board. Proper analysis of each of the projects must be completed to ensure accurate results and accurate cost saving projections. The long term viability of CEEF hinges on precise work and following the spirit of the policies. While the board may change or overrule policies which may become dated or inapplicable, CEEF will continue if members promote energy efficiency and carbon neutrality at Calvin.

Appendix A1: Calvin Energy Efficiency Fund Policies

Introduction

Calvin College seeks to be a community of caretakers for and agents of renewal in God's creation. The Environmental Stewardship Committee has already submitted a Statement on Sustainability (SOS) to the greater Calvin community as a proposal, exemplifying "starting points for education an action" concerning creation care and sustainability initiatives. The SOS contains guidelines pertaining to 13 areas, including energy. The energy guidelines emphasize the need for "improved energy systems and more efficient use of energy resources" while also promoting energy conservation and reduction of carbon dioxide emissions. These guidelines directly tie into the goals of the Calvin Energy Efficiency Fund.

The Calvin Energy Efficiency Fund is a proposal to Calvin College to implement a revolving fund which will fund projects which promote energy efficiency, renewable energy, carbon dioxide reduction, and other sustainability initiatives.

Mission Statement

The purpose of the Calvin Energy Efficiency Fund is to pursue our calling to be stewards of God's creation by implementing a process through which Calvin's Campus can promote and realize a goal of energy stewardship and accommodate renewable and sustainable energy- and cost-saving projects.

Fund Management

1. There shall be a *CEEF Board* which approves projects.
    a. The board must be comprised of the following individuals:
        i. An individual from Calvin's financial department
        ii. The Student Senate President or Vice President
        iii. The Calvin Sustainability Coordinator
        iv. A representative from Physical Plant
        v. Up to three at-large members
    b. The board membership term shall be 3 years in length, with the exception of the Student Senate representative whose term can be shorter. The term shall be renewable up to three times.
    c. The Calvin College Committee on Governance shall be responsible for assigning new members to the *CEEF Board*.
    d. The *CEEF Board* shall discuss project proposals, possible project modifications, validity of *CEEF Club* project economic calculations, and issues raised by the *CEEF Intern*.
    e. The *CEEF Board* may make suggestions for more sustainable behavior or operations (that do not necessitate funding from the CEEF) to the Environmental Stewardship Committee.
2. There shall be a *CEEF Club* that is a part of Student Organizations.
    a. The faculty advisor for the club shall be the Sustainability Coordinator.

    b. The club shall be responsible for soliciting project ideas, researching, evaluating feasibility in accordance with CEEF policies, conducting cost analyses, and estimating cash flows of the projects. Any ideas from the greater Calvin community for CEEF projects shall be brought to the attention of any member of the *CEEF Club* or submitted electronically to the club via the Project Proposal Form.
3. There shall be a *CEEF Intern* that is the hired liaison between the *CEEF Board* and the *CEEF Club*.
    a. The intern shall be a paid position that earns internship credit.
    b. The intern shall be paid in accordance with Calvin's student wage structure.
    c. The intern shall report to the Sustainability Coordinator.
    d. The intern's duties shall include the following:
        i. Presenting summaries of proposed projects to the *CEEF Board* for evaluation.
        ii. Managing analyses of projects and delegating research tasks to *CEEF Club* members.
        iii. Facilitating decision making within the *CEEF Club*.
        iv. Conducting the final cost and cash flow analyses for proposed projects.
        v. Recruiting for the *CEEF Club* at Cokes & Clubs or other events.
        vi. Presenting a summary of CEEF projects once every semester in a seminar to bring awareness to the Calvin community, while also raising interest for the *CEEF Club*.
        vii. Expected to work 10-15 hours per week.
    e. The intern shall be selected by the *CEEF Board* after an application and interviewing process has been completed.
        i. Preference shall be given to a junior or senior Engineering or Business/Accounting major. Other majors can be reviewed by the board to determine eligibility for the position.
        ii. Preference shall be given to an individual who has previously participated in the *CEEF Club*.

Project Types and Requirements

1. All projects shall be approved by a majority vote by the *CEEF Board* prior to implementation.
    a. Every project that is brought to the *CEEF Board* by the *CEEF Intern* must be approved or rejected.
2. All CEEF projects shall be separated into two categories: Blue and Green projects.
    a. Blue projects shall be short term energy efficiency and fossil fuel reducing projects which provide cost savings payback to the CEEF.
    b. Green projects shall be carbon reducing and renewable energy promoting ventures, including long term energy efficiency projects. They shall also include projects which promote CEEF and sustainability initiatives to the Calvin College community.
3. Blue projects:
    a. Shall have a complete payback in ≤ 10 years in order to be approved.

    b. Shall be submitted to the *CEEF Board* and must include the following documentation:
        i. Projection of significant energy savings, measureable in the form of therms, kilowatt-hours, gallons (e.g. water, fuel, etc.), or any applicable units.
        ii. Statement of historical, current, and future projections of energy price variances.
        iii. Estimated incremental labor and material costs to implement and maintain the project.
        iv. An estimate of the uncertainty of cost savings calculations.
        v. A summary of time value of money cash flow for the lifetime of the project while under CEEF.

4. Green projects:
    a. Shall raise awareness for renewable energy alternatives, sustainable behavior, carbon neutrality or other environmentally sustainable initiatives.
    b. Include projects which have payback periods that exceed 10 years and require blue project documentation criteria.
5. All projects:
    a. Must not conflict with current Calvin policies concerning the Calvin community and culture.
    b. Move toward the goal of obtaining a carbon neutral campus (i.e. projects cannot add to carbon emissions).
    c. Do not fully expend the CEEF project account.
    d. Do not promote increased usage of fossil fuels.
    e. Do not promote investment into non-renewable energy (e.g. nuclear energy, toxic materials, unsustainable alternatives, etc.).

Project Life Cycle

Phase I: Project Proposal

1. Project proposers shall complete Phase I of the Project Proposal Form and electronically submit it to the *CEEF Club*.

Phase II: Initial Project Review

1. The *CEEF Intern* shall review project proposals and evaluate each based on the CEEF policies concerning project criteria.
    a. If passed, the *CEEF Intern* shall document reasons for approval in Phase II of the Project Proposal Form and delegate analysis and research tasks to members of the *CEEF Club*.
    b. If rejected, the *CEEF Intern* shall document reasons for rejection in Phase II of the Project Proposal Form and return to the proposer.
        i. The proposer can re-submit the project after modifying, and re-submitting a new Project Proposal Form with the initial (rejected) form attached.

Phase III: Detailed Project Analysis

1. The *CEEF Club* shall fully document findings (e.g. cost savings, energy usage, etc.) in Phase III of the Project Proposal Form.

Phase IV: Final Project Review

1. The *CEEF Intern* shall gather all projects that have passed Phase III and present them to the *CEEF Board.*
2. The *CEEF Board* shall evaluate the proposed projects based on financial savings, project feasibility, fund cash flow, etc.
    a. If passed, the board shall complete Phase IV of the Project Proposal Form. The project can then enter Phase V, upon stated date.
    b. If rejected, the board shall complete Phase IV of the Project Proposal Form and return to the *CEEF Intern.*

Phase V: Project Implementation

1. In Phase V, the *CEEF Board* shall work with the proper department to establish the project start date and the project implementation shall begin.
    a. Copies of all project documents shall be passed on to the department in charge of project implementation (maintenance, etc.).

Phase VI: Project Active Period

1. Phase VI is the active period of a project –after implementation and prior to retirement.
    a. 100% of savings generated from Blue and Green projects return to the CEEF.
    b. Maintenance on projects in Phase VI shall follow CEEF policies.

Phase VII: Project Retirement

1. Phase VII is the retirement of a project.
    a. A CEEF project shall be retired at the end of the fifth year after its payback is completed.
    b. All costs related to and savings generated from retired projects shall be assumed by Calvin College.

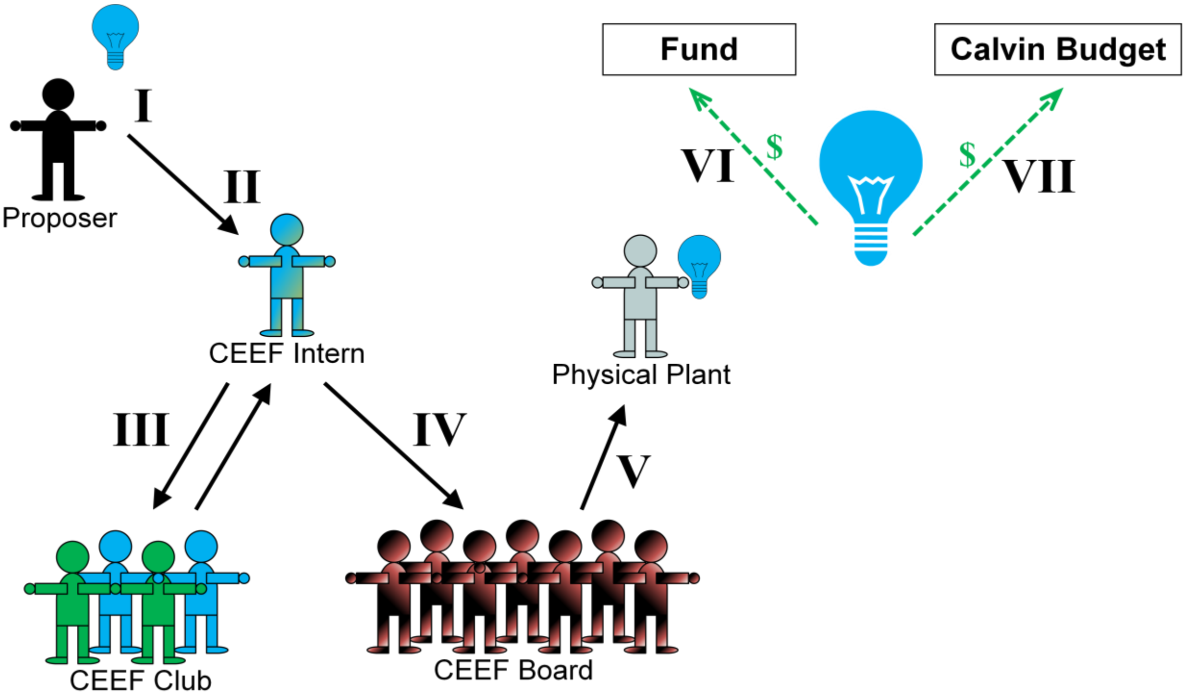


Figure A1-1. **The Project Life Cycle showing Phases I through VII**

CEEF Cost Responsibilities

1. The fund shall provide payment for all labor and materials for a *CEEF Board* approved project.
    a. If projects overlap with current Calvin College projects, only incremental labor or materials shall be paid by CEEF.
2. The CEEF shall not be used for payment of *CEEF Board* members. Being a member of the board is a voluntary activity.
3. The CEEF shall pay for the *CEEF Intern* position.
4. The CEEF shall not be used for other projects besides CEEF projects.
5. Expensive maintenance on an existing CEEF project, as determined by the *CEEF Board*, shall be considered a new project.

Fund Allocation Criteria

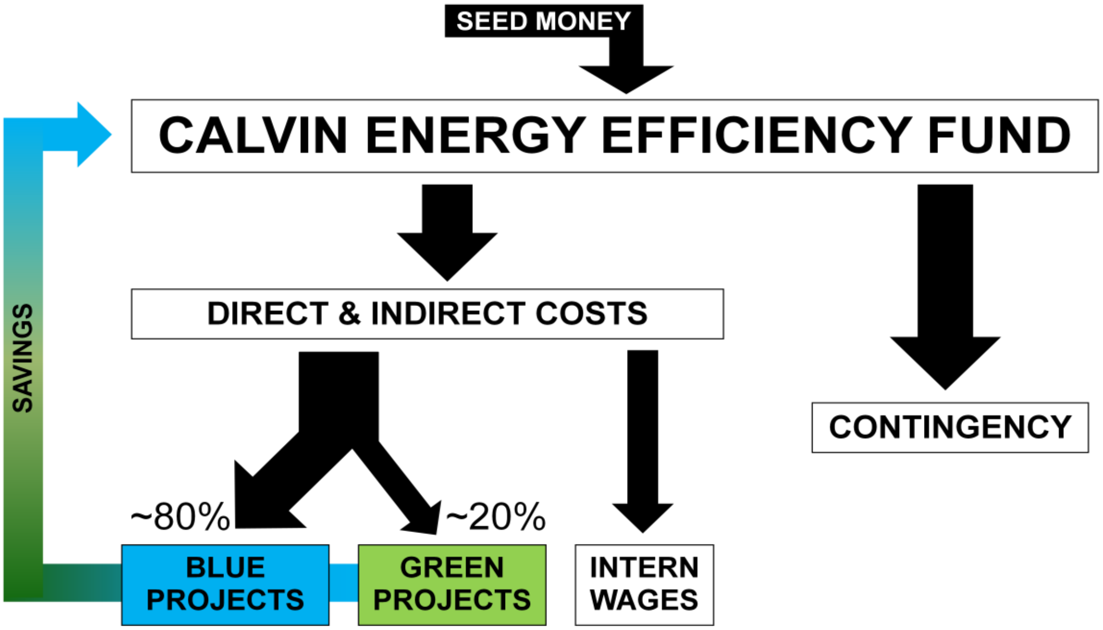


Figure A1-2. The Calvin Energy Efficiency Fund allocation diagram

1. The CEEF shall cover all direct costs related to project funding along with CEEF related indirect costs.
    a. Direct Costs
        i. Approximately 80% of project spending shall be designated for Blue projects.
        ii. Approximately 20% of project spending shall be designated for Green projects.
    b. Indirect Costs
        i. *CEEF Intern* wages
2. 10% of the CEEF shall be allocated as a dedicated savings (contingency) and shall act as a dynamic minimum, which increases with CEEF growth.

a. All CEEF income shall renew the 10% contingency before continuing implementation of new projects.
b. The contingency fund shall ensure CEEF growth and account for unexpected maintenance costs.

The growth and replenishment of the CEEF contingency is shown in Figure 3.

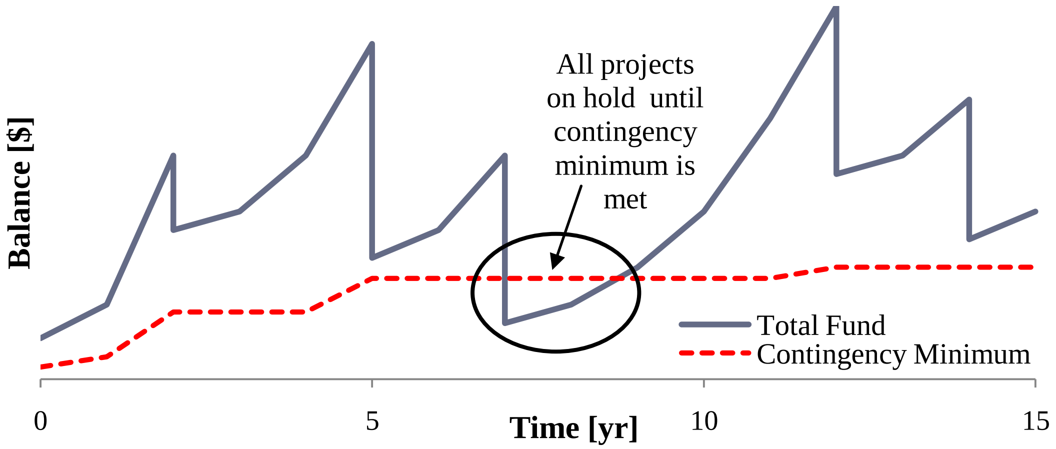
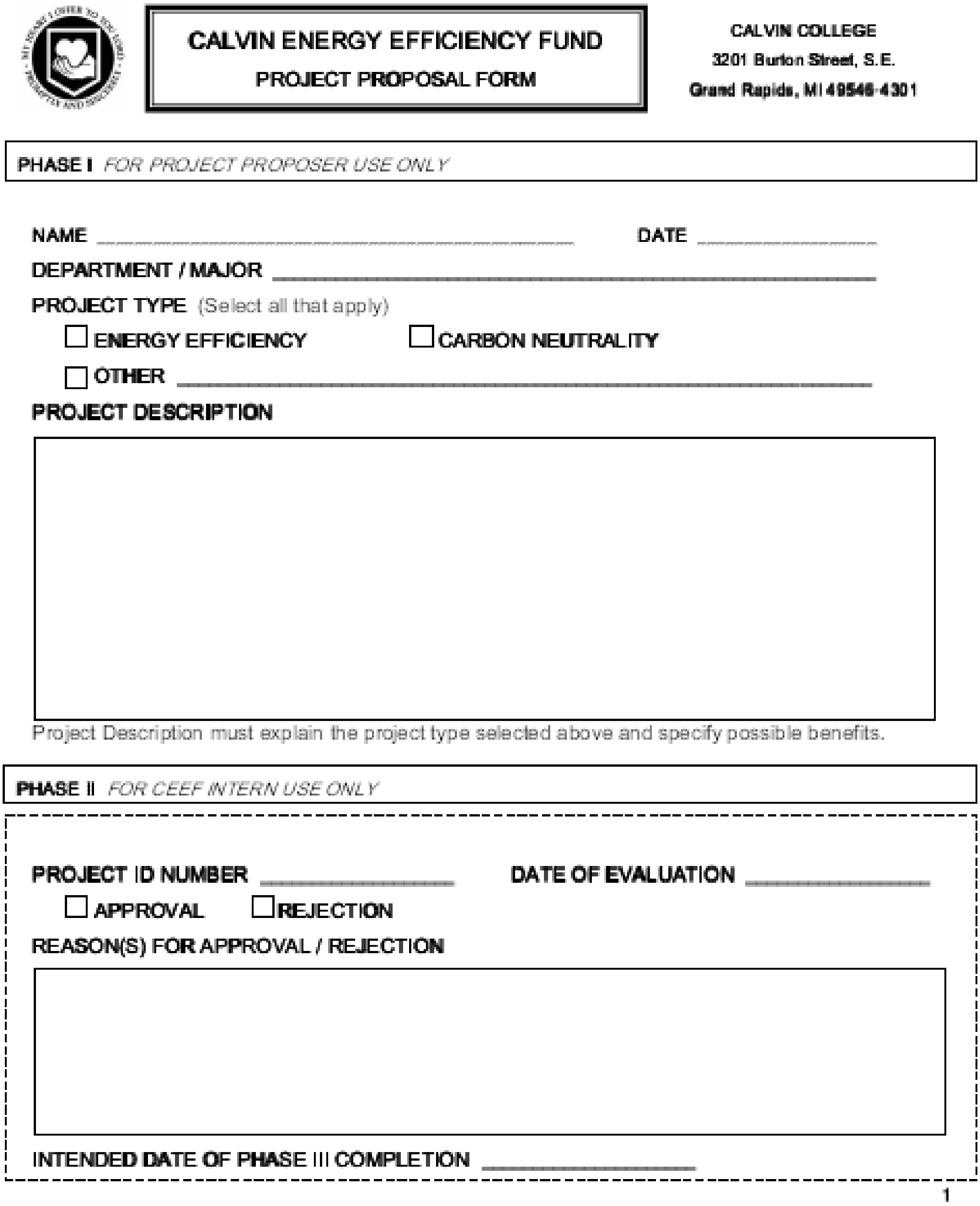


Figure A1-3. The dynamic CEEF contingency in relation to the total fund balance

Appendix A2: Project Proposal Form



CALVIN ENERGY EFFICIENCY FUND

PROJECT PROPOSAL FORM

CALVIN COLLEGE
3201 Burton Street, S.E.
Grand Rapids, MI 49546-4301

PHASE I *FOR PROJECT PROPOSER USE ONLY*

NAME ______________________________ **DATE** ______________

DEPARTMENT / MAJOR ______________________________________

PROJECT TYPE (Select all that apply)

☐ **ENERGY EFFICIENCY** ☐ **CARBON NEUTRALITY**

☐ **OTHER** ______________________________________

PROJECT DESCRIPTION

Project Description must explain the project type selected above and specify possible benefits.

PHASE II *FOR CEEF INTERN USE ONLY*

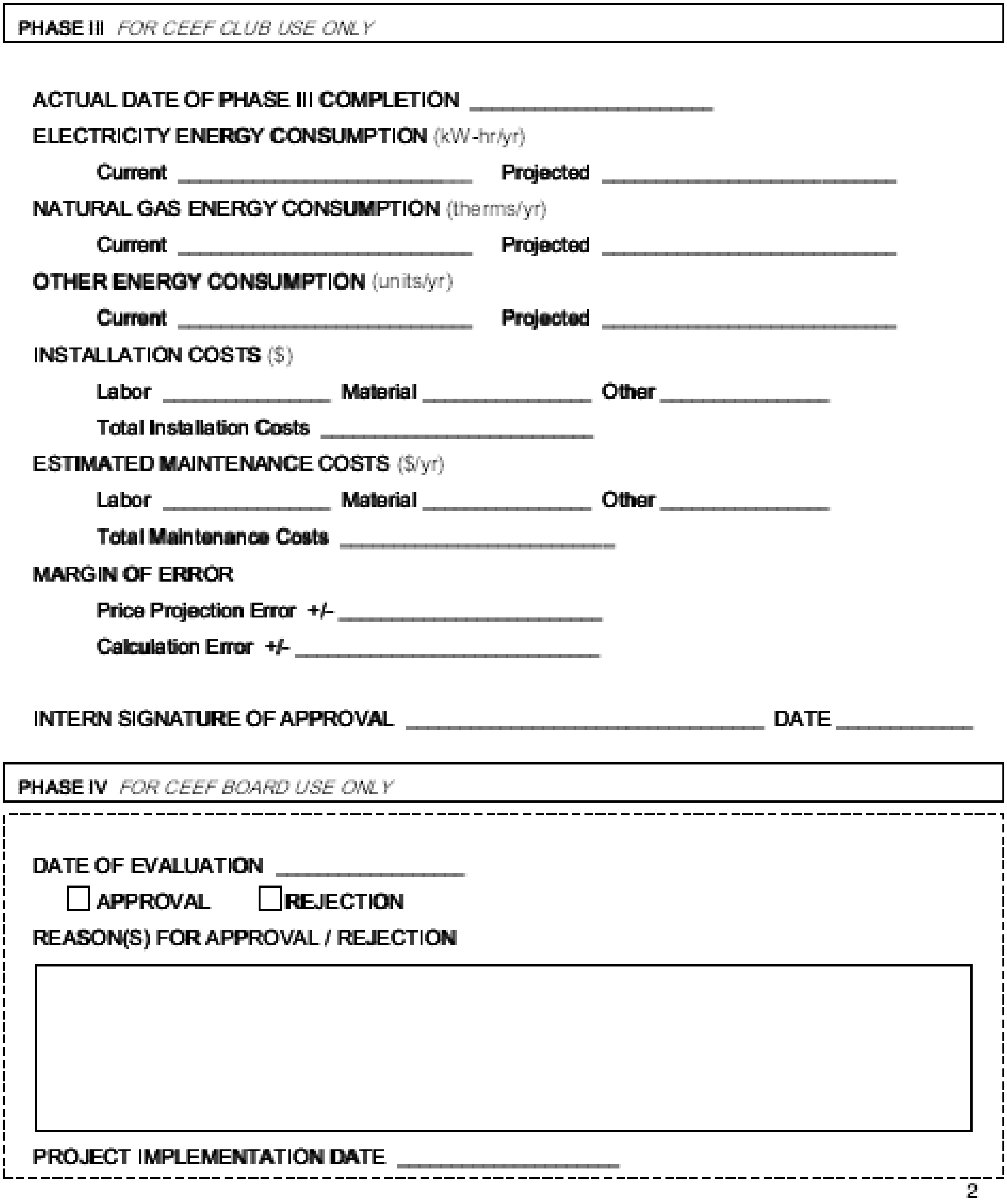
PROJECT ID NUMBER ______________ **DATE OF EVALUATION** ______________

☐ **APPROVAL** ☐ **REJECTION**

REASON(S) FOR APPROVAL / REJECTION

INTENDED DATE OF PHASE III COMPLETION ______________

1



PHASE III *FOR CEEF CLUB USE ONLY*

ACTUAL DATE OF PHASE III COMPLETION ____________________

ELECTRICITY ENERGY CONSUMPTION (kW-hr/yr)

Current ________________________ Projected ________________________

NATURAL GAS ENERGY CONSUMPTION (therms/yr)

Current ________________________ Projected ________________________

OTHER ENERGY CONSUMPTION (units/yr)

Current ________________________ Projected ________________________

INSTALLATION COSTS ($)

Labor ______________ Material ______________ Other ______________

Total Installation Costs ______________________

ESTIMATED MAINTENANCE COSTS ($/yr)

Labor ______________ Material ______________ Other ______________

Total Maintenance Costs ______________________

MARGIN OF ERROR

Price Projection Error +/- ______________________

Calculation Error +/- _________________________

INTERN SIGNATURE OF APPROVAL ______________________________ DATE ___________

PHASE IV *FOR CEEF BOARD USE ONLY*

DATE OF EVALUATION _______________

☐ APPROVAL ☐ REJECTION

REASON(S) FOR APPROVAL / REJECTION

PROJECT IMPLEMENTATION DATE __________________

Appendix B

CEEF Finances

Introduction

The Financial Team analyzed the monetary feasibility of each project pursued by the technical teams. Energy savings were collected to determine the financial savings of each project. The projects were ranked based on their payback periods and implemented in the cash flow diagram accordingly.

Description

Using energy projections and energy savings from the technical groups, the Financial Team computed the cost savings. The energy models, for therms and kilowatts, were taken from the U.S. Department of Energy. The model was extended linearly between the years of 2030 and 2058 because the Department of Energy model only projected through 2030. Each project was evaluated for three cases: pessimistic, nominal, and optimistic. The description for each case can be seen below in Table B1.

Table B1: Pessimistic, Nominal, and Optimistic Case Descriptions

	Pessimistic	**Nominal**	**Optimistic**
Upfront Costs	High ↑	Nominal -	Low ↓
Ongoing Costs	High ↑	Nominal -	Low ↓
Energy Savings	Low ↓	Nominal -	High ↑
Energy Cost Projection	Low ↓	Nominal -	High ↑
Opportunity Cost of Capital	High ↑	Nominal -	Low ↓
Inflation Rate	High ↑	Nominal -	Low ↓
Fund Investment	Low ↓	Nominal -	High ↑
Intern Costs	High ↑	Nominal -	Low ↓

To analyze each project, the assumption was made that installation was immediate. Each project was compared to a nominal 6% opportunity cost of capital. Each project was evaluated for every year on the fifty year energy projection. The account of the CEEF is continually invested in a nominal interest bank account. Upfront and ongoing costs are projected solely based on inflation. The intern pay is projected to be 8 $/hr for 10-15 hrs per week and 32 weeks per year. The savings and costs are balanced annually.

Results

Based on a potential seed amount of $100,000, the potential project implementation schedule can be seen in Table B2.

Table B2: Project Implementation Dates

2009	**Forced Computer Shutdown** **Dorm Hall Lights** **Dorm Tunnels**
2010	**Motion Sensors** **Light Harvesting** **Chapel Airlock**
2011	**Light Replacement**

These projects were scheduled based upon the time of their payback. The Commons Windows and Solar Water Heating projects were not scheduled. The Commons Windows project would be better integrated into the upcoming renovation of Commons. The Solar Water Heating was not scheduled because the initial cost was outside the scope of the initial seed money. The financial calculations for each project can be seen in the Appendix. The cash flow of the scheduled projects can be seen below in Figure B1.

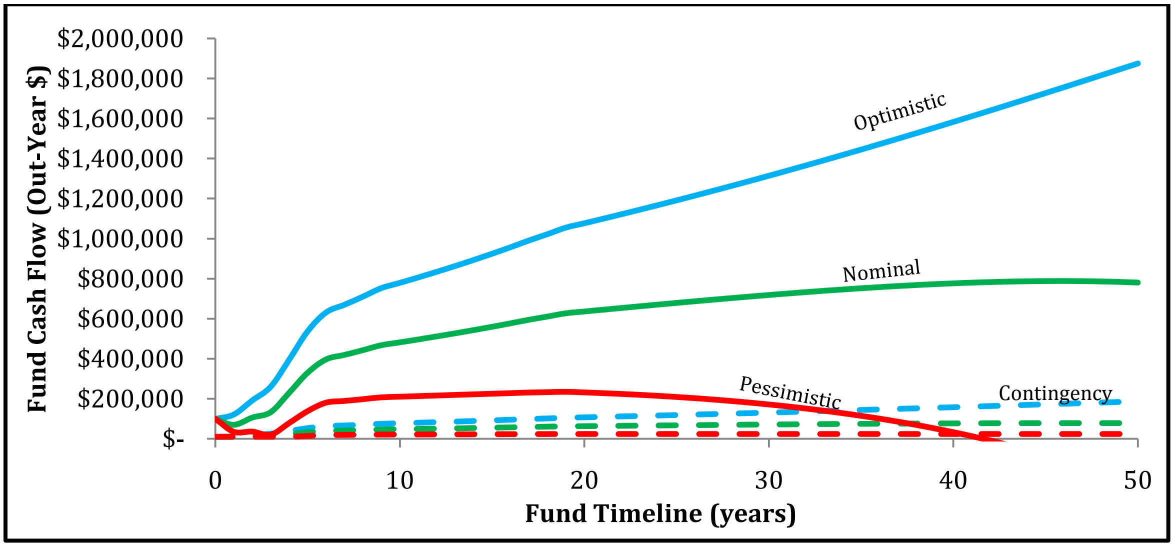


Figure B1: Cash Flow Diagram

Conclusion

The Financial Team has determined that the majority of these projects are financially feasible with potential cost savings for Calvin. In addition to goals of financial stewardship the fund also shows environmental responsibility. The CEEF is expected to be sustainable as long as new and viable projects are introduced.

Appendix B1: Table of Content

Optimistic Case

Fund Cash Flow

Project Cash Flow Summary

Tech Group 1 – Project 1: Light Replacement

Tech Group 1 – Project 2: Motion Sensors

Tech Group 1 – Project 3: Light Harvesting

Tech Group 2 – Project 1: Chapel Airlock

Tech Group 2 – Project 2: Forced Computer Shutdown

Tech Group 2 – Project 3: Solar Water Heating

Tech Group 3 – Project 1: Dorm Hall Lights

Tech Group 3 – Project 2: Commons Dining Hall Windows

Tech Group 3 – Project 3: Dorm Tunnels

See the included CD for the excel file containing this appendix:

\CEEF\Financial Group\finalanalysis.xlsx

Appendix C

North Hall Lighting Fixture Replacement

Introduction

Currently, the classrooms, computer labs, and faculty offices in North Hall at Calvin College use lighting fixtures that are designed for, and use T12 fluorescent lamps. These products are currently being phased out in the lighting industry are will no longer be available in five to ten years. The new lighting fixture that is quickly becoming the industry standard is the T5 fixture, which has already been installed in the hallways of North Hall. This project will examine the feasibility of replacing the current T12 fixtures in North Hall with the new T5 fixtures, and the energy savings that this would bring.

Description

In order to determine the annual energy savings by implementing the new lighting fixtures, the current number of fixtures had to be counted. All three floors of North Hall were included, and the total number of light fixtures affected by this project came to 459. This number includes 248 fixtures in computer labs and classrooms, and 211 fixtures in faculty offices. This number does not include any hallway lighting, as these fixtures have already been updated.

Another benefit of the new T5 fixtures is that they output a great deal of light. A comparison test was done to see the different amount of light output by the old and new fixtures. Currently, a regular North Hall faculty office has two T12 fixtures installed. Don Winkle, an electrician at Calvin College's physical plant, installed a single T5 fixture in a second office of similar size. A light meter was used to take the light level in each office in various locations. The results of these light readings are included in Appendix C1. It was found that a single T5 fixture could replace the current office setup of two T12 fixtures without significant light loss. This means by replacing the North Hall lighting fixtures, the total number of fixtures may be brought down from 459 to 354.

In order to measure the energy usage of each fixture, the amount of electrical current (in Amps) was measured going into each kind of fixture. It was measured that a currentT12 fixture uses about 0.75 A, while a single T5 fixture uses only about 0.5 A. Using the following formula, where V is the supplied voltage in Volts and P is the power used in Watts, the current draw of each fixture was used to find the energy use per lighting fixture.

$$P = V \cdot I \tag{C1}$$

Next, the current lighting energy usage and predicted lighting energy usage needed to be calculated. In order to do this, the number of hours per day the lights are on in North Hall was predicted. This was done by splitting the calendar year into two portions: the academic year and the summer. Then, the number of hours per day that the lights are on was estimated based on observation and previous personal experiences. Each type of room, classroom and office, was given a specific number of hours per day. Using the length of each portion of the calendar year, the number of hours per year for each room was calculated. By multiplying this number by the energy usage found in equation (1) and summing for the total number of lighting fixtures, the annual energy usage for each type of fixture was calculated.

Results

After performing the above analysis, the total energy usage using both T5 and T12 fixtures is shown below. Upper and lower uncertainty values were also calculated by adjusting the predicted daily usage of the light fixtures. These usage assumptions are included in Appendix C2.

Table C1: **Current and Projected North Hall Lighting Energy Usage**

	T12 Fixtures		T5 Fixtures	
Annual Energy Usage (per classroom fixture)	162	*kWh/yr*	108	*kWh/yr*
Annual Energy Usage (per office fixture)	226.8	*kWh/yr*	151.2	*kWh/yr*
Total Annual Energy Usage	88030.8	*kWh/yr*	42811.2	*kWh/yr*
Total Annual Energy Savings			45219.6	*kWh/yr*

Conclusion

By replacing the current lighting fixtures in the North Hall classrooms and offices, Calvin College will save approximately 45,000 kW-hr per year. However, there are additional benefits to changing from the current T12 fixtures besides just an energy savings. The lamps used in each fixture have an approximately equal lifespan, 20,000 hours, but those used in T5 fixtures do not lose their light output or begin to flicker as time goes on. This is often a common complaint of T12 lamps. Also, the new T5 fixtures require only two lamps per fixture, as opposed to the three lamps needed per T12 fixture. This will also bring a savings to Calvin College due to the lower number of lamps that need replacing and the staff time that is needed to replace time. Another benefit to Calvin will be a reduced heat load due to fluorescent lighting. The new T5 lamps give off less heat than the currently used T12 lamps. This may bring a savings by requiring less air-conditioning during the summer months. However, this energy savings is unable to be included due to there being no feasible way to measure the energy required to offset the heat given off by a single lighting fixture. Yet another benefit of switching to these new fixtures is that an RT5 fixture requires one electronic ballast per fixture, while a T12 fixture requires two magnetic ballasts per fixture. Lighting ballasts are used to control the starting and operating voltages of fluorescent lamps. By reducing the number of ballasts involved in lighting, Calvin College may see a financial savings in the future due to the reduction of replacement parts needed. Overall, this project is definitely feasible and will provide Calvin College with an immediate energy savings, along with numerous other benefits.

Appendix C1: Light Output Comparison

Table C1-1: North Hall Office Light Illuminance Comparison

	Office of L. Van Drunen		Office of B. Medema	
	Two T12 fixtures	**One T5 fixture**	**Two T12 fixtures**	**One T5 fixture**
	Illuminance [*fc*]	**Illuminance [*fc*]**	**Illuminance [*fc*]**	**Illuminance [*fc*]**
Floor, under fixture	27.3	30.9	18.4	26.8
Corner Window	7	9.2	6.6	9.3
Computer	35.7	32	15.7	24.3
Shelf	20.8	17.9	9.8	12.5
Corner Heater	14.8	18.1	11.8	17.5

Table C1-2: North Hall Classroom Light Illuminance Comparison

	ROOM 064	ROOM 168
	Illuminance [*fc*]	**Illuminance [*fc*]**
Middle	71.4	68.9
Front	49.5	54.5
Left	17.6	35.8
Right	24.2	32.7
Back	45.5	48.8

Appendix C2: Energy Usage Calculations

Table C2-1: **Current and Project Energy Calculations**

	Current Lighting			**Proposed Lighting**	
Current Draw (per fixture)	0.75	*A*		0.5	*A*
System Voltage	120	*V*		120	*V*
Energy Usage	0.09	*kW*		0.06	*kW*
Daily Classroom Usage (academic year)	10	*hrs*		10	*hrs*
Daily Office Usage (academic year)	12	*hrs*		12	*hrs*
Daily Classroom Usage (summer)	0	*hrs*		0	*hrs*
Daily Office Usage (summer)	6	*hrs*		6	*hrs*
# of Classroom Fixtures	248			248	
# of Office Fixtures	211			106	
Annual Energy Usage (per classroom fixture)	162	*kW-hr/yr*		108	*kW-hr/yr*
Annual Energy Usage (per office fixture)	226.8	*kW-hr/yr*		151.2	*kW-hr/yr*
Annual Energy Usage (North Hall)	88030.8	*kW-hr/yr*		42811.2	*kW-hr/yr*
Annual Energy SAVINGS (North Hall)	0	*kW-hr/yr*		45219.6	*kW-hr/yr*

Table C2-2: **Upper and Lower Uncertainty Energy Calculations**

	Lower Uncertainty			**Upper Uncertainty**	
Current Draw (per fixture)	0.5	*A*		0.5	*A*
System Voltage	120	*V*		120	*V*
Energy Usage	0.06	*kW*		0.06	*kW*
Daily Classroom Usage (academic year)	12	*hrs*		8	*hrs*
Daily Office Usage (academic year)	12	*hrs*		10	*hrs*
Daily Classroom Usage (summer)	4	*hrs*		0	*hrs*
Daily Office Usage (summer)	8	*hrs*		4	*hrs*
# of Classroom Fixtures	248			248	
# of Office Fixtures	106			106	
Annual Energy Usage (per classroom fixture)	144	*kW-hr/yr*		86.4	*kW-hr/yr*
Annual Energy Usage (per office fixture)	158.4	*kW-hr/yr*		122.4	*kW-hr/yr*
Annual Energy Usage (North Hall)	52502.4	*kW-hr/yr*		34401.6	*kW-hr/yr*
Annual Energy SAVINGS (North Hall)	35528.4	*kW-hr/yr*		53629.2	*kW-hr/yr*

Appendix C3: *Lithonia Lighting*® RT5™ Features

Catalog Number	
Notes	Type

FEATURES & SPECIFICATIONS

INTENDED USE

RT5 is designed for applications that require the extremely energy efficient delivery of comfortable volumetric light from a lay-in fixture that is appealing and shallow in depth. Ideal for offices, schools, hospitals, retail and numerous other commercial applications.

OPTICAL SYSTEM

Delivers volumetric lighting by filling the entire volume of space with light, delivering the ideal amount to walls, cubicles, work surfaces and people.

Luminous characteristics are carefully managed at high angles, providing just enough intensity to deliver the volumetric effect.

Regressed, two-piece refractive system obscures and softens the lamp and smoothly washes the reflector with light.

Linear faceted reflector softens and distributes light into the space and minimizes the luminance ratio between the fixture and the ceiling.

Mechanical cut-off across the reflector and fresnel refraction along the refractor provide high angle shielding and a quiet ceiling.

Sloped endplates provide a balanced fixture to ceiling ratio while enhancing the perception of fixture depth.

CONSTRUCTION

Impact modified acrylic prismatic refractor with polymer light-diffusing film.

Rugged, one-piece, cold-rolled steel reflector with embossed facets. Polyester powder paint after fabrication.

Rigid structure with ballast box and endplates with integral T-bar clips.

Fixtures may be mounted end-to-end.

ELECTRICAL SYSTEM

Highly efficient program-start electronic ballasts, Class P, thermally protected, resetting, HPF, non-PCB, UL Listed, CSA Certified, sound rated A. Premium T5 lamp with enhanced phosphors and 85 CRI. Ballast/lamp efficacy up to 100+ LPW. Lamp is TCLP compliant.

0.95 ballast factor standard for typical applications. 1.15 ballast factor or F54T5HO lamping available for higher ceiling height applications.

Bi-level dimming option allows system to be switched to 50% power for compliance with common energy codes while maintaining fixture appearance.

S5 option available for use with SIMPLY5™ Lighting Intelligence system with multi-level dimming. See SYNERGY® Lighting Controls specification sheets for more information.

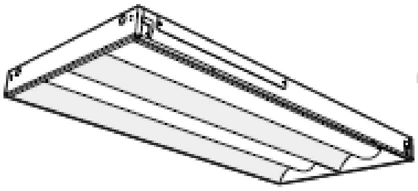
MAINTENANCE

Side mounted ballast tray accessed by removing adjacent ceiling tile. Ballast tray may be removed from fixture during service.

Lamps accessed by squeezing refractor to release from retention tabs.

LISTING

UL Listed (standard). Optional: Canada CSA or cUL. Mexico NOM.

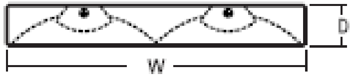


2RT5

2'x 4'
2 Lamps
Premier T5

Specifications

Length: 48 (1218)
Width: 24 (610)
Depth: 3-1/8 (79)



All dimensions are inches (millimeters) unless otherwise specified.

WARRANTY

Fixture guaranteed for one year against mechanical defects in manufacture. Lamp and ballast system warranty (24 months for lamp, 60 months for ballast) by lamp and ballast manufacturer.

Protected by one or more of US Patents Nos. 7,229,192; D541,467; D541,468; D544,633; D544,634; D544,992; D544,933 and additional patent pending.

Specifications subject to change without notice.

ORDERING INFORMATION

For shortest lead times, configure product using **standard options (shown in bold).**

Example: 2RT5 28T5 MVOLT GEB95 LPM835P

2RT5

Series	
2RT5	**Recessed T5**

Lamp type	
28T5	**28W T5 (46")**
54T5HO	54W T5 (46")[1]

Voltage
MVOLT[2]
347[3]

Ballast	
GEB95	**0.95 ballast factor**
GEB95S	**0.95 ballast factor, step dimming**
GEB115	1.15 ballast factor
GEB115S	1.15 ballast factor, step dimming
GEB10PS	1.0 ballast factor, program start
S5	0.95 ballast factor SIMPLY5 system[4]
S5115	1.15 ballast factor SIMPLY5 system[4]
GEB10PS	1.0 ballast factor, program start[1]
GEB80	.80 ballast factor[1]
GEB80S	.80 ballast factor, step dimming[1]

Lamp[4]	
LPM835P	**Premier 3500°K 28W lamp**
LPM830P	Premier 3000°K 28W lamp
LPM841P	Premier 4100°K 28W lamp
LP835	3500°K 54W lamp
LP830	3000°K 54W lamp
LP841	4100°K 54W lamp

Options	
GLR	Internal fast-blow fuse[5]
PWS1836	6' prewire, 3/8" diameter, 18-gauge, 3-wire (n/a with GEB95S)[6]
PWS1846	6' prewire, 3/8" diameter, 18-gauge, 4-wire[7]
EL14	**Emergency battery pack**[8]
EL65	Emergency battery pack[8]
HW	Hardwire for S5 system; replaces RELOC®
CSA	Listed and labeled to comply with Canadian standards
QFC_	Quick-flex cable[9]
BDP	Ballast disconnect plug (meets codes that require in-fixture disconnect)

NOTES:

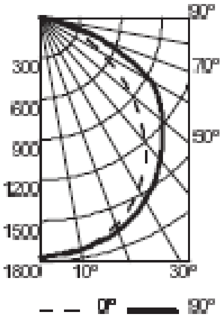
1 For T5HO applications, use GEB10PS, GEB80 or GEB80S ballast.
2 MVOLT (120-277 volts), 50-60HZ.
3 For 347V, use GEB95S or GEB10PS.
4 SIMPLY5 includes 13' S5 SSC RELOC® wiring system, specify voltage unless HW (hardwire) or PWS is ordered.
5 Must specify voltage, 120 or 277.
6 For use with standard ballast.
7 For use with step dimming ballast.
8 See PS1400QD spec sheet for EL lumen output information.
9 Required. All fixtures shipped with lamps installed.

Fluorescent

Sheet #: 2RT5-2x4 VRL-100

2RT5 Volumetric Recessed Lighting 2' x 4'

2RT5 28T5 GEB95 LPM835P, (2) FP28/835/PM/ECO lamps, 2730 lumens per lamp, s/m 1.2 (along) 1.3 (across), test no. LTL13260



CP Summary

	0°	90°
0°	1770	1770
5°	1766	1750
15°	1695	1707
25°	1555	1623
35°	1339	1473
45°	1044	1260
55°	695	1071
65°	393	715
75°	179	257
85°	30	21
90°	0	0

Coefficients of Utilization

pf	20%								
pc	80%			70%			50%		
pw	70%	50%	30%	50%	30%	10%	50%	30%	10%
RCR 0	107	107	107	105	105	105	100	100	100
1	96	94	91	92	89	86	88	86	83
2	89	82	76	81	75	70	77	73	69
3	82	72	65	71	64	59	68	63	58
4	75	64	56	63	56	50	61	54	49
5	69	57	49	56	49	43	54	48	43
6	63	52	44	51	43	38	49	42	37
7	58	47	39	46	39	33	45	38	33
8	56	43	35	42	35	30	41	34	30
9	51	39	32	39	32	27	38	31	27
10	48	36	29	36	29	24	35	28	24

Zonal Lumen Summary

Zone	Lumens	% Lamp	% Fi
0° - 30°	1383	25.3	28.
0° - 40°	2264	41.5	46.
0° - 60°	3976	72.8	81.
0° - 90°	4906	89.9	100
90° - 180°	0	0.0	0.0
0° - 180°	4906	89.9	100

Efficiency: 89.9%

LER: 80.4 lpw

*The LER (Luminaire Efficacy Rating) is the lumens per watt rating for this fixture. It is used to compare the energy efficiency of various products. This photometric report is based upon IES testing procedures, as stated in LM-41-1998. The reported lumen rating is based upon lamp manufacturer's published lumen output for the cold spot temperature measured during lamp calibration.

Ballast	Input Wattage 120/277
GEB95 GEB95S	60/58
GEB95S @50% power mode	28/28
GEB115 GEB115S	73/71
GEB115S @50% power mode	35/35
GEB80 GEB80S	96/93
GEB80S @50% power mode	52/51
S5	60/58

T5/T8 Energy Comparison

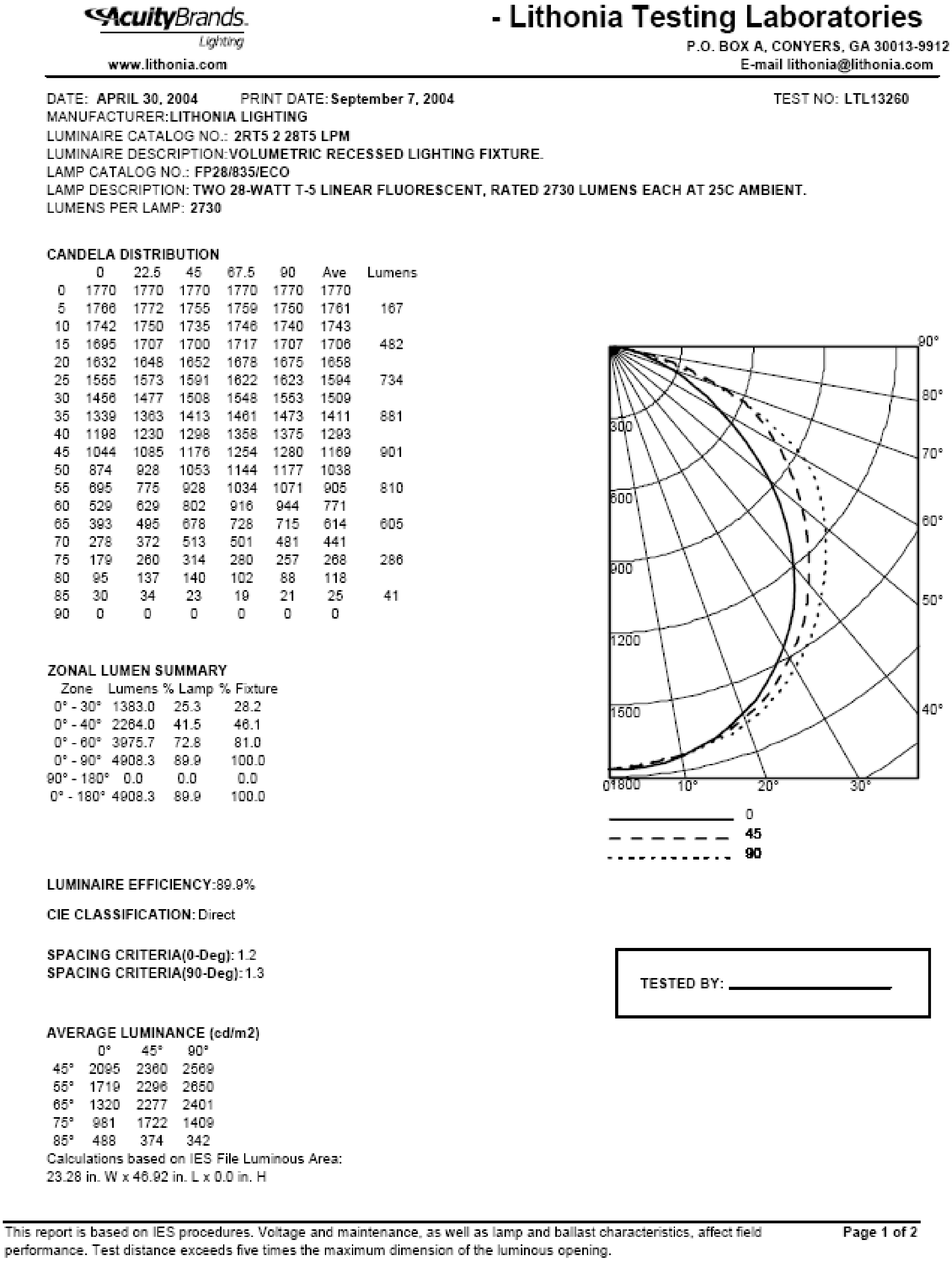
System	*Lamp Type*	*Ballast Factor*	*Input Watts*	Watts Saved Compared to T8
3-lamp T8	F32T8	0.88	–	–
2RT5 2-lamp T5	F28T5	0.95	58	30
2RT5 2-lamp T5	F28T5	1.15	71	17

LITHONIA LIGHTING®
An Acuity Brands Company

Sheet #: 2RT5-2x4

Lithonia Lighting
Fluorescent
One Lithonia Way, Conyers, GA 30012
Phone: 800-858-7763 Fax: 770-929-8789
www.lithonia.com

Appendix C4: *Lithonia Lighting*® RT5™ Light Level Testing



AcuityBrands Lighting

www.lithonia.com

- Lithonia Testing Laboratories

P.O. BOX A, CONYERS, GA 30013-9912
E-mail lithonia@lithonia.com

DATE: **APRIL 30, 2004** PRINT DATE: **September 7, 2004** TEST NO: **LTL13260**
MANUFACTURER: **LITHONIA LIGHTING**
LUMINAIRE CATALOG NO.: **2RT5 2 28T5 LPM**
LUMINAIRE DESCRIPTION: **VOLUMETRIC RECESSED LIGHTING FIXTURE.**
LAMP CATALOG NO.: **FP28/835/ECO**
LAMP DESCRIPTION: **TWO 28-WATT T-5 LINEAR FLUORESCENT, RATED 2730 LUMENS EACH AT 25C AMBIENT.**
LUMENS PER LAMP: **2730**

CANDELA DISTRIBUTION

	0	22.5	45	67.5	90	Ave	Lumens
0	1770	1770	1770	1770	1770	1770	
5	1766	1772	1755	1759	1750	1761	167
10	1742	1750	1735	1746	1740	1743	
15	1695	1707	1700	1717	1707	1706	482
20	1632	1648	1652	1678	1675	1658	
25	1555	1573	1591	1622	1623	1594	734
30	1456	1477	1508	1548	1553	1509	
35	1339	1363	1413	1461	1473	1411	881
40	1198	1230	1298	1358	1375	1293	
45	1044	1085	1176	1254	1280	1169	901
50	874	928	1053	1144	1177	1038	
55	695	775	928	1034	1071	905	810
60	529	629	802	916	944	771	
65	393	495	678	728	715	614	605
70	278	372	513	501	481	441	
75	179	260	314	280	257	268	286
80	95	137	140	102	88	118	
85	30	34	23	19	21	25	41
90	0	0	0	0	0	0	

———	0
– – – – – –	45
- - - - - - - - - - -	90

ZONAL LUMEN SUMMARY

Zone	Lumens	% Lamp	% Fixture
0° - 30°	1383.0	25.3	28.2
0° - 40°	2264.0	41.5	46.1
0° - 60°	3975.7	72.8	81.0
0° - 90°	4908.3	89.9	100.0
90° - 180°	0.0	0.0	0.0
0° - 180°	4908.3	89.9	100.0

LUMINAIRE EFFICIENCY: 89.9%

CIE CLASSIFICATION: Direct

SPACING CRITERIA(0-Deg): 1.2
SPACING CRITERIA(90-Deg): 1.3

TESTED BY: ____________________

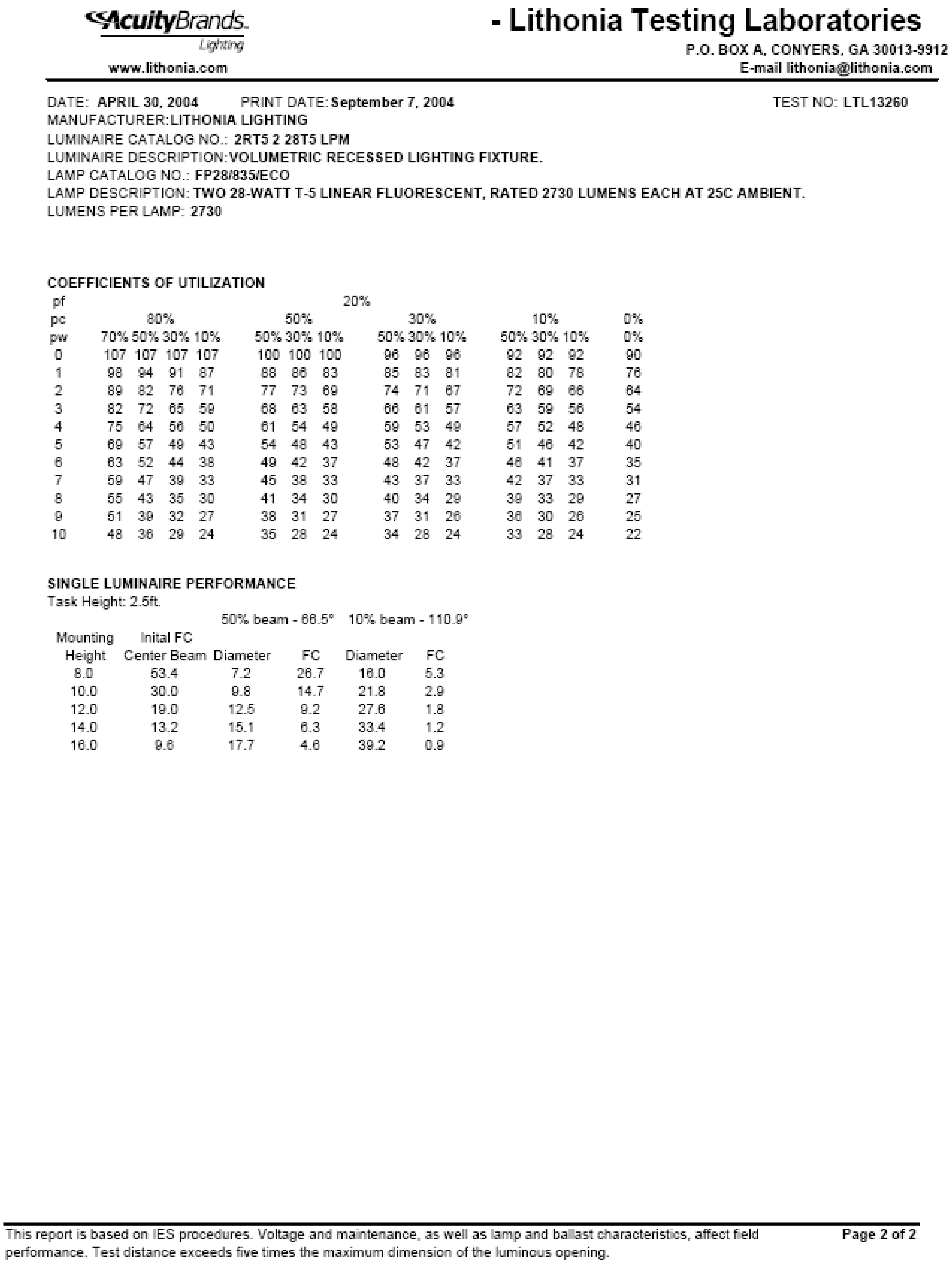
AVERAGE LUMINANCE (cd/m2)

	0°	45°	90°
45°	2095	2360	2569
55°	1719	2296	2650
65°	1320	2277	2401
75°	981	1722	1409
85°	488	374	342

Calculations based on IES File Luminous Area:
23.28 in. W x 46.92 in. L x 0.0 in. H

This report is based on IES procedures. Voltage and maintenance, as well as lamp and ballast characteristics, affect field performance. Test distance exceeds five times the maximum dimension of the luminous opening.

Page 1 of 2



AcuityBrands Lighting

www.lithonia.com

- Lithonia Testing Laboratories

P.O. BOX A, CONYERS, GA 30013-9912
E-mail lithonia@lithonia.com

DATE: **APRIL 30, 2004** PRINT DATE: **September 7, 2004** TEST NO: **LTL13260**
MANUFACTURER: **LITHONIA LIGHTING**
LUMINAIRE CATALOG NO.: **2RT5 2 28T5 LPM**
LUMINAIRE DESCRIPTION: **VOLUMETRIC RECESSED LIGHTING FIXTURE.**
LAMP CATALOG NO.: **FP28/835/ECO**
LAMP DESCRIPTION: **TWO 28-WATT T-5 LINEAR FLUORESCENT, RATED 2730 LUMENS EACH AT 25C AMBIENT.**
LUMENS PER LAMP: **2730**

COEFFICIENTS OF UTILIZATION

pf	20%													
pc	80%				50%			30%			10%			0%
pw	70%	50%	30%	10%	50%	30%	10%	50%	30%	10%	50%	30%	10%	0%
0	107	107	107	107	100	100	100	96	96	96	92	92	92	90
1	98	94	91	87	88	86	83	85	83	81	82	80	78	76
2	89	82	76	71	77	73	69	74	71	67	72	69	66	64
3	82	72	65	59	68	63	58	66	61	57	63	59	56	54
4	75	64	56	50	61	54	49	59	53	49	57	52	48	46
5	69	57	49	43	54	48	43	53	47	42	51	46	42	40
6	63	52	44	38	49	42	37	48	42	37	46	41	37	35
7	59	47	39	33	45	38	33	43	37	33	42	37	33	31
8	55	43	35	30	41	34	30	40	34	29	39	33	29	27
9	51	39	32	27	38	31	27	37	31	26	36	30	26	25
10	48	36	29	24	35	28	24	34	28	24	33	28	24	22

SINGLE LUMINAIRE PERFORMANCE
Task Height: 2.5ft.

		50% beam - 66.5°		10% beam - 110.9°	
Mounting Height	Inital FC Center Beam	Diameter	FC	Diameter	FC
8.0	53.4	7.2	26.7	16.0	5.3
10.0	30.0	9.8	14.7	21.8	2.9
12.0	19.0	12.5	9.2	27.6	1.8
14.0	13.2	15.1	6.3	33.4	1.2
16.0	9.6	17.7	4.6	39.2	0.9

This report is based on IES procedures. Voltage and maintenance, as well as lamp and ballast characteristics, affect field performance. Test distance exceeds five times the maximum dimension of the luminous opening.

Appendix C5: Individual Component Pricing

Table C5-1: Individual Component Pricing

Cost	Component
$130	RT% Fixture (includes fixture, ballast, and two T5 lamps)
$100	Replacement Ballast
$5.21	Replacement T5 Lamp

Appendix C6: Fluorescent Lamp Cost History and Forecast

Table C6-1: Fluorescent Lamp Cost History and Forecast

Time (years)	T-12	T-8	T-5
-10	$ 3.00	$ 4.50	
-3	$ 1.30	$ 2.00	$ 6.50
0	$ 1.23	$ 1.75	$ 5.21
3	$ 1.40	$ 1.75	$ 5.00
10	$ 2.00	$ 1.75	$ 4.00

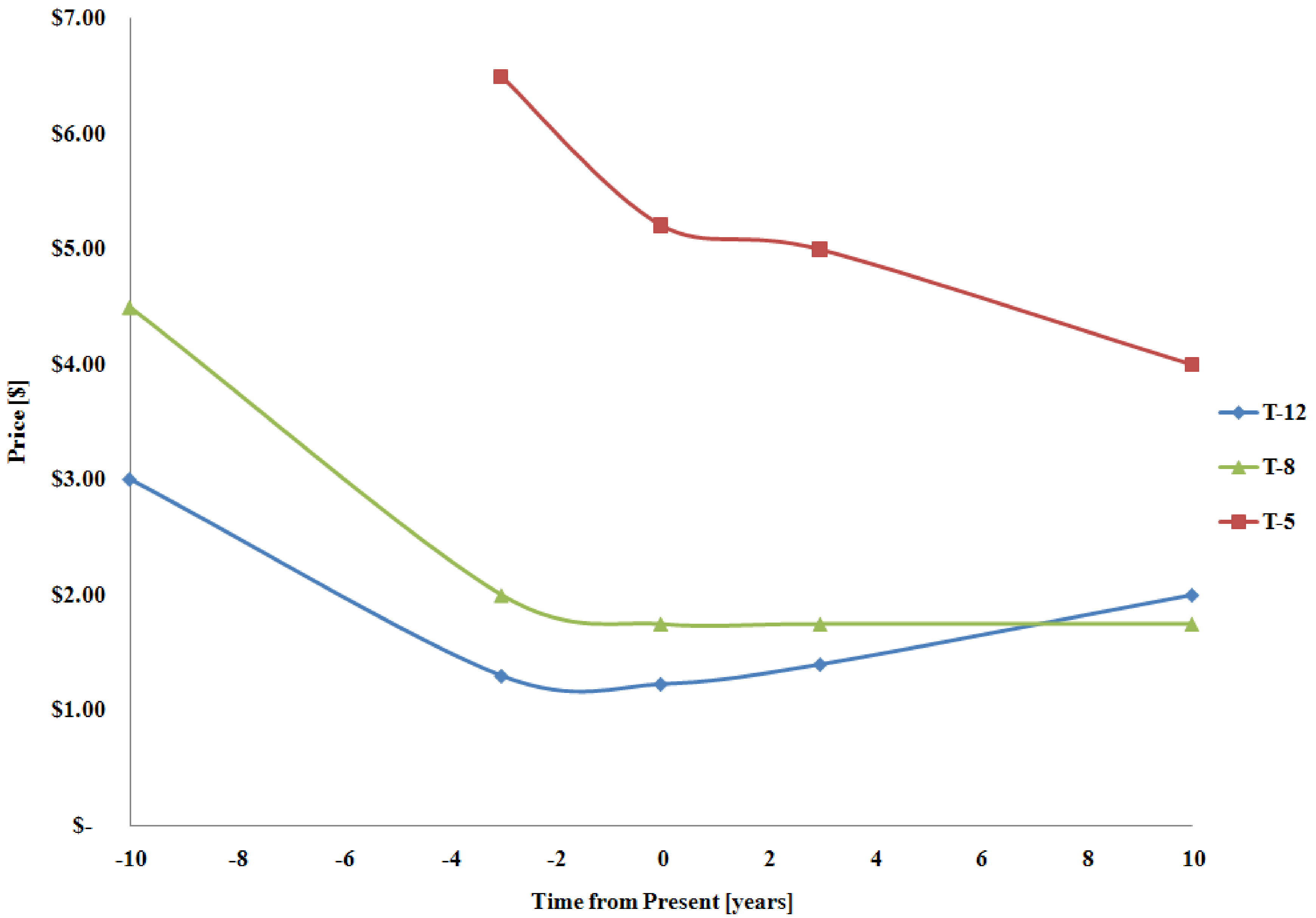


Figure C6-1: Bulb Prices, History and Forecast

Appendix D

Motion Sensors

Introduction

The objective for the motion sensor project was to determine the energy savings accumulated by installing motion sensors in the residence hall basements. The scope of this project will include 3 areas of each basement wing: the study room, the laundry room, and the common room. The energy currently used in the residence hall basements will be compared to the projected amount of energy used with the proposed motion sensor system.

Description

The current energy consumption of the lights in the residence hall basements was calculated based on the equation:

$$E_{usage}=I \cdot V \tag{D.1}$$

where I is the current draw per lamp, V is the system voltage, and E_{usage} is the energy used per lamp. This value was multiplied by the total number of lamps to find the total energy usage in kW of the lamps in the residence hall basement wings.

Values were estimated for the duration of time per day in which the lights are on in the residence hall basements (Table D1). A second set of duration values were estimated for the amount of time the lights would be on with the proposed motion sensor system. The energy usage value was used along with the time estimates to calculate the energy usage per year for the current and proposed set-ups. This was repeated for best and worst case duration times, by adjusting the estimated time the lights will be on with the proposed set-up.

Table D1: **Estimated Light Usage Time**

	Current	Nominal	Worst Case	Best Case
Daily Study Room Usage	16 *hrs/day*	10 *hrs/day*	12 *hrs/day*	8 *hrs/day*
Daily Laundry Room Usage	12 *hrs/day*	4 *hrs/day*	6 *hrs/day*	2 *hrs/day*
Daily Common Room Usage	24 *hrs/day*	16 *hrs/day*	18 *hrs/day*	14 *hrs/day*

The duration estimates were based on the experience of team members and consultation with current residence hall residents. It was assumed that there would be no usage of basements lights during the summer weeks and breaks and that usage is constant throughout the academic year.

The installation cost of the proposed system was calculated using labor and material costs obtained from Don Winkle of Calvin's Physical Plant. Material costs include the cost of each sensor package (quoted by West Michigan Lighting) and the cost of wiring needed to install each package. The motion sensors used will WattStopper dual technology sensors in the common rooms and study rooms, and WattStopper wall mounted infrared technology sensors will be used in each laundry room.

Results

The proposed motion sensor installation in the residence hall basements would save Calvin College approximately 86.4 MW-h/year in the nominal case (Table D2).

Table D2: Energy Savings

	Energy Savings *(kW-h/yr)*
Nominal	86416.2432
Best	109734.912
Worst	63097.5744

The installation cost for the nominal case is $25900, and the best and worst cases for cost are found by adjusting the estimated labor costs (Table D3). The cost of labor was adjusted by varying the time to install each sensor.

Table D3: Installation Cost

	Installation Cost *($)*
Nominal	25900
Best	23310
Worst	28490

The above installation costs were compared to the cost savings associated with the above reduced energy consumption to determine the time needed to for the project to pay for itself.

Conclusion

The proposed project is a valuable option as a potential CEEF project. Because of its relatively low up-front cost, it pays off quickly and offers high economic and energy savings. It can also be installed relatively quickly; all installation could be completed over an academic break such as Christmas break or over the summer. Motion sensors are a viable option for the residence hall basements, and a good investment for Calvin College.

Appendix D1: Cost Data and Assumptions

Table D1-1: Cost Data

Installation/Material costs	
Material/Labor Cost, Study rooms *[$/room]*	300
Material/Labor Cost, Laundry rooms *[$/room]*	150
Material/Labor Cost, Larger Common rooms *[$/room]*	600
Motion Sensor Cost	
DT-300 (dual technology, ceiling mounted) *[$]*	150
DT-200 (dual technology, wall mounted) *[$]*	50

Table D1-2: Assumptions

No usage during summer months
Price per unit= $150 (dual technology)
Use dual technology for all applications (only $10 extra)
One sensor (WattStopper DT-300) covers a 40' x 40' square area (detecting hand motion)
Use wall-mounted sensor for laundry rooms ($50)
Constant usage during academic year
4 DT-300 sensors needed per wing for common room

Appendix D2: Energy and Installation Cost Results

					Proposed Setup - Uncertainties			
	Current Setup		**Proposed Setup**		**Worst Case**		**Best Case**	
Current Draw (per lamp) - ASSUMING T8 LAMPS	0.21	*A*	0.21	*A*	0.21	*A*	0.21	*A*
System Voltage	120	*V*	120	*V*	120	*V*	120	*V*
Energy Usage	0.0252	*kW*	0.0252	*kW*	0.0252	*kW*	0.0252	*kW*
Daily Study Room Usage (current)	16	*hrs/day*	10	*hrs/day*	12	*hrs/day*	8	*hrs/day*
Daily Laundry Room Usage (current)	12	*hrs/day*	4	*hrs/day*	6	*hrs/day*	2	*hrs/day*
Daily Common Room Usage (current)	24	*hrs/day*	16	*hrs/day*	18	*hrs/day*	14	*hrs/day*
# of Study Room Fixtures (avg)	20	*fixtures*	20	*fixtures*	20	*fixtures*	20	*fixtures*
# of Laundry Room Fixtures (avg)	12	*fixtures*	12	*fixtures*	12	*fixtures*	12	*fixtures*
# of Commom Room Fixtures (avg)	30	*fixtures*	30	*fixtures*	30	*fixtures*	30	*fixtures*
Annual Energy Usage (per study room)	3919.104	*kWh/yr*	2449.44	*kWh/yr*	2939.328	*kWh/yr*	1959.552	*kWh/yr*
Annual Energy Usage (per laundry room)	2645.3952	*kWh/yr*	881.7984	*kWh/yr*	1322.6976	*kWh/yr*	440.8992	*kWh/yr*
Annual Energy Usage (per common room)	8817.984	*kWh/yr*	5878.656	*kWh/yr*	6613.488	*kWh/yr*	5143.824	*kWh/yr*
Annual Energy Usage (per basement wing)	15382.4832	*kWh/yr*	9209.8944	*kWh/yr*	10875.5136	*kWh/yr*	7544.2752	*kWh/yr*
Days lights on each year	243	*days/yr*	243	*days/yr*	243	*days/yr*	243	*days/yr*
TOTAL ANNUAL ENERGY USAGE (total of all wings)	215354.7648	*kWh/yr*	128938.5216	*kWh/yr*	152257.19	*kWh/yr*	105619.853	*kWh/yr*
TOTAL ANNUAL ENERGY SAVINGS (total of all wings)	0	*kWh/yr*	86416.2432	*kWh/yr*	63097.5744	*kWh/yr*	109734.912	*kWh/yr*
Installation Cost (Materials+ Labor)	0	*$*	25900	*$*	23310	*$*	28490	*$*

Appendix D3: Financial Submittal Sheet

Table D3-1: Motion Sensor Project Financial Sheet

Group Name	Technical Group 1			
Project Name	Lamp Replacement			
Description	Replace current North Hall light fixtures			
Implementation	Time-span	~1 month to install		
Electricity	Current Energy Consumption *(kW-hrs/yr)*	88,030.80	**Min**	**Max**
	Projected Energy Consumption *(kW-hrs/yr)*	42,811.20	52502.4	34401.6
Natural Gas	Current Energy Consumption *(Therms/yr)*	0.00		
	Projected Energy Consumption *(Therms/yr)*	0.00		# of fixtures
				352
Other	Current Energy Consumption *(Units/yr)*	0.00		
	Projected Energy Consumption *(Units/yr)*	0.00		
Installation	Labor Cost	$ 6,160.00		
	Material Cost	$ 53,260.00		
	Other Cost		**Min**	**Max**
	Total Installation Costs	$ 59,420.00	$ 53,478.00	$ 65,362.00
	Ongoing Costs *($/yr)*	$ 87.92		

Appendix E

Hekman Library Light Harvesting

Introduction

The goal of this project was to investigate a specific area of campus (namely the fifth floor of the Hekman Library) to see how much usable sunlight was being let in through nearby windows, and to determine how much energy could be saved by installing a light harvesting system to turn off the lights when they are not needed.

Description

In order to properly judge how much energy would be saved, the operating conditions of the current and proposed system needed to be determined. First, the current operating conditions were estimated to be 121 fixtures (2 bulbs each), running continuously during standard operating hours of the library. The proposed system would monitor these fixtures in 5 different lighting zones (North, South, East, and West facing walls, and Rev. H. J. Kuiper Reading Room), turning off unneeded fixtures as light levels increase from natural light. Figure E1 below shows a diagram of the proposed lighting zones.

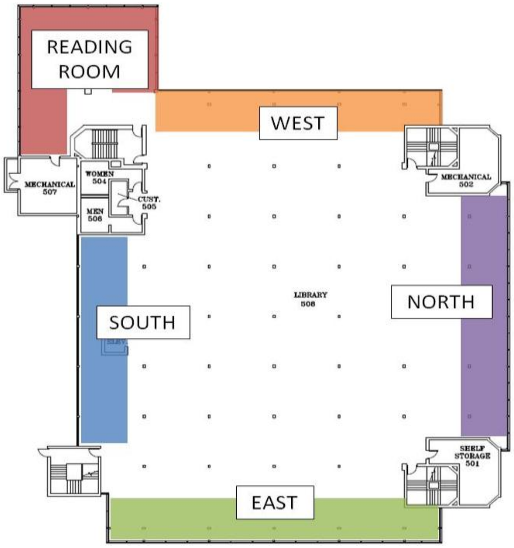


Figure E1. **Hekman Library Lighting Control Zones**

For a good estimate of how much energy would be saved with the proposed system, an analysis of the amount of available daylight for harvesting indoors was needed. The outdoor light levels were measured using a light sensor that output the light intensity in footcandles. Then, the indoor light levels were recorded with the interior lights off. This gave a good approximation of how much light entered the building through the windows.

Next, a minimum light level needed to be obtained. To do this, light levels were simply recorded at night, when no exterior light was entering the buildings, with the regular interior lights on.

Once a minimum allowable interior light level was obtained, and an estimated percentage of natural daylight that enters the building was determined, an energy savings analysis could be performed using previously recorded sunlight data. The data used for this project came from the Grand Rapids airport, which supplied sunlight in lux. Lux can be easily converted to footcandles (1 lux = 0.093 fc).

After average sunlight data was obtained, using the previous two calculations yielded a yearly energy savings.

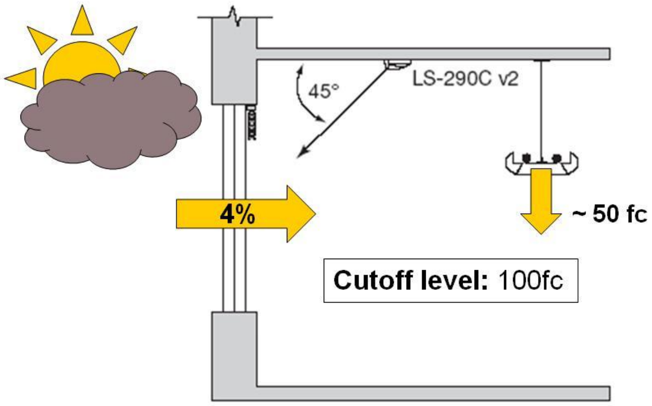


Figure E2. Indoor Light from Fixture and Sunlight

Cost data was obtained with the help of Kendall Electric, West Michigan Lighting, and Calvin's Physical Plant. Each of the five zones in the proposed system would require a package containing a power pack, photo sensor, on/off controller, and enclosure. This package contains what is necessary to control the lights based on the ambient light intensity in the room.

Results

The total projected energy savings for this project comes to about 12.3 MW-h/year, assuming a 3.7% light infiltration rate from available outdoor light, and a minimum indoor lighting cutoff of 100 footcandles. This is a conservative estimate as the minimum allowable indoor light is 46.6 footcandles.

The light harvesting can only be utilized up to 15 feet from a window. At distances further than 15 feet from the window, the light loses too much intensity and is no longer usable.

The installation costs for this project include $500 per zone for the upfront equipment cost, $1400 for installation labor ($35/hour for 8 hours per zone), and another $420 for miscellaneous installation materials. The total installation cost for the proposed system comes to $4320.

Conclusion

This project has a relatively low installation cost, and has the potential to save even more energy than projected. It is because of these reasons that the project is a good candidate for a CEEF project. Installation times are slightly longer than comparable projects, but are not unreasonable. Other areas of campus could also benefit from this type of system, and should be included in future CEEF research.

Appendix E1: Library Light Usage Energy Savings

Outdoor Light Level	1000	**Fc**
Cutoff Light Level (ON/OFF)	100	**Fc**
Lights OFF	2021	**hrs/yr**

Zone	**Avg. Night Light Level [Fc]**	**Light Level (Fixtures off) [Fc]**	**Ratio of Light (Zone over Outdoor)**
North-Facing Wall	52.17	43.28	0.0433
East-Facing Wall	34.36	43.22	0.0432
South-Facing Wall	54.23	18.30	0.0183
West-Facing Wall	47.17	29.23	0.0292
Rev. HJ Kuiper Reading Room	46.84	52.51	0.0525
		AVERAGE	0.0373

Proposed Setup

Zone	**Fixtures**	**Current Draw (per fixture) [A]**	**Zone Power Usage [kW]**	**Current Energy Usage [kW-hr/yr]**	**Projected Energy Usage [kW-hr/yr]**	**Energy Savings [kW-hr/yr]**
North-Facing Wall	32	0.42	1.61	6930.20	3670.73	3259.47
East-Facing Wall	19	0.42	0.96	4114.81	2179.50	1935.31
South-Facing Wall	17	0.42	0.86	3681.67	1950.08	1731.59
West-Facing Wall	21	0.42	1.06	4547.94	2408.92	2139.03
Rev. HJ Kuiper Reading Room	32	0.42	1.61	6930.20	3670.73	3259.47
	121		**Total**	26204.82	13879.96	12324.87

Uncertainty (Lower)

Zone	**Fixtures**	**Current Draw (per fixture) [A]**	**Zone Power Usage [kW]**	**Current Energy Usage [kW-hr/yr]**	**Projected Energy Usage [kW-hr/yr]**	**Energy Savings [kW-hr/yr]**
North-Facing Wall	32	0.42	1.61	6683.44	3423.97	3259.47
East-Facing Wall	19	0.42	0.96	3968.29	2032.98	1935.31
South-Facing Wall	17	0.42	0.86	3550.58	1818.99	1731.59
West-Facing Wall	21	0.42	1.06	4386.01	2246.98	2139.03
Rev. HJ Kuiper Reading Room	32	0.42	1.61	6683.44	3423.97	3259.47
			Total	25271.77	12946.90	12324.87

Uncertainty (Upper)

Zone	**Fixtures**	**Current Draw (per fixture) [A]**	**Zone Power Usage [kW]**	**Current Energy Usage [kW-hr/yr]**	**Projected Energy Usage [kW-hr/yr]**	**Energy Savings [kW-hr/yr]**
North-Facing Wall	32	0.42	1.61	7176.96	3917.49	3259.47
East-Facing Wall	19	0.42	0.96	4261.32	2326.01	1935.31
South-Facing Wall	17	0.42	0.86	3812.76	2081.17	1731.59
West-Facing Wall	21	0.42	1.06	4709.88	2570.85	2139.03
Rev. HJ Kuiper Reading Room	32	0.42	1.61	7176.96	3917.49	3259.47
			Total	27137.88	14813.01	12324.87

COST CALCULATIONS	**Labor Cost [$/hr]**	**Installation Time [hrs]**	**Sensor Package Cost [$]**
North-Facing Wall	35	8	500
East-Facing Wall	35	8	500
South-Facing Wall	35	8	500
West-Facing Wall	35	8	500
Rev. HJ Kuiper Reading Room	35	8	500

	Materials [$]	**Labor [$]**	**Sensor Packages [$]**	**TOTAL [$]**
Total Initial Costs	420	1400	2500	4320

Assumptions

"Current Energy Usage" assumes every fixture in that zone is on during open hours of the library

All fixtures draw an equal amount of current: 0.42 A (0.21 A per lamp)

"Projected Energy Usage" includes assumptions stated on sheet2

Lights turn off if light sensed (incoming outdoor light + light from lamps) is greater than 80 Fc

Appendix E2: Library Light Usage Hours

Proposed Setup

Time Period	Period Length [days/yr]	Light Usage [hrs/day]	Total Usage [hrs/yr]
Summer (Mon-Thurs)	64	13.5	864
Summer (Fri)	17	9	153
Summer (Sat)	17	4.5	76.5
Fall Sem. (Mon-Thurs)	60	17	1020
Fall Sem. (Fri)	15	13	195
Fall Sem. (Sat)	15	11.5	172.5
Interim (Mon-Thurs)	14	17	238
Interim (Fri)	4	13	52
Interim (Sat)	4	11.5	46
Spring Sem. (Mon-Thurs)	64	17	1088
Spring Sem. (Fri)	16	13	208
Spring Sem. (Sat)	16	11.5	184
		Total	4297

hrs/yr

Uncertainty (Lower)

Time Period	Period Length [days/yr]	Light Usage [hrs/day]	Total Usage [hrs/yr]
Summer (Mon-Thurs)	64	13	832
Summer (Fri)	17	8.5	144.5
Summer (Sat)	17	4	68
Fall Sem. (Mon-Thurs)	60	16.5	990
Fall Sem. (Fri)	15	12.5	187.5
Fall Sem. (Sat)	15	11	165
Interim (Mon-Thurs)	14	16.5	231
Interim (Fri)	4	12.5	50
Interim (Sat)	4	11	44
Spring Sem. (Mon-Thurs)	64	16.5	1056
Spring Sem. (Fri)	16	12.5	200
Spring Sem. (Sat)	16	11	176
		Total	4144

hrs/yr

Uncertainty (Upper)

Time Period	Period Length [days/yr]	Light Usage [hrs/day]	Total Usage [hrs/yr]
Summer (Mon-Thurs)	64	14	896
Summer (Fri)	17	9.5	161.5
Summer (Sat)	17	5	85
Fall Sem. (Mon-Thurs)	60	17.5	1050
Fall Sem. (Fri)	15	13.5	202.5
Fall Sem. (Sat)	15	12	180
Interim (Mon-Thurs)	14	17.5	245
Interim (Fri)	4	13.5	54
Interim (Sat)	4	12	48
Spring Sem. (Mon-Thurs)	64	17.5	1120
Spring Sem. (Fri)	16	13.5	216
Spring Sem. (Sat)	16	12	192
		Total	4450

hrs/yr

Assumptions

Proposed Data assumes lights are turned on 1/2 hour before library opens

Uncertainty Data assumes lights are on 1/2 longer or shorter per day than proposed

All data refers to the previous summer and current academic year.

All data does not include special hours such as: exam hours, holidays, special hours, or breaks (spring break, christmas break, interim break, etc.)

All data refers to normal library operating hours during each part of the year (per campus safety's website and librarian contact)

Appendix E3: Library Measured Light Levels

ENGR 333 - CEEF - TECHNICAL TEAM 1

Library Light Harvesting Project

Flourescent Light Levels

** Light levels measured with Extech Model 401027 Pocket Foot Candle Light Meter*

Date	11/18/2008
Time	9:00 PM

AVERAGE LEVEL	46.6 Fc

Zone	Level [Fc]	Avg [Fc]
East	41.5	34.4
	36	
	29.8	
	34.5	
	32	
	28.5	
	38.2	
South	52	54.2
	55.4	
	52	
	34	
	67.7	
	64.3	
West	46.3	47.2
	54.3	
	50.5	
	41.8	
	40	
	50.1	
North	51.5	52.2
	68.2	
	58.7	
	28.7	
	53.5	
	52.4	
Reading Room	52.6	46.8
	42.4	
	57.1	
	54.2	
	42.2	
	46.1	
	28.6	
	51.5	
AVERAGE	46.6	

Lights off - measured light level from ambient light through windows

Date	11/21/2008
Time	12:00 PM

AVERAGE LEVEL	37.8 Fc

Zone	Level [Fc]	Avg [Fc]
East	47.2	43.2
	48.1	
	41.7	
	47.1	
	50.1	
	25.1	
South	22.5	18.3
	22.3	
	21.6	
	17.5	
	13.1	
	12.8	
West	18	29.2
	30.6	
	33.4	
	29	
	33.9	
	30.5	
North	41.8	43.3
	47.1	
	50.1	
	42.8	
	37.4	
	40.5	
Reading Room	89.8	52.5
	75.7	
	51.3	
	41	
	36	
	45.1	
	28.7	
AVERAGE	37.8	

Appendix E4: BT-203 Power Pack

WattStopper
legrand

LightSaver®

BT-203 Power Pack

Installation Instructions

SPECIFICATIONS

UL and cUL Listed

Voltages	100–277VAC 50/60Hz
Secondary Power	1A @24VDC
Contact Ratings	620W @120 or 277VAC
Operating Temperature	32°–104°F (0-40°C)
Dimensions	2.76" x 3.57" x 2.36" (70.0mm x 90.5mm x 60.0mm)

DESCRIPTION

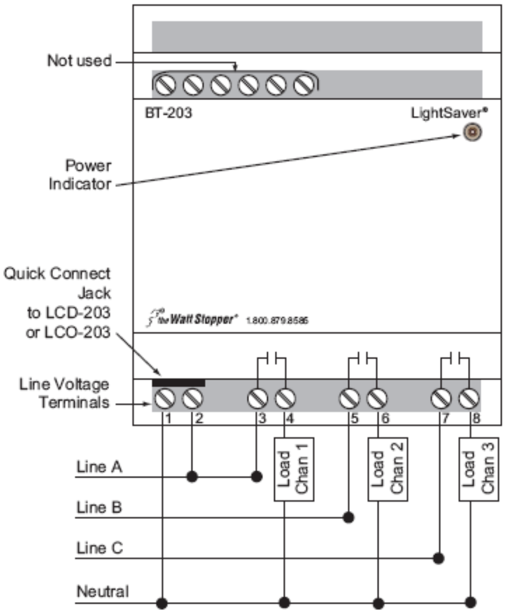
The BT-203 power pack is designed for use with the Lightsaver LCD-203 and LCO-203 Daylighting controllers. The BT-203 supplies low voltage power to the controller. It has three normally open relays used to switch line voltage in response to signals from the connected controller.

Low voltage and control signalling is passed between the controller and power pack using a quick connect cable fitted with RJ12 connectors at each end. Do not connect the quick connect cable to the controller until all other wiring is complete and you are ready to power-up the system.

WIRING

⚠ WARNING ⚠

TURN THE POWER OFF AT THE CIRCUIT BREAKER BEFORE INSTALLING POWER PACKS
ONLY QUALIFIED ELECTRICIANS SHOULD ATTEMPT TO INSTALL WATT STOPPER POWER PACKS



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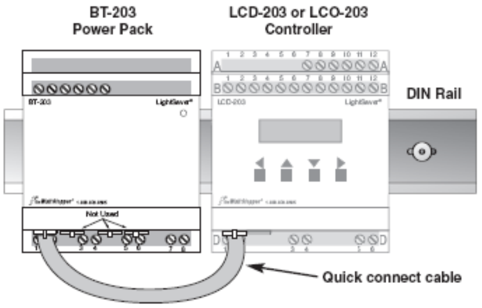


OPERATION

The BT-203 supplies 24VDC to the controller. If the current drawn from the BT-203 exceeds specifications the +24VDC output shuts down and the LED turns off. After the fault condition is cleared and the power is cycled, the BT-203 automatically attempts to restore the +24VDC output.

LED Indicator

The BT-203 has a green LED indicator. It illuminates when power is applied and the power pack is operating within specifications.

Installation Notes

- BT-203 power packs are designed for installation inside lighting panels or electrical enclosures that are fitted with a DIN-rail.
- Line and low voltage must be separated. Line and low voltage wires must not enter the enclosure through the same knockout.
- Power packs must be installed in accordance with state, local and national electrical codes and requirements.
- The quick connect cable is 12" long (30.5mm). It is supplied with the controller, which is either the Lightsaver LCD-203 or LCO-203.
- After initial wiring is complete, check wiring diagram to verify power pack is wired correctly. Improper wiring can cause damage to power pack, lighting system, and the Lightsaver controller.

2800 De La Cruz Boulevard, Santa Clara, CA 95050
Technical Support: 800.879.8585 • 972.578.1699
www.wattstopper.com
04250r1 02/2005

Appendix E5: LS-290C v2 Photocell

LightSaver®

LS-290C v2 Photocell

Installation Instructions

SPECIFICATIONS

UL and cUL Listed, Class 2

Voltage	24VDC
Signal range	0-10VDC
Light level range	selectable, 3 to 300fc, 30 to 3000fc, 60 to 6000fc

DESCRIPTION

The LS-290C v2 is a low voltage photocell used with a LightSaver LCD-203 or LCO-203 daylighting controller. The LS-290C v2 photocell senses light levels and signals this data to the controller. The LS-290C v2 is powered by the controller.

Photocell Placement

The photocell is designed for mounting in a dry location that views daylight. The photocell should not directly view illumination from an electric light source. Figure 1 shows the LS-290C v2 field of view.

Where windows are the primary source of daylight, the photocell typically mounts on the ceiling between the window and the first row of fixtures (see Figure 2). The photocell points toward the window.

For skylight applications, the photocell mounts in the lightwell of the skylight and should view the incoming daylight. Typically, the photocell is aimed toward the skylight. The light level range adjustment jumper may need to be changed to 60-6000fc for skylight applications.

Light Level Testing

Before installing the photocell, verify the daylight levels on a sunny day at the proposed location of the photocell. With the lights switched off, use a light meter to read the daylight level. Orient the light meter in the same direction that the photocell will view. The light levels under sunny conditions must be at least 35 footcandles. If the light levels are less, you should select another location or reorient the photocell.

INSTALLATION

Wiring and Testing

Maximum wire distance from the controller to the LS-290C v2 is 250 feet. Use 22 AWG 3-conductor twisted cable, equal to Belden 8443.

1. To access the LS-290C v2 wiring terminals, insert a small, flat-blade screwdriver into a slot on the housing and remove the base from the lens assembly.
2. Review the Mounting section to determine how the cable to the controller will enter the photocell housing. Modify either the lens housing or the base as instructed in Final Mounting, step 2A or 2B.
3. Connect wiring to the controller as shown in Figure 4. (If flush mounting, feed the cable through the base before terminating.)
4. Make sure the footcandle range jumper is in the correct position for the expected light level. (See Range Adjustment on the next page, and the controller instructions for information about photocell range adjustment.)
5. Return the base to the lens assembly.
   a) Align the arrow and sun icon inside the base with the lens.
   b) Use gentle pressure to snap the parts together.
6. Power-up the controller. Verify the photocell wiring by reading the controller display. As you cover and uncover the photocell, the reading should change. The controller reading shows the minimum value of the programmed range if the light level is below the range, or if the photocell is not properly connected.

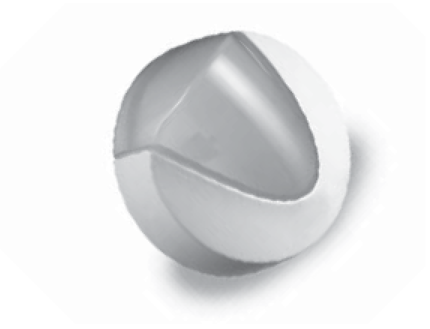


Figure 1: Field of view & mounting

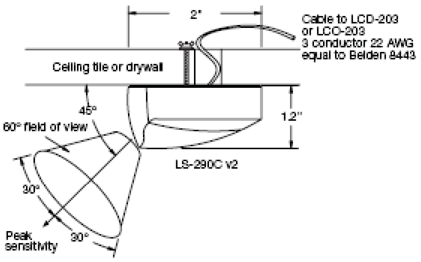


Figure 2: Placement

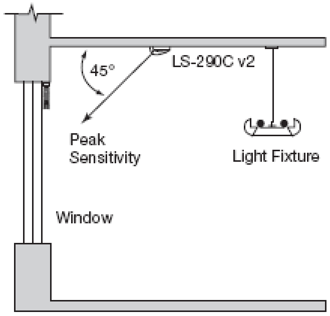
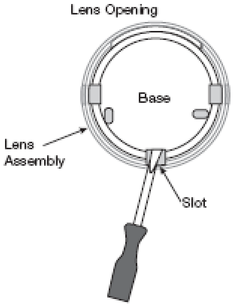


Figure 3: Removing base from lens assembly



Range Adjustment

The 2-pin jumpers next to the wiring terminals set the light level range for the LS-290C v2. In most applications, the default range of 30 to 3000 footcandles is appropriate. This range is also the default programmed into the LCD-203 and LCO-203 controller's "Daylight Factor" section. If the range needs to change (e.g., 3-300fc for darker applications, 60-6000fc for skylight applications) be sure the controller programming matches the jumper setting on the LS-290C v2.

MOUNTING

After selecting a location and wiring it to the controller, test for the optimum lens orientation before permanently mounting the photocell.

The LS-290C v2 kit comes with a circular piece of double-sided foam adhesive tape. You can use this tape to temporarily mount the photocell during placement testing.

CAUTION: The tape may permanently adhere to some surfaces. The surface may be damaged if the tape is removed.

Final Mounting

The LS-290C v2 can be mounted so that the cable enters through the photocell base and is not visible (Flush Mount) or so that the cable exits the side of the lens assembly and runs along the exterior of the ceiling or wall (Surface Mount). See Figures 3-6.

1. Remove the base from the lens assembly.
2. Open a wire entry location in either the Base or the Lens Assembly. See Figure 5.

   A. Flush Mount (wire entry through base)
   Use this mounting procedure when the wires will be concealed within the wall or ceiling.

      A1. Put the base on a sturdy, flat surface so that the inside of the base is on the flat surface and the outside of the base is facing you. Locate the horseshoe shaped area in the center of the base.

      A2. Apply firm pressure to the center of the horseshoe with a punch tool and tap with a hammer to knockout the wire entry.

      A3. Thread the cable from the controller through the outside of the base toward the inside.

   -or-

   B. Surface Mount (wire entry through lens assembly)
   Use this procedure when the wires will run on the surface of the wall or ceiling.

      B1. Locate the wire entry location in the opaque white plastic cover at the opposite side from the translucent lens opening.

      B2. Use needle nose pliers or wire cutters to break away the white plastic covering the wire entry.

3. Connect the wires to the terminals on the lens assembly as shown in Figure 4.
4. Return the base to the lens assembly.
   a) Align the arrow and sun icon inside the base with the lens opening.
   b) Use gentle pressure to snap the parts together.
5. Remove the opaque white cover from the photocell. Insert a thin screwdriver blade between the white cover and the lens opening as shown in Figure 6, then pop off the white cover.
6. Secure the photocell with screws (not provided). Use two #4 screws of the appropriate length. For ceiling tiles, use machine screws with appropriate washers and nuts. Use wood or masonry screws for solid surfaces. Figure 1 shows flush mounting to a ceiling tile or drywall using machine screws, washers and wing nuts.

   Insert screws through the mounting holes as shown in Figure 6. Make sure the placement and orientation is the same as it was during testing. Tighten the screws and fastening hardware.
7. Snap the white cover in place over the lens assembly.

Figure 4: Wiring Diagram

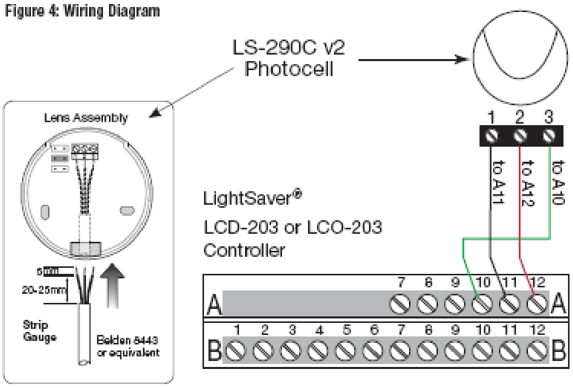


Figure 5: Wire entry locations

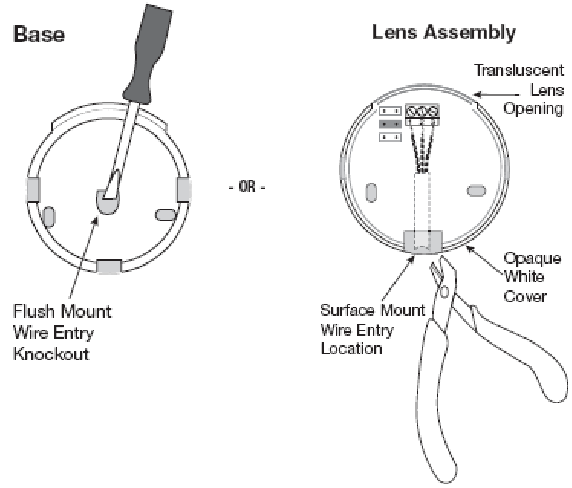
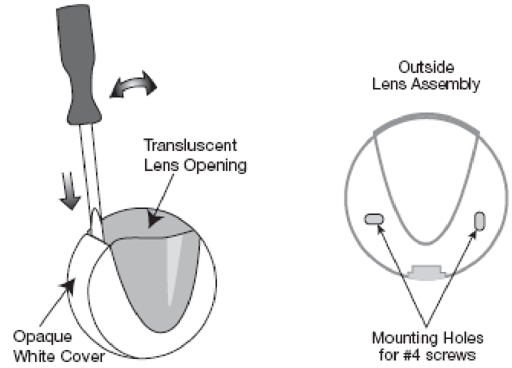


Figure 6: Removing the cover from the photocell for mounting



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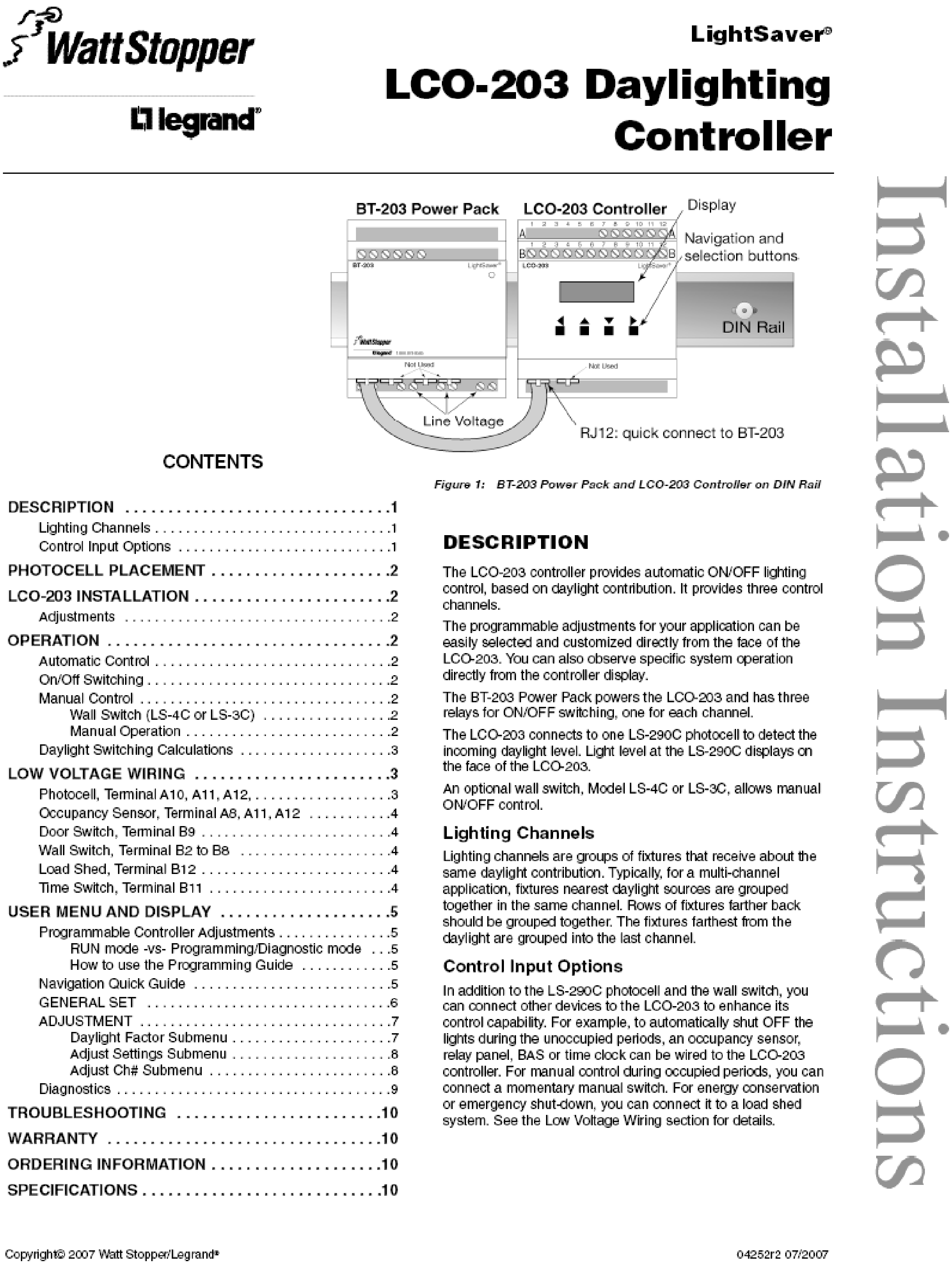
Appendix E6: LCO-203 Daylighting Controller

(incomplete installation sheet – full sheet available at www.wattstopper.com)



WattStopper
legrand®

LightSaver®

LCO-203 Daylighting Controller

Installation Instructions

Figure 1: BT-203 Power Pack and LCO-203 Controller on DIN Rail

CONTENTS

DESCRIPTION

The LCO-203 controller provides automatic ON/OFF lighting control, based on daylight contribution. It provides three control channels.

The programmable adjustments for your application can be easily selected and customized directly from the face of the LCO-203. You can also observe specific system operation directly from the controller display.

The BT-203 Power Pack powers the LCO-203 and has three relays for ON/OFF switching, one for each channel.

The LCO-203 connects to one LS-290C photocell to detect the incoming daylight level. Light level at the LS-290C displays on the face of the LCO-203.

An optional wall switch, Model LS-4C or LS-3C, allows manual ON/OFF control.

Lighting Channels

Lighting channels are groups of fixtures that receive about the same daylight contribution. Typically, for a multi-channel application, fixtures nearest daylight sources are grouped together in the same channel. Rows of fixtures farther back should be grouped together. The fixtures farthest from the daylight are grouped into the last channel.

Control Input Options

In addition to the LS-290C photocell and the wall switch, you can connect other devices to the LCO-203 to enhance its control capability. For example, to automatically shut OFF the lights during the unoccupied periods, an occupancy sensor, relay panel, BAS or time clock can be wired to the LCO-203 controller. For manual control during occupied periods, you can connect a momentary manual switch. For energy conservation or emergency shut-down, you can connect it to a load shed system. See the Low Voltage Wiring section for details.

Appendix F

Forced Computer Shutdown

Introduction

With the large number of computers on campus, having the machines stay on during all times of the day when no one is using them is using unnecessary energy. The forced computer shutdown project for the Calvin Energy Efficiency Fund analyzes the energy saved if computers across campus are forced to turn off during times of the day when students and staff are not using them.

Description

The first step to analyzing the power consumption and savings was to find the power consumption of the computers currently being used on Calvin's campus. Calvin presently owns 2,838 operating computers. Due to the wide variety of models, the power consumption of the most common computers, iMacs, PCs and info Xpress, was taken. A detailed description of the computers can be seen in Appendix F1. The power consumption of the different models of computers was measured with a Kill-A-Watt meter. Readings were taken while the computer was on, while the computer was off and while the computer was on standby. The average power consumption of the computers in each mode was calculated.

The second step in the analysis was to differentiate not only between the model of computer, but also the main user. The peak usage time for different computers greatly varied. For accuracy in the calculations, the total number of computers was separated into Lab computers (computers in different labs around campus), Staff computers (the computers used by Calvin Staff and faculty), and Other computers (info Xpress Stations, Dorm computers)

For each category of computers, different shutdown hours and applicable year applied. For the Lab and Other computers, 200 days per year were used to calculate the energy consumption savings while 300 days per year were used for the Staff computers. The different category computers were also varied in the times where the forced shutdown would apply.

The next action for the analysis was to estimate the amount of computers that are currently on during the projected shutdown hours, the estimated amount of Mac computers that would remain off during forced shutdown hours and the estimated amount of PCs that would remain off during forced shutdown hours. These numbers were estimated for an optimum, nominal and pessimistic case, and then checked with CIT for accuracy. These estimations can be seen in Table F1. Although CIT did not have any definite values, based on a study at another college roughly the same size as Calvin, CIT confirmed the approximations.

Based on these approximations, the total power consumption while having the computers on and off for each category of computers were calculated using equations F1 and F2.

$$\text{ComputerPowerConsumption}_{\text{on}} = \{[(\#_{\text{Mac}} \times \text{AvgPowerOn}_{\text{Mac}}) + (\#_{\text{PC}} \times \text{AvgPowerOn}_{\text{PC}})]\text{Hours}_{\text{shutdown}}\}\%_{\text{CurrentlyOn}} \tag{F1}$$

$$\text{ComputerPowerConsumption}_{\text{off}} = [(\#_{\text{Mac}} \times \text{AvgPowerOn}_{\text{Mac}} \times \%\text{MacOff}_{\text{shutdown}}) + (\#_{\text{PC}} \times \text{AvgPowerOn}_{\text{PC}} \times \%\text{PCOff}_{\text{shutdown}})]\text{Hours}_{\text{shutdown}} \tag{F2}$$

The power consumption savings per day were calculated by calculating the difference between the total power consumption with the computers on and the total power consumption with the computers during shutdown hours. The power consumption savings per year was calculated by converting the power consumption savings per day to power consumption savings per year based on the applicable days per year for each category of computers.

The cost of the project for the nominal case was calculated to be $7.10 per work station ($20,434 total). This cost is a onetime cost because there was no relicensing renewal fee for the software that was chosen by CIT.

Results

The results of the forced computer shutdown analysis are presented below in Table F2. This table shows results from the optimistic, nominal and pessimistic energy savings analyses.

This project has a relatively inexpensive cost for implementing. CIT has already researched software that can make a forced shutdown possible. The chosen software, Deep Freeze, cost $7.10 per work station. The total project cost for the nominal case was calculated to be $20,609 for purchasing and installing (an estimated $35/hr for 5 hours installation cost) the software for a forced computer shutdown. The cost for the project changed for both the optimistic and pessimistic case, with varying costs for software and labor. These values can be seen in Appendix F5. The software is already compatible with their current system. Deep Freeze includes a function that calculates the watts that are being saved while the computers are turned off. The forced computer shutdown project results could be monitored through this feature the software provides.

Conclusion

After analysis, it is definite that this project should be implemented. There will be minimal installation costs and the cost of the project is negligible compared to the energy saved in the optimistic, nominal and even pessimistic analysis. This project might cause problems for students and staff as they adjust to not having computers on all night, but this inconvenience is worth the cost due to the energy saved by this project. Although the analysis relies heavily on the use of estimated percentages of current and projected computer usage, the analysis proves that this simple shutdown can save large amounts of energy even if the approximations vary.

Table F1: Estimations for Computer Shutdown Analysis

	Lab	Staff	Other
Forced Shutdown hours	1am-7am	6pm-7am	1am-7am
Percent of Windows computers that will remain off during shutdown hours	100% Opt	95% Opt	95% Opt
	98% Nom	90% Nom	90% Nom
	80% Pess	80% Pess	80% Pess
Percent of Mac computers that will remain off during shutdown hours	100% Opt	95% Opt	100% Opt
	98% Nom	90% Nom	95% Nom
	80% Pess	80% Pess	80% Pess
Percent of computers that remain on during shutdown hours currently	50% Opt	70% Opt	95% Opt
	40% Nom	60% Nom	80% Nom
	30% Pess	40% Pess	70% Pess

Table F2: Energy Savings Results

	Pessemistic	Nominal	Optimistic
Lab Computers	27,409 [kWh/yr]	36,697 [kWh/yr]	46,263 [kWh/yr]
Staff Computers	130,722 [kWh/yr]	198,449 [kWh/yr]	232,213 [kWh/yr]
Other Computers	99,234 [kWh/yr]	113,455 [kWh/yr]	135,099 [kWh/yr]
Total Energy Savings	257,565 [kWh/yr]	348,601 [kWh/yr]	413,575 [kWh/yr]

Appendix F1: Measured Computer Consumption

Computer Power Consumption Testing

Computer Model	**Monitor Type**	**Location**	**On Power (kW)**	**Off Power (kW)**	**Standby Power (kW)**
Windows Computers					
Dell Optiplex 745	17" LCD	SB 120	0.1	0.002	0.002
Dell Optiplex GX620	17" LCD	ITC	0.11	0.004	0.005
Dell Optiplex GX 60	17" CRT	ITC Info xPress	0.115	0.001	N/A
		Average Consumption	0.108	0.002	0.004
Mac Computers					
iMac	17" LCD	ITC	0.053	0	0.002
		Average Consumption	0.053	0.000	0.002
Other Computers					
AMD 64 Athalon X2	2 19" LCD	SB 354	0.064	0.000	0.001
Dell Optiplex GX 60	15" LCD	Info xPress	0.065	0.002	N/A

Appendix F2: Nominal Value Calculations

Power Savings Calculations- 88% of computers are PC's, 12% are Mac's

Lab computers

Total Number of Computers	860
Number of Windows Computers on Campus	622
Number of Mac Computers on Campus	238
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	98%
Assumed percent of mac computers that will remain off during this entire time	98%
Assumed percent of computers that currently remain on during the night	40%
Number of applicable days per year	200

Staff Computers

Total Number of Computers	860
Number of Windows Computers on Campus	757
Number of Mac Computers on Campus	103.2
Hours per day off (6 p.m. to 7 a.m.)	13
Assumed percent of windows computers that will remain off during this entire time	90%
Assumed percent of mac computers that will remain off during this entire time	90%
Assumed percent of computers that currently remain on during the night	60%
Number of applicable days per year	300

All Remaining Computers (info Xpress, Dorm Labs, etc.)

Total Number of Computers	1118
Number of Windows Computers on Campus	1118
Number of Mac Computers on Campus	0
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	90%
Assumed percent of mac computers that will remain off during this entire time	95%
Assumed percent of computers that currently remain on during the night	80%
Number of applicable days per year	200

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	192
Total Power consumption during night while in standby (kW-hr / day)	15.6
Total Power consumption during night while off (kW-hr / day)	9

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	682
Total Power consumption during night while in standby (kW-hr / day)	33.4
Total Power consumption during night while off (kW-hr / day)	21

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	581
Total Power consumption during night while in standby (kW-hr / day)	21.1
Total Power consumption during night while off (kW-hr / day)	14

Total Network Savings

Total yearly power savings by having computers in standby (kW-hr / year)	341956
Total yearly power savings by having computers off (kW-hr / year)	348601

Projected electrical cost ($ / kW-hr)	$ 0.092
Projected cost savings ($ / year)	$ 32,071

Software Costs

Cost / workstation (one time cost: http://www.faronics.com/html/calculator.asp)	$ 7.20
Total yearly software costs	$20,434

Payback Period

Payback Period (months)	8

Appendix F3: Optimistic Value Calculations

Power Savings Calculations- 88% of computers are PC's, 12% are Mac's

Lab computers

Total Number of Computers	860
Number of Windows Computers on Campus	622
Number of Mac Computers on Campus	238
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	100%
Assumed percent of mac computers that will remain off during this entire time	100%
Assumed percent of computers that currently remain on during the night	50%
Number of applicable days per year	200

Staff Computers

Total Number of Computers	860
Number of Windows Computers on Campus	757
Number of Mac Computers on Campus	103.2
Hours per day off (6 p.m. to 7 a.m.)	13
Assumed percent of windows computers that will remain off during this entire time	95%
Assumed percent of mac computers that will remain off during this entire time	95%
Assumed percent of computers that currently remain on during the night	70%
Number of applicable days per year	300

All Remaining Computers (info Xpress, Dorm Labs, etc.)

Total Number of Computers	1118
Number of Windows Computers on Campus	1118
Number of Mac Computers on Campus	0
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	95%
Assumed percent of mac computers that will remain off during this entire time	100%
Assumed percent of computers that currently remain on during the night	95%
Number of applicable days per year	200

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	240
Total Power consumption during night while in standby (kW-hr / day)	15.9
Total Power consumption during night while off (kW-hr / day)	9

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	796
Total Power consumption during night while in standby (kW-hr / day)	35.3
Total Power consumption during night while off (kW-hr / day)	22

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	690
Total Power consumption during night while in standby (kW-hr / day)	22.3
Total Power consumption during night while off (kW-hr / day)	15

Total Network Savings

Total yearly power savings by having computers in standby (kW-hr / year)	406610
Total yearly power savings by having computers off (kW-hr / year)	413575

Projected electrical cost ($ / kW-hr)	0.092
Projected cost savings ($ / year)	$ 38,049

Software Costs

Cost / workstation (one time cost: http://www.faronics.com/html/calculator.asp)	7.20
Total yearly software costs	$ 20,434

Payback Period

Payback Period (months)	6

Appendix F4: Pessimistic Value Calculations

Power Savings Calculations- 88% of computers are PC's, 12% are Mac's

Lab computers

Total Number of Computers	860
Number of Windows Computers on Campus	622
Number of Mac Computers on Campus	238
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	80%
Assumed percent of mac computers that will remain off during this entire time	80%
Assumed percent of computers that currently remain on during the night	30%
Number of applicable days per year	200

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	144
Total Power consumption during night while in standby (kW-hr / day)	12.7
Total Power consumption during night while off (kW-hr / day)	7

Staff Computers

Total Number of Computers	860
Number of Windows Computers on Campus	757
Number of Mac Computers on Campus	103.2
Hours per day off (6 p.m. to 7 a.m.)	13
Assumed percent of windows computers that will remain off during this entire time	80%
Assumed percent of mac computers that will remain off during this entire time	80%
Assumed percent of computers that currently remain on during the night	40%
Number of applicable days per year	300

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	455
Total Power consumption during night while in standby (kW-hr / day)	29.7
Total Power consumption during night while off (kW-hr / day)	18

All Remaining Computers (info Xpress, Dorm Labs, etc.)

Total Number of Computers	1118
Number of Windows Computers on Campus	1118
Number of Mac Computers on Campus	0
Hours per day off (1 a.m. to 7 a.m.)	6
Assumed percent of windows computers that will remain off during this entire time	80%
Assumed percent of mac computers that will remain off during this entire time	80%
Assumed percent of computers that currently remain on during the night	70%
Number of applicable days per year	200

Total Consumptions

Total Power consumption during night while on (kW-hr / day)	509
Total Power consumption during night while in standby (kW-hr / day)	18.8
Total Power consumption during night while off (kW-hr / day)	13

Total Network Savings

Total yearly power savings by having computers in standby (kW-hr / year)	251761
Total yearly power savings by having computers off (kW-hr / year)	257565

Projected electrical cost ($ / kW-hr)	$0.092
Projected cost savings ($ / year)	$23,696.00

Cost / workstation (one time cost: http://www.faronics.com/html/calculator.asp)	$7.20
Total yearly software costs	$20,433.60

Payback Period

Payback Period (months)	10

Appendix F5: Financial Data

Please fill in one of these sheets for every project you have				
Group Name	Group 2			
Project Name	Forced Computer shutdown			
Description	Force computers to be shut down during specified hours			
Implementation	Time-span	1 week		
		Pessimistic	Nominal	Optimistic
Electricity	Current Energy Consumption (kW-hrs/yr)	266973	359,324	424834
	Projected Energy Consumption (kW-hrs/yr)	9408	10723	11259
Natural Gas	Current Energy Consumption (Therms/yr)			
	Projected Energy Consumption (Therms/yr)			
Other	Current Energy Consumption (Units/yr)			
	Projected Energy Consumption (Units/yr)			
Installation	Labor Cost	$ 35	$ 175	$ 300
	Material Cost			
	Other Cost	$ -	$ 20,434	$ 20,434
	Total Installation Costs	$ 35	$ 20,609	$ 20,734
	Ongoing Costs ($/yr)	$ -	$ -	$ 3,405.60
	Total Cost of Project	$ 35	$ 20,609	$ 24,140
Additional Notes				

Appendix G

Solar Water Heating

Introduction

In efforts to create a more energy efficient campus, it is reasonable to try to harness the free energy that is around us. One way of doing this is solar water heating. This appendix delves into the details of a proposed solar water heating system and its initial cost and energy savings.

Description

Solar water heating systems come in a variety of setups. Due to the Michigan climate and the possible size of the solar water heating network, an active, indirect system is recommended. An active system uses pump to circulate a fluid through the network of solar collectors. A fluid, such as glycol, is used in an indirect system to transfer heat energy from the collectors through a heat exchanger to the water. The advantage of using this system is that heated glycol moves to the heat exchanger with little loss due to natural convection and that glycol will not freeze during the winter months. A schematic of what the system could look like is shown in Figure G1.

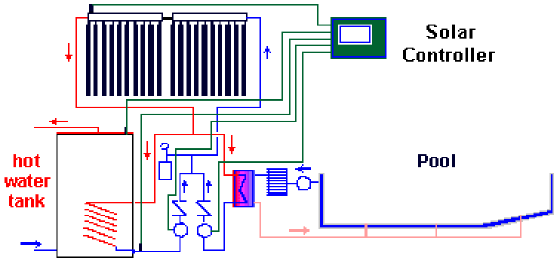


Figure G1: **Example Schematic of Solar Water Heating System**

Results

Using annual average solar radiation data from thermotechs.com, the average daily radiation was found for Detroit Michigan. It is assumed that this quantity will be similar to Grand Rapids Michigan. The average daily radiation data can be found in Appendix G1.

For the purpose of this analysis, it was assumed that the solar water heating would be used to heat the pool in the Venema Aquatic Center. In this case, the water temperature is maintained at approximately 80˚F. The target increase of water temperature out of the pool heater is 60˚F. With a glycol temperature of 170˚F into the heat exchanger, it is assumed that the exit temperature of the glycol will be only slightly warmer than the exit temperature of the water.

The ideal location for the solar collectors is on the roof of the south side of the Venema Aquatic Center. Although the system is scalable (see appendix G2), this location would allow a maximum of 1000 collectors. Using the solar radiation data and a manufacture supplied solar collector efficiency of 70%, an estimate of the available energy can be made.

A cost estimate for the solar collectors was obtained from Thermomax-Group (www.thermomax-group.com) and is $3,435 per panel. The quote and resulting e-mail conversation can be found in Appendix G3. Knowing that the largest possible system would have the greatest amount of head loss, a pump was sized to cover this situation. The pump cost is estimated to be around $1700 and a sample pump can be found in Appendix G4. A heat exchanger price was found by scaling a known exchanger and using the Marshall-Swift Index to bring the price to current dollars. The piping cost was also roughly estimated. The calculations can be found in Appendix G5. It should be noted that the price of the solar collectors far outweigh the cost of the remaining components. If an analysis were done with significantly fewer panels, a more detailed component cost estimate should be done.

Conclusion

Assuming a 1000 panel solar collector array, the estimated annual energy savings is and component costs can be found in Table G1 and G2. Unfortunately, there is error associated with the calculations. A pessimistic scenario assumes the solar radiation is 10% lower than reported and the collector price and labor plus material costs are 5% and 10% higher, respectively. The optimistic scenario assumes the solar radiation data is 10% higher than reported and the collector price and labor plus material costs are 20% and 10% lower, respectively. Once installed, the actual energy savings can be metered through an optional extension of the control unit.

Table G1: Estimated Energy Savings

Optimistic [*therms/yr*]	Nominal [*therms/yr*]	Pessimistic [*therms/yr*]
108,600	98,800	88,900

Table G2: Estimated Costs

Component	Optimistic [$]	Nominal [$]	Pessimistic [$]
Solar Collectors	2,840,000	3,435,000	3,656,500
Pump	N/A	1,700	N/A
Heat Exchanger	N/A	31,300	N/A
Piping	12,900	14,300	15,700
Labor	40,500	45,000	49,500
TOTAL	2,926,400	3,527,300	3,754,700

GMB Architects was contacted to determine the maximum allowable weight of the Fieldhouse roof. The inquiry was inconclusive (see Appendix G6), but it is expected that a support frame will have to be constructed that will focus the weight of the collectors directly onto the roof trusses. A revised analysis of the trusses with the added weight will have to be conducted.

Appendix G1 – Solar Radiation Data

The solar radiation data, figure G2, used in the calculations were found from on the solar collector manufacture's web site: http://www.thermotechs.com/DetroitMI.htm. The interpreted values used in the calculations are found in appendix G5.

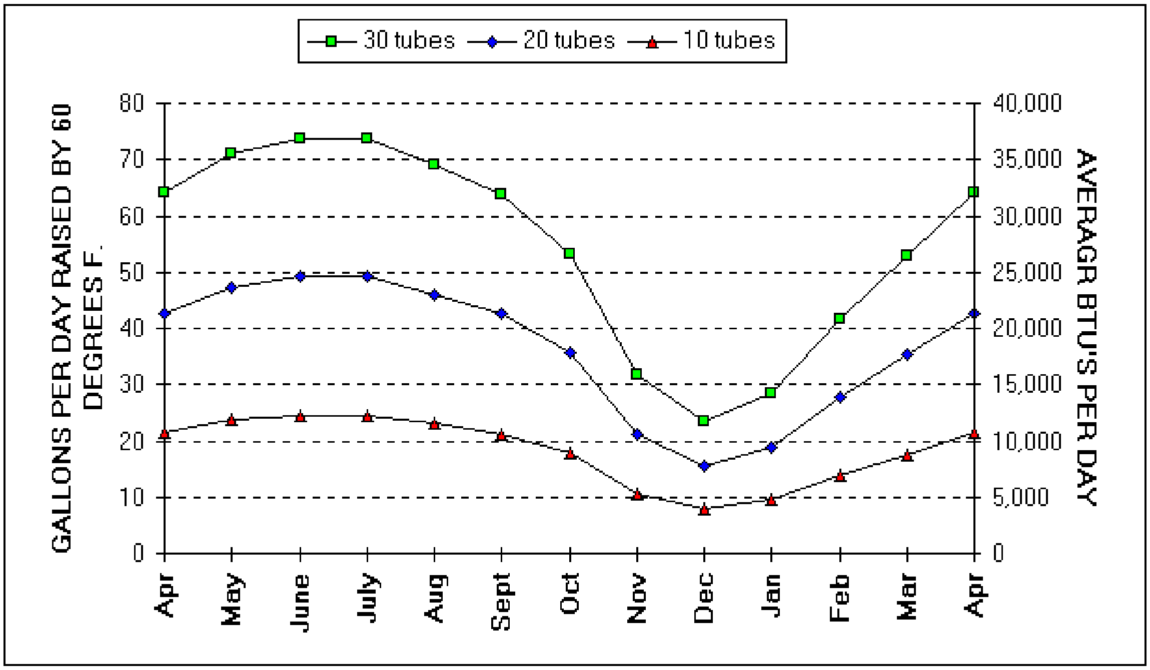


Figure G2: **Average Thermal Energy per Day for Detroit MI**

Appendix G2 – Energy and Cost per Number of Panels

The proposed solar energy system is scalable. Although the analysis was figured using the maximum allowable number of panels, fewer panels can be chosen. Scaling down the system would mean less energy capacity but also a smaller pump and heat exchanger would be required as well as lower material and labor cost. The energy and cost variance as a function of number of panels can be seen in figures G3 and G4, respectively. Although the figure G4 does not account for the change in pump, heat exchanger, material or labor costs, it can be assumed that these values will not have a noticeable impact on the overall trend of the system.

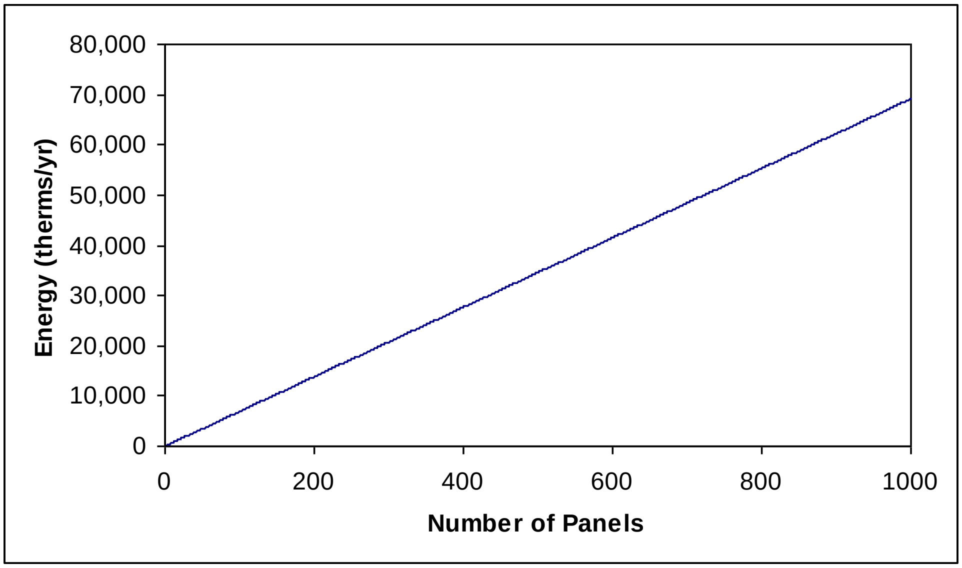


Figure G3: **Solar Energy per Year as a Function of the Number of Panels**

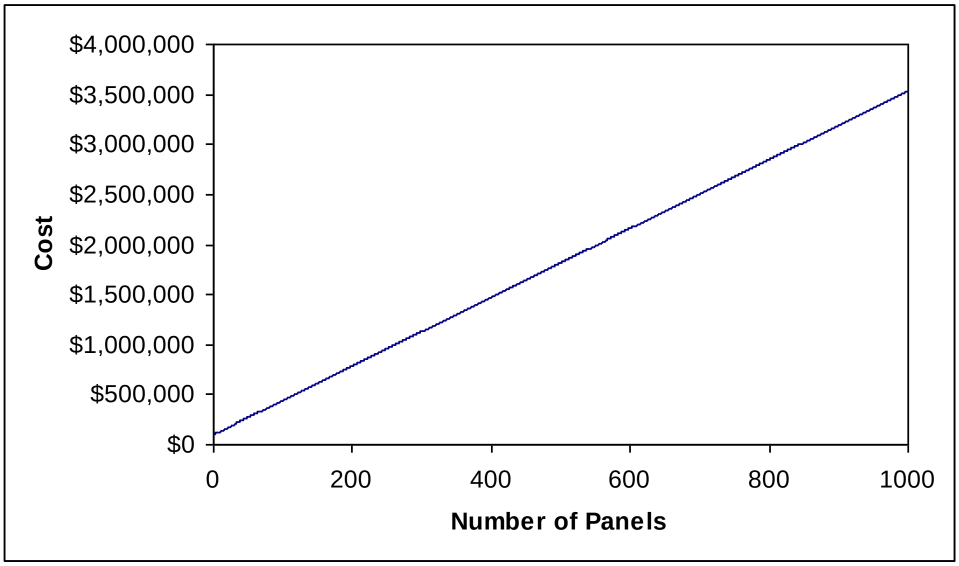


Figure G4: **System Cost as a Function of the Number of Panels**

Appendix G3 – Solar Collector Cost Quote

Luke Martin <lukemartin9@gmail.com>

Fwd: FW: Website Comment - Sales

4 messages

Tim LaRonde <tim@aurora-energy.com> **Fri, Oct 10, 2008 at 9:20 AM**

To: lam9@calvin.edu

Cc: mahjouri@thermomax.com

Hello Luke Martin:

Thank you for your interest in our solar products. In terms of pool and space heating, you have two options:

1) The first involves employing pre-assembled unglazed tube mat solar collector modules that are used to exclusively heat pool water directly.

2) The second approach entails the utilization of Thermomax evacuated tubes in an integrated system design to provide heat for both the pool and space needs.

1) Solar pool heating/unglazed collector- First, the pool solar heating system can be of the unglazed variety that would require a collector area at least equal to the 2/3 surface area of your pool. This approach would deliver a pool temperature of approximately 8-12 degrees warmer than it would be without the solar contribution. Throughout the summer, a higher range could be expected; in fact, the system may be operated at night to cool the pool water if it gets too warm.

This system would be plumbed from the downstream side of the filter through a three-way diverting valve that permits directing the pool water either up to the solar collector or diverting it, bypassing the collector loop, and returning it to the pool without being heated. If the solar collectors are to be mounted above the pool water level, a swing or spring check valve will be required on the outlet of the filter before the diverting valve to prevent filter back-washing when the filter pump shuts off and the collector loop drains back to the pool.

Controlling the solar collection is accomplished most simply by a pool filter pump timer set to turn the pump on at 9:00 A.M. and off at 4:00 P.M. Assuming an uninterrupted power source, this is a very reliable approach to controlling the system's operation. The only additional control variable is the diverting three-way valve. It is possible to use this type of approach for spring, summer and fall operations, but in the winter months, it is best to have a motor mounted on the diverting valve that is controlled by a solar temperature differential controller such as SMT 100. This device has two PT100 sensors that continuously read the temperature of the solar collector and the pool water and rotate the motorized valve to divert pool water to the collector loop whenever there's sufficient temperature to be worthwhile.

It is assumed that local plumbing suppliers can provide PVC pipe and fittings to run from the filter system to the collector and back again. It is necessary to know the inside and outside diameters of this piping to properly size component connections. The voltage, phase and cycles per second characteristics of the power feeding the pool pump as well as its horsepower rating all must be known.

2) Thermomax Solar Evacuated Tubes integrated pool and space heating design - The second option for using solar would be to employ Thermomax evacuated tubes to heat the pool in summer and space in winter. This approach is more costly initially, but may be more cost effective in the life cycle. Determining variables include your current energy expense for heating your domestic water. Another key element is the amount of hot water typically used per day by your household.

A heat exchanger would be used to heat the pool water while a freeze protected heat transfer fluid would run directly through the exclusive Thermomax evacuated tube, insulated header system. This solar loop would have its own pump, and the pool water /heat exchanger would have its own separate differential temperature-controlled three-way valve as discussed before.

There would also need to be an additional three-way valve on the solar loop that would allow the solar heat to be directed to either the space heating coil or pool heat exchanger. With this design, the solar loop diverting valve is controlled by a simple thermostat that reads the tank water temperature near the bottom.

For Options 2 details and schematic drawings, please refer to: the http://www.thermotechs.com/appli.htm.

If you have further questions, please do not hesitate to contact us again.

Regards,

Tim LaRonde

Please re-send a copy of this e-mail with your response.

Aurora Energy Inc., THERMOMAX USA
9009 Mendenhall Court, Suite E
Columbia, MD 21045
Website http://www.thermomax.com
Voice (410) 997-0778
Fax (410) 997-0779
E-Mail info@thermotechs.com

-----Original Message-----
From: Thermomax.com@web1.connext.net [mailto:Thermomax.com@web1.connext.net]

Sent: Thursday, October 09, 2008 2:03 PM
To: mahjouri@thermotechs.com
Subject: Website Comment - Sales

Hello,

Name : Luke Martin

E-Mail or Phone Number: lam9@calvin.edu

Topic : Sales

Comment : To whom it may concern:

I am representing Calvin College in Grand Rapids MI and we are interested in solar water heating for our new pool complex. Our pool has 850,000 gallon capacity and is used year round. How would I go about getting a quote on this system?

Thanks

Luke Martin <lam9@calvin.edu> **Fri, Oct 10, 2008 at 9:52 AM**

To: Nate Wybenga <natewybenga@gmail.com>, Ken Haan <khaanjr@gmail.com>

I got an e-mail back from that Thermomax company. I asked how I would go about getting a quote and they just gave me background information. You can read it if you want.

Luke

[Quoted text hidden]

Nate Wybenga <njw5@calvin.edu> **Thu, Oct 16, 2008 at 1:27 PM**

To: tim@aurora-energy.com

Cc: "Ken Haan Jr." <khaanjr@gmail.com>, Luke Martin <lukemartin9@gmail.com>

Hello Tim,

We would like to get an estimate for just a 30 tube evacuated-tube solar collector. What is the cost of just the collector? What are the dimensions of the collector? What is the approximate weight of the collector? And, are discounts offered for buying multiple collectors?

We are designing our own system, and may scale up in size with multiple collectors, but need these estimates for the collector to determine the feasibility.

Thanks!

--Nate Wybenga

[Quoted text hidden]

Nate Wybenga <njw5@calvin.edu> **Thu, Oct 23, 2008 at 10:44 AM**

To: Luke Martin <lukemartin9@gmail.com>, "Ken Haan Jr." <kwh3@calvin.edu>

---------- Forwarded message ----------
From: **Tim LaRonde** <tim@aurora-energy.com>
Date: Thu, Oct 23, 2008 at 10:52 AM
Subject: Fwd: FW: Website Comment - Sales
To: njw5@calvin.edu
Cc: mahjouri@thermomax.com

Hello Nate Wybenga:

MAZ 30 Collector Price: $ 3,435.00 Plus Shipping & Handling.
Includes manifold, 30 tubes, manual air vent and mounting hardware for a sloped roof. Prices subject to change.

Regards,

Tim
[Quoted text hidden]

Appendix G4 – Sample Pump

The following is a .pdf file downloaded from Flint and Walling, Inc. It is a sample pump that could be used for the solar water heating system.

FLINT & WALLING, INC.

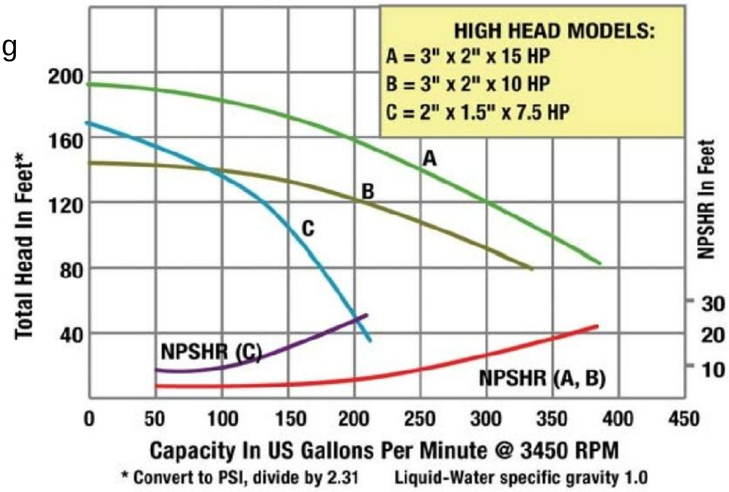
"C5" Series Heavy Duty Straight Centrifugal Pumps

- Investment cast 316 stainless steel construction with Viton seals or cast iron construction with Buna seals
- Stainless steel impellers with solids handling capacity of 1/8 - 3/16".
- 3 HP to 15 HP NEMA JM motors, three phase TEFC
- High flow and high head designs
- Max. temperature

Viton®: 200° F

Buna N: 180° F

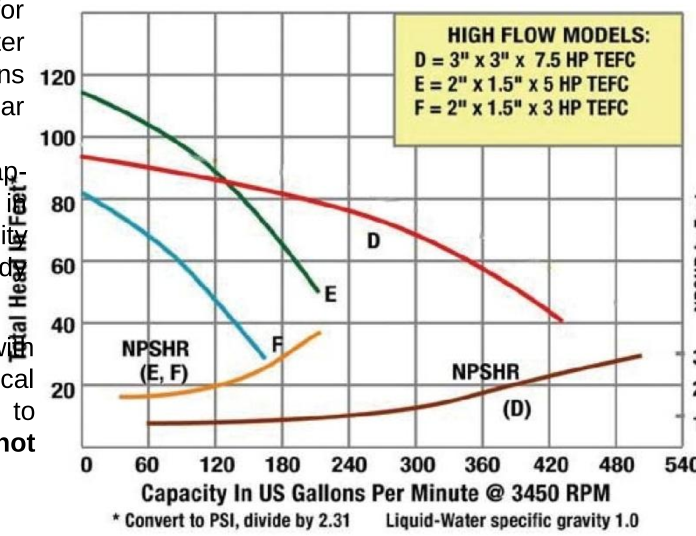
- Front drain plugs located 90° apart
- Max head 194 Ft. (100 PSI)
- Max flow 425 GPM
- Max working pressure 150 PSI



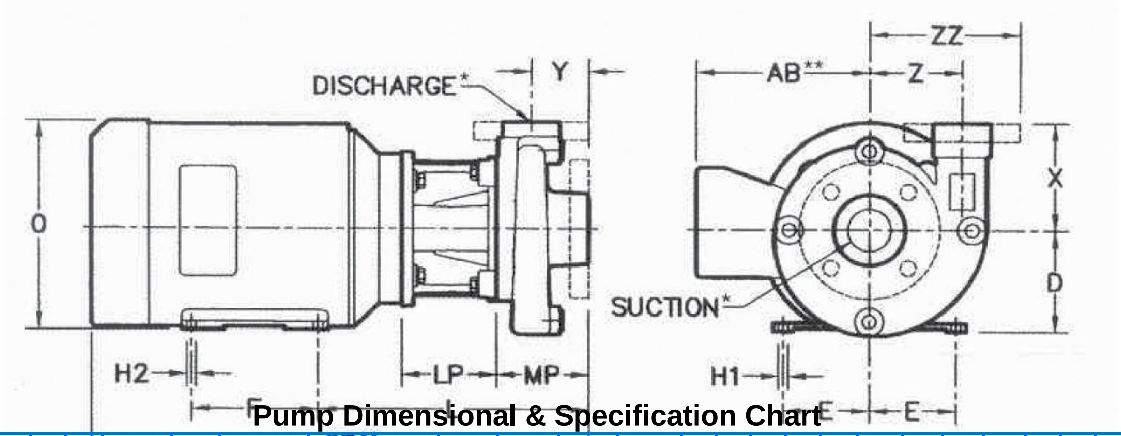
F&W Heavy Duty Straight Centrifugal pumps are suited for liquid transfer, heating and cooling, recirculation, booster service and other industrial applications. Applications include, but are not limited to cooling towers and car washes.

Stainless Steel units are especially effective in applications where rust and/or corrosion can develop in systems. Semi-open impeller features self-cleaning ability that makes the unit useful in applications involving muddy or dirty liquids as well as clean, clear fluids.

Discharge position can be adjusted in 90° increments with vent and drain plugs for all positions. Type 21 mechanical seal and O-ring casing seal. Pumps are close-coupled to totally enclosed fan cooled (TEFC) motors. **Pumps are not self-priming and require flooded suction.**



HEAVY DUTY STRAIGHT CENTRIFUGAL PUMPS



Pump Dimensional & Specification Chart

CI Model No.	SS Model No.	HP	PH	Frame	ENC	Voltage @ 60 Hz	Full Load Amps	S.F. Amp	SUC*	DIS*	AB**	CP**	D	E	F	H1	H2	L	LP	MP	O	X	Y	Z	ZZ	Ship Wt # CI	Ship Wt # SS
C55A303T	C55S303T	3	3	182JM	TEFC	230/460	8/4	9/5	2	1-1/2	7.5	21.6	4.5	3.8	4.5	0.4	0.4	12.7	4.1	4.0	9.3	4.8	2.5	4.0	N/A	98	83
C55A503T	C55S503T	5	3	184JM	TEFC	230/460	13/7	15/8	2	1-1/2	7.5	21.6	4.5	3.8	5.5	0.4	0.4	11.8	4.1	4.0	9.3	4.8	25	4.0	N/A	108	110
C57A753T	C57S753T	7.5	3	184JM	TEFC	230/460	19/10	22/11	3	3	7.5	22.4	4.5	3.8	5.5	0.4	0.4	12.5	4.1	4.8	9.3	6.5	2.8	4.5	N/A	122	117
C55A753T	C55S753T	7.5	3	184JM	TEFC	230/460	19/10	22/11	2	1-1/2	7.5	21.4	4.5	3.8	5.5	0.4	0.4	11.5	3.5	4.4	9.3	5.9	2.4	3.8	N/A	105	108
C56A1003T	C56S1003T	10	3	184JM	TEFC	230/460	24/12	31/16	3	2	7.5	21.5	4.5	3.8	5.5	0.4	0.4	11.7	3.5	4.4	9.3	5.0	2.8	4.8	N/A	117	120
C56A1503T	C56S1503T	15	3	215JM	TEFC	230/460	36/18	41/21	3	2	8.3	26.0	5.3	4.3	7.0	0.4	0.4	12.5	3.5	4.5	10.9	5.0	2.8	4.8	N/A	190	195

ALL MODELS: CONN TYPE – NPT
Standard NPT (female) pipe thread.
(*) This dimension may vary due to motor manufacturer's specifications
(*) 3-Phase motors can also operate on 50 Hz. (This will change the Full Load Amps, Service Factor and RPM)
NOTE: Dimensions have a tolerance of ± 1/8"
NOTE: Electric supply for ALL motors must be within ± 10% of nameplate voltage rating (ex. 230V ± 10% = 207 to 253) CI = Cast Iron Construction with SS Impeller and Buna N Seals, Max. Temperature 180° F
SS = All 316 Stainless Steel Construction with Viton® Seals, Max. Temperature 200° F

Standard Features

- Stainless steel and cast iron construction
- Buna N or Viton® mechanical seal and o-rings depending on model
- Stainless steel hardware
- NEMA TEFC three phase motors
- Self-cleaning stainless steel impeller

- Discharge rotates in 90° Increments
- Max. working pressure to 150 PSI
- Max. temperature:
  200° F Viton®
  180° F Buna N

FLINT & WALLING, INC.

PRICE PAGE 15
EFFECTIVE 8/25/08
SUPERSEDES 3/17/08

CENTRIFUGAL PUMPS, END SUCTION AND SELF PRIMING*

A

			SINGLE PHASE			THREE PHASE			
HP	**MOTOR TYPE**	**MATERIAL**	**MODEL NO.**	**SHIP WT. LBS.**	**LIST PRICE**	**MODEL NO.**	**SHIP WT. LBS.**	**LIST PRICE**	**SUCTION & DISCHARGE INCHES**
C3 SERIES - END SUCTION CENTRIFUGAL- STAINLESS STEEL IMPELLER - NEMA J MOTOR									
1/2	TEFC	CAST S.S.	C31S051T	33	$ 946.00	C31S053T	31	$ 968.00	3/4 x 1/2
1		CAST S.S.	C32S101T	39	$ 1,122.00	C32S103T	36	$ 1,122.00	1 x 3/4
2		CAST S.S.	C33S201T	52	$ 1,357.00	C33S203T	50	$ 1,379.00	1-1/4 x 1
C4 SERIES - END SUCTION CENTRIFUGAL- STAINLESS STEEL IMPELLER - NEMA J MOTOR									
3/4	TEFC	C.I.	C43A071T	46	$ 905.00	C43A073T	44	$ 901.00	1-1/4 x 1
		CAST S.S.	C43S071T	46	$ 1,420.00	C43S073T	44	$ 1,432.00	
1 1/2		C.I.	C43A151T	55	$ 1,009.00	C43A153T	53	$ 1,035.00	
		CAST S.S.	C43S151T	55	$ 1,559.00	C43S153T	53	$ 1,570.00	
2		C.I.	C44A201T	65	$ 1,144.00	C44A203T	60	$ 1,181.00	1-1/2 x 1-1/4
		CAST S.S.	C44S201T	65	$ 1,802.00	C44S203T	60	$ 1,824.00	
3		C.I.	C44A301T	74	$ 1,323.00	C44A303T	66	$ 1,353.00	
		CAST S.S.	C44S301T	74	$ 1,955.00	C44S303T	66	$ 1,973.00	
C5 SERIES - END SUCTION CENTRIFUGAL- STAINLESS STEEL IMPELLER - JM MOTOR									
3	TEFC	C.I.	▨	▨	▨	C55A303T	98	$ 1,663.00	2 x 1-1/2
		CAST S.S.	▨	▨	▨	C55S303T	98	$ 2,400.00	
5		C.I.	▨	▨	▨	C55A503T	108	$ 1,910.00	
		CAST S.S.	▨	▨	▨	C55S503T	108	$ 2,684.00	
7 1/2		C.I.	▨	▨	▨	C55A753T	105	$ 2,280.00	
		CAST S.S.	▨	▨	▨	C55S753T	105	$ 3,009.00	
		C.I.	▨	▨	▨	C57A753T	122	$ 2,220.00	3 x 3
		CAST S.S.	▨	▨	▨	C57S753T	122	$ 3,248.00	
10		C.I.	▨	▨	▨	C56A1003T	117	$ 2,706.00	
		CAST S.S.	▨	▨	▨	C56S1003T	117	$ 3,644.00	
15		C.I.	▨	▨	▨	C56A1503T	190	$ 3,207.00	
		CAST S.S.	▨	▨	▨	C56S1503T	190	$ 4,081.00	
C6, C7 SERIES - END SUCTION CENTRIFUGAL - STAINLESS STEEL IMPELLER - NEMA J MOTOR									
3/4	TEFC	STAMPED S.S.	C63071T	38	$ 860.00	C63073T	31	$ 860.00	1-1/4 x 1
1 1/2		STAMPED S.S.	C64151T	50	$ 1,024.00	C64153T	43	$ 1,024.00	1-1/2 x 1-1/4
3		STAMPED S.S.	C65301T	57	$ 1,256.00	C65303T	54	$ 1,256.00	2 x 1-1/2
2		STAMPED S.S.	C74201T	50	$ 1,275.00	C74203T	54	$ 1,275.00	1-1/2 x 1-1/4
3		STAMPED S.S.	C74301T	59	$ 1,398.00	C74303T	58	$ 1,398.00	
2" HIGH PRESSURE SELF PRIMING CENTRIFUGAL - STAINLESS STEEL IMPELLER - JM MOTOR									
5	TEFC	C.I.	SPA50A1	146	$ 2,915.00	SPA50A3	130	$ 2,269.00	2 x 2
7 1/2		C.I.				SPA75A3	134	$ 2,437.00	

* Special order - Allow 10 days for shipment

LIST PRICE IN U.S. CURRENCY
PRICES SUBJECT TO CHANGE WITHOUT NOTICE

Appendix G5 – Calculations

```
error_btu = 1
error_panel = 1.05
error_labor = 1.0

"!Average btu's per day separated by month... 1 is Apr, 2 is may...."
"http://www.thermotechs.com/DetroitMI.htm"
H[1] = N_collectors*32000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[2] = N_collectors*36000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[3] = N_collectors*37000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[4] = N_collectors*37000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[5] = N_collectors*35000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[6] =  N_collectors*32500 [BTU/day] * convert(BTU/day, kW) * error_btu
H[7] = N_collectors*26000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[8] = N_collectors*16000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[9] = N_collectors*12000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[10] = N_collectors*14000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[11] =N_collectors* 21000 [BTU/day] * convert(BTU/day, kW) * error_btu
H[12] =  N_collectors*26000 [BTU/day] * convert(BTU/day, kW) * error_btu

"!Calculated Flow Rates of the glycol through the system"
C_P_glycol = 0.55* convert(BTU/lbm-F, kJ/kg-C)
C_P_H2O = CP(H2O, T= 27 [C]) "80 deg F temperature of the water-- an approximate value"

DELTAT_H2O = 33.33 [C] "60 degree teperature increase of the water"
T_in_H2O = converttemp(F,C,60)
T_out_H2O = T_in_H2O + DELTAT_H2O

T_in_glycol = converttemp(F,C, 170) "For now, we need to assume an inlet temperature of the glycol into the heat exchanger"
T_out_glycol = T_out_H2O + 2 [C] "assume the glycol leaves a little warmer than the inlet temperature of the water."

duplicate i=1,12
H[i] = efficiency*m_dot_glycol[i] * C_P_glycol *(T_in_glycol - T_out_glycol)
H[i] = m_dot_H2O[i]*C_P_H2O*DELTAT_H2O
end duplicate

sec_per_month = (31557600 / 12) [s]
efficiency = 0.7

N_collectors = 1000
E_tot =  SUM(( H[i] * sec_per_month ), i = 1,12) * convert(kJ, therms) * 1 [1/year]

"!Collector Costs"
Cost_per_collector = 3435 [$]
Cost_collectors = Cost_per_collector * N_collectors * error_panel

"!Labor Costs"
labor_hours = 1.5 [hr] * N_collectors
hours_cost = 30 [$/hr]
Cost_labor = labor_hours * hours_cost * error_labor

"!Pump Costs"
Length_dwg = 28.75
Height_dwg = 6.625
```

```
Scale = .125 [in/ft]
L_Fieldhouse = Length_dwg * (1 / Scale)
H_Fieldhouse = Height_dwg * (1 / Scale)

L_pipe_elevation = H_Fieldhouse * 2                "Pipes running vertically"
L_pipe_header = L_Fieldhouse * 3                   "Pipes running horizontally"

L_pipe_tot = L_pipe_elevation + L_pipe_header
mu = 0.007[Pa-s] * convert(Pa-s, kg/m-s)
L = L_pipe_tot *convert(ft,m)
Re = (density_glycol * v_dot_glycol * D_pipe) / (mu)

f = (64 / Re)
deltaP_p = f * L / D_pipe * ((density_glycol * v_dot_glycol^2) / 2) * convert(n/m^2, kPa)
deltaP_C30 = N_collectors * 35[Pa] * convert(Pa, kPa)   "Found from Figure 9 pg. 12"

deltaP_sys = deltaP_p + deltaP_C30                 "Assumed 1000 panels w/ 30 tubes, and no negligible
pressure drop across HXER"

Head_loss = L_pipe_elevation * convert(ft,m) + ((deltaP_sys * convert(kPa,Pa)) / (density_glycol * g)) +
v_dot_glycol^2 / (2 * g)
g = 9.81
Head_loss_english = Head_loss * convert(m,ft)

Cost_pump = 1663 [$]
"http://www.flintandwalling.com/pdfdocs/Price%20Pages/2008-
August%20Price%20Pages/INDIVIDUAL%20PAGES/FW0004%20pg15%20cent%20cont%20%200808.pdf"
"http://www.flintandwalling.com/pdfdocs/FandWCATALOGS/FW0724%20FW%20High%20Cap%20Centrifugals.pdf"

"!Heat Exchanger Analysis"
DELTAT_in = T_in_glycol - T_in_H2O
DELTAT_out = T_out_glycol - T_out_H2O
DELTAT_LM = (DELTAT_in - DELTAT_out) / ln(DELTAT_in/DELTAT_out)
Duplicate i=1,12
    Q_dot[i] = m_dot_glycol[i]*C_p_glycol*DELTAT_LM
End Duplicate
U = .600 [kW/m^2-C] "Assumed based on research for various types of heat exchangers and fluids"
Duplicate i=1,12
    Q_dot[i] = UA[i]*DELTAT_LM
End Duplicate
UA = max(UA[1],UA[2],UA[3],UA[4],UA[5],UA[6],UA[7],UA[8],UA[9],UA[10],UA[11],UA[12])
UA = U*A
Cost_heat_xgr_1990 = 32720 [$]*(A/100[m^2])^(0.5) "scaled exponent base on average to accomidate for small A"
Cost_heat_xgr = Cost_heat_xgr_1990*(1469.5/993.4) "Uses Marshell Swift Index Cost Estimate Technique"

"!Piping Costs"
m_dot_max_glycol = max(m_dot_glycol[1], m_dot_glycol[2], m_dot_glycol[3], m_dot_glycol[4], m_dot_glycol[5],
m_dot_glycol[6], m_dot_glycol[7], m_dot_glycol[8], m_dot_glycol[9], m_dot_glycol[10], m_dot_glycol[11],
m_dot_glycol[12])
density_glycol = 1.11 [g/cm^3] * convert(g/cm^3, kg/m^3)
Vol_dot_glycol = (m_dot_max_glycol/density_glycol)
Vol_dot_gpm = Vol_dot_glycol * convert(m^3/s, gpm)

v_dot_glycol = Vol_dot_glycol / A_xsec_glycol
v_dot_glycol = 1.25 [m/s] "recommended maximum velocity by the manufacturer"
```

```
A_xsec_glycol = (PI/4)* D_pipe^2

"Unit Cost: http://www.onlinemetals.com/merchant.cfm?pid=931&step=4&showunits=inches&id=57&top_cat=0 of 1.5
inch NOM stainless steel"
C_unit_pipe = (143.46/8) [$/ft]

Cost_piping = C_unit_pipe * L_pipe_tot

"!Total Costs"
Cost_total = Cost_collectors + Cost_labor + Cost_pump + Cost_heat_xgr + Cost_piping
```

SOLUTIONS:

```
A=41.73 [m^2]                          g=9.81 [m/s^2]
A_xsec_glycol=0.007836 [m^2]           Head_loss=36.23 [m]
Cost_collectors=3.607E+06 [$]          Head_loss_english=118.9 [ft]
Cost_heat_xgr=31265 [$]                Height_dwg=6.625 [in]
Cost_heat_xgr_1990=21136 [$]           hours_cost=30 [$/hr]
Cost_labor=45000 [$]                   H_Fieldhouse=53 [ft]
Cost_per_collector=3435 [$]            L=242.6 [m]
Cost_piping=14274 [$]                  labor_hours=1500 [hr]
Cost_pump=1663 [$]                     Length_dwg=28.75 [in]
Cost_total=3.699E+06 [$]               L_Fieldhouse=230 [ft]
C_p_glycol=2.303 [kJ/kg-C]             L_pipe_elevation=106 [ft]
C_P_H2O=1.872 [kJ/kg-C]                L_pipe_header=690 [ft]
C_unit_pipe=17.93 [$/ft]               L_pipe_tot=796 [ft]
deltaP_C30=35 [kPa]                    mu=0.007 [kg/m-s]
deltaP_p=6.809 [kPa]                   m_dot_max_glycol=10.87 [kg/s]
deltaP_sys=41.81 [kPa]                 N_collectors=1000
DELTAT_H2O=33.33 [C]                   Re=19799
DELTAT_in=61.11 [C]                    Scale=0.125 [in/ft]
DELTAT_LM=17.29 [C]                    sec_per_month=2.630E+06 [s]
DELTAT_out=2 [C]                       T_in_glycol=76.67 [C]
density_glycol=1110 [kg/m^3]           T_in_H2O=15.56 [C]
D_pipe=0.09988 [m]                     T_out_glycol=50.89 [C]
efficiency=0.7                         T_out_H2O=48.89 [C]
error_btu=1                            U=0.6 [kW/m^2-C]
error_labor=1                          UA=25.04 [kW/C]
error_panel=1.05                       Vol_dot_glycol=0.009795 [m^3/s]
E_tot=98770 [therms/year]              Vol_dot_gpm=155.3 [gpm]
f=0.003233                             v_dot_glycol=1.25 [m/s]
```

H[i] [kW]	m_dot_glycol[i [kg/s]	m_dot_H2O[i] [kg/s]	Q_dot[i] [kW]	UA[i] [kW/C]
390.8	9.403	6.262	374.3	21.65
439.6	10.58	7.045	421.1	24.36
451.8	10.87	7.24	432.8	25.04
451.8	10.87	7.24	432.8	25.04
427.4	10.28	6.849	409.4	23.68
396.9	9.55	6.36	380.1	21.99
317.5	7.64	5.088	304.1	17.59
195.4	4.702	3.131	187.1	10.83
146.5	3.526	2.348	140.4	8.12
171	4.114	2.74	163.8	9.473
256.4	6.171	4.109	245.6	14.21
317.5	7.64	5.088	304.1	17.59

Appendix G6 – GMB Architects Roof Loading

Luke Martin <lukemartin9@gmail.com>

Roof Loading on Calvin College Feildhouse Complex

3 messages

Luke Martin <lukemartin9@gmail.com> **Wed, Nov 12, 2008 at 11:00 AM**

To: davidb@gmb.com

David Bolt,

I'm working with a group at Calvin College that is looking into the possibility of adding solar water heating to the campus. Our preferred location for the solar collectors is on the roof of the south side of the Venema Aquatic Center of the new Fieldhouse Complex your company designed for us. We are concerned about the maximum roof loading as we do not want to compromise the structural integrity of the building. Henry DeVries recommended we talk to you to determine the maximum allowable weight of the solar collectors.

Thanks in advance for your cooperation,

Luke Martin
lam9@calvin.edu

Luke Martin <lam9@calvin.edu> **Tue, Nov 18, 2008 at 11:52 AM**

To: davidb@gmb.com

Cc: hdevries@calvin.edu, Nate Wybenga <njw5@calvin.edu>, Ken Haan <kwh3@calvin.edu>

David,

I am sorry to bother you again, but it has been nearly a week and I haven't gotten a response back regarding the fieldhouse roof loading. Is any progress being made?

Thanks,
Luke Martin

[Quoted text hidden]

David Bolt <davidb@gmb.com> **Mon, Nov 24, 2008 at 5:14 PM**

To: Luke Martin <lam9@calvin.edu>

Cc: hdevries@calvin.edu, Nate Wybenga <njw5@calvin.edu>, Ken Haan <kwh3@calvin.edu>

Luke,

Our Structural Engineers have reviewed this request. It appears that we are currently maximizing the loading of the roof (allowing for a safety factor) for the Aquatic Center and the Fieldhouse. Without more specific information regarding the loads you are proposing or the specific locations, it is hard to approve the addition of any loads to this structure. Of greater concern, however, is the potential for fastening of solar panels on this roof. The Aquatic Center has a continuous vapor barrier around the entire shell of the building which is critical to the operation of the pool environment. Sorry that this is not the positive answer you were looking for. Please let me know if there is additional information you wish to supply to us for further review.

Thank you,

David Bolt, AIA, LEED AP
GMB Architects-Engineers
85 East Eighth Street, Suite 200
Holland, MI 49423
Tel: 616.796.0200
Fax: 616.796.0201

[Quoted text hidden]

Appendix G7 – Sample Instillation

The following figure, Figure G5, is a Thermomax instillation using the proposed solar collectors. This instillation is at the Department of Transportation in Kalamazoo, Michigan.

Figure G5: Sample Instillation

Appendix H

Chapel Airlock Installation

Introduction

The objective of this project was threefold: First, to analyze the energy saved by the installation of vestibule doors (instead of the current single-bank doors) on the Calvin College chapel entrance (located on the patio level). Second, to estimate the cost of the project. Third, to design a system to monitor cost savings as a result of the project. See Figure H1 for a photograph of the proposed vestibule entrance location.

Description

Heat loss savings analysis of installing the proposed vestibule entrance in place of the current single-bank entrance was conducted using equation H1.

$$\dot{\mathrm{Q}}_{\mathrm{savings}} = \left(\dot{\mathrm{m}}_{\mathrm{air,single-bank}} - \dot{\mathrm{m}}_{\mathrm{air,vestibule}}\right)\mathrm{C}_{\mathrm{p,air}}\Delta\mathrm{T} \qquad \text{(H1)}$$

In equation H1, $C_{p,air}$ is the specific heat of air. ΔT is the temperature difference between the indoors and the outdoors. In this model the indoor temperature was assumed to be held at 68 °F year-round. The outdoor temperature was calculated using the average monthly temperatures for Grand Rapids over the past 20 years. See Table H1 for a listing of the temperatures used.

To determine the entrance infiltration rate ($\dot{\mathrm{m}}_{\mathrm{air,}}$) of air through the entrance for both single-bank and vestibule door configurations Figures H2, H3, and H4 were used. These figures were taken from *Modifying Habits Towards Sustainability: A Study of Revolving Door Usage on the MIT Campus* by B.A. Cullum, Olivia Lee, Sittha Sukkasi, and Dan Wesolowski. Figure H2 was used to determine the entrance coefficient for the single-bank configuration based on a traffic rate of 100 people/hr/door. This was the estimated maximum traffic flow rate applicable for 9 months of the year when school was in session. Figure H3 was used to determine the entrance coefficient for the vestibule configuration based on the same traffic rate. The pressure differential of the chapel lobby and patio was measured to be 0.01 inches of H_2O using an inclined monometer. Based on the entrance coefficients for the vestibule and single-bank doors and the pressure differential, Figure H4 was used to determine the entrance infiltration rate. The infiltration rate for each door configuration, in units of ft^3/minute/door, was then scaled to ft^3/month using the fact that there are 6 doors at the chapel entrance. The monthly infiltration rate for the 3 months of summer was approximated to be ½ the monthly infiltration rate calculated for the 9 months during the school year.

Heat loss savings were then calculated on a monthly basis using equation H1. The total yearly heat loss savings were calculated by the sum of all the monthly savings. See Appendix H1 for all calculations.

Estimation of construction costs for the installation of a vestibule entrance was based on a 2008 Michigan construction cost quote database (www.get-a-quote.net). This estimate was also verified by a licensed contractor.

Results

The difference in infiltration rate between the vestibule entrance and the single-bank entrance was calculated to be 200 ft^3/minute/door during the school year and 100 ft^3/minute/door in the summer. The nominal energy savings were calculated to be 1636 therms/year. The optimistic energy savings were calculated to be 1963 therms/year (20% over nominal). The pessimistic energy savings were calculated to be 818 therms/year (50% under nominal). The construction costs for a vestibule entrance were estimated to be $18,212.

Conclusion

Because the data procured from figures H2 thru H4 was in a very uncertain region of the figures (in the very lower corner), and because the figures are based on empirical data, there was a large uncertainty estimation for this project (20% over nominal, 50% under nominal). This uncertainty also takes into account current entrance habits such as having people to hold open the doors prior to chapel to greet attendees which may not change with the addition of a vestibule entrance (hence the uncertainty emphasizes lower energy savings).

The traffic rate used in the calculations was high. However, because only the *difference* in heat loss between vestibule and single-bank entrances was calculated, the error in using a high traffic rate was minimized by both door configurations using the high rate.

The most accurate way to monitor energy savings with a vestibule entrance would be by isolating the HVAC in the chapel lobby. In the isolated system, heating and cooling air thru-put (with the vestibule entrance installed) could be compared to historical thru-put with a single-bank entrance and Equation H1 could be used to calculate energy savings. If no historical data has been gathered, data would need to be collected this year prior to project implementation next year (as determined by the financial team).

Energy savings from the installation of the entrance will need to be calculated using the monitoring equipment rather than the estimations outlined in this tech memo because of the high uncertainty in the calculations. Because this project has been designated a green project (with a payback period greater than 10 years) the CEEF is not dependent on energy savings from this project to develop the fund, and even if energy savings are lower than expected implementation of this project will still be successful.

Figure H1: Calvin College Chapel Entrance and Proposed Vestibule Location

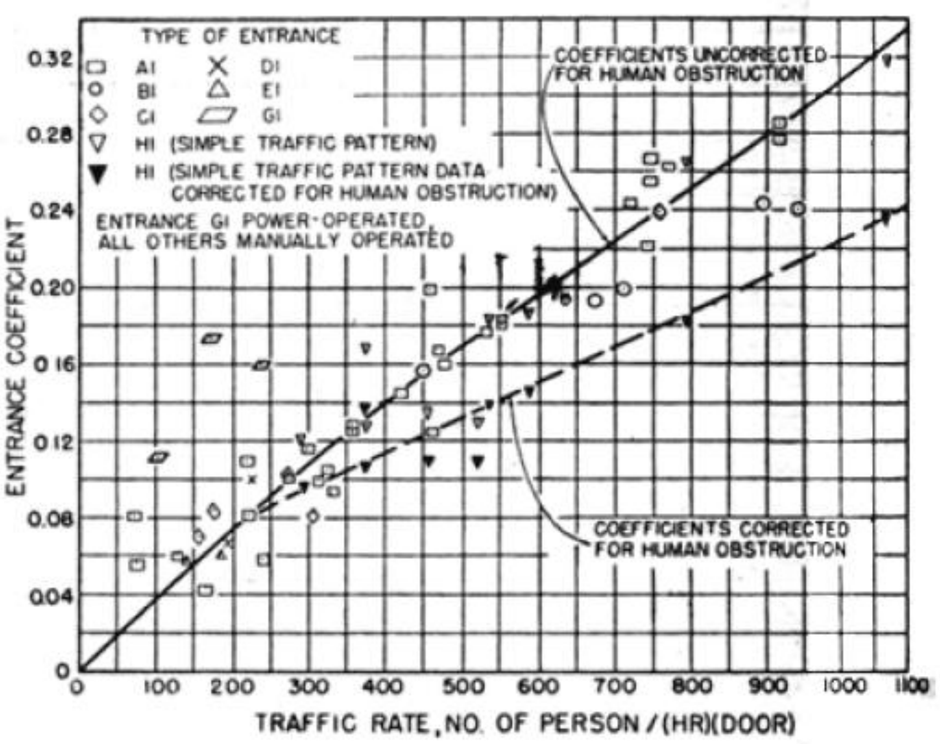


Figure H2: Single-Bank Entrance Coefficient as a Function of Traffic Rate

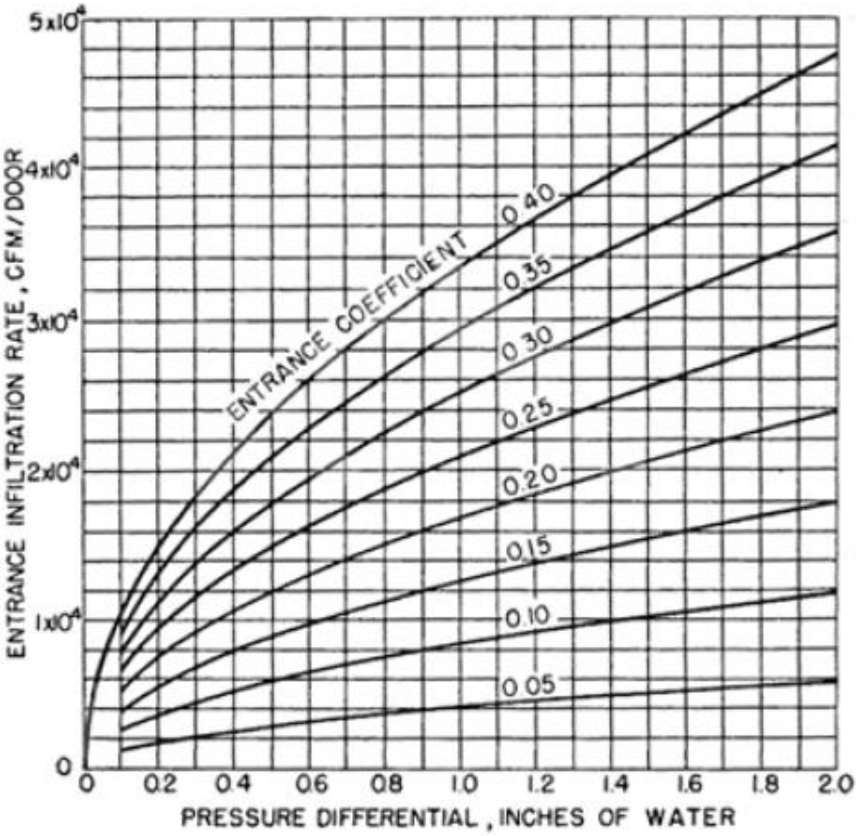


Figure H4: Air Infiltration Rates as a Function of Pressure Differential and Entrance Coefficient

Table H1: Average Monthly Temperatures for Grand Rapids used in Analysis (temperature averages compiled from averaging a variety of sources)

Month	Average Temperature (°F)
January	26
February	28
March	39
April	51
May	64
June	73
July	78
August	75
September	67
October	55
November	42
December	31

Appendix H1: Calculations

Nate Wybenga, Luke Martin, Ken Haan
CEEF Technical Team 2
Engineering 333
11/22/08

Final Cost Analysis for Chapel Airlock

Temperature Data for Grand Rapids, Michigan, 1 = Jan, 2=Feb...

School Months

T_1 = **ConvertTemp** (F , C , 26) Jan

T_2 = **ConvertTemp** (F , C , 28) Feb

T_3 = **ConvertTemp** (F , C , 39) Mar

T_4 = **ConvertTemp** (F , C , 51) April

T_5 = **ConvertTemp** (F , C , 64) May

T_6 = **ConvertTemp** (F , C , 67) Sept

T_7 = **ConvertTemp** (F , C , 55) Oct

T_8 = **ConvertTemp** (F , C , 42) Nov

T_9 = **ConvertTemp** (F , C , 31) Dec

Summer Months, June, July, August

T_{10} = **ConvertTemp** (F , C , 73)

T_{11} = **ConvertTemp** (F , C , 78)

T_{12} = **ConvertTemp** (F , C , 75)

Assumed Constant temperature and pressure indoors

$T_{indoors}$ = **ConvertTemp** (F , C , 68)

$P = 101.3$ [kPa]

Conversion Factors

$number_{doors} = 6$

$number_{minutes,per,hour} = 60$ [min/hr]

$number_{hours,per,day} = 18$ [hr/day]

$number_{days,per,month} = 30$ [days/month]

Data from figure H2, H3 in tech memo

$\dot{Traffic} = 100$ [ppl/hr-door]

about 10,000 entries/exits per day, divided by 18 hours, 6 doors- Note: this traffic rate is high, but necessary for use with the graphs

$Entrance_{co,single} = 0.04$

$Entrance_{co,vestibule} = 0.005$

Data from figure H4 in tech memo

$P_{diff} = 0.01$ [inH2O] Pressure Differential Measured with Inclined Monometer

$A_{ir,schoolyear} = 200$ [ft^3/min-door]

air flow rate difference between vestibule and single bank enterances during the school year

$A_{ir,summer} = 100$ [ft^3/min-door]

During the summer the volumetric infiltration rate is assumed to be half the volumetric infiltration rate during the school year due to a lower traffic rate

Energy Savings Analysis

During the school year

$density_{air,i} = \rho(\text{'Air'}, T=T_i, P=P)$ for i = 1 to 9

$$\Delta \dot{m}_{v,sb,schoolyear,i} = A_{ir,schoolyear} \cdot number_{doors} \cdot number_{minutes,per,hour} \cdot number_{hours,per,day} \cdot number_{days,per,month} \cdot \left| 0.028316847 \cdot \frac{m^3}{ft^3} \right| \cdot density_{air,i} \quad \text{for } i = 1 \text{ to } 9$$

$CP_i = \mathbf{Cp}(\text{'Air'}, T=T_i)$ for i = 1 to 9

$$\dot{Q}_{savings,i} = \Delta \dot{m}_{v,sb,schoolyear,i} \cdot CP_i \cdot \left[\left| T_i - T_{indoors} \right| \right] \quad \text{for } i = 1 \text{ to } 9$$

During the Summer

$density_{air,i} = \rho(\text{'Air'}, T=T_i, P=P)$ for i = 10 to 12

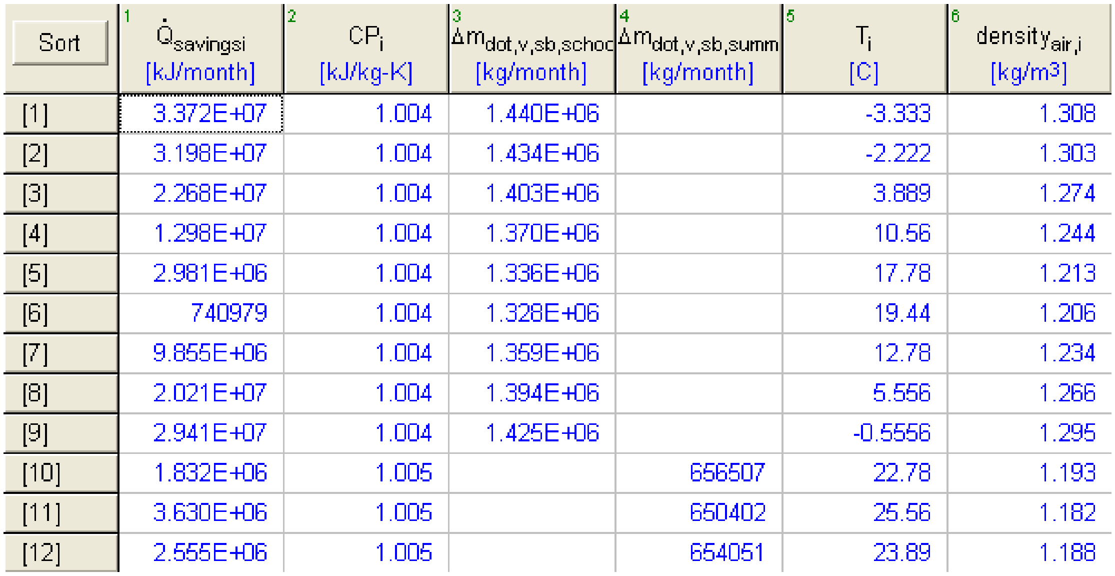
$$\Delta \dot{m}_{v,sb,summer,i} = A_{ir,summer} \cdot number_{doors} \cdot number_{minutes,per,hour} \cdot number_{hours,per,day} \cdot number_{days,per,month} \cdot \left| 0.028316847 \cdot \frac{m^3}{ft^3} \right| \cdot density_{air,i} \quad \text{for } i = 10 \text{ to } 12$$

$CP_i = \mathbf{Cp}(\text{'Air'}, T=T_i)$ for i = 10 to 12

$$\dot{Q}_{savings,i} = \Delta \dot{m}_{v,sb,summer,i} \cdot CP_i \cdot \left[\left| T_i - T_{indoors} \right| \right] \quad \text{for } i = 10 \text{ to } 12$$

Total yearly energy saved

$$\dot{Q}_{total,saved,per,year} = \sum_{i=1}^{12} \left(\dot{Q}_{savings,i} \right) \cdot 1 \text{ [1/year]} \cdot \left| 0.00000947817 \cdot \frac{therms}{kJ} \right|$$



Sort	1 $\dot{Q}_{savingsi}$ [kJ/month]	2 CP_i [kJ/kg-K]	3 $\Delta m_{dot,v,sb,schoc}$ [kg/month]	4 $\Delta m_{dot,v,sb,summ}$ [kg/month]	5 T_i [C]	6 $density_{air,i}$ [kg/m3]
[1]	3.372E+07	1.004	1.440E+06		-3.333	1.308
[2]	3.198E+07	1.004	1.434E+06		-2.222	1.303
[3]	2.268E+07	1.004	1.403E+06		3.889	1.274
[4]	1.298E+07	1.004	1.370E+06		10.56	1.244
[5]	2.981E+06	1.004	1.336E+06		17.78	1.213
[6]	740979	1.004	1.328E+06		19.44	1.206
[7]	9.855E+06	1.004	1.359E+06		12.78	1.234
[8]	2.021E+07	1.004	1.394E+06		5.556	1.266
[9]	2.941E+07	1.004	1.425E+06		-0.5556	1.295
[10]	1.832E+06	1.005		656507	22.78	1.193
[11]	3.630E+06	1.005		650402	25.56	1.182
[12]	2.555E+06	1.005		654051	23.89	1.188

Appendix I

Dorm Tunnels

Introduction

Currently, steam and hot warter are produced in the Science Building Power Plant (SBPP) and the Knollcrest Dining Hall (KDH) to heat and cool campus. The main purpose of this project was to analyze the energy and cost savings for connecting the 63% efficient boilers which supply the dorms north of dorm road and the KDH to the heating and cooling loop that originates in the SBPP with new 92% efficient boilers. Once this ground work was completed, the information was passed on to the Financial Group and discussed the financial feasibility.

Description

The first step in this project was to get a tour of the facilities of interest, lead by Paul Pennock. Paul took the group through KDH and SBPP, and explained the current hot water loops north of dorm road. Once the group had a good understanding of the current and proposed systems (see Figures I1 and I2), the next step was to obtain past energy data from the Physical Plant.

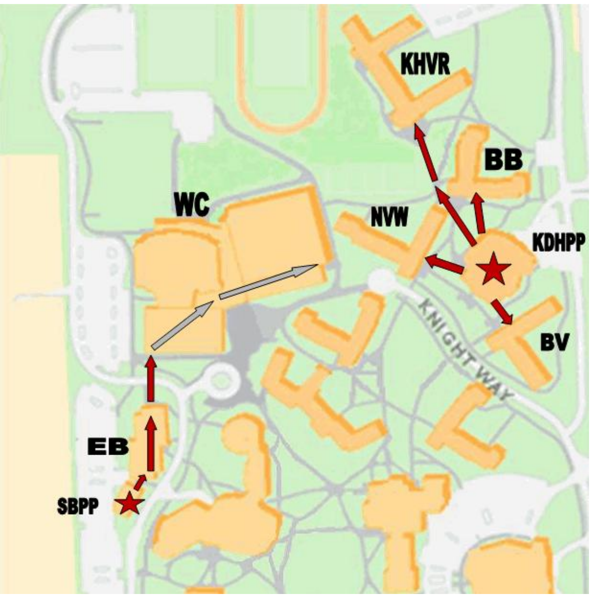


Figure I1: **Existing Hot Water Loop**

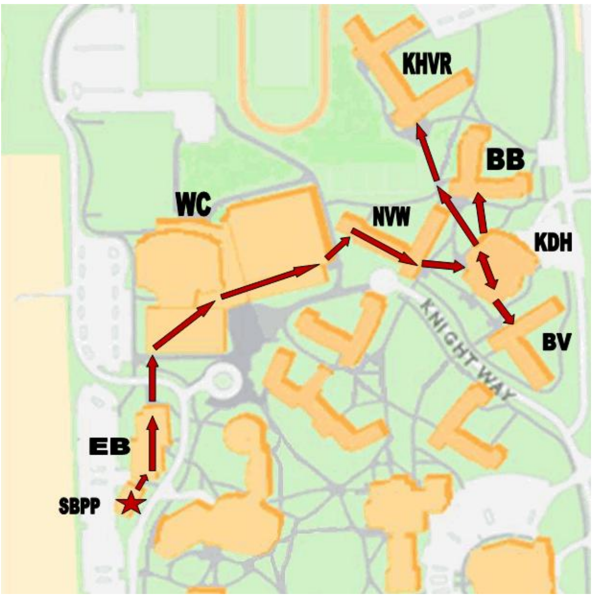


Figure I2: **Proposed Hot Water Loop**

This data would be the basis of the energy saving potential of the project. One assumption in these calculations is that KDH had some new, more efficient hot water boilers installed over the past summer to supply the domestic hot water to the four dorms north of dorm road and KDH. These new boilers allowed one of the old steam boilers to be taken off line. This was an issue for the team because there is no way to tell how much energy will already be saved this year due to the new boilers, so projected energy savings would be less accurate. To overcome this problem, Paul gave the group his most accurate guess as to how much steam was previously dedicated to the heating of the dorms: 75%. This allowed the group to simply take a fraction of the previous energy consumption (the portion of energy that went to heating the dorms and KDH) and continue with the calculations. Since the energy savings were based off an educated guess, high and low values were also calculated to show the possible savings range due to error. The tables can be seen in full detail in Appendix I1. This assumption can be revisited at the end of the year when actual data has been collected. An important aspect of this project was to calculate how much it would cost to connect the northern dorm system to the SBPP. The group knew there were existing hot and cold water pipes already run through the new Wellness Center. In order to determine where these main pipes ended and new pipes could be hooked up, the group took a tour of the new Wellness Center lead by Elliott Van Stelle. During this tour the group discovered that the main pipes were already extended to the end of the Wellness Center closest to Noordwier-Vander Werp, which was where the team was planning to connect the system to the northern dorm loop. The distance to and through NVW was measured. After measuring this, the team was able to determine how much piping needed to be run to connect the loop, and decided that another tunnel would be the best way to do that. After talking with Physical Plant employees, the group found a good reference book for construction pricing: RSMeans. The prices from this book were used to construct the tunnel component by component; including materials and labor, and a nominal value was obtained. Error was accounted for by calculating a minimum and maximum cost based on the error of each tunnel component. To view the full details of the cost of the tunnel, see Appendix I2. The tunnel cross section is shown in Appendix I3. Once the data collection for the cost of the tunnel and the energy savings was obtained, the information was passed on to the financial group.

Results

The total amount of energy saved with this proposed project along with the error data (maximum and minimum costs) are shown below in Table I1 along with the minimum, nominal, and maximum cost of building the tunnel.

Table I1: **Energy Savings and Tunnel Cost**

	Pessimistic	**Nominal**	**Optimistic**
Energy Savings [*therms/yr*]	45036	51106	59731
Tunnel Cost [*$*]	74692.09	83501.25	92798.61

Conclusion

Our group determined from the calculations that this project would be feasible both technically and financially. There is a short payback period for the project although there is high initial cost because of the high energy savings. After looking over our data, the financial group also decided that the project was feasible and decided to attempt to implement it during the first year.

Appendix I1: KDH Heating Data

Table I1-1: **4 Year Average Natural Gas Usage [therms/yr]**

January	February	March	April	MayT	June	July	August	September	October	November	December	**Total**
32347	30424	26712	19928	12668	5255	4564	5267	9952	17976	24147	26932	**216171**

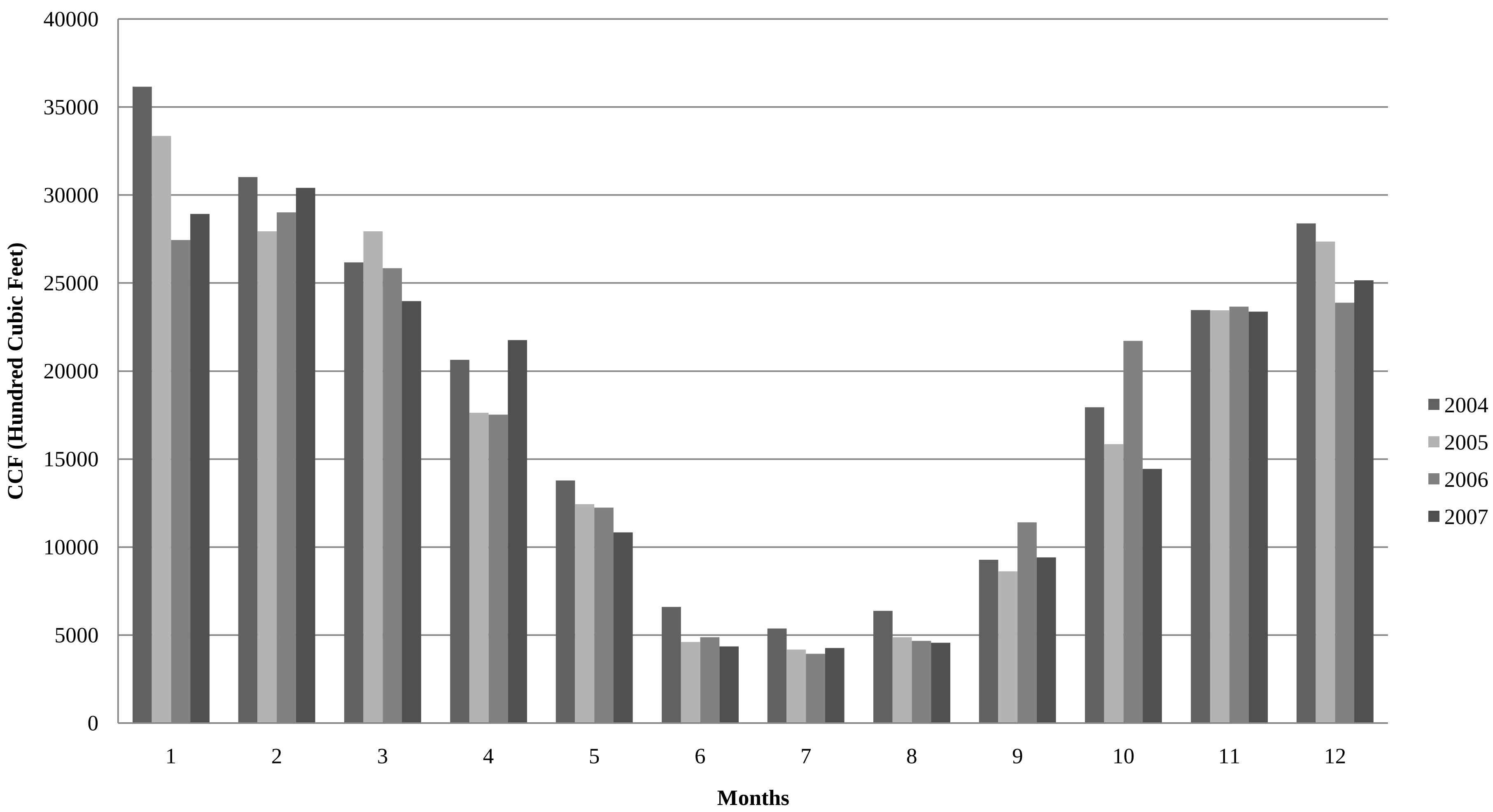


FIGURE I1-1: KDH Natural Gas Monthly Usage

Appendix I2

Detailed Tunneling Cost Data

Tunnel length: 200 feet

Piping through Nord: 225 feet

			R.S. Means Page #		Nom Cost			Min Cost	Error Reasoning	Max Cost	Error Reasoning
Excavation											
6' - 10' deep, 1.5 yd^3, excavator	2.82	\$/yd^3	page 523	10' deep	3342.22	$		3008	10% error	3676.44	10% error
need 16' horizontally - 8' for concrete, then 4' on either side for safety (putting up forms and supports)											
Compact											
Vibratory plate, 8" lifts, common fill	1.95	\$/yd^3	page 534	6"	57.78	$		52	10% error	115.56	If compact 12"
8' wide of compacting for concrete											
Concrete											
Footing , over 5 yd^3, direct chute (Floor)	19	\$/yd^3	page 65	8" thick	750.62	$	96" wide	562.96	If 6" thick	938.27	If 10" thick
Slab, 6"+ (Lid)	13.85	\$/yd^3	page 65	10" thick	683.95	$	96" wide	512.96	If 8" thick + 5% error	820.74	If 12" thick
8" (Wall)	25.50	\$/yd^3	page 65	8" thick	1679.01	$	80" tall	1259.26	If 6" thick	2098.77	If 10" thick
Waterproofing											
3 coat, 3/8" thick (Seams)	17.64	\$/yd^2	page 180	4" wide strip	522.67	$		470.40	10% error	1045.33	If 8" wide strip
Pipe											
18' lengths, Ductile Iron, Mech. Joints	60.50	$/lf	page 570	12"	25712.5	$		23141.25	10% error	28283.75	10% error
12" diameter											
Pipe Insulation											
Fiberglass, 2" wall, 0.5" iron pipe size											
12" dia	24	$/lf	page 419	12"	10200	$		9180	10% error	11220	10% error
Add 3 linear feet for each fitting	24 fittings			12"	1728	$		1555.20	10% error	1900.80	10% error
Add 4 linear feet for each flange				12"	?	$					
Backfill											
Dozer	1.44	\$/yd^3	page 532		1024	$		921.6	10% error	1126.4	10% error
Seed											
44 lb/1000 yd^2	0.45	\$/yd^2	page 562		160	$		152	5% error	168	5% error

Without cooling pipes	**TOTAL COST**	83501.25	$	74692.09	$	92798.61	$
	Cost/foot	417.51	$/ft	373.46	$/ft	463.99	$/ft
	Cost/yard	1252.52	$/yd	1120.38	$/yd	1391.98	$/yd

Additional cost for cooling pipes 75281 $

Appendix I3: Proposed Tunnel Cross-section

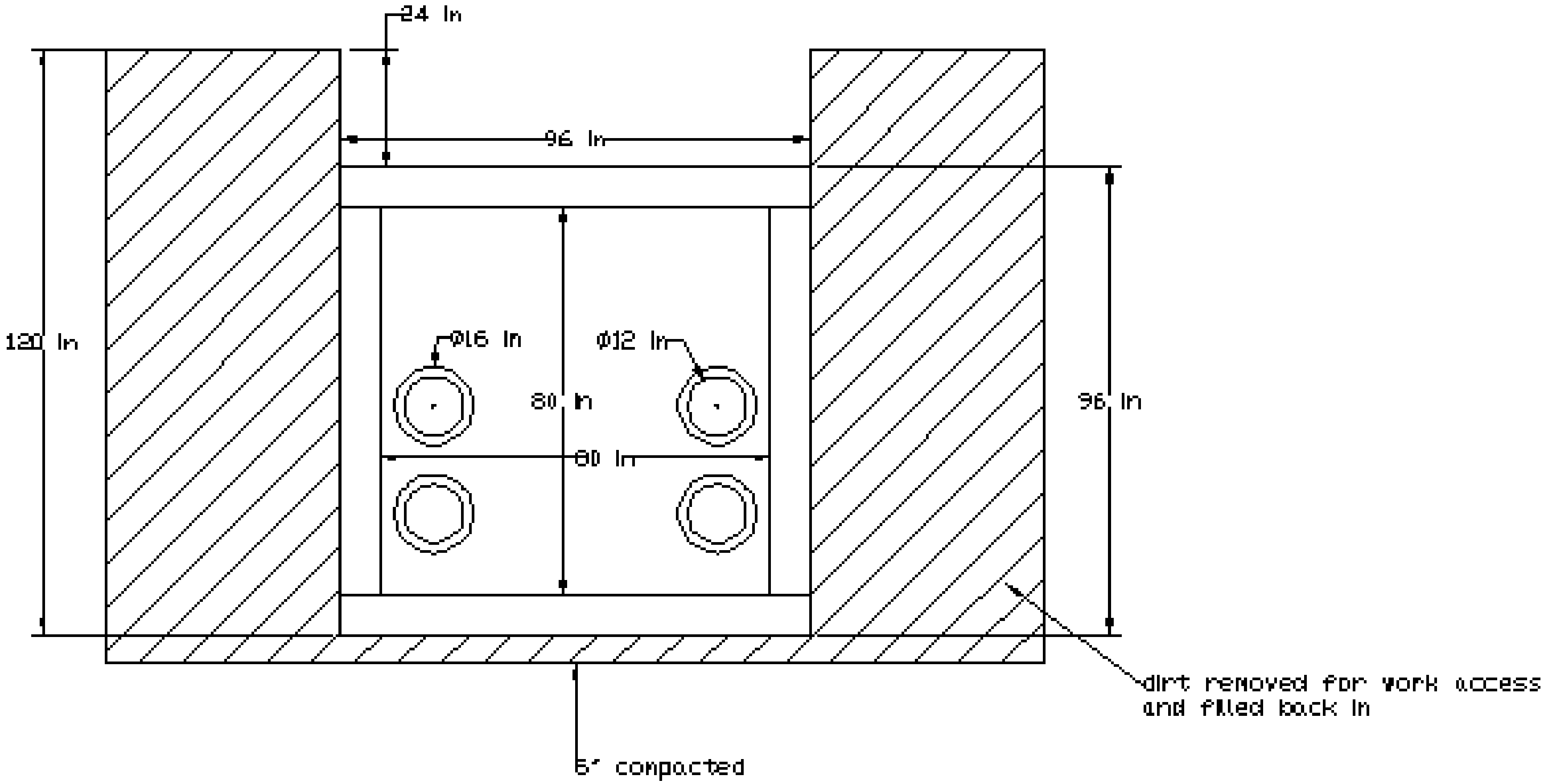


Figure I3-1: Tunnel Cross Section

Appendix J

Commons Dining Hall Windows

Introduction

Windows are a necessary aesthetic part of most buildings. However, windows are also a significant source of heat loss during the winter and heat gain during the summer. These heat transfers must be offset by either heating or cooling the building, which can become expensive in large buildings.

Fortunately, replacing older, thermally-inefficient windows with new high efficiency windows can greatly reduce the costs of heating and air conditioning. As part of the Calvin Energy Efficiency Fund project, the thermodynamic and financial effects of replacing the windows in Commons Dining Hall were examined. The results were exciting: Calvin College can save over 24,000 therms of natural gas per year in heating expenses and over 2,000 kW-hr per year in cooling expenses for an initial cost of only $165,000.

Data

The first step in assessing the costs and rewards of replacing the windows in the Commons Dining Hall was to gather the necessary information. This information came in several forms and from several places.

First, some measures of the average climate in West Michigan were necessary before a thorough analysis could be begun. Heating and cooling degree days, supplied by National Oceanographic and Atmospheric Administration (NOAA), gave an indication of the average outdoor temperature. A heating degree day is the number of degrees between the outside temperature and 65 °F summed over time, in this case 1 month. A cooling degree day is similar, but for temperatures below 65°F.

Solar heat gain factors (SHGF) were also used in the analysis. A SHGF is the rate at which solar radiation would pass through an eighth inch piece of glass at a given latitude, day, time, and orientation. Values of the SHGF for West Michigan were found in the 1997 ASHRAE Fundamentals Handbook.

In addition to data about the climate, information was needed about the windows. The team contacted Vos Glass Inc, the company which installed the current Commons Dining Hall windows. Vos Glass graciously provided complete thermal data on the current windows, as well as thermal data on high efficiency windows (see Exhibits) and an installation estimate replacing all the Commons Dining Hall windows with the high efficiency windows.

Analysis

Heat transfer through windows occurs along two paths. The first is via conduction and convection, and is caused by a difference in temperatures across the window. Heat transfer due to conduction and convection was modeled using the heating and cooling degree days, the U-value (insulation factor) of the windows, and the total window area (3,493 square feet). The amount of heat that travels through the window can be found with

$$\mathrm{Q} = \mathrm{CDD} \cdot \mathrm{U} \cdot \mathrm{A} \tag{J1}$$

where Q is the total heat transfer in a month, CDD is the cooling degree days reported for the month of interest, U is the insulation value of the window, and A is the area of the windows. The same analysis can be repeated for the heating degree days reported during the month, and then the values for all 12 months can be summed to complete the year long analysis.

Heat can also travel through a window as solar radiation. This kind of heat transfer is independent of the outside or inside temperatures, and can only add heat to a building. To analyze the heat absorbed through the windows of Commons Dining Hall, the shading coefficients (SC) of the windows and the SHGF were used. A shading coefficient is a ratio of the amount of heat that passes through the window to the amount of heat that passes through an eighth inch sheet of glass under the same conditions. Solar heat gain can be found using

$$\dot{Q} = \mathrm{SHGF} \cdot \mathrm{A} \cdot \mathrm{SC} \qquad \text{(J2)}$$

where Q is the heat transfer rate, SHGF is the solar heat gain factor, A is the window area, and SC is the shading coefficient of the window. Equation 2 was used to find the average heat transfer rate through both the current and new windows for every month of the year. Total heat transfer was then found by estimating the effective hours of sunlight each side of Commons Dining Hall sees each month, and multiplying that estimated time by the calculated rate of heat transfer.

Once both the convection/conduction and solar radiation heat transfers were found, the totals were added together to create a net heating and cooling load for each month. The efficiencies of the boiler and chiller systems were then taken into account, to find the total energy necessary to make up the heat loss through the windows.

Conclusion and Recommendations

Analyzing the Commons Dining Hall windows revealed that over 24,000 therms of natural gas and 2,000 kW-hr of electricity could be saved each year if the current windows were replaced with more efficient, double-paned windows. The installation cost for this project would be approximately $165,000. Because of the large amount of natural gas saved, and the escalating costs of natural gas in recent years, this project could provide immense benefits to both Calvin College and the Calvin Energy Efficiency Fund. If paired with the upcoming remodel of Commons this upfront cost could be reduced. Energy efficiency projects are plentiful on our campus and a great way for Calvin to be stewards of resources and mindful of God's creation.

Table J1: **Heating and Cooling Degree Days for Greater Grand Rapids**

Month	**Cooling Degree Days (*°F-day)***	**Heating Degree Days (*°F-day*)**
January	10.25	832.75
February	6.5	743
March	23	552.75
April	34.75	304.75
May	114.25	134.25
June	232.75	27.5
July	341.25	4.75
August	324.25	11
September	180.5	53.25
October	64	237.75
November	16.5	484.25
December	8.5	779.25

Table J2: **Solar Heat Gain Factors for Grand Rapids (*BTU/hr-ft^2*)**

Month	**North***	**South***	**West***
January	20	254	21
February	24	241	25
March	29	206	31
April	34	154	36
May	37	113	40
June	38	95	41
July	38	109	41
August	35	149	38
September	30	200	32
October	25	234	27
November	20	250	21
December	18	253	19

*Indicates the direction the window faces

Table J3: **Analysis of Cooling Load due to Conduction/Convection**

MONTH	**Cooling Degree Days** *[°F-day]*	**Heat Transfer with Current Windows**		**Heat Transfer with New Windows**		**Energy Savings from Window Replacement** *[kW-hr/mo]*
		[Btu/mo]	*[kW-hr/mo]*	*[Btu/mo]*	*[kW-hr/mo]*	
January	10.25	837796	245.53	300747	88.14	157.39
February	6.5	531285	155.70	190718	55.89	99.81
March	23	1879933	550.95	674848	197.78	353.18
April	34.75	2840333	832.42	1019607	298.82	533.60
May	114.25	9338361	2736.80	3352232	982.44	1754.36
June	232.75	19024101	5575.41	6829164	2001.43	3573.98
July	341.25	27892478	8174.48	10012685	2934.43	5240.05
August	324.25	26502963	7767.25	9513884	2788.24	4979.01
September	180.5	14753384	4323.79	5296087	1552.13	2771.66
October	64	5231117	1533.09	1877837	550.34	982.75
November	16.5	1348647	395.25	484130	141.88	253.37
December	8.5	694758	203.61	249400	73.09	130.52
	Yearly Totals	**110875155**	**32494**	**39801338**	**11665**	**20830**

Table J4: **Analysis of Heating Load due to Conduction/Convection**

MONTH	**Heating Degree Day [*°F-day*]**	**Heat Transfer with Current Windows**		**Heat Transfer with New Windows**		**Energy Savings from Window Replacement [*Therms/mo*]**
		[*Btu/mo*]	**[*Therms/mo*]**	**[*Btu/mo*]**	**[*Therms/mo*]**	
January	832.75	68065821	680.66	24433884	244.34	436.32
February	743	60729997	607.30	21800512	218.01	389.29
March	552.75	45179685	451.80	16218348	162.18	289.61
April	304.75	24909107	249.09	8941731	89.42	159.67
May	134.25	10973085	109.73	3939056	39.39	70.34
June	27.5	2247746	22.48	806883	8.07	14.41
July	4.75	388247	3.88	139371	1.39	2.49
August	11	899098	8.99	322753	3.23	5.76
September	53.25	4352453	43.52	1562419	15.62	27.90
October	237.75	19432782	194.33	6975870	69.76	124.57
November	484.25	39580755	395.81	14208476	142.08	253.72
December	779.25	63692934	636.93	22864130	228.64	408.29
	Yearly Totals	**340451707**	**3405**	**122213433**	**1222**	**2182**

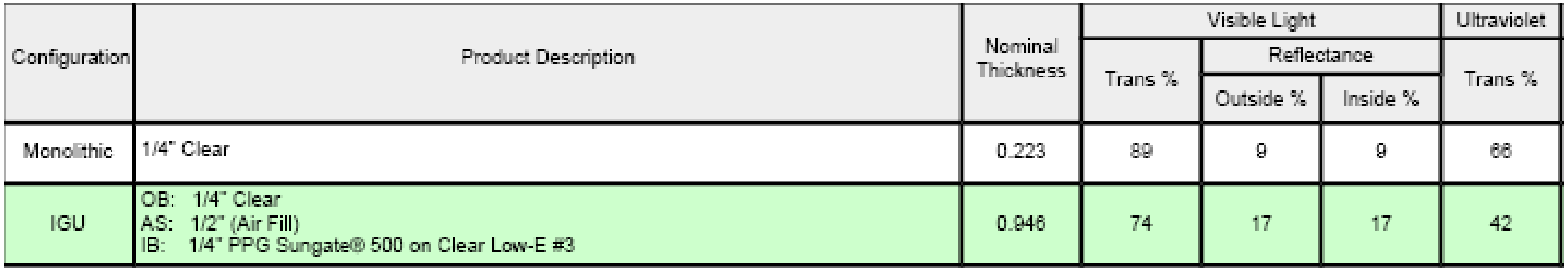
Table J5: Solar Heat Gain Factors

MONTH	Estimated hours of sunlight per day (at max heat transfer)	Current Heat Transfer (*kW-h*)	Projected Heat Transfer (*kW-h*)	Energy Savings from Window Replacement (*kW-h*)
January	4	141.87	114.71	27.17
February	4	517.20	418.16	99.04
March	5	679.46	549.35	130.11
April	6	1750.64	1415.41	335.23
May	6	2911.51	2353.98	557.52
June	7	4102.46	3316.88	785.58
July	8	4389.39	3548.87	840.52
August	7	2882.97	2330.92	552.06
September	6	1148.25	928.37	219.88
October	5	288.86	233.54	55.31
November	5	166.92	134.96	31.96
December	4	0.00	0.00	0.00
	Yearly Totals	**18979.53**	**15345.15**	**3634.38**

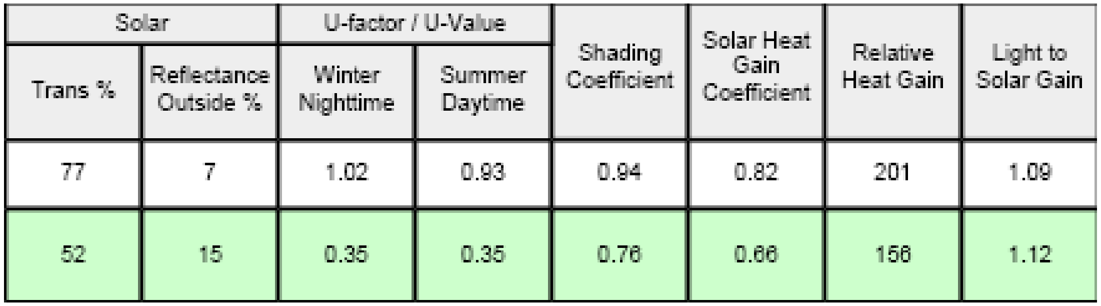
Table J6: Results of Replacing Commons Dining Hall Windows

MONTH	Heating			Cooling		
	Current Heating [*therms*]	Projected Heating [*therms*]	Heating Saved [*therms*]	Current Cooling [*kW-hr*]	Projected Cooling [*kW-hr*]	Cooling Saved [*kW-hr*]
January	681	244	436	381	198	183
February	607	218	389	287	162	125
March	452	162	290	696	315	381
April	249	89	160	972	412	560
May	110	39	70	2848	1073	1776
June	22	8	14	5691	2095	3596
July	4	1	2	8320	3052	5268
August	9	3	6	7927	2917	5010
September	44	16	28	4495	1690	2804
October	194	70	125	1693	680	1013
November	396	142	254	562	277	285
December	637	229	408	338	182	156
Yearly Totals	3405	1222	2182	34211	13053	21158

Table J7: **Thermal data for Existing (Top Row) and Proposed (Bottom Row) Windows**



Configuration	Product Description	Nominal Thickness	Visible Light			Ultraviolet
			Trans %	Reflectance		Trans %
				Outside %	Inside %	
Monolithic	1/4" Clear	0.223	89	9	9	66
IGU	OB: 1/4" Clear AS: 1/2" (Air Fill) IB: 1/4" PPG Sungate® 500 on Clear Low-E #3	0.946	74	17	17	42



Solar		U-factor / U-Value		Shading Coefficient	Solar Heat Gain Coefficient	Relative Heat Gain	Light to Solar Gain
Trans %	Reflectance Outside %	Winter Nighttime	Summer Daytime				
77	7	1.02	0.93	0.94	0.82	201	1.09
52	15	0.35	0.35	0.76	0.66	156	1.12

Appendix J1: Bibliography

National Climatic Data Center Online. 8 Dec. 2008. NOAA. 8 Dec. 2008 <http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp# >.

ASHRAE. "Table 18, Chapter 29." ASHRAE Handbook 1997 Fundamentals. 1997. 29.32

Appendix K

Dorm Hall Light

Introduction

Of the three R's – reduce, reuse, recycle – this project focuses on reducing our energy consumption. Specifically, we propose that the timers in the dorms that control when half of the lights shut off be adjusted. We suggest that the times should include another 5 hours during the daytime hours. Currently, the system shuts off half of the lights during the hours of 11pm – 6am. We propose adding the hours of 11am – 4pm when student activity is low and sunlight is present. By reducing the amount of time the lights are on, Calvin's electricity costs will be lowered.

Description

To calculate the energy savings that Calvin would incur, the first step was to go through each floor of each dorm and count the number of light fixtures present. The one exception to this was in the van Reken wings. Here, different style lighting is used that is not controlled by the timers and was therefore excluded from the calculations. While counting the lights, the wattage of the bulbs was also recorded – this defines the energy consumption rate of the bulbs.

The total energy savings in kilowatt-hours per year is then

$$\text{Energy Savings} = \text{N}_{\text{bulbs}} \cdot \text{P}[\text{kW}] \cdot \text{H}\left[\frac{\text{hrs}}{\text{day}}\right] \cdot \ 365 \left[\frac{\text{days}}{\text{yr}}\right] \tag{K1}$$

where N_{bulbs} is the total number of bulbs that turn off, P is the bulb power in kilowatts, H is the number of extra hours per day to be included for shut-off (which in this case is 5hrs).

There will also be implementation costs for the project, or costs that are necessary to start the project. An estimated 1 hour of labor is required to go around to the dorms and update the timers.

Results

The total number of bulbs counted was 536. To calculate the total number that will turn off, the number of lights on each floor was counted, divided by two, and rounded down to the nearest integer where appropriate; doing so resulted in a total of 254 bulbs that turn off with the timers. The bulb power rating was found to be 40 watts (or .04 kW). Assuming that the lights remain on the timers during the summer months and that the proposed 5-hour extension is approved, Calvin can save approximately 18,500 kW-hrs as seen in Table K1 below.

Table K1: Summary of Results

Number of Shut-Off Bulbs	254
Number of Extra Off Hours	5
Bulb Power (kW)	0.04
Days per Year	365
Savings (kW)	18542

Conclusion

This is a feasible project for Calvin to consider from a technical and financial perspective. There aren't new systems to hook up or monitor, the only thing necessary is for one person to update the timers; approximately one hour of labor. Financially, the project sees savings instantly and pays back in almost within the first week of implementation. This project is a great way to reduce Calvin's energy consumption.

Appendix K1: Dorm Hall Lighting Summary

	FLOOR	TOTAL LIGHTS	HALF (TURN OFF)
SCHULTZE - ELDERSVELD	1S	11	5
	2S	12	6
	3S	11	5
	1E	11	5
	2E	12	6
	3E	11	5
BOLT - HEYNS - TIMMER	1B	11	5
	2B	12	6
	3B	11	5
	1H	11	5
	2H	12	6
	3H	11	5
	GT	14	7
	1T	14	7
	1T	14	7
ROOKS - VAN DELLEN	1VD	11	5
	2VD	12	6
	3VD	11	5
	1R	11	5
	1R	12	6
	2R	11	5
BEETS - VEENSTRA	1B	11	5
	2B	12	6
	3B	11	5
	1V	11	5
	2V	12	6
	3V	11	5

	FLOOR	TOTAL LIGHTS	HALF (TURN OFF)
NOORDEWIER - VANDERWERP	1N	17	8
	2N	18	9
	3N	17	8
	1VW	11	5
	2VW	12	6
	3VW	11	5
BOER - BENNINK	1B	11	5
	2B	12	6
	3B	11	5
	1B	11	5
	2B	12	6
	3B	11	5
KALSBEEK - HUIZENGA - VAN REKEN	1K	11	5
	2K	12	6
	3K	11	5
	1H	11	5
	2H	12	6
	3H	11	5
	1vR	-	-
	2vR	-	-
	3vR	-	-

	TOTAL LIGHTS	HALF (TURN OFF)
TOTALS	**536**	**254**

Appendix K2: Energy Savings Calculations

Table K2-1. **Current Lighting Conditions**

Current Situation: Wattage = 40 W/bulb and 1 bulb/fixture Hours full use = 6AM - 11PM = 17 hrs/day				
	Hours [hrs/day]	**Watts** [W]	**Electricity** [W-hr/day]	**Electricity** [kW-hr/year]
Half On:	7	11280	78960	28820
All On	17	21440	364480	133035
TOTAL:	24	32720	443440	161856

Table K2-2. **Proposed Lighting Conditions**

Proposed Solution: Wattage = 40 W/bulb and 1 bulb/fixture Hours full use = 6AM - 11AM, 4PM - 11PM = 12 hrs/day				
	Hours [hrs/day]	**Watts** [W]	**Electricity** [W-hr/day]	**Electricity** [kW-hr/year]
Half On	12	11280	135360	49406
All On	12	21440	257280	93907
TOTAL:	24	32720	392640	143314

Table K2-3. **Energy Use Summary**

Annual Energy Use *[kW-hrs]*	
Current	161856
Proposed	143314
Savings	18542

Table K2-4. **Project Costs**

Upfront Labor Costs	
Time *[hrs]*	~1
Pay Rate *[$/hr]*	35
Total Costs *[$]*	35