EVALUATION OF ALTERNATIVE METAL STUD FRAMING TO REDUCE THERMAL BRIDGING IN EXTERIOR WALLS

By

BRIAN KEVIN BENNETT

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2011

To my mom without whom I would not be here today

ACKNOWLEDGMENTS

I would like to thank Dr. Srinivasan, Dr. Muszynski and Dr. Issa for taking the time to serve on my committee and assist with this research. Particular gratitude is extended to Dr. Srinivasan for his guidance, support and patience during my efforts to complete this thesis.

I thank my sons, Kyle and Michael. They are my life and the motivation in all that I do. When I am uncertain and feeling blue, all I have to do is imagine their beautiful faces, and I am reinvigorated and ready to take on the world one more time.

Above all others, I would like to thank my mom, Evelyn Bennett, for all of her amazing love and support. She picked me up when I was at my lowest and has kept me walking ahead when I didn't know that I could. My mother is my greatest blessing.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS 4

LIST OF TABLES 7

LIST OF FIGURES 9

CHAPTER

1 INTRODUCTION 13

Background 13
Statement of Purpose 14
Objectives 14

2 LITERATURE REVIEW 16

The Building Envelope 16
Exterior Wall Systems 17
Wall types 17
Heat Transfer 21
U-Factor Determination 23
Parallel Flow Method 25
Isothermal Planes Method 25
Modified Zone Method 25
2D Heat Flow Analysis 26
3D Heat Flow Analysis 27
Equivalent Wall Model 27
Testing 27
Energy Analysis 28
Economic Analysis 29
Initial & Future Expenses 29
Residual Value 30
Study Period 30
Real Discount Rate 30
Constant-Dollars 31
Present Value 31

3 RESEARCH METHODOLOGY 33

Overview 33
Step 1: Identification of Alternative Materials 34
Step 2: Material Properties 34
Step 3: Energy Analyses 36

Step 4: Cost Analyses 38

4 RESULTS AND ANALYSES 39

Overview....39
Section One: Alternative Metal Framing Solutions....39
Ridged Flanged Studs....40
Slit Web Studs 42
Aerogel Strips 44
Dimpled Flange Studs 45
Ceramic Coated Studs 47
Section Two: U-Factors 49
Parallel Path Method Results....50
Isothermal Planes Method Results 51
2D Heat Flow Analysis 51
Section Three: Energy Analyses....52
Section Four: Cost Analyses....53
Energy Costs....53
Construction Costs....54
Life Cycle Costs 55

5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 57

Summary....57
Matrix of Results 58
Conclusions....60
Limitations....60
Recommendations for Future Study 60

A U-FACTOR CALCULATIONS – PARALLEL PATH METHOD....62

B U-FACTOR CALCULATIONS – ISOTHERMAL PLANES METHOD....64

C U-FACTOR CALCULATIONS – 2D HEAT FLOW ANALYSIS 66

D DECREASED HEATING LOADS FROM WALL CONDUCTION 70

E DECREASED COOLING LOADS FROM WALL CONDUCTION 73

F ANNUAL ENERGY SAVINGS....76

G LIFE CYCLE COST ANALYSES....79

LIST OF REFERENCES....127

BIOGRAPHICAL SKETCH 130

LIST OF TABLES

Table page

4-1 R-values and U-factors using ASHRAE Table 5-H calculation methods 49

4-2 Total decreased energy loads from wall conduction (kWh) 52

4-3 Projected annual energy savings.....54

4-4 Construction unit costs per sf of opaque exterior wall area.....55

4-5 Estimated years to reach breakeven. 55

5-1 Matrix of results.....58

A-1 Code-minimum wall U-factor. Parallel path method.....62

A-2 Rinker exterior wall U-factor. Parallel path method.....62

A-3 Slit web, ridged & dimpled flange stud wall U-factors. Parallel path method 62

A-4 Aerogel strip wall assembly U-factor. Parallel path method 63

A-5 Thermal ceramic coated stud assembly U-factor. Parallel path method.....63

B-1 Code-minimum exterior wall U-factor. Isothermal planes method 64

B-2 Rinker Hall exterior wall U-factor. Isothermal planes method.....64

B-3 Slit web, ridged & dimpled flange wall U-factors. Isothermal planes method.....64

B-4 Aerogel strip wall assembly U-factor. Isothermal planes method.....65

B-5 Thermal ceramic coated stud assembly U-factor. Isothermal planes method. 65

D-1 Decreased heating loads. Heating loads. Zone 1 - Miami, FL.....70

D-2 Decreased heating loads. Zone 2 - Gainesville, FL 70

D-3 Decreased heating loads. Zone 3 - Atlanta, GA.....70

D-4 Decreased heating loads. Zone 4 - Seattle, WA.....71

D-5 Decreased heating loads. Zone 5 - Chicago, IL. 71

D-6 Decreased heating loads. Zone 6 - Helena, MT.....71

D-7 Decreased heating loads. Zone 7 - Minot, ND....72

D-8 Decreased heating loads. Zone 8 – Nome, AK....72

E-1 Decreased cooling loads. Zone 1 - Miami, FL....73

E-2 Decreased cooling loads. Zone 2 - Gainesville, FL....73

E-3 Decreased cooling loads. Zone 3 - Atlanta, GA....73

E-4 Decreased cooling loads. Zone 4 - Seattle, WA....74

E-5 Decreased cooling loads. Zone 5 - Chicago, IL....74

E-6 Decreased cooling loads. Zone 6 - Helena, MT....74

E-7 Decreased cooling loads. Minot, ND....75

E-8 Decreased cooling loads. Zone 8 – Nome, AK....75

F-1 Annual Energy Savings. Zone 1 - Miami, FL....76

F-2 Annual Energy Savings. Zone 2 - Gainesville, FL....76

F-3 Annual Energy Savings. Zone 3 - Atlanta, GA....76

F-4 Annual Energy Savings. Zone 4 - Seattle, WA....77

F-5 Annual Energy Savings. Zone 5 - Chicago, IL....77

F-6 Annual Energy Savings. Zone 6 - Helena, MT....77

F-7 Annual Energy Savings. Zone 7 - Minot, ND....78

F-8 Annual Energy Savings. Zone 8 – Nome, AK....78

LIST OF FIGURES

Figure page

2-1 Examples of mass walls 18

2-2 Example of metal building wall 19

2-3 Example of steel-framed wall 20

2-4 Example of wood framed wall 20

3-1 Methodology flowchart 33

3-2 Code-minimum exterior wall assembly 35

3-3 Rinker Hall exterior wall assembly 36

3-4 ASHRAE Map of US climate zones 37

4-1 ThermaChannel. Image from ThermaChannel, Inc 40

4-2 ThermaChannel cross-section with dimensions 40

4-3 ThermaChannel cross-section with dimensions 41

4-4 Slit Web Stud. Image from ORNL. 42

4-5 ThermaChannel cross-section with dimensions 43

4-6 Aerogel strips being applied to metal stud. Image from ThermaBlok 44

4-7 ThermaChannel cross-section with dimensions 45

4-8 Dimpled flange stud 46

4-9 Dimpled flange stud wall assembly 46

4-10 Thermal ceramic coated stud wall assembly 48

4-11 R-value calculation results comparison. 49

4-12 U-factor calculation results comparison. 50

4-13 2D heat flow analysis. Code-minimum wall 51

4-14 Decreased energy loads for each wall assembly type 53

4-15 Decreased energy costs for each wall assembly type 54

4-16 Projected breakeven years.....56

C-1 2D heat flow analysis. Rinker Hall wall 66

C-2 2D heat flow analysis. Ridged flange stud wall.....67

C-3 2D heat flow analysis. Slit web stud wall 67

C-4 2D heat flow analysis. Dimpled flange stud wall 68

C-5 2D heat flow analysis. Aerogel strip stud wall. 68

C-6 2D heat flow analysis. Ceramic coated stud wall 69

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Building Construction

EVALUATION OF ALTERNATIVE METAL STUD FRAMING
TO REDUCE THERMAL BRIDGING IN EXTERIOR WALLS
By

B. Kevin Bennett

August 2011

Chair: Ravi Srinivasan
Major: Building Construction

Thermal bridging is a transfer of energy through the most thermally conductive material in an otherwise well insulated assembly. In the case of exterior building walls constructed with metal studs, the steel framing is the path of least resistance of thermal energy within the system. As a consequence, the thermal performance of exterior wall systems is degraded and higher energy costs are incurred.

The purpose of this thesis is to evaluate several innovative materials and products that appear capable of significantly reducing the thermal bridging effect experienced in exterior metal stud framing. This research evaluates and compares these products, based upon their thermal performance and associated initial and life cycle costs.

The heat conduction properties of each of the alternative products were determined as components within Code-minimum compliant wall system assemblies using two-dimensional heat transfer analysis software. The U-factors of each of the wall assemblies were then entered into building energy simulation models based upon the design of Rinker Hall at the University of Florida to project annual energy savings based upon the anticipated heating and cooling loads resulting from exterior wall heat conduction.

To further understand how climatic variances could affect thermal performance, simulations were created for each of the energy models in each of eight US climate zones. The national average for the cost of electricity per unit in kilowatt hours was then applied to the energy loads determined for each model. Additionally, cost estimates were prepared for each of the wall type assemblies to understand the initial cost implications associated with each of the alternative products.

The energy load differentials were then applied to life cycle cost analyses to determine the overall cost effectiveness of each of the alternative products over an extended period of 30 years. This process took initial costs, projected energy savings, discount rates and energy inflation rates into account to determine which of the products, if any, would be recommended by this study.

CHAPTER 1
INTRODUCTION

Background

In recent years, the threats posed by escalating energy prices, dwindling natural resources and the possibility of dramatic global climate change has increasingly focused attention on the level of energy expended on the operation and maintenance of commercial buildings. A study conducted in 2010 by the U.S. Department of Energy (DOE) estimated that commercial and residential buildings combined accounted for nearly 40% of all energy consumption in the U.S. in 2008 (DOE 2010). The US National Science & Technology Council (NSTC) projects that worldwide energy consumption by buildings will be greater than the transportation and industrial sectors combined by 2025 (NSTC 2008).

Mitigating heat transfer through the exterior building envelope, which serves as the physical barrier between the exterior and interior environment, is a critical component in increasing the energy efficiency of buildings. The traditional solution has been to fill the cavity space of a building's exterior walls with as much low energy conductive material (such as fiberglass insulation) as possible. Unfortunately, this approach is limited due to the placement of other highly conductive materials within the walls, such as steel studs, that create thermal bridging.

Thermal bridging is a transfer of energy through the most thermally conductive material in an otherwise well-insulated assembly. In the case of exterior building walls constructed with metal studs, the steel framing is the path of least resistance for thermal energy within the system. As a consequence, the thermal performance of the exterior wall system is degraded and higher energy costs are incurred. The degradation in the energy performance of exterior wall systems

due to metal stud thermal bridging is estimated to be as high as 55% (Kosny and Desjarlais 2001).

Statement of Purpose

The purpose of this research was to evaluate several innovative materials and products that appeared capable of significantly reducing the thermal bridging effect experienced in exterior metal stud framing. These products were evaluated and compared based upon their thermal performance and associated initial and life cycle costs as components within an exterior wall system. Ultimately, the goal of the research was to determine the most energy efficient and cost effective method of constructing exterior wall systems using steel framing.

Objectives

The objective of this research was to determine the ability of alternative metal framing products designed to increase the energy performance of exterior wall system assemblies. Using the thermal requirements of a Code-minimum wall as a basis of evaluation, this research followed the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) prescriptive methods for determining building envelope U-factors. These ASHRAE prescriptive procedures were used to determine the U-factors for exterior wall assemblies that incorporated each of the alternative metal framing products. Additionally, two-dimensional heat flow analysis software was utilized to achieve more refined and accurate U-factors.

Following the determination of U-factors, using the Code-minimum wall assembly as a baseline for evaluation, building energy simulation computer models were developed for each of wall system scenarios for each of the eight climate zones in the US. The primary building energy use simulation program used in this research was Equest 3.64 which was developed by the Lawrence Berkley National Laboratory (LBNL) on behalf of the DOE.

For cost perspective and economic viability, analyses were conducted to determine the initial construction cost increases expected from each of the products. Coupled with the energy performance data, this information was used to develop life cycle costs analyses (LCCA) for each alternative. Ultimately, the objective of the LCCA's was to provide insight as to whether or not the alternative metal framing products being considered in this research could provide dividends in the future and how soon.

CHAPTER 2
LITERATURE REVIEW

The Building Envelope

The United States Code of Federal Regulations defines the building envelope as "the elements of a building that enclose conditioned spaces through which thermal energy may be transferred to or from the exterior or to or from unconditioned space" (10 C.F.R. § 434.201 2010). ASHRAE defines the building envelope as the "physical separation between the indoor and outdoor elements" (ASHRAE 2009). In essence, the building envelope helps protect a building's interior, contents, equipment, systems and occupants from the outside environment. The building envelope keeps rain and other elements out and helps to maintain comfortable environmental conditions for the people who live in, work in and visit buildings.

In reference to energy function and performance, a building envelope must serve three broad functions in energy efficient buildings (Straub & Burnett 2005):

- **Support** the efforts of mechanical systems to resist the transfer of heat into or out of a building's conditioned spaces
- **Control** the flow of matter and energy into and out of a building, including: rain, air, heat and vapor
- **Finish** to ensure that human comfort needs are met

A building envelope is made up of many complex, multi-layered assemblies, including: roofs, above and below-grade walls, elevated slabs and slabs-on-grade, fenestration and doors. Although the integrities of all the assemblies within a well-designed building envelope are critical components in creating an energy efficient building, exterior walls are of particular importance. Typically, exterior walls comprise the greatest area of a building's envelope, have the greatest complexity and are the most likely source of intrusion by air and water.

Exterior Wall Systems

Designers of exterior walls must balance a daunting multitude of concerns in their efforts to provide the "ideal" assembly. ASHRAE describes the ideal envelope assembly as one that "would control exterior loads in response to coincident internal loads to achieve a thermal balance for each set of conditions" (ASHRAE 2009). In addition to decisions which shape the parameters within which exterior wall systems are designed, including aesthetics, function, durability, maintainability, fire-rating, acoustics and budget, considerations that must be contemplated by designers regarding high-performing, energy-efficient buildings include:

- Air infiltration
- Moisture protection
- Thermal performance

Wall types

Wall type decisions are heavily influenced simply by the intended function of the facility being designed. For example, industrial facilities are often designed with initial economy in mind rather than aesthetics and pre-engineered metal buildings designs are selected for this reason. Typically, although not always the case, the exterior walls of pre-engineered metal buildings are clad in sheet metal. Most commonly in US residential construction, exterior wall assemblies are composed of wood stud framing with an exterior sheathing layer, gypsum board on the interior and fiberglass insulation infilling the cavity spaces between the studs. Metal stud framing is generally more common in commercial construction in the US.

ASHRAE Handbook - Fundamentals classifies four types of above-grade exterior wall types as follows (ASHREA 2009):

- Mass walls
- Metal building walls
- Steel-framed walls
- Wood-framed walls and others

Mass walls are walls that are constructed with solid heavy material such concrete, masonry, stone or earth with a heat capacity exceeding 7 (BTU/ft^2) per ASHRAE 90.1 standards. ASHRAE further indicates that walls constructed with lightweight materials with a unit weight not greater than 120 (lbs/ft^3) must have a heat capacity of greater than 5 (BTU/ft^3 · ºF) in order to qualify as a mass wall.

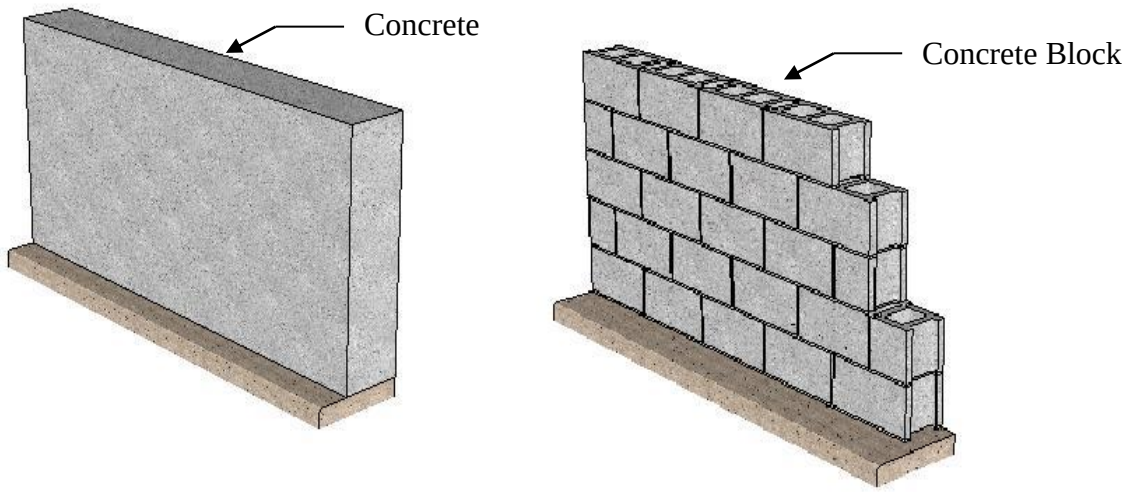

Figure 2-1. Examples of mass walls.

Mass walls have high thermal mass, meaning that they have the capacity to store heat energy which allows for passive cooling and heating of buildings. In a passive heating scenario, the thermal mass of a mass wall absorbs and stores heat energy from sunlight during the day. During cooler nighttime hours, the wall's stored energy is dissipated by radiation to warm a building. For passive cooling scenarios, the thermal mass of a mass wall is capable of absorbing the internal heat of a building and dissipating the heat energy to the exterior of the building at night.

Metal Building Walls are associated with pre-fabricated metal buildings and typically have exterior metal panels attached directly to horizontal metal supports called girts that span

between the building's structural support columns. Insulation is typically installed between the interior face of the metal panels and the horizontal steel girls.

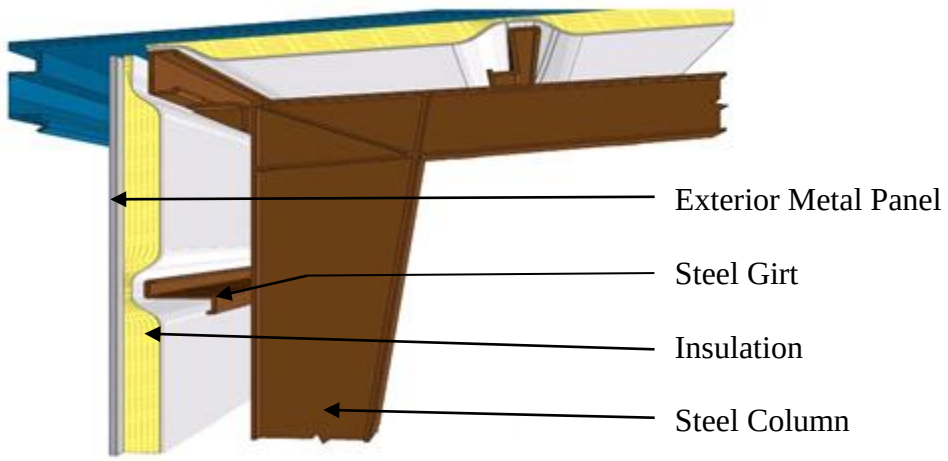

Figure 2-2. Example of metal building wall.

Steel-Framed walls are constructed with metal stud framing members. This is a very common construction type in US commercial, institutional and some residential buildings because non-combustible assemblies are usually required by building codes for many of these classes of construction.

A myriad of benefits has increased the popularity of metal stud framing in the US construction industry. Its low weight and high strength relative to wood framing are important factors; however, ease and speed of erection are the most significant positive attributes of metal stud framing.

Metal studs have a particularly significant disadvantage in relation to wood framing: steel is approximately 357 times more thermally conductive than wood. Simply put, this means that steel framing members within exterior wall systems are the primary conduit in which heat is transferred either into or out of a building's interior space. Based upon studies conducted by the

Oak Ridge National Laboratory (ORNL), steel studs decrease the thermal resistance of a wall assembly by as much as 55% (Kosny and Desjarlais 2001).

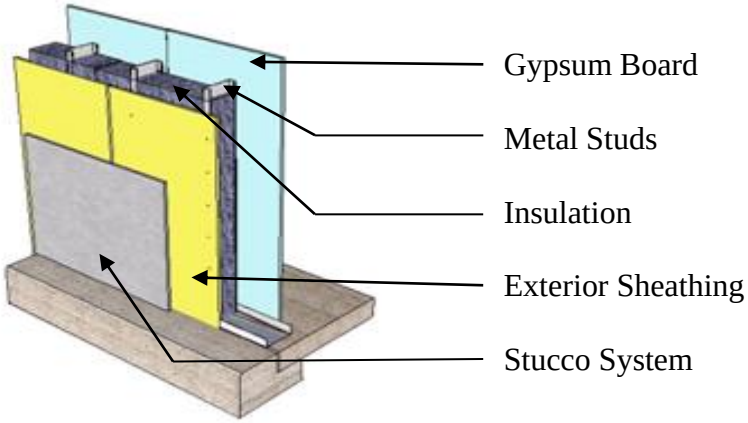

Figure 2-3. Example of steel-framed wall.

Wood-framed walls are defined by ASHRAE as walls constructed with wood framing or any type of wall construction that does not qualify as a mass, metal building or steel-framed wall. In US residential construction, wood framing is the predominant building technique due to its economy. Typically, gypsum board is attached to the interior face of 2x4 wood studs, exterior sheathing materials are attached to the outside face of the studs and the cavity space created between the interior and exterior sheathing materials is filled with insulating materials.

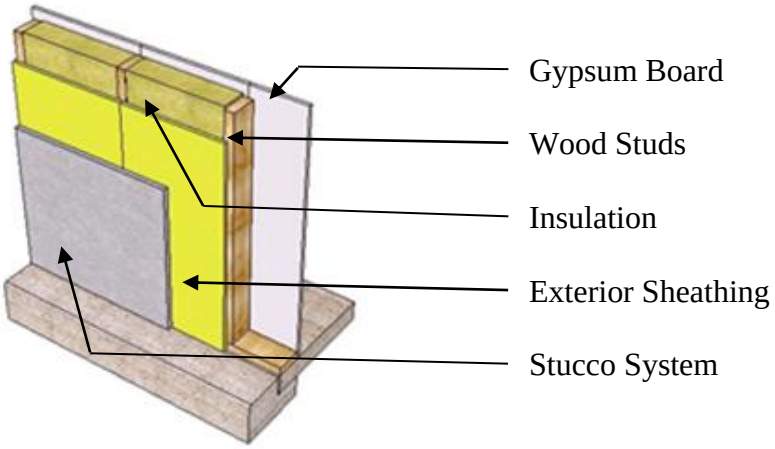

Figure 2-4. Example of wood framed wall.

Ultimately, regardless of type, the ability of an exterior wall to either conduct or resist the transfer of heat energy is a critical concern when designing energy-efficient buildings. This characteristic is a primary determining factor in the sizing and usage of HVAC equipment and, as a consequence, the levels of energy necessary to condition the interior space of a building.

Heat Transfer

The exchange of heat from one material to another is known as heat transfer. There are three forms of heat transfer that affect the energy performance of a building envelope: conduction, convection and radiation. Conduction is an exchange of thermal energy that occurs when materials are in direct contact with one another. Convection occurs when the flow of gases or fluids carries thermal energy from one material to another. Radiation is the transfer of thermal energy through transparent mediums, or even in the absence of any medium at all (e.g. a vacuum) via electromagnetic waves.

The primary means of decreasing heat transfer in the opaque portions of building envelopes is by limiting conduction. This is typically achieved by the incorporation of thermal insulating materials within the cavity spaces of envelope assemblies. The ability of a material to resist the transfer of heat through conduction is known as its thermal resistivity. The unit of measure for the thermal resistivity of a material is expressed as ($hr \cdot ft^2 \cdot {}^oF/Btu$). The reciprocal of thermal resistivity is known as thermal conductivity and is the property of a material to conduct heat. The unit of measure for thermal conductivity is expressed is as ($Btu/hr \cdot ft^2 \cdot {}^oF$).

In the US construction industry, the thermal conductivity or resistivity of a material is typically rated in terms of their R-value or its reciprocal U-value. These values take into account the actual thicknesses of materials. Materials with higher R-values are thermally superior to those with lower R-values. Materials with lower U-values perform better thermally to those with higher U-values.

While R-values and U-values are associated with single specific materials, U-factors were developed to provide insight into how assemblies of materials perform thermally as integrated units. ASHRAE defines a U-factor as "the steady-state heat conduction through the assembly" (ASHRAE 2009). U-factors are often associated with window units or building envelope assemblies such as walls or roofs. This nomenclature provides guidance to designers and constructors as to the energy efficiency of building assemblies.

Beyond thermal conductivity and resistivity, there are other thermo-physical properties of building materials within an opaque envelope system that determine their ability to transfer or resist the flow of heat energy. These properties include: density, heat capacity, and surface characteristics with respect to radiation (emissivity and reflectivity).

The density of a material is defined as its mass per unit volume. The unit for density is pounds per cubic foot (lbs/ft^3). A material's density is a factor in the determination of its heat capacity.

Heat capacity is the product of a material's density and its specific heat. Heat capacity is defined by ASHRAE as "the amount of heat that must be added to one square unit of surface area in order to elevate the temperature of the construction uniformly by one degree Fahrenheit" (ASHRAE 2009). Heat capacity is expressed in terms of British thermal units per square foot per degree Fahrenheit ($Btu/ft^2 \cdot {}^{o}F$).

The heat capacity of a material is significant in determining the quantity of thermal mass in an exterior wall or floor assembly, and thus is a critical component in determining an envelope's performance factor. For example, the degree of thermal mass differentiates whether a wall can be classified as a mass wall per ASHRAE 90.1 standards.

Surface emissivity and reflectivity are not actually material properties. Rather they are attributes of a material's surface. Emissivity describes the ability of a surface to emit heat by radiation. Conversely, reflectivity is the reciprocal of emissivity and describes the ability of a surface to reflect solar radiation.

Reflectivity and emissivity are dimensionless properties and range in value on a scale from 0 to 1. A material that is highly reflective would have an emissivity coefficient closer to 1; a material that is highly reflective would have an emissivity coefficient closer to 0. For example asphalt has an emissivity coefficient of 0.93; polished gold has an emissivity of 0.025. No material can have an emissivity of coefficient of either 0 or 1 as these values are theoretical extremes.

U-Factor Determination

The most basic method of calculating U-factors of opaque exterior wall assemblies is the clear wall method. The clear wall area is the portion of an exterior wall that is uncluttered by architectural details such as framing and material intersections such as concrete balconies. This type of analysis only takes into account the exterior sheathing, stud cavity and insulation and interior sheathing materials. Essentially, it disregards the thermal effects of other significant construction features, including steel framing.

The degradation to thermal performance due to the inclusion of metal studs is known as the framing effect. Research by ORNL estimates the decrease in exterior wall assembly U-factors to be 30% to 50% with clear wall calculations versus those taking the metal stud framing into account (Kosny and Desjarlais 2001).

The impact of inclusion of metal studs on an exterior wall assembly is illustrated in Figure 2-5. Both wall assemblies depicted are composed of 5/8" interior gypsum board, R-13 fiberglass insulation, 5/8" exterior gypsum board and 7/8" stucco system. Both wall assemblies are modeled to assess thermal performance in two-dimensional heat flow analysis software (THERM 6.3). The upper wall assembly is modeled without studs and the lower is modeled with 3 5/8" metal studs at 16" on center. The wall without metal studs is determined to have a U-factor of 0.0365. The inclusion of metal studs in the lower wall degrades the thermal performance of the wall to a U-factor of 0.0625 or 41.6%.

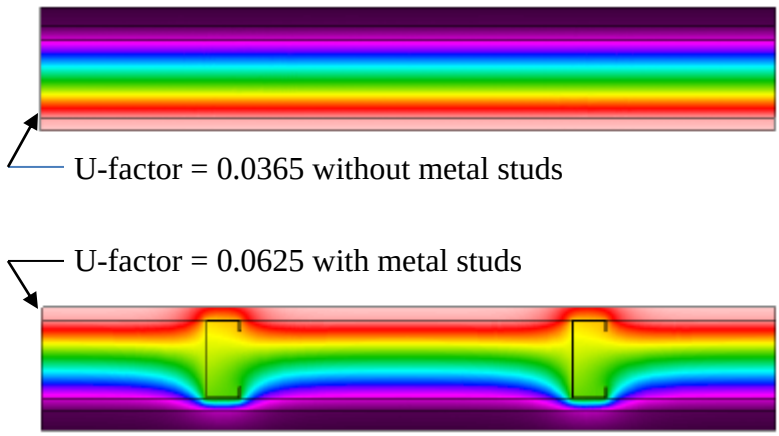

Figure 2-5. U-factor degradation due to metal studs in wall assembly.

Table 5-H of the 2009 ASHRAE Handbook – Fundamentals establishes several methods for calculating U-factors of various building assemblies. The methods for above-grade walls include:

- Parallel Flow Method
- Isothermal Planes Method
- Modified Zone Method
- 2D Calculation Method
- Testing

Parallel Flow Method

The parallel flow method is slightly more advanced than the clear method in that it takes the framing effect into account by calculating a weighted average of clear wall areas and framed wall areas. In this method, U-factors of clear wall assembly areas and U-factors of framed wall assembly areas are multiplied by their respective percentages of wall area and summed. The parallel flow method is acceptable in Table 5-H of the 2009 ASHRAE Handbook - Fundamentals for wood-framed walls; however it is not approved for calculating U-factors of steel-framed walls.

Although the parallel path method is considered to be more accurate than the clear wall approach, it typically underestimates the actual area of framing in exterior wall systems once corners, intersection and openings are taken into account. The other significant shortcoming of this method is that it treats framing members as if they were solid block of material. This is not quite so problematic in the case of wood framing. However, a problem arises with this approach when the framing is C-shaped metal studs as these members are not solid blocks.

Isothermal Planes Method

The isothermal planes method is slightly more sophisticated than the parallel flow method. In this approach, only the materials between the interior and exterior sheathing are modified by their respective percentages of wall area. Although the isothermal planes method is acceptable for calculating U-factors of above-grade steel-framed walls under ASHRAE Standard 90.1, the standard requires the application of adjustment factors per Table A9.2B to the insulating layer.

Modified Zone Method

The modified zone method was developed by ORNL to specifically assist in the thermal evaluation of metal framed assemblies. ORNL researchers have demonstrated the modified zone

method to be the most reliable prescriptive calculation method based upon comparative laboratory test results and finite element analysis.

Similarly to the parallel flow method, the modified zone method performs calculations on both the framed and non-framed areas of an assembly then combines the results using a weighted average formula. This approach involves dividing an assembly into zones and increasing the width of the stud flange to a value equal to the ratio of the thermal resistivity of the finish material to the thermal resistivity of the cavity insulation. The application of the modified zone method is only applicable to assemblies with C-shaped metal framing elements.

2D Heat Flow Analysis

Two-dimensional heat flow analysis is a complex mathematical analysis used to determine U-factors of complex building assemblies. Unlike one-dimensional calculation methods, this more advanced method does not assume that heat flows in a direct line from one side of a boundary to the other. This process takes into account lateral conductive and convective heat flow to provide U-factor results for the assemblies in a steady state. The approach subdivides the elements of assemblies into many smaller pieces and calculates the thermal relationship between each.

Two-dimensional heat flow analysis is based upon electric circuit theory and is typically conducted with the assistance of computer simulation programs. One such program (THERM) was developed by the Lawrence Berkley National Laboratory (LBNL) and is based upon the finite-element method.

The deficiency found in most two-dimensional heat flow analysis programs is that they are only capable of analyzing wall assemblies as a series of one-dimensional layers. The problem in this approach is that the effects of thermal bridges are not accounted for in the transient response of assemblies (Enermodal 2001).

3D Heat Flow Analysis

In the next step in the evolution of heat flow analysis, ORNL developed finite difference computer code which was incorporated into a program known as Heating 7.2. Although not created specifically for evaluating building envelopes, this program is able to map heat flows through wall assemblies to solve steady-state and transient heat conduction problems in three-dimensional Cartesian coordinates.

Despite the advancements that three-dimensional heat flow analysis programs provide, the significant drawback experienced by users is the long series of response factors that sometimes must be input. For massive walls, 60 to as many as 150 numbers, multiplied by 3, must be input accompanied by the troublesome modification of the program source code to enable this type of wall data input (Kosny and Kossecka 2001).

Equivalent Wall Model

The development of a simplified approach to determining wall assembly U-factors is known as the equivalent wall model (Kossecka and Kosny 1996). Developed by ORNL, practitioners of this approach are able create theoretical homogeneous walls with the identical material properties (conductivity, resistivity, density, heat capacity) of multi-layer walls that have already been laboratory tested and modeled in three-dimensional software by ORNL researchers. In this manner, the transient conditions and dynamic response of walls under design are considered equivalent to actual previously tested and catalogued wall system assemblies.

Testing

The most accurate U-factor determination method is actual laboratory testing. ASHRAE Standard 90.1 allows for three types of testing procedures:

- Guarded Hot Plate (ASTM C-177)
- Heat Flow Meter (ASTM C-518)
- Hot Box Apparatus (C-1363)

Figure 2-6. Guarded hot-box testing apparatus. Image from Butler Manufacturing.

Under these procedures, sample wall sections measuring 8’-0” by 8’-0” are constructed and placed into testing units. Heat flow is determined by measuring the energy required to maintain the steady-state temperature on the warm side of the wall. Although these testing methods provide the most reliable and accurate data, high costs and lengthy durations pose a significant disadvantage.

Energy Analysis

Building energy use simulations are computer models created to predict a building’s annual energy consumption. Building energy models should include all the necessary operating and design parameters that affect the energy consumption levels of a facility. Such parameters include the thermal performance abilities of envelope assemblies and components; electrical requirements of lighting, receptacles, HVAC equipment; building and space functions and occupancy counts. Simulation models are able to account for the location and orientation of a building and utilize historic weather data. All of this information is correlated and interpreted by

the computer program to predict a building's energy consumption on an hourly basis for years in advance.

Economic Analysis

The US General Accountability Office (GAO) defines Life Cycle Cost (LCC) as "the overall estimated cost for a particular program alternative over the time period corresponding to the life of the program, including direct and indirect initial costs plus any periodic or continuing costs for operation and maintenance". Life Cycle Cost Analysis (LCCA) is a financial method for determining the total costs associated with owning and operating a facility over a period of time. LCCA's also provide a means of comparing the life-cycle benefits of one alternative versus another in planning and design stages.

Although each of the below are not necessarily needed for every LCCA, the financial components that typically must be determined in the creation of LCCA are as follows: initial expenses, future expenses, residual value, study period, real discount rate, constant-dollars and present value.

Initial & Future Expenses

The first factors in LCCA creation are related to the costs associated with a facility prior to and following occupation. The expenses incurred prior to occupation are referred to as initial expenses or initial investment costs. Initial expenses are generally associated with the following cost categories: land acquisition, site investigation, design services, construction, construction management, equipment & technology and contingency.

The expenses that are projected to be incurred after occupancy has commenced are as referred to as future expenses and are generally associated with the following cost categories:

- Operational costs: Expenses incurred in the ongoing operation of a facility. Includes utility (e.g. electricity, water, gas, steam), waste removal, custodial, grounds, insurance and lease expenses.

- Maintenance and repair costs: These expenses can be either scheduled or unscheduled and are associated with the upkeep of a facility. An example of a scheduled cost would be the replacement of HVAC air filters on a regular interval. An example of an unscheduled expense would be the unexpected repair of a HVAC unit due to malfunctions or breakdowns.

- Replacement costs are the expenses associated with the scheduled replacement of building components or systems. An example of a scheduled expense would be the replacement of an HVAC unit at the end of its expected lifetime.

Residual Value

Residual or salvage value is the value of a facility or facility component at the end of its useful life. Residual values can be positive or negative. A positive residual value indicates an expense is expected to be incurred. An example of positive residual value would be the cost incurred to an owner for the demolition of a facility. A negative residual value indicates revenue is expected to be realized. An example of negative residual value would be the scrap value of a building's steel structure following demolition.

Study Period

The study period is the length of time that an LCCA is designed to evaluate. In the evaluation of a building or building component, study periods typically span a 20 to 40 year period. Although a study period can cover the entire expected lifespan of a facility, it is not necessary to use this approach.

Real Discount Rate

The discount or capitalization rate is a multiplier used to convert the future anticipated returns from an investment to a present value. The discount rate allows an investor to assess the time value of money associated an investment by converting future values to present values. The discount rate is reflective of an investor's anticipated minimum rate of return in relation to the next best alternative. Discount rates can be either nominal discount rates or real discount rates; the former factors in the rate of inflation while the latter does not.

Constant-Dollars

Constant-dollars is a measurement of comparative purchasing power associated with a reference year without factoring in inflation rates. This provides building owners the ability to assess alternatives that may have differing lifespans. For example, one HVAC unit might have an expected life of 20 years while another might be expected to last only 15 years. The need to estimate the replacement cost associated with the 15-year unit while factoring in increases in labor and material costs is eliminated. The initial and future costs of installing a new HVAC unit are the same; the time value of money is instead accounted for by the real discount rate in LCCA's.

Present Value

Present value is defined by the GAO as "the worth of a future stream of returns or costs in terms of money paid immediately (or at some designated date)". The concept behind present value is that a dollar available today has greater worth than a dollar at a future date because the former invested could be invested and earning interest.

To calculate present value, the discount rate and incurred date of the expense are used. Present values of initial expenses require no additional calculations to determine their value because present value and initial costs are equal at that time. Present values of future expenses are time dependent, however.

Future costs are either recurring costs or one-time costs. Recurring costs are costs that are anticipated to occur in regular annual intervals. One-time costs are typically associated with replacement costs and do not occur on an annual basis.

The formula to determine the present value of one-time costs is as follows:

$$PV = A_t \times \frac{1}{(1 + d)^t}$$

- PV = Present value
- A_t = Amount of one-time cost
- d = Discount rate
- t = Time in years

The formula to determine the present value of recurring costs is as follows:

$$PV = A_0 \times \frac{1 + d\ ^{t} - 1}{d\ \times (1\ + d)^t}$$

- PV = Present value
- A_0 = Amount of one-time cost
- d = Discount rate
- t = Time in years

CHAPTER 3
RESEARCH METHODOLOGY

Overview

The research methodology of this report consists of four modules: (1) Identification of alternative framing materials, (2) Determination of the U-factors of a baseline Code-compliant wall assembly and wall assemblies with the alternative framing materials incorporated, (3) Development of building energy models, and (4) Cost analyses to determine the most effective long-term solution. In order to assess how varying climate conditions can impact the thermal performance of a building, each solution is modeled in each of the eight US climate zones.

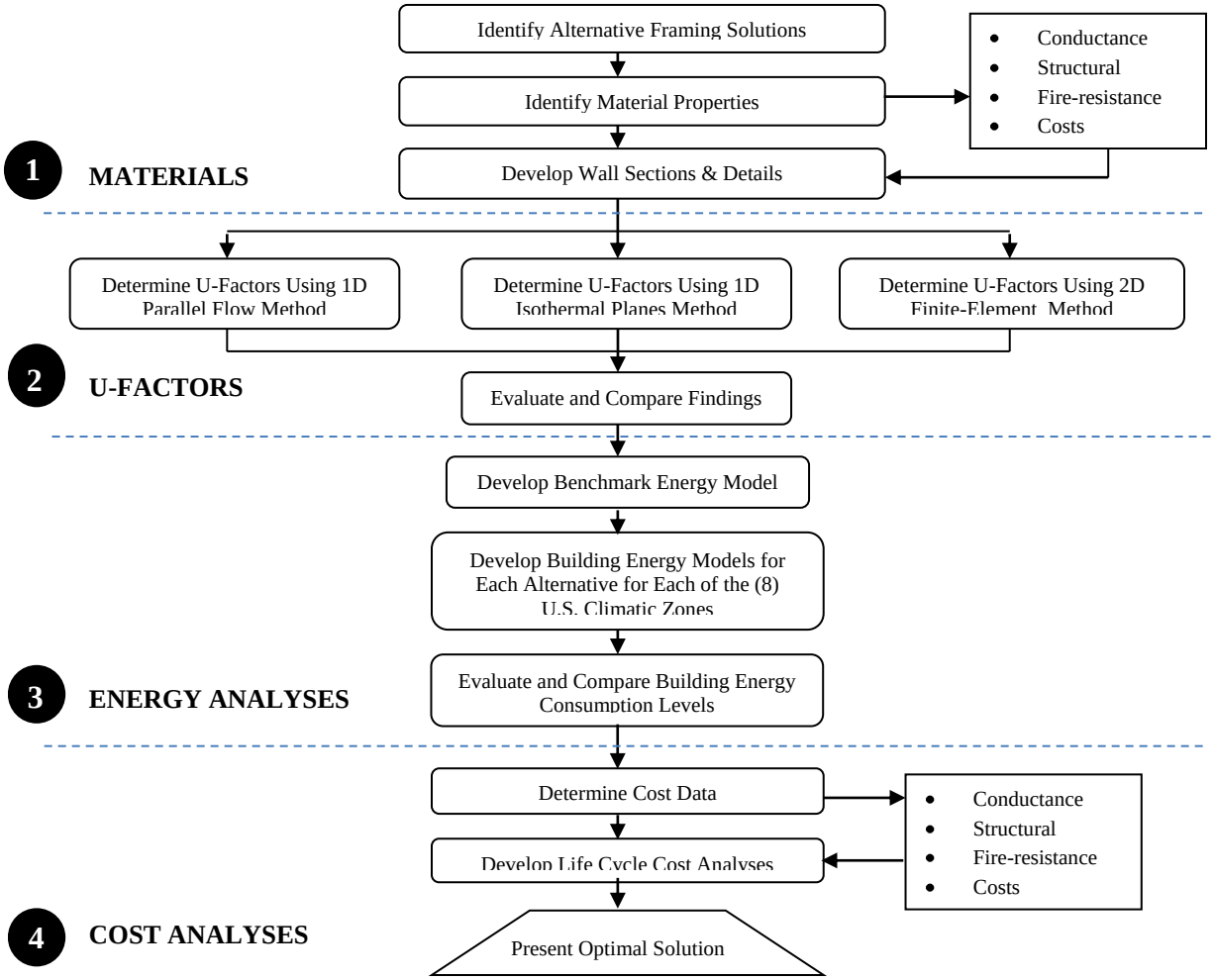

Figure 3-1. Methodology flowchart.

Step 1: Identification of Alternative Materials

Five alternative metal framing options designed to improve building energy performance were evaluated. These alternative framing products were selected for study because of their potential to decrease the thermal bridging effect in metal framing components. Three of the solutions evaluated attempt to achieve this goal by altering the configuration/design of the metal stud; the other two solutions attempt to decrease thermal bridging by the application of topical materials with low thermal conductivity.

Step 2: Material Properties

In order to evaluate the impact on thermal performance of the alternative materials, the thermo-physical properties of the each of these materials had to be identified. This research utilized manufacturer literature for this information. However, because the energy performance of exterior wall systems are dependent upon the interrelated thermal dynamics of all the materials within the systems, the thermo-physical properties of all the components within each assembly had to be identified, as well. This research utilized for material properties that was available from highly regarded sources such as ASHRAE, DOE and the National Fenestration Rating Council (NFRC).

Using the ASHRAE approved methods defined in Table 5-H of the ASHRAE Handbook - Fundamentals (parallel flow, isothermal planes and two-dimensional heat flow analysis), the U-factors for a Code-minimum exterior wall assembly, each of the alternative wall assemblies and the Rinker Hall wall assembly were determined per the requirements of each method.

In this study, a Code-minimum wall assembly is composed of an interior sheathing layer of 5/8” gypsum board, exterior sheathing layers that include 5/8” exterior sheathing board, water-resistant membrane and 7/8” stucco system, and thermal insulation in the cavity spaces. Per the

requirements of Table 5.5 of ASHRAE Standard 90.1 for above-grade steel-framed walls, the R-value of the cavity insulation material was established at the minimum value of R-13.

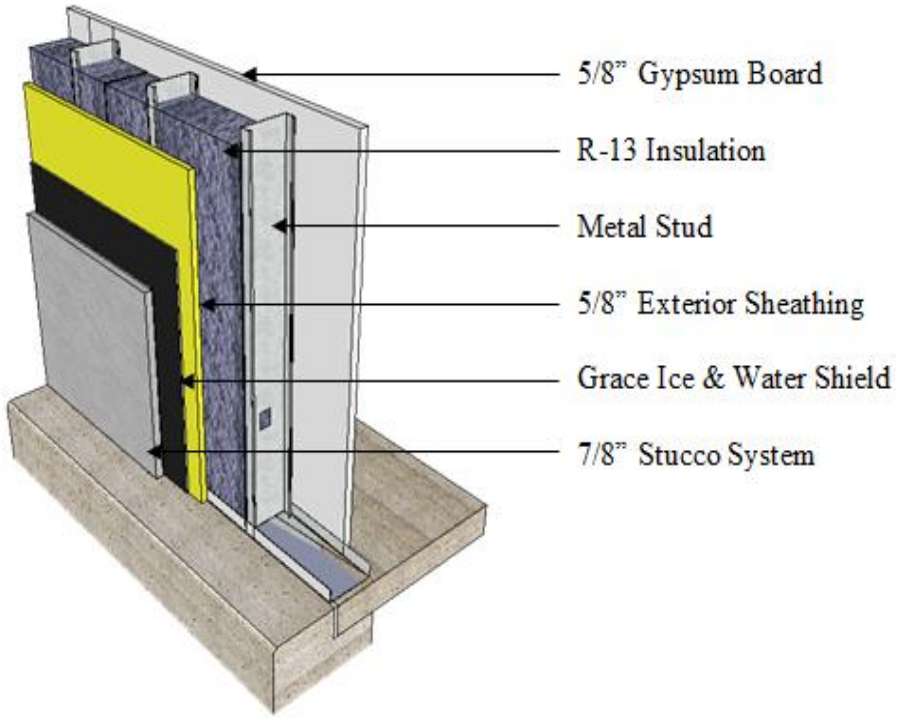

Figure 3-2. Code-minimum exterior wall assembly.

Rinker Hall at the University of Florida was selected as a model building to evaluate the alternative products and the expected improvements to energy performance. A review of the building's construction plans identified the components and assemblies of Rinker Hall's exterior walls. The interior sheathing layers included 2x2 wood blocking attached directly to the inside flanges of the metal stud framing, 1 ½" insulation board installed between the blocking members and 5/8" gypsum board. The exterior sheathing materials included a layer of 5/8" exterior sheathing board, water-resistant membrane and an aluminum panel rain screen system. The cavity insulation material was rated as R-21.

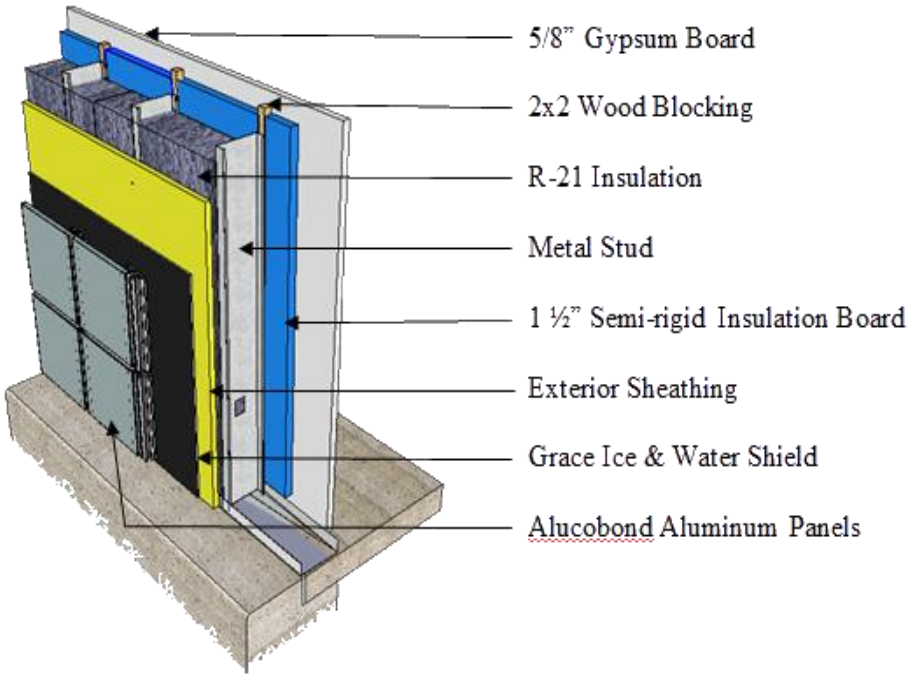

Figure 3-3. Rinker Hall exterior wall assembly.

Two-dimensional heat flow analysis was performed by modeling the Code-minimum and Rinker Hall walls in THERM 6.3 to determine the U-factors for each assembly. Additionally, wall sections that modified the Code-minimum wall by incorporating the alternative products were modeled in THERM 6.3 to determine their respective U-factors.

Step 3: Energy Analyses

Following the determination of U-factors, using the design of Rinker Hall as a base building model, building energy computer models were developed for each of wall system scenarios. The building energy use simulation program used in this research was Equest 3.64 which was developed by the Lawrence Berkley National Laboratory (LBLN) on behalf of the DOE. The purpose of the energy analyses was to determine building heating and cooling loads resulting specifically from wall conduction.

To further refine the energy model analyses, energy models were developed for one city in each of the eight ASHRAE defined climatic zones in the US.

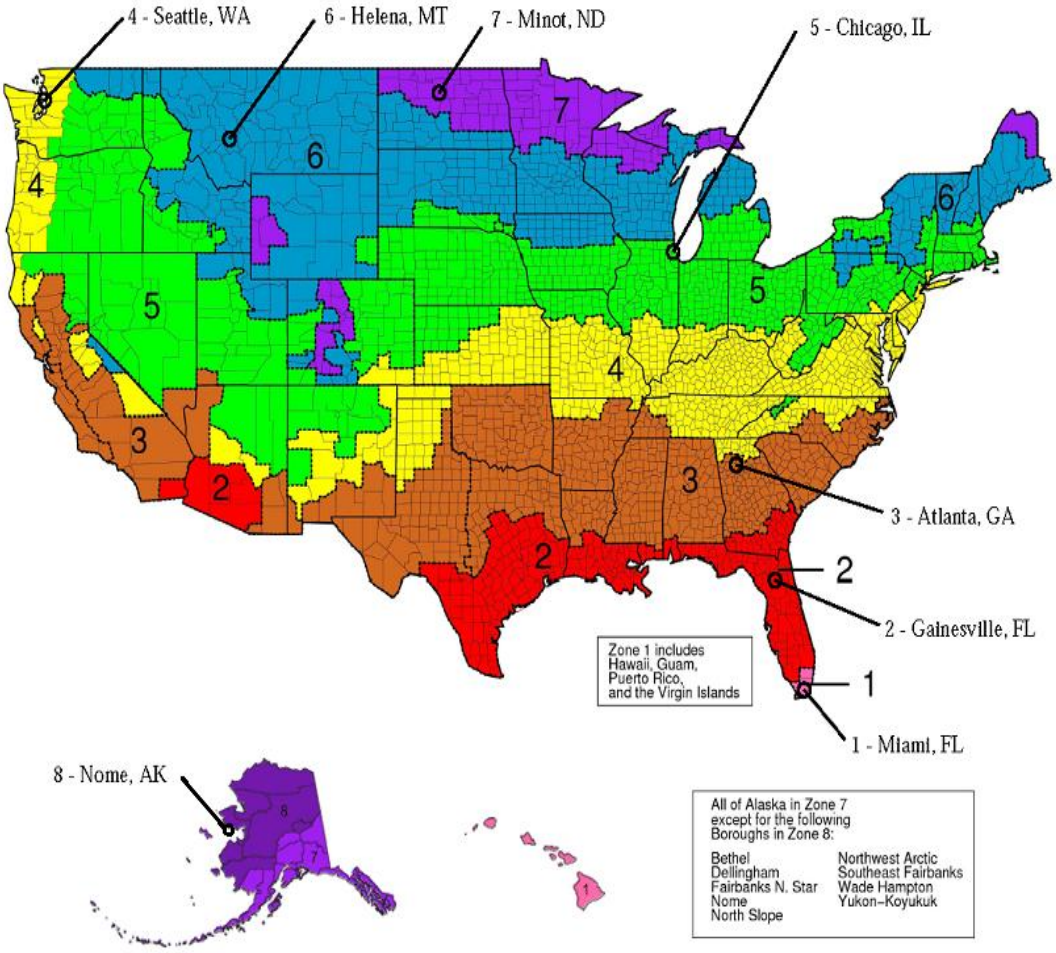

Figure 3-4. ASHRAE Map of US climate zones.

The locations selected are as follows:

- Zone 1: Miami, FL
- Zone 2: Gainesville, FL
- Zone 3: Atlanta, GA
- Zone 4: Seattle, WA
- Zone 5: Chicago, IL
- Zone 6: Helena, MT
- Zone 7: Minot, ND
- Zone 8: Nome, AK

Step 4: Cost Analyses

In order to calculate life cycle costs for each of the exterior wall assemblies, it was first necessary to determine the annual energy cost savings anticipated from each of the alternative products. To accomplish this, the national average unit for a kilowatt of electrical cost was applied to the energy savings projected for each energy model based upon the improvements to heating and cooling loads from specifically related to exterior wall conduction.

Next, it was necessary to determine the additional construction costs associated with the substitution of each of the alternative products into a Code-minimum wall. Unit cost estimates for the Code-minimum, Rinker Hall and alternative wall assemblies were developed based upon information provided by material manufacturers and RS Means Cost Data and applied to quantity take-offs of materials needed for the Rinker exterior wall system.

Finally, once the cost savings expected from increased energy performances and initial cost increases associated with construction were established, this information was used to generate LCCA's. The LCCA's incorporate other financial data such as interest rates, discount rates, general inflation rates and energy inflation rates to provide insight as to whether or not an investment being considered today to improve the energy performance of a building's exterior wall systems could provide dividends in the future and how soon.

CHAPTER 4
RESULTS AND ANALYSES

Overview

The results and analyses portion of this report is divided into four sections. The first section describes the alternative framing products that were reviewed in this research. The second section details the U-factors determinations based upon the approved calculation methods specified in ASHRAE Handbook – Fundamentals (Table 5-H) for these alternative products as substitute components incorporated into Code-minimum exterior wall assemblies. The third section details the building energy analyses performed incorporating the wall assembly U-factors calculated in Step 2 in energy models of Rinker Hall in each of the eight US climatic zones. The fourth section examines the estimated additional initial costs and projected energy savings for each scenario in life cycle cost analyses.

Section One: Alternative Metal Framing Solutions

This research identified and reviewed several alternative products that appeared likely to have some degree of ability in decreasing thermal bridging in metal framing. After reviewing options currently available, the following five candidates were selected for this study:

- Ridged flange studs
- Slit web studs
- Dimpled flange stud
- Aerogel strips
- Thermal ceramic coated studs

The candidate products were evaluated based the following criteria:

- Thermal performance
- Structural performance
- Fire-rating performance
- Cost data

Ridged Flanged Studs

Ridged flange studs approach decreasing thermal bridging by altering the configuration of the stud so that contact between the stud flanges and interior/exterior sheathing is minimized. The flanges of the stud are bent to form parallel ridges so that the middle flange areas are held away from sheathing materials by 1/4” to 1/2”.

Ridged flange studs were developed by Portland architect LeRoy Flanders and patented and marketed under the brand name ThermaChannel. Although a US patent for ThermaChannel was issued in 1997, a ThermaChannel representative indicated that the product has never been commercially produced nor installed in any building (G. Seeberger, ThermaChannel, personal communication, June 16, 2011).

Figure 4-1. ThermaChannel. Image from ThermaChannel, Inc.

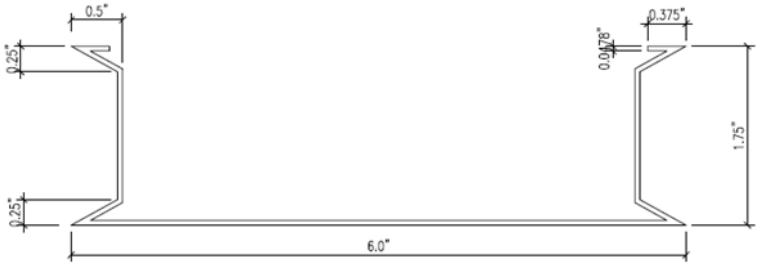

Figure 4-2. ThermaChannel cross-section with dimensions.

Thermal performance. ThermaChannel was tested by the ORNL and results indicated that the insulation efficiency of exterior walls constructed with this type of stud had a minimum 10% increase (Strohl 1995).

Structural performance. Structurally, the inwardly bent flanges may cause this type of stud to have a decreased ability to withstand lateral loads due to the flanges being 1/4" to 1/2" closer to the centerline of the stud. However, this decrease may be offset by the additional strength that would be created by the corrugation effect created by the bent flanges. An estimated decrease in the structural ability of ridged flange studs is not available; however the diminishment appears to be low.

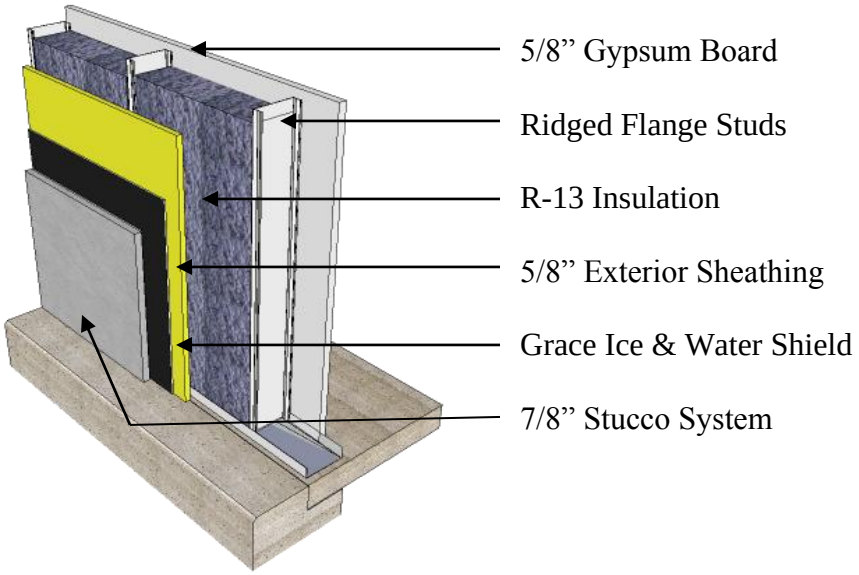

Figure 4-3. ThermaChannel cross-section with dimensions.

Fire-rating performance. From a combustibility perspective, the use of this type of stud does not create any additional concerns as it is composed of steel like a conventional metal stud.

Cost data. Due to the bent configuration, ridged flanged studs cost approximately 15% more than conventional C-shaped studs. Because of the added bends, more steel material is needed to manufacture these types of studs. Based 2011 RS Means cost data, conventional C-

shaped 6-inch 16-gage metal framing with studs spaced at 16” has an assumed cost of $3.27 per square foot of framed exterior wall area (labor, material and OH&P). Based upon this information, the assumed cost for ridged flanged studs with the same specifications is approximately $3.76 per square foot of framed exterior wall area.

Slit Web Studs

The manufacturers of slit web studs approached breaking the metal framing thermal bridge by modifying the web of the stud. Rather than having a solid web similar to conventional C-shaped studs, slit web studs have thin openings or slots cut into the web of the stud. These openings run parallel to the length of the stud and are typically 3/16” to 1/4” wide and 3 1/2” long. The purpose of the openings is to break the thermal connection between the interior flange of the stud and the exterior flange.

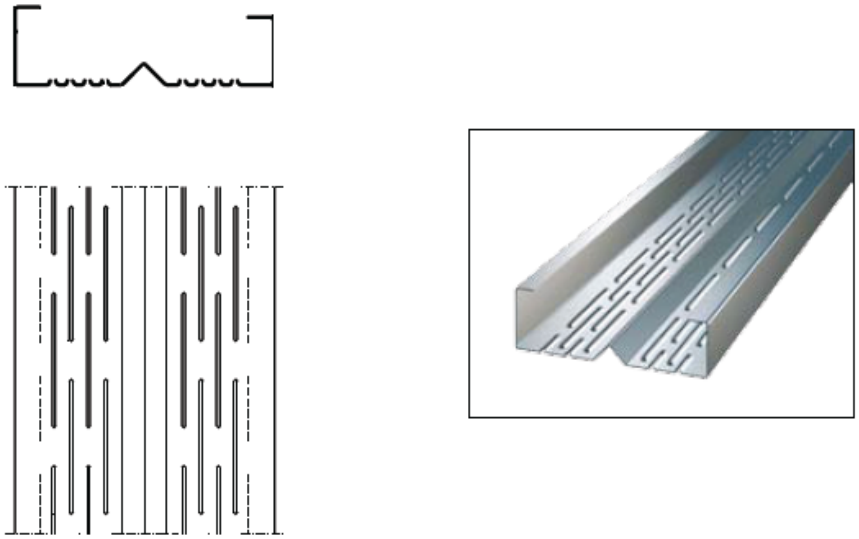

Figure 4-4. Slit Web Stud. Image from ORNL.

Thermal performance. Hot-box testing by ORNL determined that a minimum 10% increase in thermal performance could be realized by the substitution of slit web studs in lieu of

convention studs when incorporated in to a Code-minimum exterior wall assembly. Research by ORNL conducted for the American Iron & Steel Institute estimated that 2.0 to 2.6 additional R-value could be gained by the substitution of triangular cutout studs (Elhajj 2006).

Structural performance. The openings in the web of the studs may cause some structural concerns. A study conducted by the U.S. Steel Laboratory found an 8-10% decrease in lateral load strength in walls constructed with 18 gauge slit web studs (McDermott 1975).

Fire-rating performance. From a combustibility perspective, the use of this type of stud would not create any additional concerns as it is composed of steel like a conventional metal stud.

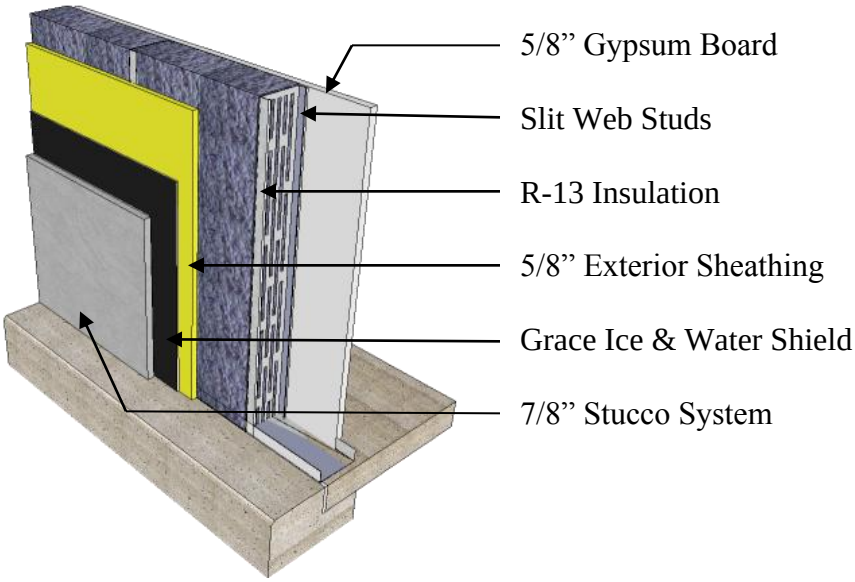

Figure 4-5. ThermaChannel cross-section with dimensions.

Cost data. A study conducted for the American Iron & Steel Institute indicated that the material cost increases for the manufacture and installation of slit web studs were not significantly more than conventional studs (Elhajj 2006). Based 2011 RS Means cost data, conventional C-shaped 6-inch 16-gage metal framing with studs spaced at 16” on-center has an assumed cost of $3.27 per square foot of framed exterior wall area (labor, material and OH&P).

Based upon an estimated cost increase of 5%, the unit cost for a wall constructed similarly with slit web studs is assumed to be $3.43.

Aerogel Strips

Aerogel was developed by NASA and is considered to have the lowest bulk density of any known porous solid. According to manufacturer literature from ThermaBlok, these strips are designed to be adhered to the interior face of metal studs on the backside of gypsum wallboard. The material is intended to create a thermal break between the metal framing and interior gypsum board.

Figure 4-6. Aerogel strips being applied to metal stud. Image from ThermaBlok.

Thermal performance. ThermaBlok product literature indicates that their aerogel strip product (3/8" thick x 1.5" wide x 48" long) provides an R-value of 10.3 per inch. Hot-box testing conducted by the Oak Ridge National Laboratory found that internal surface temperatures between the metal stud and the center of a metal stud wall assembly cavity were reduced by 5º F (Kosny et al. 2007).

Structural performance. The addition of Aerogel strips between the inside stud flange and interior gypsum board would not compromise structural integrity.

Fire-rating performance. Due to its high degree of thermal resistance, Aerogel products do not raise any combustibility concerns, including off-gassing. Manufacturer literature from

ThermaBlok indicates that the products have a flame index of “0” and a smoke index of “0”. The application of this material on metal studs within a building’s exterior wall assembly would not present any fire-rating issues.

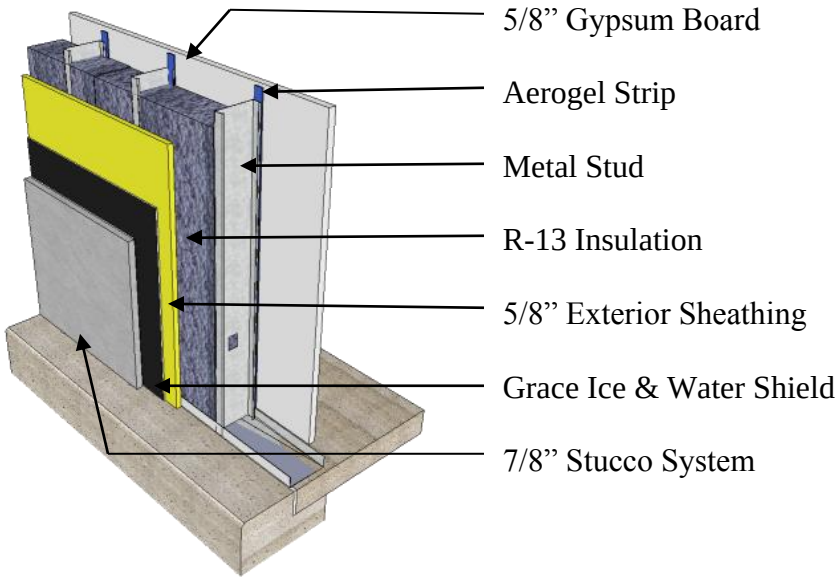

Figure 4-7. ThermaChannel cross-section with dimensions.

Cost data. Although Aerogel provides significant thermal insulating attributes, the limiting factor is its relatively high cost (Kosny and Yarbrough 2007). According to a ThermaBlok representative, the material is approximately $1.00 per linear foot for 1 1/2” wide strips (Steve Hibbins, personal communication, June 16, 2011). This unit price translates to nearly $30,000 of additional costs when applied to the estimated 30,000 linear feet of exterior metal studs necessary for Rinker Hall. Therefore, the square foot unit cost increase to apply ThermaBlok aerogel strips relative to the 13,642 square feet of Rinker Hall’s exterior wall metal framing is $2.16.

Dimpled Flange Studs

Similarly to ridged flange studs, the concept behind dimpled flange studs is to decrease surface contact between the metal framing and interior/exterior sheathing layers. Raised dimples

on the flanges on the stud reduce serve this purpose and contact surface area is reduced by approximately 67%.

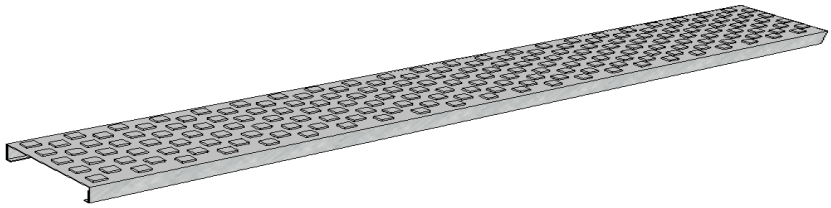

Figure 4-8. Dimpled flange stud.

Thermal performance. The National Association of Home Builders Research Center estimated that dimpled flange studs could improve the R-value of an exterior wall assembly by approximately 0.61 (Elhajj 2006)

Structural performance. No information was available to determine whether or not the flange dimples decreased the structural ability of a metal stud.

Fire-rating performance. From a combustibility perspective, the use of this type of stud does not create any additional concerns as it is composed of steel like a conventional metal stud.

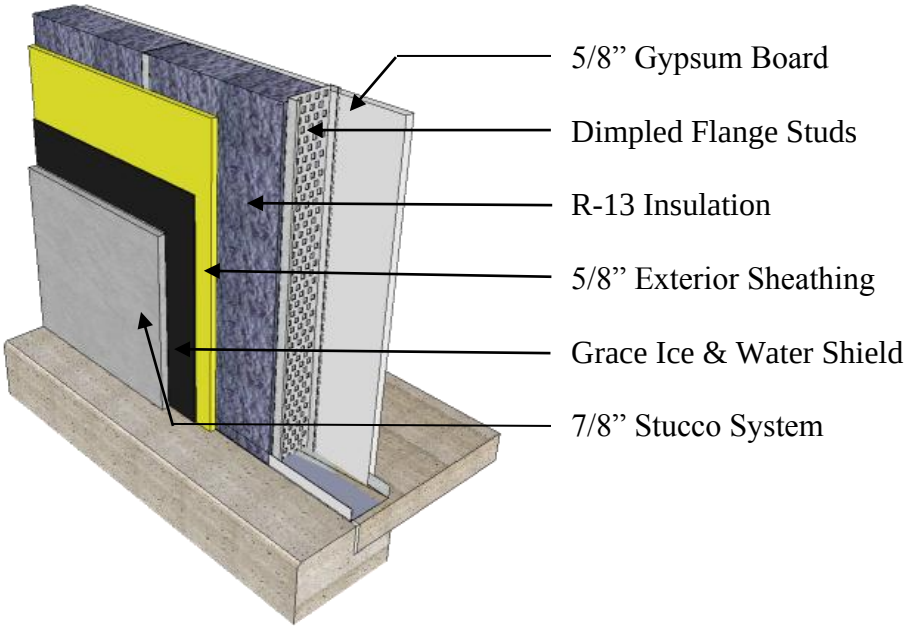

Figure 4-9. Dimpled flange stud wall assembly.

Cost data. A study conducted by the National Association of Home Builders Research Center indicated that the material cost increases for the manufacture and installation of dimpled flange studs were marginal in relation to conventional studs (Elhajj 2006). Based 2011 RS Means cost data, conventional C-shaped 6-inch 16-gage metal framing with studs spaced at 16" on-center has an assumed cost of $3.27 per square foot of framed exterior wall area (labor, material and OH&P). Based upon an estimated 5% increase in costs, the unit cost for a wall constructed similarly with dimpled flange studs is assumed to be $3.43.

Ceramic Coated Studs

In this scenario, metal studs are coated with thermally resistant ceramic material in order to decrease the thermal bridging effect. This report examined a ceramic coating manufactured by Superior Products headquartered in Shawnee, Kansas marketed as SuperTherm.

Thermal performance. Manufacturer literature for SuperTherm indicates that the product has thermal conductance of 0.31 BTU/($ft^2 \cdot hr \cdot °F$). However, because the thickness of the material is only a 16 mil coating (wet), its ability to reduce thermal bridging due to conductance is not significant. The review of existing literature indicates that the primary insulating ability of this product is its ability to reflect radiation and is typically applied to exterior surfaces such as roofs and holding tanks.

Structural performance. The application of a ceramic coating to metal studs would not have an impact upon structural performance.

Fire-rating performance. A review of manufacturer literature indicates that SuperTherm meets the requirements of ASTM E 84-89[a] and has a flame index of "0" and a smoke index of

"0". The application of this material on metal studs within a building's exterior wall assembly would not present any fire-rating issues.

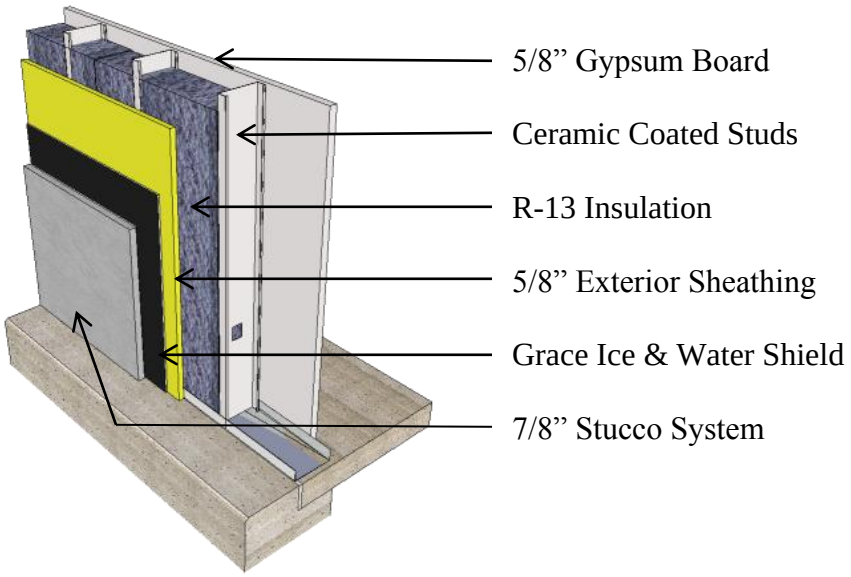

Figure 4-10. Thermal ceramic coated stud wall assembly.

Cost data. Based upon price information from Home Depot, SuperTherm retails for $475 for a 5-gallon bucket or $95 per gallon. Manufacturer literature indicates that the product covers 100 square feet per gallon which translates to a material cost of $0.95 per square foot. A 6-inch C-shaped metal has approximately 1.75 square feet of surface area per linear foot. Therefore, the material cost per linear foot of stud is $1.66.

Labor costs, per 2011 RS Means cost data, are $0.25 per square foot for spray coating. Based upon the 1.75 square foot of surface area per linear foot of 6-inch metal stud, the labor costs per linear foot of stud is $0.44.

Based upon the above cost data, the assumed combined material and labor costs to apply a 16-mil (wet) coat of SuperTherm to 6-inch C-shaped metal studs is $2.10 per linear foot of stud. This unit price translates to nearly $63,000 of additional costs when applied to the estimated 30,000 linear feet of exterior metal studs necessary for Rinker Hall.

Section Two: U-Factors

Using the methods approved by ASHRAE Table 5-H for above ground metal framed walls, R-values and U-factors for each of the wall system assemblies were calculated. The results of all three of these methods are summarized in Table 4-1.

Table 4-1. R-values and U-factors using ASHRAE Table 5-H calculation methods.

Wall Assembly Type	Parallel Flow Method		Isothermal Planes Method		2D Heat Flow Analysis Method (THERM)	
	R-Value	U-Factor	R-Value	U-Factor	R-Value	U-Factor
Rinker Hall	28.61	0.035	30.34	0.033	22.73	0.044
Code Minimum	14.16	0.071	14.94	0.067	16.03	0.063
Slit Web Stud	23.18	0.043	23.96	0.042	22.73	0.041
Ridged Flange Stud	23.18	0.043	23.96	0.042	20.33	0.049
Dimpled Flange Stud	23.18	0.043	23.96	0.042	21.28	0.047
Aerogel Strip	26.73	0.037	27.82	0.036	23.26	0.043
Ceramic Coated Stud	23.19	0.043	23.99	0.042	19.23	0.052

The average R-values of the assemblies using the parallel flow method, isothermal planes method and THERM are 23.17, 24.14 and 20.80, respectively. The parallel flow and isothermal planes R-values provide relatively close results (the latter is on average only 4% greater than the former). However, the values obtained using THERM consistently reflect more conservative R-values with an average differential of 10.2% less versus the parallel flow and 13.8% less versus the isothermal path method.

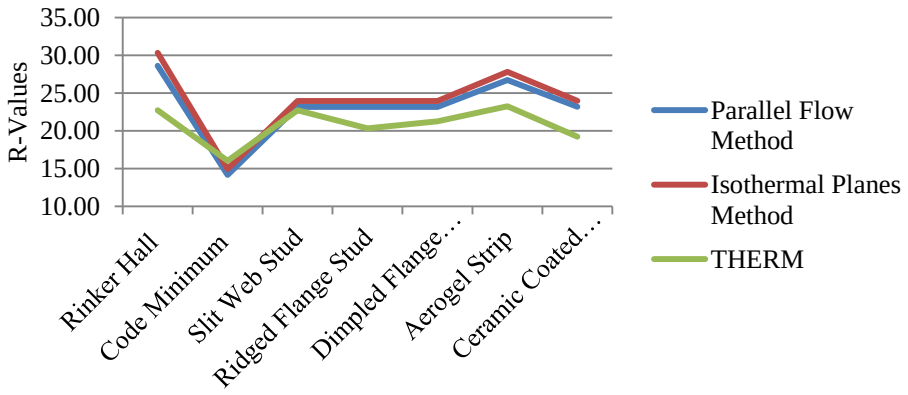

Figure 4-11. R-value calculation results comparison.

The average U-factors of the assemblies using the parallel flow method, isothermal planes method and THERM are 0.045, 0.043 and 0.049, respectively. Similarly to the R-value results, the parallel flow and isothermal planes R-values are relatively close; the latter is on average slightly more than 4% greater than the former. However, the values obtained using THERM consistently reflect more conservative U-factors with an average differential of 7.6% higher versus the parallel flow and 11.4% higher versus the isothermal path method.

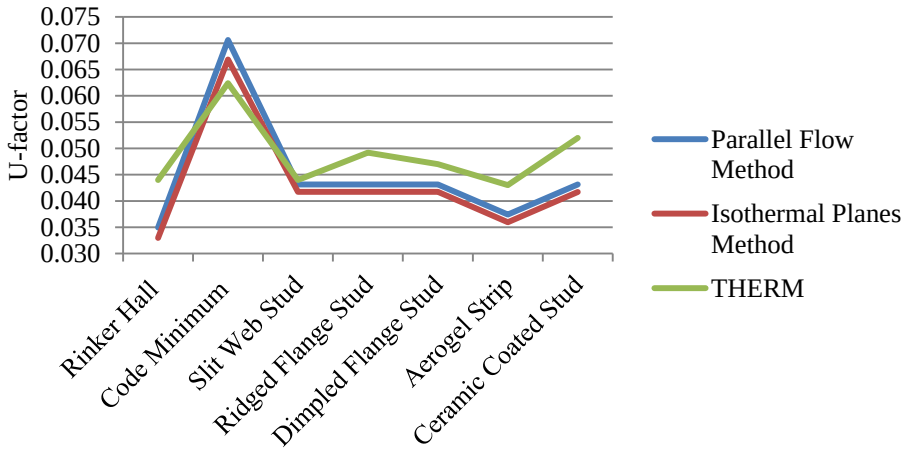

Figure 4-12. U-factor calculation results comparison.

Parallel Path Method Results

As explained in the Literature Review section of this report, the parallel path method takes a weighted average of clear wall areas and framed wall areas to measure thermal performance. In the parallel path method, the U-factor of the clear wall assembly area and the U-factor of the framed wall assembly area are multiplied by their respective percentages of wall area and then added together. In this study, the U-factors of the clear wall areas and the U-factors of the framed wall areas are modified by their percentages of wall area, 92% and 8%, respectively. Appendix A of this report provides detailed results of the parallel path method on each of the wall assemblies.

Isothermal Planes Method Results

As discussed in the Literature Review section of this report, in the isothermal planes method, only the materials between the interior and exterior sheathing are modified by their respective percentages of wall area. In this study, R-values of the interior and exterior sheathing assemblies are taken at full value while the cavity insulation and metal framing are modified by their percentages of wall area, 92% and 8%, respectively. Appendix B of this report provides detailed results of the parallel path method on each of the wall assemblies.

2D Heat Flow Analysis

Two-dimensional heat flow analysis of a Code-minimum wall modeled in THERM 6.3 indicated that the assembly had a U-factor of 0.0625. A graphic depiction of the THERM model for the Code-minimum wall is represented in Figure 4-13.

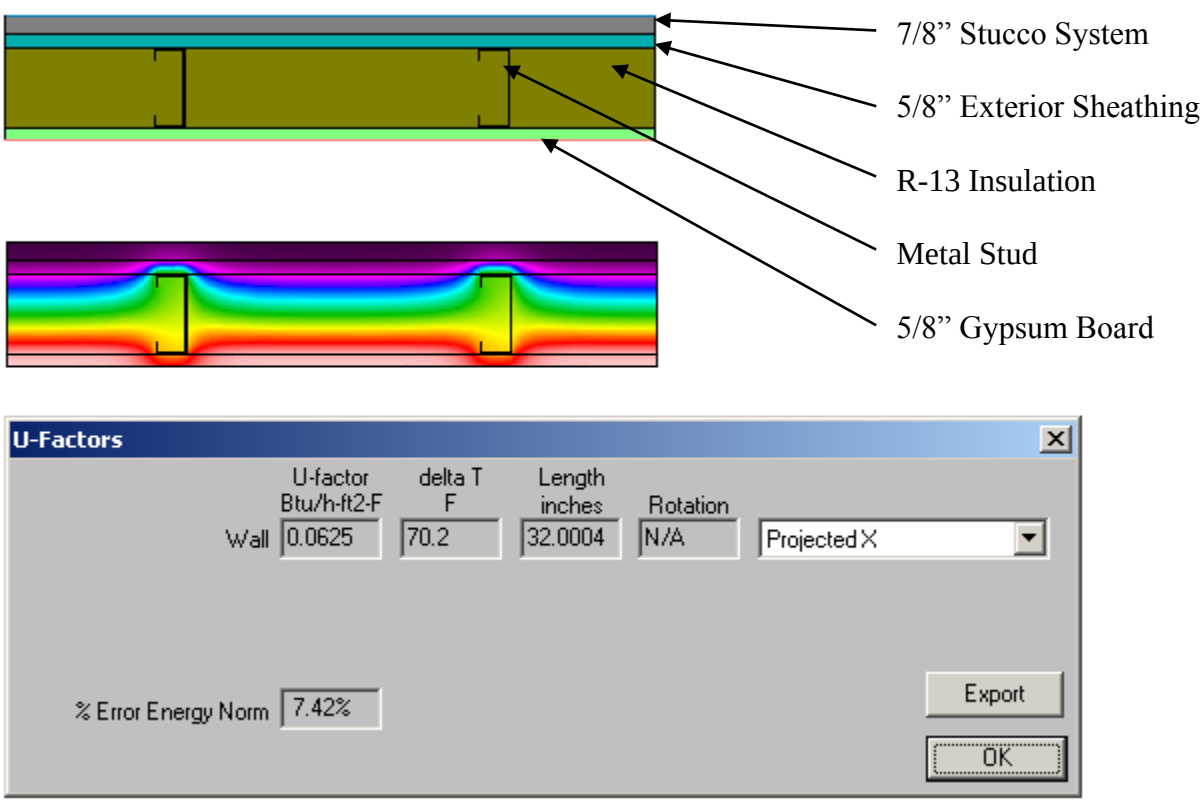

Figure 4-13. 2D heat flow analysis. Code-minimum wall.

Two-dimensional heat flow analysis of the Rinker Hall wall assembly and wall assemblies incorporating the alternative products indicated the following U-factors:

- Rinker Hall: 0.044
- Slit web studs: 0.041
- Ridged flange studs: 0.049
- Dimpled flange studs: 0.047
- Aerogel strips: 0.043
- Ceramic coated studs: 0.052

Graphical depictions of each of these results similar to Figure 4-13 are included in Appendix C of this report.

Section Three: Energy Analyses

The energy simulation models of Rinker Hall developed in THERM 6.3 were able to provide the heating and cooling loads specifically from exterior wall conduction. This information was provided in terms of BTU's and needed to be converted to kWh for this report in order to calculate projected energy cost savings. The conversion from BTU's to kWh's was achieved by dividing each of the BTU results by 3,414.3.

Table 4.2 provides a summary of these results. The results reported in Table 4.2 are the projected decreases in energy loads as compared to the baseline Code-minimum wall assembly. Detailed information is available Appendices D and E of this report.

Table 4-2. Total decreased energy loads from wall conduction (kWh).

Wall Type	Climate Zone							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dimpled Flange Stud	2,301	2,308	3,421	4,626	5,766	6,588	7,643	11,259
Ridged Flange Stud	2,530	2,683	3,764	5,091	6,344	7,249	8,412	12,392
Ceramic Coated Stud	2,668	2,729	4,105	5,557	6,921	7,914	9,180	13,526
Rinker Hall	4,144	4,159	6,165	8,363	10,399	11,901	13,794	20,358
Slit Web Stud	4,144	4,159	6,165	8,363	10,399	11,901	13,794	20,358
Aerogel Strip	4,374	4,435	6,507	8,832	10,979	12,568	14,565	21,502

A graphical depiction of these results (Figure 4.14) shows aerogel strips provided the greatest decrease in projected energy savings followed closely by the slit web stud alternative and the actual wall assembly used in the design and construction of Rinker Hall. Also, the projected energy cost savings increase from warmer to colder climates.

Because the slit web wall and Rinker Hall wall sections were determined to have the same energy performance abilities in the two-dimensional heat flow analysis, their lines in Figure 4-14 are overlaid.

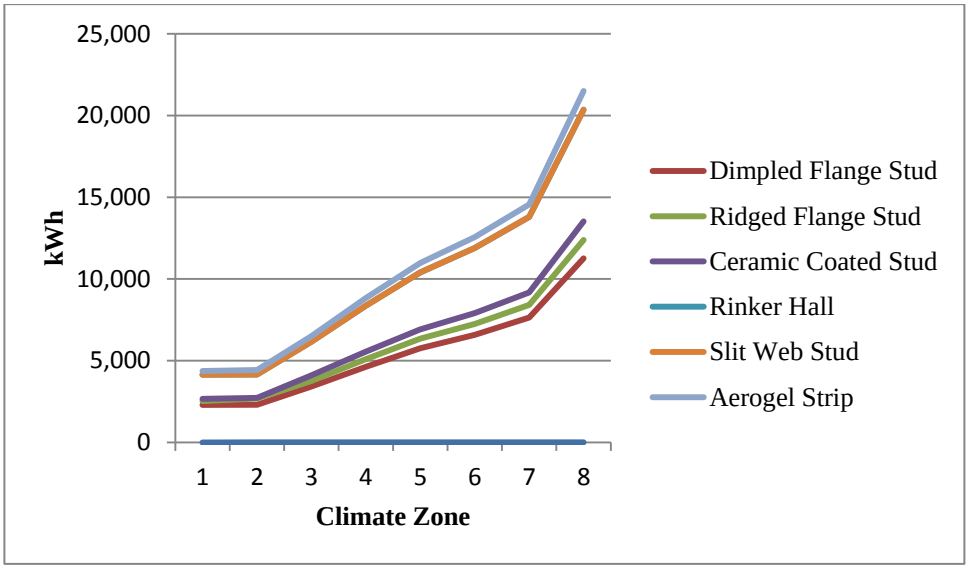

Figure 4-14. Decreased energy loads for each wall assembly type.

Section Four: Cost Analyses

Energy Costs

Once the decreased energy loads were established for each of the wall assembly types (Table 4-2), the next step was to apply an estimated cost per kWh of energy expected from local utilities (Table 4.3). This study used the 2011 national average rate of $0.125 per kWh as published by the US Energy Information Administration (EIA). Detailed information on the energy costs associated with each wall system assembly evaluated is included in Appendix F of this report.

Table 4-3. Projected annual energy savings.

Wall Type	Climate Zone							
	1	2	3	4	5	6	7	8
Dimpled Flange Stud	$288	$288	$428	$578	$721	$824	$955	$1,407
Ridged Flange Stud	$316	$335	$471	$636	$793	$906	$1,052	$1,549
Ceramic Coated Stud	$334	$341	$513	$695	$865	$989	$1,147	$1,691
Rinker Hall	$518	$520	$771	$1,045	$1,300	$1,488	$1,724	$2,545
Slit Web Stud	$518	$520	$771	$1,045	$1,300	$1,488	$1,724	$2,545
Aerogel Strip	$547	$554	$813	$1,104	$1,372	$1,571	$1,821	$2,688

Similarly to the projected decreased energy loads from wall conduction (Figure 4-14), graphical depiction of these results (Figure 4.15) indicated that aerogel strips provided the greatest decrease in projected energy cost savings followed closely by the slit web stud alternative and the actual wall assembly used in the design and construction of Rinker Hall. Likewise, the projected energy cost savings increase from warmer to colder climates.

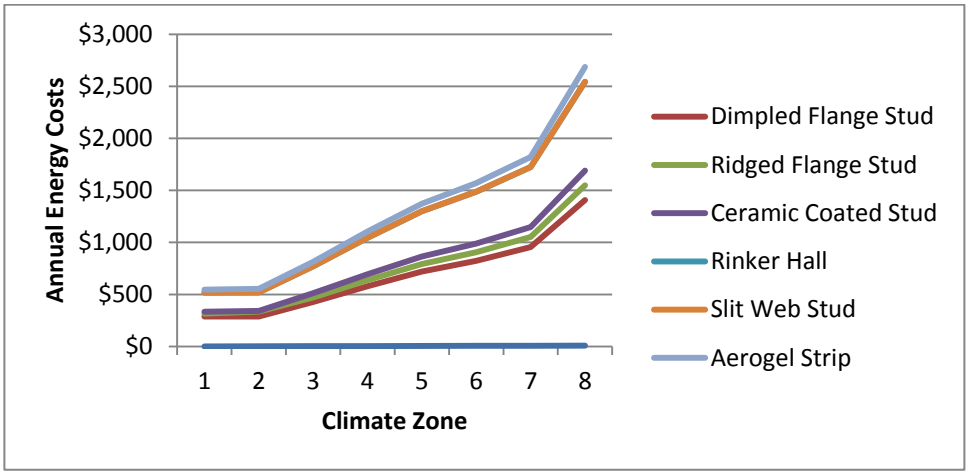

Figure 4-15. Decreased energy costs for each wall assembly type.

Construction Costs

Before LCCA's could be prepared, it was next necessary to create unit cost estimates for each of the wall assembly types based upon the square feet of opaque exterior wall area. These unit cost estimates are provided in Table 4-4 of this report.

Table 4-4. Construction unit costs per sf of opaque exterior wall area.

Material	Code Mini-mum ($/sf)	Slit Web Stud ($/sf)	Dimpled Flange Stud ($/sf)	Ridged Flange Stud ($/sf)	Rinker Hall ($/sf)	Aerogel Strips ($/sf)	Ceramic Coated Stud ($/sf)
Metal Stud	$3.27	-	-	-	$3.27	$6.00	$6.00
Ridged Flange Stud	-	-	-	$3.76	-	-	-
Slit Web Stud	-	$3.43	-	-	-	-	-
Dimpled Flange Stud	-	-	$3.43	-	-	-	-
Aerogel Strip	-	-	-	-	-	$2.16	-
Ceramic Coating	-	-	-	-	-	-	$4.62
Fiberglass Insulation (R-13)	$0.76	-	-	-	-	-	-
Fiberglass Insulation (R-19)	-	$0.82	$0.82	$0.82	$0.82	$0.82	$0.82
2x2 Wood Blocking	-	-	-	-	$1.27	-	-
Semi-Rigid Insulation (1.5")	-	-	-	-	$1.17	-	-
Gypsum Board, 5/8"	$1.40	$1.40	$1.40	$1.40	$1.40	$1.40	$1.40
TOTAL PER SF	$5.43	$5.65	$5.65	$5.98	$7.93	$10.38	$12.84

Life Cycle Costs

The LCCA's created in this report provided insight regarding the year that projected energy savings could eclipse the increased initial investments for the alternative metal stud products. The estimated breakeven years for each alternative product in each of the eight US climate zones are provided in Table 4-5 and depicted graphically in Figure 4-16. Some of the breakeven projections, including those for the Rinker Hall, ceramic coated stud and aerogel strip wall assemblies, fell outside of the 30-year study period and were not determined by this research.

Table 4-5. Estimated years to reach breakeven

Wall Type	ASHRAE Climate Zones							
	1	2	3	4	5	6	7	8
Rinker Hall	>30	>30	>30	>30	>30	>30	27.7	19.7
Ceramic Coated Stud	>30	>30	>30	>30	>30	>30	>30	>30
Aerogel Strip	>30	>30	>30	>30	>30	>30	>30	22.1
Dimpled Flange Stud	9.8	9.8	6.7	5	4.1	3.6	3.1	2.1
Ridged Flange Stud	21	20	14.6	11	9	7.9	6.8	4.7
Slit Web Stud	5.6	5.6	3.8	2.8	2.3	2	1.7	1.2

A graphical depiction of the projected breakeven years for each of the wall systems evaluated is provided in Figure 4-15.

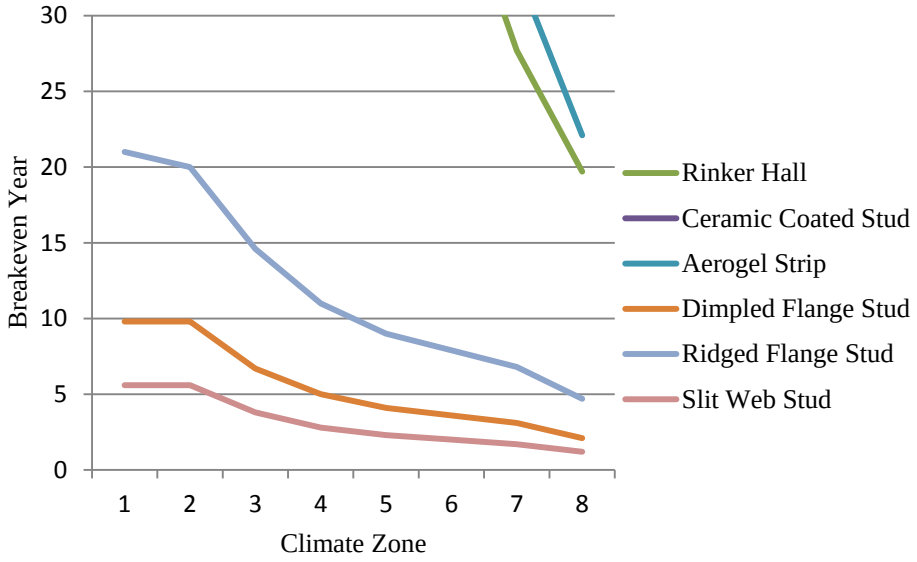

Figure 4-16. Projected breakeven years.

CHAPTER 5
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The goal of this research was to identify either a metal stud substitute or additive product capable of reducing the thermal bridging effect in exterior building walls. This research considered thermal effectiveness, structural properties, combustibility and overall life cycle costs.

To evaluate the products selected for research, the thermal effectiveness of each of the alternatives was modeled as substitute components within a Code-minimum exterior wall assembly using two-dimensional heat transfer analysis software. This process determined the U-factors of each of the wall assemblies which were then entered into a building energy simulation model based upon the design of Rinker Hall at the University of Florida.

Each of the energy models provided data regarding the cooling and heating loads specifically related to conduction through the exterior wall systems. To further understand how climatic variances could affect thermal performance, simulations were created for each of the energy models in each of eight US climatic zones. The national average for the cost of electricity per unit in kilowatt hours was then applied to the energy loads determined for each model. Additionally, cost estimates were prepared for each of the wall type assemblies to understand the initial cost implications associated with the alternative products.

The energy load differentials were then applied to life cycle cost analyses to determine the overall cost effectiveness of each of the alternative products over an extended period of 30 years. This process took initial costs, projected energy savings, discount rates and energy inflation rates into account to determine which of the products, if any, would be recommended by this study.

Matrix of Results

The matrix of results (Table 5.1) visually depicts the recommendations of this study for each of the products in each of the eight US climatic zones. Superior products were able to balance the higher initial construction costs against the projected annual energy saving in fewer years. The term used for year that energy savings was anticipated to eclipse initial costs is the "breakeven" year.

Each of the scenarios was rated either "Good", "Fair" or "Poor" based upon the following criteria:

- Good: Break even in 10 years or less
- Fair: Break even in 10 to 20 years
- Poor: Break even greater than 20 years

Table 5-1. Matrix of results.

Wall Type	ASHRAE Climate Zones							
	1	2	3	4	5	6	7	8
Ceramic Coated Stud	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Aerogel Strip	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Rinker Hall	⊗	⊗	⊗	⊗	⊗	⊗	⊗	○
Ridged Flange Stud	⊗	○	○	○	●	●	●	●
Dimpled Flange Stud	●	●	●	●	●	●	●	●
Slit Web Stud	●	●	●	●	●	●	●	●

● Good ○ Fair ⊗ Poor

The ceramic coated stud received poor ratings in all climate zones because it provided the least degree of thermal performance and highest initial costs. Ceramic coated did not achieve breakeven within the 30-year study period in any climate zone. The thermal ability of this product appears to be reflecting solar radiation. Although it has good resistance to heat conduction, a relatively thin coating applied to metal studs does not provide sufficient energy

savings to overcome its initial costs. The application of ceramic coatings to metal studs to reduce thermal bridging cannot be recommended by this study.

Although aerogel strips provided the highest degree of projected energy savings, the material also had the second highest initial costs. Similarly to the ceramic coated stud, its high initial costs were too great to be overcome by projected energy saving. The exterior wall assembly with aerogel strips incorporated only achieved breakeven in Climate Zone 8 in year 27.7. Based upon the evaluation of this research, aerogel strips, at their current price point, cannot be recommended by this study and received poor ratings in all eight climate zones.

The ridged flange stud concept was better able to balance energy saving against initial costs; however, the product received a poor rating in Climate Zone 1 because the projected breakeven year was not estimated to occur until year 21. The product fared better in and received fair ratings in climate zones 2, 3, and 4 with breakeven projected in occur years 20, 14.6 and 11, respectively. The ridged flange stud received good ratings in Climate Zone 5, 6, 7 and 8 with energy savings projected to surpass initial costs within the initial ten year period of the study. Based upon this study, ridged flange studs can be recommended as a product capable of reducing the effects of metal thermal bridging in Climate Zones 5, 6, 7 and 8.

The dimpled flange stud was the study's second best performing product and received good ratings in all climate zones. Dimple flange studs were able to achieve breakeven within the initial ten year study period in all eight climate zones. Based upon this study, dimpled flange studs can be recommended as a product capable of reducing the effects of metal thermal bridging in all eight US climate zones.

The best performing product evaluated in this study was the slit web stud. This product received good ratings in all eight climate zones with breakeven years all occurring within the

initial ten year period. Based upon this study, slit web studs can be recommended as a product capable of reducing the effects of metal thermal bridging in all eight US climate zones.

Conclusions

- It is possible to significantly reduce thermal heat transfer through metal stud framing in the opaque areas of a building's exterior wall assembly.
- Altering the design/configuration of metal studs achieves greater thermal performance than attempting to reduce thermal bridging through the application of topical insulating products.
- Due to the greater area available to manipulate, higher thermal performance can be achieved by altering the web area of metal studs rather than the flange areas.
- The application of all of the methods evaluated achieved better results in colder climates than warmer ones.

Limitations

It is important to note that this research is based upon using the design and function of Rinker Hall at the University of Florida as base model. Although the U-factor inputs were adjusted for each model in each climate zone, the design and function of Rinker Hall is nonetheless reflective of a specific building typology: educational buildings with a higher than average internal load. It is possible that a change in building type could yield differing results.

Recommendations for Future Study

Although this study provides valuable insight into the reduction of energy costs associated with thermal heat transfer through the opaque portions of above-grade exterior wall systems, there are many avenues available for further refinement and research. Some of the possibilities include:

- Alternative materials to steel that might be readily available, less thermally conductive, and have equivalent or superior structural and fire-rating capabilities. The initial costs to manufacture and install an alternative stud product using such a hypothetical material would be critical considerations to evaluate. Ideally, such a product could be derived from existing waste streams to lessen the impacts upon the environment and existing natural resources. One possibility that was suggested to this researcher, although it has not been explored, is the use of recycled tire materials.

- Possible alternative metal stud configurations to combine some of the ideas presented in this study. Perhaps a combination slit web and dimpled flange stud would provide even greater thermal performance than either single configuration alone.

- Deeper research into why the solutions presented in this study are more effective in colder climates than in warmer areas. The products studied were - across the board – more capable of resisting the transfer of heat out of a building than into a building.

- Research that considers the interactions and effects of thermal bridging between metal stud framing and other building components or assemblies such as balconies, window units or slab/roof intersections.

- Based upon the conversation with the representative that designed the ridged flange product (ThermaChannel), getting their product to market has been difficult due to the reluctance of existing metal stud manufactures to produce non-standard studs. Perhaps further research could convince building owners, designers and Code authorities of the effectiveness of alternative stud designs to reduce building energy costs. This may provide encouragement to stud manufacturers to start producing alternately configured metal studs that can help reduce thermal bridging in metal-framed exterior walls.

APPENDIX A
U-FACTOR CALCULATIONS – PARALLEL PATH METHOD

Table A-1. Code-minimum wall U-factor. Parallel path method.

Element	R-Value		Data Source
	Cavity	Stud	
Exterior Air Film	0.17	0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly	0.18	0.18	ColoradoEnergy.org
Grace Ice & Water Shield	0.00	0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing	0.56	0.56	ColoradoEnergy.org
Metal Stud	-	0.69	ASHRAE Fundamentals 2009 (Chapter 27)
Fiberglass Batt Insulation (R-13)	13.00	-	ColoradoEnergy.org
Gypsum Board, 5/8"	0.56	0.56	Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68	0.68	ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	15.15	2.84	
OVERALL R-VALUE		14.16	Weighted average: 92% cavity / 8% framing
U-FACTOR		0.071	(15.15x .92) + (2.84 x 0.08) = 14.16

Table A-2. Rinker exterior wall U-factor. Parallel path method.

Element	R-Value		Data Source
	Cavity	Stud	
Exterior Air Film	0.17	0.17	ASHRAE 90.1-2010 (Section A9.4.1)
Alucobond Alum Panel - 4mm	0.05	0.05	Manufacturer Data Sheet
Air Cavity	0.91	0.91	ASHRAE 90.1-2010 (Table A9.4A)
Grace Ice & Water Shield	0.00	0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing	0.56	0.56	ColoradoEnergy.org
Metal Stud	-	0.69	ASHRAE Fundamentals 2009 (Chapter 27)
2x2 Wood Blocking	-	1.88	ColoradoEnergy.org
Cellulose Insulation (6")	22.80	-	ColoradoEnergy.org
Semi-Rigid Insulation (1-1/2")	4.50	4.50	ColoradoEnergy.org
Gypsum Board, 5/8"	0.56	0.56	ASHRAE Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68	0.68	ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	30.23	10.00	
OVERALL R-VALUE		28.61	Weighted average: 92% cavity / 8% framing
U-FACTOR		0.035	(30.23 x .92) + (10.00 x 0.08) = 28.61

Table A-3. Slit web, ridged & dimpled flange stud wall U-factors. Parallel path method.

Element	R-Value		Data Source
	Cavity	Stud	
Exterior Air Film	0.17	0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly	0.18	0.18	ColoradoEnergy.org
Grace Ice & Water Shield	0.00	0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing	0.56	0.56	ColoradoEnergy.org
Metal Stud	-	0.69	ASHRAE Fundamentals 2009 (Chapter 27)
Cellulose Insulation (6")	22.80	-	ColoradoEnergy.org
Gypsum Board, 5/8"	0.56	0.56	Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68	0.68	ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	24.95	2.84	
OVERALL R-VALUE		23.18	
U-FACTOR		0.043	

Table A-4. Aerogel strip wall assembly U-factor. Parallel path method.

Element	R-Value		Data Source
	Cavity	Stud	
Exterior Air Film	0.17	0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly	0.18	0.18	ColoradoEnergy.org
Grace Ice & Water Shield	0.00	0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing	0.56	0.56	ColoradoEnergy.org
Metal Stud	-	0.69	ASHRAE Fundamentals 2009 (Chapter 27)
Aerogel Strip (3/8")	3.86	-	Manufacturer Data Sheet
Cellulose Insulation (6")	22.80	-	ColoradoEnergy.org
Gypsum Board, 5/8"	0.56	0.56	Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68	0.68	ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	28.81	2.84	
OVERALL R-VALUE		26.73	
U-FACTOR		0.037	

Table A-5. Thermal ceramic coated stud assembly U-factor. Parallel path method.

Element	R-Value		Data Source
	Cavity	Stud	
Exterior Air Film	0.17	0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly	0.18	0.05	ColoradoEnergy.org
Grace Ice & Water Shield	0.00	0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing	0.56	0.56	ColoradoEnergy.org
Metal Stud	-	0.69	ASHRAE Fundamentals 2009 (Chapter 27)
Thermal Ceramic Coating	-	0.31	Manufacturer Data Sheet
Cellulose Insulation (6")	22.80	-	ColoradoEnergy.org
Gypsum Board, 5/8"	0.56	0.56	Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68	0.68	ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	24.95	3.02	
OVERALL R-VALUE		23.19	
U-FACTOR		0.043	

APPENDIX B
U-FACTOR CALCULATIONS – ISOTHERMAL PLANES METHOD

Table B-1. Code-minimum exterior wall U-factor. Isothermal planes method.

Material	Int Sheath	Cav Insul	Stud	Ext Sheath	Data Source
Exterior Air Film				0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly				0.05	Manufacturer Data Sheet
Air Cavity				0.91	ASHRAE 90.1-2010 (Table A9.4A)
Ice & Water Shield				0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing				0.56	ColoradoEnergy.org
Metal Stud			0.69		ASHRAE Fundamentals 2009 (Cpt 27)
Fiberglass Insul. (R-13)		13.00			ColoradoEnergy.org
Gypsum Board, 5/8"	0.56				Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68				ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	1.24	13.00	0.69	1.69	
OVERALL R-VALUE	14.94				
U-FACTOR	0.067				

Table B-2. Rinker Hall exterior wall U-factor. Isothermal planes method.

Material	Int Sheath	Cav Insul	Stud	Ext Sheath	Data Source
Exterior Air Film				0.17	ASHRAE 90.1-2010 (Section A9.4.1)
Alucobond Alum Panel				0.05	Manufacturer Data Sheet
Air Cavity				0.91	ASHRAE 90.1-2010 (Table A9.4A)
Ice & Water Shield				0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing				0.56	ColoradoEnergy.org
Metal Stud			0.69		ASHRAE Fundamentals 2009 (Cptr 27)
Cellulose Insulation (6")		22.80			ColoradoEnergy.org
2x2 Wood Blocking	1.88				ColoradoEnergy.org
Semi-Rigid Insulation	4.50				ColoradoEnergy.org
Gypsum Board, 5/8"	0.56				Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68				ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	7.62	22.80	0.69	1.69	
OVERALL R-VALUE	30.34				
U-FACTOR	0.033				

Table B-3. Slit web, ridged & dimpled flange wall U-factors. Isothermal planes method.

Material	Int Sheath	Cav Insul	Stud	Ext Sheath	Data Source
Exterior Air Film				0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly				0.05	Manufacturer Data Sheet
Air Cavity				0.91	ASHRAE 90.1-2010 (Table A9.4A)
Ice & Water Shield				0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing				0.56	ColoradoEnergy.org
Metal Stud			0.69		ASHRAE Fundamentals 2009 (Cptr 27)
Cellulose Insulation (6")		22.80			ColoradoEnergy.org
Gypsum Board, 5/8"	0.56				Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68				ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	1.24	22.80	0.69	1.69	
OVERALL R-VALUE	23.96				
U-FACTOR	0.042				

Table B-4. Aerogel strip wall assembly U-factor. Isothermal planes method.

Material	Int Sheath	Cav Insul	Stud	Ext Sheath	Data Source
Exterior Air Film				0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly				0.05	Manufacturer Data Sheet
Air Cavity				0.91	ASHRAE 90.1-2010 (Table A9.4A)
Grace Ice & Water Shield				0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing				0.56	ColoradoEnergy.org
Metal Stud			0.69		ASHRAE Fundamentals 2009 (Chapter 27)
Cellulose Insulation (6")		22.80			ColoradoEnergy.org
Aerogel Strip (3/8")	3.86				Manufacturer Data Sheet
Gypsum Board, 5/8"	0.56				Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68				ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	5.10	22.80	0.69	1.69	
OVERALL R-VALUE	27.82				
U-FACTOR	0.036				

Table B-5. Thermal ceramic coated stud assembly U-factor. Isothermal planes method.

Material	Int Sheath	Cav Insul	Stud	Ext Sheath	Data Source
Exterior Air Film				0.17	ASHRAE 90.1-2010 (Section A9.4.1)
7/8" Stucco Assembly				0.05	Manufacturer Data Sheet
Air Cavity				0.91	ASHRAE 90.1-2010 (Table A9.4A)
Grace Ice & Water Shield				0.00	Manufacturer Data Sheet
5/8" Exterior Sheathing				0.56	ColoradoEnergy.org
Metal Stud			0.69		ASHRAE Fundamentals 2009 (Chapter 27)
Thermal Ceramic Coating			0.31		Manufacturer Data Sheet
Cellulose Insulation (6")		22.80			ColoradoEnergy.org
Gypsum Board, 5/8"	0.56				Standard 90.1-2007 (Sec. A9.4.1)
Interior Air Film	0.68				ASHRAE 90.1-2010 (Section A9.4.1)
TOTAL R-VALUE	1.24	22.80	1.00	1.69	
OVERALL R-VALUE	23.99				
U-FACTOR	0.042				

APPENDIX C
U-FACTOR CALCULATIONS – 2D HEAT FLOW ANALYSIS

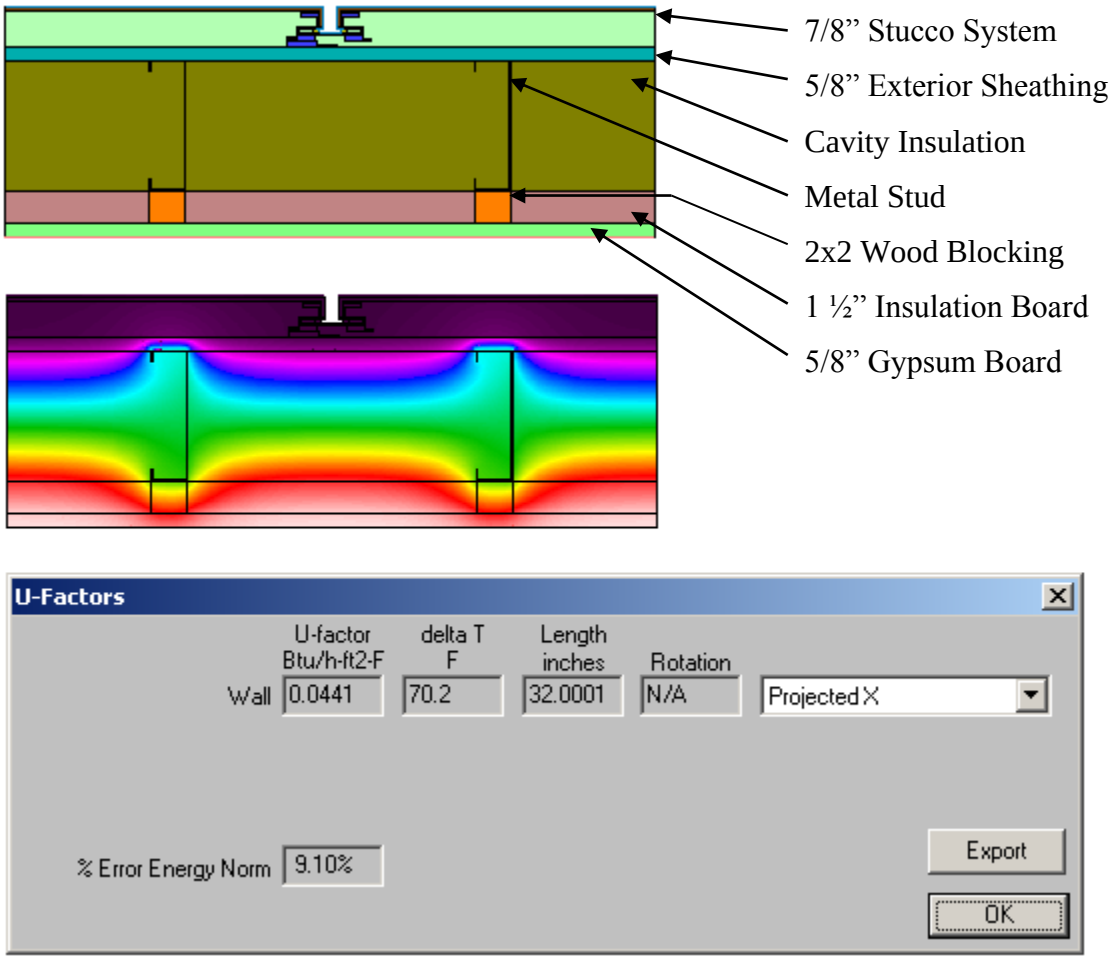

Figure C-1. 2D heat flow analysis. Rinker Hall wall.

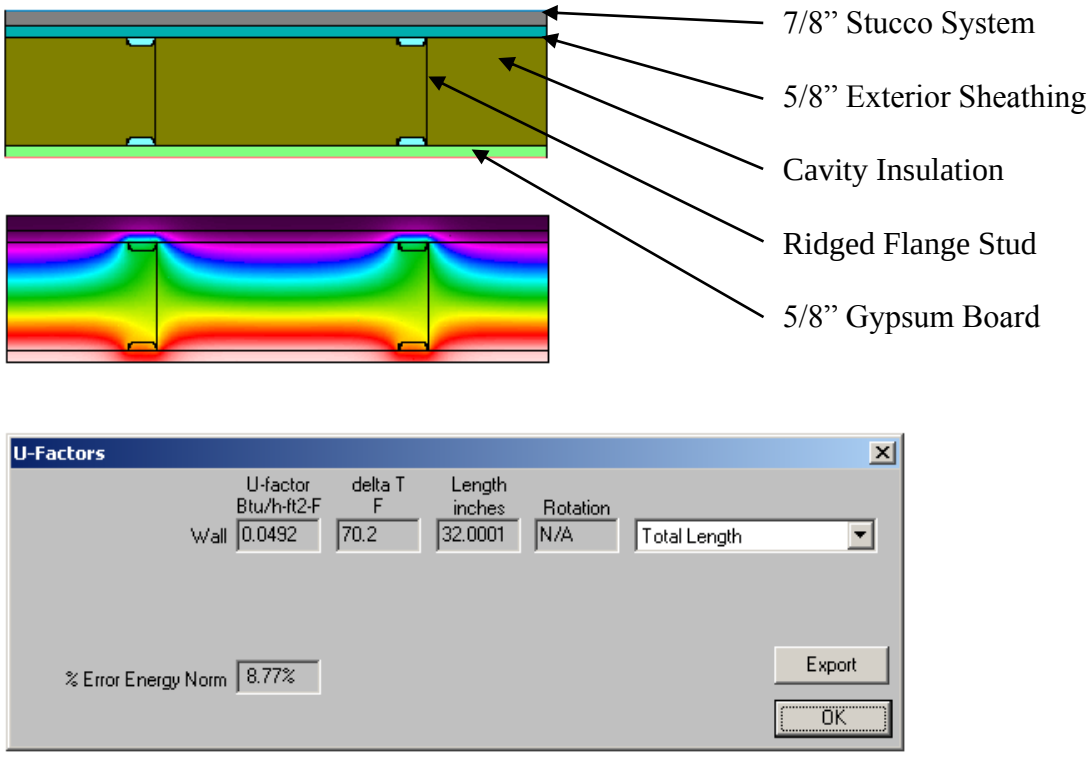

Figure C-2. 2D heat flow analysis. Ridged flange stud wall.

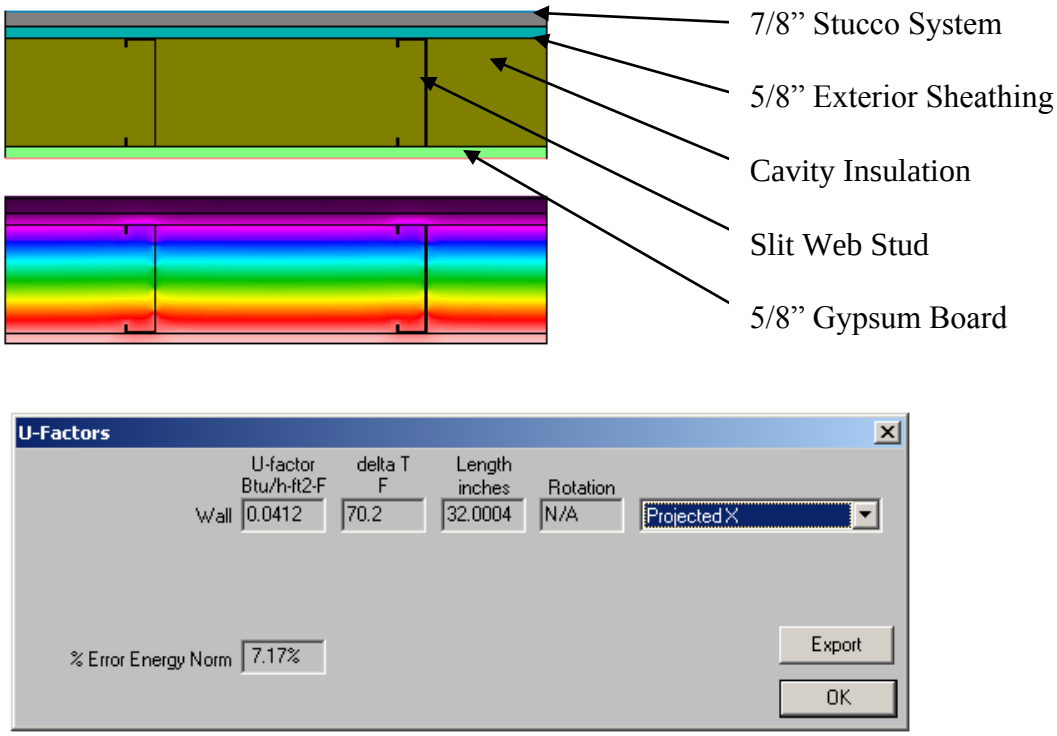

Figure C-3. 2D heat flow analysis. Slit web stud wall.

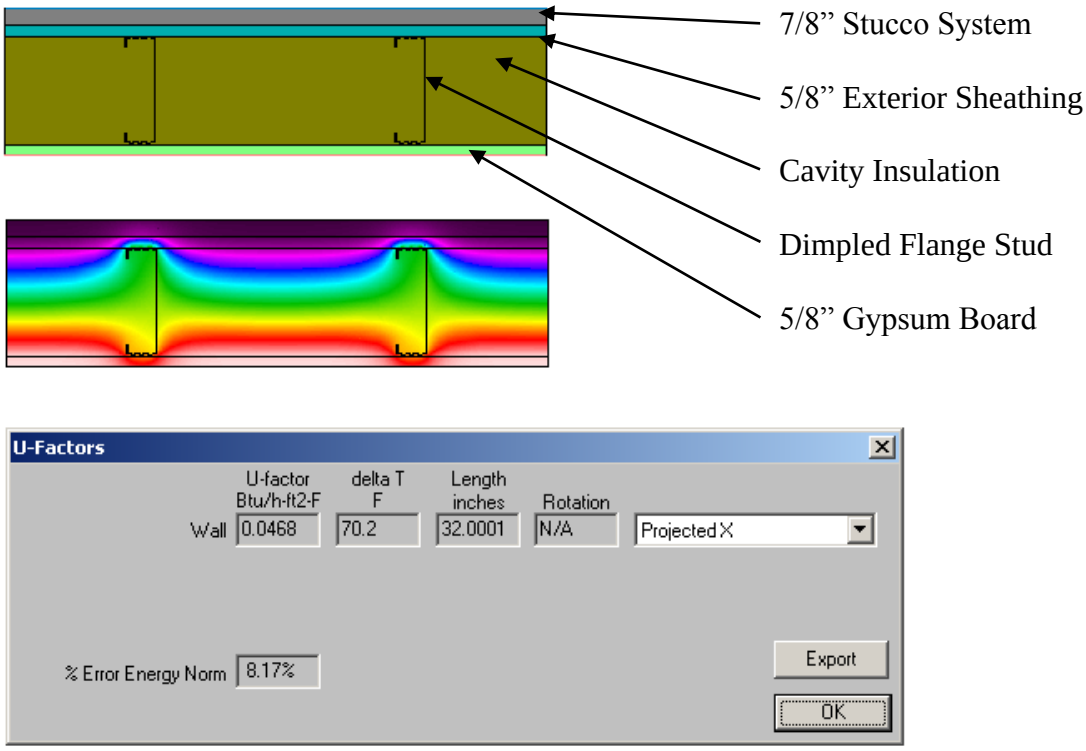

Figure C-4. 2D heat flow analysis. Dimpled flange stud wall.

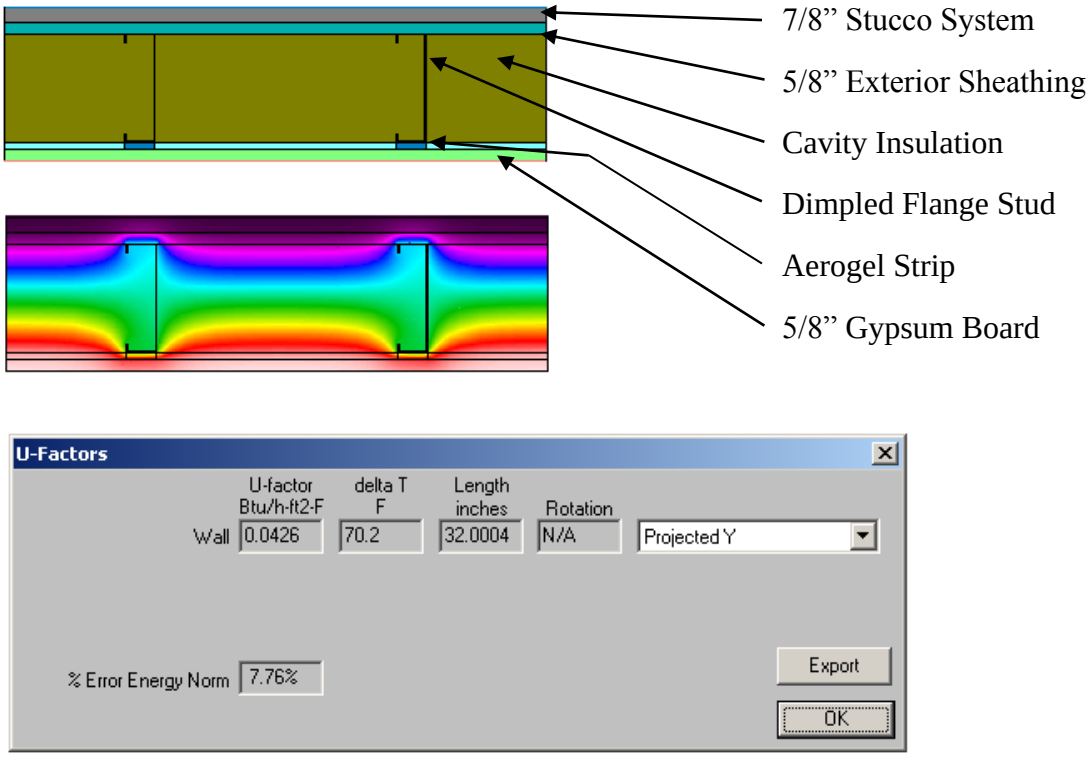

Figure C-5. 2D heat flow analysis. Aerogel strip stud wall.

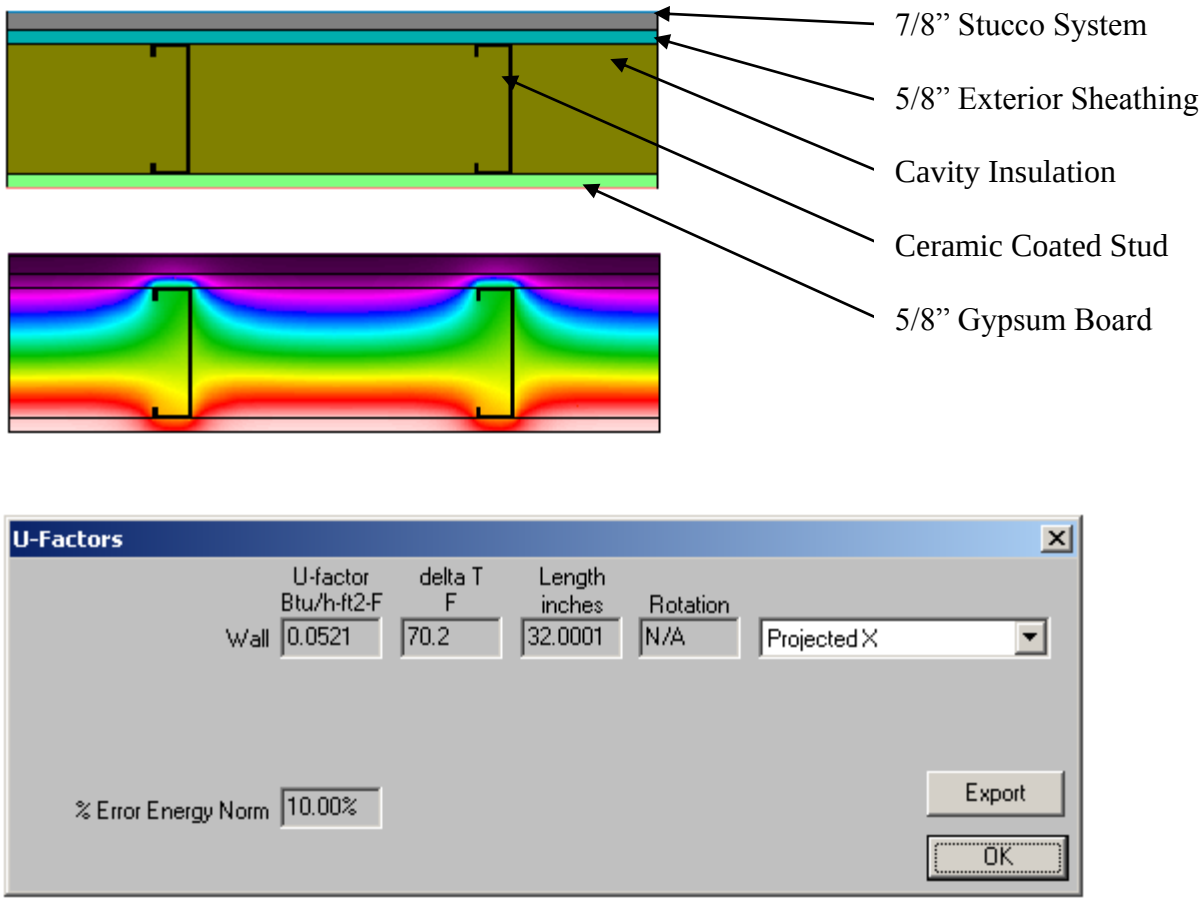

Figure C-6. 2D heat flow analysis. Ceramic coated stud wall.

APPENDIX D
DECREASED HEATING LOADS FROM WALL CONDUCTION

Table D-1. Decreased heating loads. Heating loads. Zone 1 - Miami, FL.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(20,269,405.13)	(5,936.62)	-
Rinker Hall	(14,379,143.01)	(4,211.45)	1,725.17
Ridged Flange Stud	(16,672,147.77)	(4,883.04)	1,053.59
Slit Web Stud	(14,379,143.01)	(4,211.45)	1,725.17
Dimpled Flange Stud	(16,997,383.84)	(4,978.29)	958.33
Aerogel Strip	(14,053,234.30)	(4,115.99)	1,820.63
Ceramic Coated Stud	(16,476,244.77)	(4,825.66)	1,110.96

Table D-2. Decreased heating loads. Zone 2 - Gainesville, FL.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(19,931,768.01)	(5,837.73)	-
Rinker Hall	(14,141,197.52)	(4,141.76)	1,695.98
Ridged Flange Stud	(16,541,683.97)	(4,844.82)	992.91
Slit Web Stud	(14,141,197.52)	(4,141.76)	1,695.98
Dimpled Flange Stud	(16,718,126.31)	(4,896.50)	941.23
Aerogel Strip	(14,053,234.30)	(4,115.99)	1,721.74
Ceramic Coated Stud	(16,476,244.77)	(4,825.66)	1,012.07

Table D-3. Decreased heating loads. Zone 3 - Atlanta, GA.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(58,985,465.71)	(17,276.01)	-
Rinker Hall	(42,070,213.26)	(12,321.77)	4,954.24
Ridged Flange Stud	(48,668,456.87)	(14,254.30)	3,021.71
Slit Web Stud	(42,070,213.26)	(12,321.77)	4,954.24
Dimpled Flange Stud	(49,610,464.79)	(14,530.20)	2,745.80
Aerogel Strip	(41,127,952.71)	(12,045.79)	5,230.21
Ceramic Coated Stud	(47,730,397.71)	(13,979.56)	3,296.45

Table D-4. Decreased heating loads. Zone 4 - Seattle, WA.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(96,791,800.24)	(28,348.94)	-
Rinker Hall	(69,103,226.21)	(20,239.35)	8,109.59
Ridged Flange Stud	(79,916,261.71)	(23,406.34)	4,942.61
Slit Web Stud	(69,103,226.21)	(20,239.35)	8,109.59
Dimpled Flange Stud	(81,457,244.63)	(23,857.67)	4,491.27
Aerogel Strip	(67,555,755.41)	(19,786.12)	8,562.82
Ceramic Coated Stud	(78,371,644.67)	(22,953.94)	5,395.00

Table D-5. Decreased heating loads. Zone 5 - Chicago, IL.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(117,846,342.29)	(34,515.52)	-
Rinker Hall	(84,154,567.14)	(24,647.68)	9,867.84
Ridged Flange Stud	(97,309,746.64)	(28,500.64)	6,014.88
Slit Web Stud	(84,154,567.14)	(24,647.68)	9,867.84
Dimpled Flange Stud	(99,183,535.68)	(29,049.45)	5,466.07
Aerogel Strip	(82,269,322.62)	(24,095.52)	10,420.00
Ceramic Coated Stud	(95,436,690.17)	(27,952.05)	6,563.47

Table D-6. Decreased heating loads. Zone 6 - Helena, MT.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(141,073,991.96)	(41,318.57)	-
Rinker Hall	(100,976,267.60)	(29,574.52)	11,744.05
Ridged Flange Stud	(116,664,488.43)	(34,169.37)	7,149.20
Slit Web Stud	(100,976,267.60)	(29,574.52)	11,744.05
Dimpled Flange Stud	(118,893,149.14)	(34,822.12)	6,496.45
Aerogel Strip	(98,726,579.22)	(28,915.61)	12,402.96
Ceramic Coated Stud	(114,426,874.79)	(33,514.01)	7,804.56

Table D-7. Decreased heating loads. Zone 7 - Minot, ND.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(163,279,634.15)	(47,822.29)	-
Rinker Hall	(116,665,065.81)	(34,169.54)	13,652.75
Ridged Flange Stud	(134,869,610.23)	(39,501.39)	8,320.89
Slit Web Stud	(116,665,065.81)	(34,169.54)	13,652.75
Dimpled Flange Stud	(137,466,462.35)	(40,261.98)	7,560.31
Aerogel Strip	(114,054,236.59)	(33,404.87)	14,417.42
Ceramic Coated Stud	(132,274,875.73)	(38,741.43)	9,080.85

Table D-8. Decreased heating loads. Zone 8 – Nome, AK.

Wall Type	Building heat load from wall conduction (Btu)	Building heat load from wall conduction (kWh)	Decreased heat load from wall conduction (kWh)
Code Minimum	(240,884,680.53)	(70,551.70)	-
Rinker Hall	(172,514,383.18)	(50,527.01)	20,024.69
Ridged Flange Stud	(199,253,916.50)	(58,358.64)	12,193.06
Slit Web Stud	(172,514,383.18)	(50,527.01)	20,024.69
Dimpled Flange Stud	(203,058,233.65)	(59,472.87)	11,078.83
Aerogel Strip	(168,679,075.02)	(49,403.71)	21,148.00
Ceramic Coated Stud	(195,447,043.96)	(57,243.66)	13,308.04

APPENDIX E
DECREASED COOLING LOADS FROM WALL CONDUCTION

Table E-1. Decreased cooling loads. Zone 1 - Miami, FL.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	28,542,717.93	8,359.76	-
Rinker Hall	20,283,688.06	5,940.80	2,418.95
Ridged Flange Stud	23,500,525.12	6,882.97	1,476.79
Slit Web Stud	20,283,688.06	5,940.80	2,418.95
Dimpled Flange Stud	23,957,464.33	7,016.80	1,342.96
Aerogel Strip	19,825,529.59	5,806.62	2,553.14
Ceramic Coated Stud	23,225,568.24	6,802.44	1,557.32

Table E-2. Decreased cooling loads. Zone 2 - Gainesville, FL.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	29,089,232.15	8,519.82	-
Rinker Hall	20,678,604.61	6,056.47	2,463.35
Ridged Flange Stud	23,317,362.55	6,829.32	1,690.50
Slit Web Stud	20,678,604.61	6,056.47	2,463.35
Dimpled Flange Stud	24,423,253.35	7,153.22	1,366.60
Aerogel Strip	19,825,529.59	5,806.62	2,713.21
Ceramic Coated Stud	23,225,568.24	6,802.44	1,717.38

Table E-3. Decreased cooling loads. Zone 3 - Atlanta, GA.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	13,882,372.08	4,065.95	-
Rinker Hall	9,748,862.03	2,855.30	1,210.65
Ridged Flange Stud	11,346,349.46	3,323.18	742.77
Slit Web Stud	9,748,862.03	2,855.30	1,210.65
Dimpled Flange Stud	11,577,095.29	3,390.77	675.18
Aerogel Strip	9,524,134.79	2,789.48	1,276.47
Ceramic Coated Stud	11,120,329.43	3,256.99	808.96

Table E-4. Decreased cooling loads. Zone 4 - Seattle, WA.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	3,913,432.48	1,146.19	-
Rinker Hall	3,049,117.41	893.04	253.15
Ridged Flange Stud	3,405,412.29	997.40	148.79
Slit Web Stud	3,049,117.41	893.04	253.15
Dimpled Flange Stud	3,453,218.99	1,011.40	134.79
Aerogel Strip	2,994,142.69	876.94	269.25
Ceramic Coated Stud	3,359,529.15	983.96	162.23

Table E-5. Decreased cooling loads. Zone 5 - Chicago, IL.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	5,535,741.81	1,621.34	-
Rinker Hall	3,723,013.86	1,090.42	530.92
Ridged Flange Stud	4,411,249.86	1,291.99	329.35
Slit Web Stud	3,723,013.86	1,090.42	530.92
Dimpled Flange Stud	4,511,267.81	1,321.29	300.05
Aerogel Strip	3,625,976.98	1,062.00	559.34
Ceramic Coated Stud	4,313,781.72	1,263.45	357.89

Table E-6. Decreased cooling loads. Zone 6 - Helena, MT.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	942,765.41	276.12	-
Rinker Hall	405,972.92	118.90	157.22
Ridged Flange Stud	602,663.77	176.51	99.61
Slit Web Stud	405,972.92	118.90	157.22
Dimpled Flange Stud	629,384.59	184.34	91.78
Aerogel Strip	380,617.00	111.48	164.65
Ceramic Coated Stud	569,731.93	166.87	109.26

Table E-7. Decreased cooling loads. Minot, ND.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	910,557.46	266.69	-
Rinker Hall	429,920.18	125.92	140.77
Ridged Flange Stud	598,161.94	175.19	91.50
Slit Web Stud	429,920.18	125.92	140.77
Dimpled Flange Stud	628,238.13	184.00	82.69
Aerogel Strip	405,894.74	118.88	147.81
Ceramic Coated Stud	572,621.14	167.71	98.98

Table E-8. Decreased cooling loads. Zone 8 – Nome, AK.

Wall Type	Building cool load from wall conduction (Btu)	Building cool load from wall conduction (kWh)	Decreased cool load from wall conduction (kWh)
Code Minimum	(4,652,306.25)	(1,362.59)	-
Rinker Hall	(3,512,765.16)	(1,028.84)	333.76
Ridged Flange Stud	(3,973,454.73)	(1,163.77)	198.83
Slit Web Stud	(3,512,765.16)	(1,028.84)	333.76
Dimpled Flange Stud	(4,037,323.83)	(1,182.47)	180.12
Aerogel Strip	(3,444,557.94)	(1,008.86)	353.73
Ceramic Coated Stud	(3,907,707.04)	(1,144.51)	218.08

APPENDIX F
ANNUAL ENERGY SAVINGS

Table F-1. Annual Energy Savings. Zone 1 - Miami, FL.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	4,144.13	$518.02
Ridged Flange Stud	2,530.37	$316.30
Slit Web Stud	4,144.13	$518.02
Dimpled Flange Stud	2,301.28	$287.66
Aerogel Strip	4,373.77	$546.72
Ceramic Coated Stud	2,668.28	$333.54

Table F-2. Annual Energy Savings. Zone 2 - Gainesville, FL.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	4,159.33	$519.92
Ridged Flange Stud	2,683.41	$335.43
Slit Web Stud	4,159.33	$519.92
Dimpled Flange Stud	2,307.83	$288.48
Aerogel Strip	4,434.95	$554.37
Ceramic Coated Stud	2,729.46	$341.18

Table F-3. Annual Energy Savings. Zone 3 - Atlanta, GA.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	6,164.88	$770.61
Ridged Flange Stud	3,764.47	$470.56
Slit Web Stud	6,164.88	$770.61
Dimpled Flange Stud	3,420.99	$427.62
Aerogel Strip	6,506.68	$813.33
Ceramic Coated Stud	4,105.41	$513.18

Table F-4. Annual Energy Savings. Zone 4 - Seattle, WA.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	8,362.74	$1,045.34
Ridged Flange Stud	5,091.40	$636.42
Slit Web Stud	8,362.74	$1,045.34
Dimpled Flange Stud	4,626.06	$578.26
Aerogel Strip	8,832.07	$1,104.01
Ceramic Coated Stud	5,557.23	$694.65

Table F-5. Annual Energy Savings. Zone 5 - Chicago, IL.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	10,398.76	$1,299.85
Ridged Flange Stud	6,344.23	$793.03
Slit Web Stud	10,398.76	$1,299.85
Dimpled Flange Stud	5,766.13	$720.77
Aerogel Strip	10,979.35	$1,372.42
Ceramic Coated Stud	6,921.36	$865.17

Table F-6. Annual Energy Savings. Zone 6 - Helena, MT.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	11,901.27	$1,487.66
Ridged Flange Stud	7,248.81	$906.10
Slit Web Stud	11,901.27	$1,487.66
Dimpled Flange Stud	6,588.24	$823.53
Aerogel Strip	12,567.60	$1,570.95
Ceramic Coated Stud	7,913.82	$989.23

Table F-7. Annual Energy Savings. Zone 7 - Minot, ND.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	13,793.52	$1,724.19
Ridged Flange Stud	8,412.39	$1,051.55
Slit Web Stud	13,793.52	$1,724.19
Dimpled Flange Stud	7,643.00	$955.37
Aerogel Strip	14,565.23	$1,820.65
Ceramic Coated Stud	9,179.83	$1,147.48

Table F-8. Annual Energy Savings. Zone 8 – Nome, AK.

Wall Type	Total decreased load from wall conduction (kWh)	Annual Energy Savings ($0.125 per kWh)
Code Minimum	-	-
Rinker Hall	20,358.44	$2,544.81
Ridged Flange Stud	12,391.89	$1,548.99
Slit Web Stud	20,358.44	$2,544.81
Dimpled Flange Stud	11,258.95	$1,407.37
Aerogel Strip	21,501.73	$2,687.72
Ceramic Coated Stud	13,526.12	$1,690.77

APPENDIX G
LIFE CYCLE COST ANALYSES

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	2,530.37	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$316.30	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$327.05	$327.05	$319.70	($33,784.55)	
2	$0.00	$338.17	$338.17	$323.14	($33,461.42)	
3	$0.00	$349.67	$349.67	$326.61	($33,134.81)	
4	$0.00	$361.56	$361.56	$330.12	($32,804.69)	
5	$0.00	$373.85	$373.85	$333.67	($32,471.01)	
6	$0.00	$386.56	$386.56	$337.26	($32,133.76)	
7	$0.00	$399.70	$399.70	$340.89	($31,792.87)	
8	$0.00	$413.29	$413.29	$344.55	($31,448.32)	
9	$0.00	$427.35	$427.35	$348.26	($31,100.06)	
10	$0.00	$441.88	$441.88	$352.00	($30,748.06)	
11	$0.00	$456.90	$456.90	$355.79	($30,392.28)	
12	$0.00	$472.43	$472.43	$359.61	($30,032.66)	
13	$0.00	$488.50	$488.50	$363.48	($29,669.19)	
14	$0.00	$505.11	$505.11	$367.39	($29,301.80)	
15	$0.00	$522.28	$522.28	$371.34	($28,930.46)	
16	$0.00	$540.04	$540.04	$375.33	($28,555.13)	
17	$0.00	$558.40	$558.40	$379.37	($28,175.77)	
18	$0.00	$577.38	$577.38	$383.44	($27,792.32)	
19	$0.00	$597.01	$597.01	$387.57	($27,404.76)	
20	$0.00	$617.31	$617.31	$391.74	($27,013.02)	
21	$0.00	$638.30	$638.30	$395.95	($26,617.07)	
22	$0.00	$660.00	$660.00	$400.20	($26,216.87)	
23	$0.00	$682.44	$682.44	$404.51	($25,812.36)	
24	$0.00	$705.65	$705.65	$408.86	($25,403.50)	
25	$0.00	$729.64	$729.64	$413.25	($24,990.25)	
26	$0.00	$754.45	$754.45	$417.70	($24,572.55)	
27	$0.00	$780.10	$780.10	$422.19	($24,150.36)	
28	$0.00	$806.62	$806.62	$426.73	($23,723.63)	
29	$0.00	$834.05	$834.05	$431.32	($23,292.32)	
30	$0.00	$862.40	$862.40	$435.95	($22,856.36)	

Total Value of Net Savings After 30 Years: $11,247.89 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	2,683.41	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$335.43	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$346.83	$346.83	$339.03	($33,765.22)	
2	$0.00	$358.62	$358.62	$342.68	($33,422.54)	
3	$0.00	$370.82	$370.82	$346.36	($33,076.18)	
4	$0.00	$383.42	$383.42	$350.09	($32,726.09)	
5	$0.00	$396.46	$396.46	$353.85	($32,372.24)	
6	$0.00	$409.94	$409.94	$357.66	($32,014.58)	
7	$0.00	$423.88	$423.88	$361.50	($31,653.08)	
8	$0.00	$438.29	$438.29	$365.39	($31,287.69)	
9	$0.00	$453.19	$453.19	$369.32	($30,918.37)	
10	$0.00	$468.60	$468.60	$373.29	($30,545.08)	
11	$0.00	$484.53	$484.53	$377.30	($30,167.78)	
12	$0.00	$501.01	$501.01	$381.36	($29,786.42)	
13	$0.00	$518.04	$518.04	$385.46	($29,400.96)	
14	$0.00	$535.65	$535.65	$389.61	($29,011.35)	
15	$0.00	$553.87	$553.87	$393.79	($28,617.56)	
16	$0.00	$572.70	$572.70	$398.03	($28,219.53)	
17	$0.00	$592.17	$592.17	$402.31	($27,817.22)	
18	$0.00	$612.30	$612.30	$406.63	($27,410.59)	
19	$0.00	$633.12	$633.12	$411.01	($26,999.58)	
20	$0.00	$654.65	$654.65	$415.43	($26,584.15)	
21	$0.00	$676.91	$676.91	$419.89	($26,164.26)	
22	$0.00	$699.92	$699.92	$424.41	($25,739.85)	
23	$0.00	$723.72	$723.72	$428.97	($25,310.88)	
24	$0.00	$748.32	$748.32	$433.58	($24,877.29)	
25	$0.00	$773.77	$773.77	$438.25	($24,439.04)	
26	$0.00	$800.07	$800.07	$442.96	($23,996.09)	
27	$0.00	$827.28	$827.28	$447.72	($23,548.36)	
28	$0.00	$855.40	$855.40	$452.54	($23,095.83)	
29	$0.00	$884.49	$884.49	$457.40	($22,638.42)	
30	$0.00	$914.56	$914.56	$462.32	($22,176.10)	

Total Value of Net Savings After 30 Years: $11,928.15 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	3,764.47	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$470.56	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$486.56	$486.56	$475.62	($33,628.63)	
2	$0.00	$503.10	$503.10	$480.73	($33,147.90)	
3	$0.00	$520.21	$520.21	$485.90	($32,662.00)	
4	$0.00	$537.89	$537.89	$491.13	($32,170.87)	
5	$0.00	$556.18	$556.18	$496.41	($31,674.46)	
6	$0.00	$575.09	$575.09	$501.75	($31,172.72)	
7	$0.00	$594.64	$594.64	$507.14	($30,665.58)	
8	$0.00	$614.86	$614.86	$512.59	($30,152.98)	
9	$0.00	$635.77	$635.77	$518.11	($29,634.88)	
10	$0.00	$657.38	$657.38	$523.68	($29,111.20)	
11	$0.00	$679.74	$679.74	$529.31	($28,581.89)	
12	$0.00	$702.85	$702.85	$535.00	($28,046.90)	
13	$0.00	$726.74	$726.74	$540.75	($27,506.14)	
14	$0.00	$751.45	$751.45	$546.57	($26,959.58)	
15	$0.00	$777.00	$777.00	$552.44	($26,407.14)	
16	$0.00	$803.42	$803.42	$558.38	($25,848.75)	
17	$0.00	$830.74	$830.74	$564.39	($25,284.36)	
18	$0.00	$858.98	$858.98	$570.46	($24,713.91)	
19	$0.00	$888.19	$888.19	$576.59	($24,137.32)	
20	$0.00	$918.38	$918.38	$582.79	($23,554.53)	
21	$0.00	$949.61	$949.61	$589.06	($22,965.47)	
22	$0.00	$981.90	$981.90	$595.39	($22,370.08)	
23	$0.00	$1,015.28	$1,015.28	$601.79	($21,768.29)	
24	$0.00	$1,049.80	$1,049.80	$608.26	($21,160.03)	
25	$0.00	$1,085.49	$1,085.49	$614.80	($20,545.22)	
26	$0.00	$1,122.40	$1,122.40	$621.41	($19,923.81)	
27	$0.00	$1,160.56	$1,160.56	$628.10	($19,295.71)	
28	$0.00	$1,200.02	$1,200.02	$634.85	($18,660.86)	
29	$0.00	$1,240.82	$1,240.82	$641.68	($18,019.18)	
30	$0.00	$1,283.01	$1,283.01	$648.58	($17,370.61)	

Total Value of Net Savings After 30 Years: $16,733.64 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	5,091.40	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$636.42	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$658.06	$658.06	$643.27	($33,460.98)	
2	$0.00	$680.44	$680.44	$650.18	($32,810.80)	
3	$0.00	$703.57	$703.57	$657.18	($32,153.62)	
4	$0.00	$727.49	$727.49	$664.24	($31,489.38)	
5	$0.00	$752.23	$752.23	$671.38	($30,817.99)	
6	$0.00	$777.80	$777.80	$678.60	($30,139.39)	
7	$0.00	$804.25	$804.25	$685.90	($29,453.49)	
8	$0.00	$831.59	$831.59	$693.28	($28,760.21)	
9	$0.00	$859.87	$859.87	$700.73	($28,059.48)	
10	$0.00	$889.10	$889.10	$708.27	($27,351.22)	
11	$0.00	$919.33	$919.33	$715.88	($26,635.34)	
12	$0.00	$950.59	$950.59	$723.58	($25,911.76)	
13	$0.00	$982.91	$982.91	$731.36	($25,180.40)	
14	$0.00	$1,016.33	$1,016.33	$739.22	($24,441.17)	
15	$0.00	$1,050.88	$1,050.88	$747.17	($23,694.00)	
16	$0.00	$1,086.61	$1,086.61	$755.21	($22,938.80)	
17	$0.00	$1,123.56	$1,123.56	$763.33	($22,175.47)	
18	$0.00	$1,161.76	$1,161.76	$771.53	($21,403.93)	
19	$0.00	$1,201.26	$1,201.26	$779.83	($20,624.10)	
20	$0.00	$1,242.10	$1,242.10	$788.22	($19,835.89)	
21	$0.00	$1,284.34	$1,284.34	$796.69	($19,039.20)	
22	$0.00	$1,328.00	$1,328.00	$805.26	($18,233.94)	
23	$0.00	$1,373.15	$1,373.15	$813.92	($17,420.02)	
24	$0.00	$1,419.84	$1,419.84	$822.67	($16,597.35)	
25	$0.00	$1,468.12	$1,468.12	$831.51	($15,765.84)	
26	$0.00	$1,518.03	$1,518.03	$840.46	($14,925.39)	
27	$0.00	$1,569.65	$1,569.65	$849.49	($14,075.89)	
28	$0.00	$1,623.01	$1,623.01	$858.63	($13,217.27)	
29	$0.00	$1,678.20	$1,678.20	$867.86	($12,349.41)	
30	$0.00	$1,735.25	$1,735.25	$877.19	($11,472.22)	

Total Value of Net Savings After 30 Years: $22,632.03 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	6,344.23	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$793.03	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$819.99	$819.99	$801.56	($33,302.69)	
2	$0.00	$847.87	$847.87	$810.17	($32,492.52)	
3	$0.00	$876.70	$876.70	$818.89	($31,673.63)	
4	$0.00	$906.51	$906.51	$827.69	($30,845.94)	
5	$0.00	$937.33	$937.33	$836.59	($30,009.35)	
6	$0.00	$969.20	$969.20	$845.59	($29,163.77)	
7	$0.00	$1,002.15	$1,002.15	$854.68	($28,309.09)	
8	$0.00	$1,036.22	$1,036.22	$863.87	($27,445.22)	
9	$0.00	$1,071.45	$1,071.45	$873.16	($26,572.06)	
10	$0.00	$1,107.88	$1,107.88	$882.55	($25,689.51)	
11	$0.00	$1,145.55	$1,145.55	$892.04	($24,797.48)	
12	$0.00	$1,184.50	$1,184.50	$901.63	($23,895.85)	
13	$0.00	$1,224.77	$1,224.77	$911.32	($22,984.53)	
14	$0.00	$1,266.42	$1,266.42	$921.12	($22,063.40)	
15	$0.00	$1,309.47	$1,309.47	$931.03	($21,132.38)	
16	$0.00	$1,354.00	$1,354.00	$941.04	($20,191.34)	
17	$0.00	$1,400.03	$1,400.03	$951.16	($19,240.18)	
18	$0.00	$1,447.63	$1,447.63	$961.38	($18,278.80)	
19	$0.00	$1,496.85	$1,496.85	$971.72	($17,307.08)	
20	$0.00	$1,547.74	$1,547.74	$982.17	($16,324.91)	
21	$0.00	$1,600.37	$1,600.37	$992.73	($15,332.18)	
22	$0.00	$1,654.78	$1,654.78	$1,003.41	($14,328.77)	
23	$0.00	$1,711.04	$1,711.04	$1,014.19	($13,314.58)	
24	$0.00	$1,769.22	$1,769.22	$1,025.10	($12,289.48)	
25	$0.00	$1,829.37	$1,829.37	$1,036.12	($11,253.35)	
26	$0.00	$1,891.57	$1,891.57	$1,047.26	($10,206.09)	
27	$0.00	$1,955.88	$1,955.88	$1,058.52	($9,147.56)	
28	$0.00	$2,022.38	$2,022.38	$1,069.91	($8,077.66)	
29	$0.00	$2,091.15	$2,091.15	$1,081.41	($6,996.25)	
30	$0.00	$2,162.24	$2,162.24	$1,093.04	($5,903.21)	

Total Value of Net Savings After 30 Years: $28,201.04 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 6 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	7,248.81	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$906.10	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$936.91	$936.91	$915.84	($33,188.41)	
2	$0.00	$968.76	$968.76	$925.69	($32,262.71)	
3	$0.00	$1,001.70	$1,001.70	$935.65	($31,327.07)	
4	$0.00	$1,035.76	$1,035.76	$945.71	($30,381.36)	
5	$0.00	$1,070.97	$1,070.97	$955.88	($29,425.49)	
6	$0.00	$1,107.39	$1,107.39	$966.15	($28,459.33)	
7	$0.00	$1,145.04	$1,145.04	$976.54	($27,482.79)	
8	$0.00	$1,183.97	$1,183.97	$987.04	($26,495.75)	
9	$0.00	$1,224.23	$1,224.23	$997.66	($25,498.09)	
10	$0.00	$1,265.85	$1,265.85	$1,008.38	($24,489.71)	
11	$0.00	$1,308.89	$1,308.89	$1,019.23	($23,470.48)	
12	$0.00	$1,353.39	$1,353.39	$1,030.19	($22,440.30)	
13	$0.00	$1,399.41	$1,399.41	$1,041.26	($21,399.04)	
14	$0.00	$1,446.99	$1,446.99	$1,052.46	($20,346.58)	
15	$0.00	$1,496.18	$1,496.18	$1,063.78	($19,282.80)	
16	$0.00	$1,547.05	$1,547.05	$1,075.21	($18,207.59)	
17	$0.00	$1,599.65	$1,599.65	$1,086.78	($17,120.81)	
18	$0.00	$1,654.04	$1,654.04	$1,098.46	($16,022.35)	
19	$0.00	$1,710.28	$1,710.28	$1,110.27	($14,912.08)	
20	$0.00	$1,768.43	$1,768.43	$1,122.21	($13,789.86)	
21	$0.00	$1,828.55	$1,828.55	$1,134.28	($12,655.59)	
22	$0.00	$1,890.73	$1,890.73	$1,146.47	($11,509.11)	
23	$0.00	$1,955.01	$1,955.01	$1,158.80	($10,350.31)	
24	$0.00	$2,021.48	$2,021.48	$1,171.26	($9,179.05)	
25	$0.00	$2,090.21	$2,090.21	$1,183.86	($7,995.19)	
26	$0.00	$2,161.28	$2,161.28	$1,196.59	($6,798.60)	
27	$0.00	$2,234.76	$2,234.76	$1,209.45	($5,589.15)	
28	$0.00	$2,310.74	$2,310.74	$1,222.46	($4,366.69)	
29	$0.00	$2,389.31	$2,389.31	$1,235.60	($3,131.09)	
30	$0.00	$2,470.55	$2,470.55	$1,248.89	($1,882.20)	

Total Value of Net Savings After 30 Years: $32,222.05 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	8,412.39	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,051.55	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$1,087.30	$1,087.30	$1,062.86	($33,041.39)	
2	$0.00	$1,124.27	$1,124.27	$1,074.28	($31,967.11)	
3	$0.00	$1,162.49	$1,162.49	$1,085.84	($30,881.27)	
4	$0.00	$1,202.02	$1,202.02	$1,097.51	($29,783.76)	
5	$0.00	$1,242.89	$1,242.89	$1,109.31	($28,674.45)	
6	$0.00	$1,285.15	$1,285.15	$1,121.24	($27,553.21)	
7	$0.00	$1,328.84	$1,328.84	$1,133.30	($26,419.91)	
8	$0.00	$1,374.02	$1,374.02	$1,145.48	($25,274.43)	
9	$0.00	$1,420.74	$1,420.74	$1,157.80	($24,116.63)	
10	$0.00	$1,469.04	$1,469.04	$1,170.25	($22,946.38)	
11	$0.00	$1,518.99	$1,518.99	$1,182.83	($21,763.55)	
12	$0.00	$1,570.64	$1,570.64	$1,195.55	($20,568.00)	
13	$0.00	$1,624.04	$1,624.04	$1,208.41	($19,359.59)	
14	$0.00	$1,679.26	$1,679.26	$1,221.40	($18,138.19)	
15	$0.00	$1,736.35	$1,736.35	$1,234.53	($16,903.66)	
16	$0.00	$1,795.39	$1,795.39	$1,247.81	($15,655.85)	
17	$0.00	$1,856.43	$1,856.43	$1,261.23	($14,394.62)	
18	$0.00	$1,919.55	$1,919.55	$1,274.79	($13,119.84)	
19	$0.00	$1,984.81	$1,984.81	$1,288.49	($11,831.34)	
20	$0.00	$2,052.30	$2,052.30	$1,302.35	($10,528.99)	
21	$0.00	$2,122.07	$2,122.07	$1,316.35	($9,212.64)	
22	$0.00	$2,194.23	$2,194.23	$1,330.51	($7,882.13)	
23	$0.00	$2,268.83	$2,268.83	$1,344.81	($6,537.32)	
24	$0.00	$2,345.97	$2,345.97	$1,359.27	($5,178.04)	
25	$0.00	$2,425.73	$2,425.73	$1,373.89	($3,804.15)	
26	$0.00	$2,508.21	$2,508.21	$1,388.66	($2,415.49)	
27	$0.00	$2,593.49	$2,593.49	$1,403.59	($1,011.90)	
28	$0.00	$2,681.66	$2,681.66	$1,418.69	$406.79	27.7
29	$0.00	$2,772.84	$2,772.84	$1,433.94	$1,840.73	
30	$0.00	$2,867.12	$2,867.12	$1,449.36	$3,290.09	

Total Value of Net Savings After 30 Years: $37,394.34 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Rinker Hall
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$108,178.68	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$34,104.25	**Study Period (yrs):**	30

Energy Savings:	12,391.89	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,548.99	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$34,104.25	$0.00	($34,104.25)	($34,104.25)	($34,104.25)	
1	$0.00	$1,601.65	$1,601.65	$1,565.64	($32,538.61)	
2	$0.00	$1,656.11	$1,656.11	$1,582.48	($30,956.13)	
3	$0.00	$1,712.42	$1,712.42	$1,599.49	($29,356.64)	
4	$0.00	$1,770.64	$1,770.64	$1,616.69	($27,739.95)	
5	$0.00	$1,830.84	$1,830.84	$1,634.07	($26,105.87)	
6	$0.00	$1,893.09	$1,893.09	$1,651.65	($24,454.23)	
7	$0.00	$1,957.45	$1,957.45	$1,669.41	($22,784.82)	
8	$0.00	$2,024.01	$2,024.01	$1,687.36	($21,097.47)	
9	$0.00	$2,092.82	$2,092.82	$1,705.50	($19,391.97)	
10	$0.00	$2,163.98	$2,163.98	$1,723.84	($17,668.13)	
11	$0.00	$2,237.55	$2,237.55	$1,742.37	($15,925.76)	
12	$0.00	$2,313.63	$2,313.63	$1,761.11	($14,164.65)	
13	$0.00	$2,392.29	$2,392.29	$1,780.05	($12,384.60)	
14	$0.00	$2,473.63	$2,473.63	$1,799.19	($10,585.42)	
15	$0.00	$2,557.73	$2,557.73	$1,818.53	($8,766.88)	
16	$0.00	$2,644.70	$2,644.70	$1,838.09	($6,928.80)	
17	$0.00	$2,734.62	$2,734.62	$1,857.85	($5,070.95)	
18	$0.00	$2,827.59	$2,827.59	$1,877.83	($3,193.12)	
19	$0.00	$2,923.73	$2,923.73	$1,898.02	($1,295.10)	
20	$0.00	$3,023.14	$3,023.14	$1,918.43	$623.33	19.7
21	$0.00	$3,125.93	$3,125.93	$1,939.06	$2,562.38	
22	$0.00	$3,232.21	$3,232.21	$1,959.91	$4,522.29	
23	$0.00	$3,342.10	$3,342.10	$1,980.98	$6,503.27	
24	$0.00	$3,455.73	$3,455.73	$2,002.28	$8,505.55	
25	$0.00	$3,573.23	$3,573.23	$2,023.81	$10,529.36	
26	$0.00	$3,694.72	$3,694.72	$2,045.57	$12,574.94	
27	$0.00	$3,820.34	$3,820.34	$2,067.57	$14,642.51	
28	$0.00	$3,950.23	$3,950.23	$2,089.80	$16,732.31	
29	$0.00	$4,084.54	$4,084.54	$2,112.27	$18,844.58	
30	$0.00	$4,223.41	$4,223.41	$2,134.98	$20,979.56	

Total Value of Net Savings After 30 Years: $55,083.81 **$34,104.25**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	2,668.28	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$333.54	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$344.88	$344.88	$337.12	($100,747.88)	
2	$0.00	$356.60	$356.60	$340.75	($100,407.13)	
3	$0.00	$368.73	$368.73	$344.41	($100,062.72)	
4	$0.00	$381.26	$381.26	$348.11	($99,714.61)	
5	$0.00	$394.23	$394.23	$351.86	($99,362.75)	
6	$0.00	$407.63	$407.63	$355.64	($99,007.11)	
7	$0.00	$421.49	$421.49	$359.46	($98,647.64)	
8	$0.00	$435.82	$435.82	$363.33	($98,284.31)	
9	$0.00	$450.64	$450.64	$367.24	($97,917.08)	
10	$0.00	$465.96	$465.96	$371.19	($97,545.89)	
11	$0.00	$481.80	$481.80	$375.18	($97,170.72)	
12	$0.00	$498.18	$498.18	$379.21	($96,791.51)	
13	$0.00	$515.12	$515.12	$383.29	($96,408.22)	
14	$0.00	$532.63	$532.63	$387.41	($96,020.81)	
15	$0.00	$550.74	$550.74	$391.58	($95,629.23)	
16	$0.00	$569.47	$569.47	$395.79	($95,233.45)	
17	$0.00	$588.83	$588.83	$400.04	($94,833.41)	
18	$0.00	$608.85	$608.85	$404.34	($94,429.06)	
19	$0.00	$629.55	$629.55	$408.69	($94,020.37)	
20	$0.00	$650.96	$650.96	$413.09	($93,607.29)	
21	$0.00	$673.09	$673.09	$417.53	($93,189.76)	
22	$0.00	$695.97	$695.97	$422.02	($92,767.74)	
23	$0.00	$719.64	$719.64	$426.55	($92,341.19)	
24	$0.00	$744.11	$744.11	$431.14	($91,910.05)	
25	$0.00	$769.40	$769.40	$435.78	($91,474.27)	
26	$0.00	$795.56	$795.56	$440.46	($91,033.81)	
27	$0.00	$822.61	$822.61	$445.20	($90,588.61)	
28	$0.00	$850.58	$850.58	$449.99	($90,138.63)	
29	$0.00	$879.50	$879.50	$454.82	($89,683.80)	
30	$0.00	$909.41	$909.41	$459.71	($89,224.09)	

Total Value of Net Savings After 30 Years: $11,860.91 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	2,729.46	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$341.18	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$352.78	$352.78	$344.85	($100,740.15)	
2	$0.00	$364.78	$364.78	$348.56	($100,391.59)	
3	$0.00	$377.18	$377.18	$352.31	($100,039.28)	
4	$0.00	$390.00	$390.00	$356.10	($99,683.19)	
5	$0.00	$403.26	$403.26	$359.92	($99,323.26)	
6	$0.00	$416.97	$416.97	$363.79	($98,959.47)	
7	$0.00	$431.15	$431.15	$367.71	($98,591.76)	
8	$0.00	$445.81	$445.81	$371.66	($98,220.10)	
9	$0.00	$460.97	$460.97	$375.66	($97,844.45)	
10	$0.00	$476.64	$476.64	$379.70	($97,464.75)	
11	$0.00	$492.85	$492.85	$383.78	($97,080.97)	
12	$0.00	$509.60	$509.60	$387.90	($96,693.07)	
13	$0.00	$526.93	$526.93	$392.08	($96,300.99)	
14	$0.00	$544.85	$544.85	$396.29	($95,904.70)	
15	$0.00	$563.37	$563.37	$400.55	($95,504.15)	
16	$0.00	$582.53	$582.53	$404.86	($95,099.29)	
17	$0.00	$602.33	$602.33	$409.21	($94,690.07)	
18	$0.00	$622.81	$622.81	$413.61	($94,276.46)	
19	$0.00	$643.99	$643.99	$418.06	($93,858.40)	
20	$0.00	$665.88	$665.88	$422.56	($93,435.84)	
21	$0.00	$688.52	$688.52	$427.10	($93,008.74)	
22	$0.00	$711.93	$711.93	$431.69	($92,577.05)	
23	$0.00	$736.14	$736.14	$436.33	($92,140.72)	
24	$0.00	$761.17	$761.17	$441.03	($91,699.69)	
25	$0.00	$787.05	$787.05	$445.77	($91,253.92)	
26	$0.00	$813.81	$813.81	$450.56	($90,803.36)	
27	$0.00	$841.47	$841.47	$455.41	($90,347.95)	
28	$0.00	$870.08	$870.08	$460.30	($89,887.65)	
29	$0.00	$899.67	$899.67	$465.25	($89,422.40)	
30	$0.00	$930.26	$930.26	$470.26	($88,952.14)	

Total Value of Net Savings After 30 Years: $12,132.85 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	4,105.41	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$513.18	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$530.62	$530.62	$518.69	($100,566.30)	
2	$0.00	$548.67	$548.67	$524.27	($100,042.03)	
3	$0.00	$567.32	$567.32	$529.91	($99,512.12)	
4	$0.00	$586.61	$586.61	$535.61	($98,976.51)	
5	$0.00	$606.55	$606.55	$541.37	($98,435.15)	
6	$0.00	$627.18	$627.18	$547.19	($97,887.96)	
7	$0.00	$648.50	$648.50	$553.07	($97,334.89)	
8	$0.00	$670.55	$670.55	$559.02	($96,775.87)	
9	$0.00	$693.35	$693.35	$565.03	($96,210.84)	
10	$0.00	$716.92	$716.92	$571.10	($95,639.74)	
11	$0.00	$741.30	$741.30	$577.25	($95,062.49)	
12	$0.00	$766.50	$766.50	$583.45	($94,479.04)	
13	$0.00	$792.56	$792.56	$589.73	($93,889.31)	
14	$0.00	$819.51	$819.51	$596.07	($93,293.24)	
15	$0.00	$847.37	$847.37	$602.48	($92,690.77)	
16	$0.00	$876.18	$876.18	$608.96	($92,081.81)	
17	$0.00	$905.97	$905.97	$615.50	($91,466.31)	
18	$0.00	$936.78	$936.78	$622.12	($90,844.19)	
19	$0.00	$968.63	$968.63	$628.81	($90,215.38)	
20	$0.00	$1,001.56	$1,001.56	$635.57	($89,579.80)	
21	$0.00	$1,035.61	$1,035.61	$642.41	($88,937.40)	
22	$0.00	$1,070.83	$1,070.83	$649.31	($88,288.08)	
23	$0.00	$1,107.23	$1,107.23	$656.30	($87,631.79)	
24	$0.00	$1,144.88	$1,144.88	$663.35	($86,968.43)	
25	$0.00	$1,183.81	$1,183.81	$670.49	($86,297.95)	
26	$0.00	$1,224.05	$1,224.05	$677.70	($85,620.25)	
27	$0.00	$1,265.67	$1,265.67	$684.98	($84,935.27)	
28	$0.00	$1,308.71	$1,308.71	$692.35	($84,242.92)	
29	$0.00	$1,353.20	$1,353.20	$699.79	($83,543.13)	
30	$0.00	$1,399.21	$1,399.21	$707.32	($82,835.82)	

Total Value of Net Savings After 30 Years: $18,249.18 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	5,557.23	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$694.65	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$718.27	$718.27	$702.12	($100,382.87)	
2	$0.00	$742.69	$742.69	$709.67	($99,673.20)	
3	$0.00	$767.95	$767.95	$717.30	($98,955.90)	
4	$0.00	$794.06	$794.06	$725.02	($98,230.88)	
5	$0.00	$821.05	$821.05	$732.81	($97,498.07)	
6	$0.00	$848.97	$848.97	$740.69	($96,757.37)	
7	$0.00	$877.83	$877.83	$748.66	($96,008.72)	
8	$0.00	$907.68	$907.68	$756.71	($95,252.01)	
9	$0.00	$938.54	$938.54	$764.84	($94,487.17)	
10	$0.00	$970.45	$970.45	$773.07	($93,714.10)	
11	$0.00	$1,003.45	$1,003.45	$781.38	($92,932.72)	
12	$0.00	$1,037.56	$1,037.56	$789.78	($92,142.94)	
13	$0.00	$1,072.84	$1,072.84	$798.27	($91,344.66)	
14	$0.00	$1,109.32	$1,109.32	$806.86	($90,537.80)	
15	$0.00	$1,147.03	$1,147.03	$815.53	($89,722.27)	
16	$0.00	$1,186.03	$1,186.03	$824.30	($88,897.96)	
17	$0.00	$1,226.36	$1,226.36	$833.17	($88,064.80)	
18	$0.00	$1,268.06	$1,268.06	$842.13	($87,222.67)	
19	$0.00	$1,311.17	$1,311.17	$851.18	($86,371.49)	
20	$0.00	$1,355.75	$1,355.75	$860.33	($85,511.16)	
21	$0.00	$1,401.84	$1,401.84	$869.58	($84,641.57)	
22	$0.00	$1,449.51	$1,449.51	$878.93	($83,762.64)	
23	$0.00	$1,498.79	$1,498.79	$888.39	($82,874.25)	
24	$0.00	$1,549.75	$1,549.75	$897.94	($81,976.32)	
25	$0.00	$1,602.44	$1,602.44	$907.59	($81,068.72)	
26	$0.00	$1,656.92	$1,656.92	$917.35	($80,151.37)	
27	$0.00	$1,713.26	$1,713.26	$927.22	($79,224.16)	
28	$0.00	$1,771.51	$1,771.51	$937.19	($78,286.97)	
29	$0.00	$1,831.74	$1,831.74	$947.26	($77,339.71)	
30	$0.00	$1,894.02	$1,894.02	$957.45	($76,382.26)	

Total Value of Net Savings After 30 Years: $24,702.74 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	6,921.36	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$865.17	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$894.59	$894.59	$874.47	($100,210.52)	
2	$0.00	$925.00	$925.00	$883.88	($99,326.65)	
3	$0.00	$956.45	$956.45	$893.38	($98,433.27)	
4	$0.00	$988.97	$988.97	$902.99	($97,530.28)	
5	$0.00	$1,022.60	$1,022.60	$912.70	($96,617.58)	
6	$0.00	$1,057.36	$1,057.36	$922.51	($95,695.07)	
7	$0.00	$1,093.32	$1,093.32	$932.43	($94,762.64)	
8	$0.00	$1,130.49	$1,130.49	$942.46	($93,820.19)	
9	$0.00	$1,168.92	$1,168.92	$952.59	($92,867.60)	
10	$0.00	$1,208.67	$1,208.67	$962.83	($91,904.77)	
11	$0.00	$1,249.76	$1,249.76	$973.19	($90,931.58)	
12	$0.00	$1,292.25	$1,292.25	$983.65	($89,947.93)	
13	$0.00	$1,336.19	$1,336.19	$994.23	($88,953.70)	
14	$0.00	$1,381.62	$1,381.62	$1,004.92	($87,948.79)	
15	$0.00	$1,428.60	$1,428.60	$1,015.72	($86,933.06)	
16	$0.00	$1,477.17	$1,477.17	$1,026.64	($85,906.42)	
17	$0.00	$1,527.39	$1,527.39	$1,037.68	($84,868.74)	
18	$0.00	$1,579.32	$1,579.32	$1,048.84	($83,819.89)	
19	$0.00	$1,633.02	$1,633.02	$1,060.12	($82,759.77)	
20	$0.00	$1,688.54	$1,688.54	$1,071.52	($81,688.26)	
21	$0.00	$1,745.95	$1,745.95	$1,083.04	($80,605.22)	
22	$0.00	$1,805.32	$1,805.32	$1,094.69	($79,510.53)	
23	$0.00	$1,866.70	$1,866.70	$1,106.46	($78,404.07)	
24	$0.00	$1,930.17	$1,930.17	$1,118.35	($77,285.72)	
25	$0.00	$1,995.79	$1,995.79	$1,130.38	($76,155.34)	
26	$0.00	$2,063.65	$2,063.65	$1,142.53	($75,012.80)	
27	$0.00	$2,133.81	$2,133.81	$1,154.82	($73,857.98)	
28	$0.00	$2,206.36	$2,206.36	$1,167.24	($72,690.75)	
29	$0.00	$2,281.38	$2,281.38	$1,179.79	($71,510.96)	
30	$0.00	$2,358.95	$2,358.95	$1,192.47	($70,318.49)	

Total Value of Net Savings After 30 Years: $30,766.51 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 6 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	7,913.82	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$989.23	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$1,022.86	$1,022.86	$999.86	($100,085.13)	
2	$0.00	$1,057.64	$1,057.64	$1,010.62	($99,074.52)	
3	$0.00	$1,093.60	$1,093.60	$1,021.48	($98,053.04)	
4	$0.00	$1,130.78	$1,130.78	$1,032.47	($97,020.57)	
5	$0.00	$1,169.23	$1,169.23	$1,043.57	($95,977.00)	
6	$0.00	$1,208.98	$1,208.98	$1,054.79	($94,922.21)	
7	$0.00	$1,250.09	$1,250.09	$1,066.13	($93,856.08)	
8	$0.00	$1,292.59	$1,292.59	$1,077.59	($92,778.49)	
9	$0.00	$1,336.54	$1,336.54	$1,089.18	($91,689.31)	
10	$0.00	$1,381.98	$1,381.98	$1,100.89	($90,588.41)	
11	$0.00	$1,428.97	$1,428.97	$1,112.73	($89,475.68)	
12	$0.00	$1,477.55	$1,477.55	$1,124.70	($88,350.99)	
13	$0.00	$1,527.79	$1,527.79	$1,136.79	($87,214.20)	
14	$0.00	$1,579.73	$1,579.73	$1,149.01	($86,065.19)	
15	$0.00	$1,633.44	$1,633.44	$1,161.37	($84,903.82)	
16	$0.00	$1,688.98	$1,688.98	$1,173.86	($83,729.96)	
17	$0.00	$1,746.41	$1,746.41	$1,186.48	($82,543.49)	
18	$0.00	$1,805.78	$1,805.78	$1,199.24	($81,344.25)	
19	$0.00	$1,867.18	$1,867.18	$1,212.13	($80,132.12)	
20	$0.00	$1,930.66	$1,930.66	$1,225.16	($78,906.96)	
21	$0.00	$1,996.31	$1,996.31	$1,238.34	($77,668.62)	
22	$0.00	$2,064.18	$2,064.18	$1,251.65	($76,416.96)	
23	$0.00	$2,134.36	$2,134.36	$1,265.11	($75,151.85)	
24	$0.00	$2,206.93	$2,206.93	$1,278.72	($73,873.14)	
25	$0.00	$2,281.97	$2,281.97	$1,292.46	($72,580.67)	
26	$0.00	$2,359.56	$2,359.56	$1,306.36	($71,274.31)	
27	$0.00	$2,439.78	$2,439.78	$1,320.41	($69,953.90)	
28	$0.00	$2,522.73	$2,522.73	$1,334.61	($68,619.29)	
29	$0.00	$2,608.51	$2,608.51	$1,348.96	($67,270.34)	
30	$0.00	$2,697.19	$2,697.19	$1,363.46	($65,906.87)	

Total Value of Net Savings After 30 Years: $35,178.12 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	9,179.83	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,147.48	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$1,186.49	$1,186.49	$1,159.82	($99,925.18)	
2	$0.00	$1,226.83	$1,226.83	$1,172.29	($98,752.89)	
3	$0.00	$1,268.55	$1,268.55	$1,184.89	($97,568.00)	
4	$0.00	$1,311.68	$1,311.68	$1,197.63	($96,370.36)	
5	$0.00	$1,356.27	$1,356.27	$1,210.51	($95,159.85)	
6	$0.00	$1,402.39	$1,402.39	$1,223.53	($93,936.32)	
7	$0.00	$1,450.07	$1,450.07	$1,236.68	($92,699.64)	
8	$0.00	$1,499.37	$1,499.37	$1,249.98	($91,449.66)	
9	$0.00	$1,550.35	$1,550.35	$1,263.42	($90,186.23)	
10	$0.00	$1,603.06	$1,603.06	$1,277.01	($88,909.22)	
11	$0.00	$1,657.57	$1,657.57	$1,290.74	($87,618.48)	
12	$0.00	$1,713.92	$1,713.92	$1,304.62	($86,313.87)	
13	$0.00	$1,772.20	$1,772.20	$1,318.65	($84,995.22)	
14	$0.00	$1,832.45	$1,832.45	$1,332.83	($83,662.39)	
15	$0.00	$1,894.75	$1,894.75	$1,347.16	($82,315.24)	
16	$0.00	$1,959.18	$1,959.18	$1,361.64	($80,953.59)	
17	$0.00	$2,025.79	$2,025.79	$1,376.28	($79,577.31)	
18	$0.00	$2,094.66	$2,094.66	$1,391.08	($78,186.23)	
19	$0.00	$2,165.88	$2,165.88	$1,406.04	($76,780.19)	
20	$0.00	$2,239.52	$2,239.52	$1,421.16	($75,359.03)	
21	$0.00	$2,315.67	$2,315.67	$1,436.44	($73,922.59)	
22	$0.00	$2,394.40	$2,394.40	$1,451.89	($72,470.70)	
23	$0.00	$2,475.81	$2,475.81	$1,467.50	($71,003.20)	
24	$0.00	$2,559.99	$2,559.99	$1,483.28	($69,519.92)	
25	$0.00	$2,647.03	$2,647.03	$1,499.23	($68,020.70)	
26	$0.00	$2,737.02	$2,737.02	$1,515.35	($66,505.35)	
27	$0.00	$2,830.08	$2,830.08	$1,531.64	($64,973.71)	
28	$0.00	$2,926.31	$2,926.31	$1,548.11	($63,425.60)	
29	$0.00	$3,025.80	$3,025.80	$1,564.76	($61,860.84)	
30	$0.00	$3,128.68	$3,128.68	$1,581.58	($60,279.26)	

Total Value of Net Savings After 30 Years: $40,805.74 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Thermal Ceramic Coated Stud
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$175,159.43	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$101,085.00	**Study Period (yrs):**	30

Energy Savings:	13,526.12	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,690.77	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$101,085.00	$0.00	($101,085.00)	($101,085.00)	($101,085.00)	
1	$0.00	$1,748.25	$1,748.25	$1,708.95	($99,376.05)	
2	$0.00	$1,807.69	$1,807.69	$1,727.32	($97,648.73)	
3	$0.00	$1,869.15	$1,869.15	$1,745.89	($95,902.84)	
4	$0.00	$1,932.70	$1,932.70	$1,764.67	($94,138.17)	
5	$0.00	$1,998.42	$1,998.42	$1,783.64	($92,354.53)	
6	$0.00	$2,066.36	$2,066.36	$1,802.82	($90,551.70)	
7	$0.00	$2,136.62	$2,136.62	$1,822.21	($88,729.50)	
8	$0.00	$2,209.26	$2,209.26	$1,841.80	($86,887.70)	
9	$0.00	$2,284.38	$2,284.38	$1,861.60	($85,026.09)	
10	$0.00	$2,362.05	$2,362.05	$1,881.62	($83,144.47)	
11	$0.00	$2,442.36	$2,442.36	$1,901.85	($81,242.62)	
12	$0.00	$2,525.40	$2,525.40	$1,922.30	($79,320.31)	
13	$0.00	$2,611.26	$2,611.26	$1,942.97	($77,377.34)	
14	$0.00	$2,700.04	$2,700.04	$1,963.87	($75,413.47)	
15	$0.00	$2,791.85	$2,791.85	$1,984.98	($73,428.49)	
16	$0.00	$2,886.77	$2,886.77	$2,006.33	($71,422.16)	
17	$0.00	$2,984.92	$2,984.92	$2,027.90	($69,394.26)	
18	$0.00	$3,086.41	$3,086.41	$2,049.71	($67,344.55)	
19	$0.00	$3,191.34	$3,191.34	$2,071.75	($65,272.81)	
20	$0.00	$3,299.85	$3,299.85	$2,094.02	($63,178.79)	
21	$0.00	$3,412.04	$3,412.04	$2,116.54	($61,062.25)	
22	$0.00	$3,528.05	$3,528.05	$2,139.30	($58,922.95)	
23	$0.00	$3,648.01	$3,648.01	$2,162.30	($56,760.65)	
24	$0.00	$3,772.04	$3,772.04	$2,185.55	($54,575.10)	
25	$0.00	$3,900.29	$3,900.29	$2,209.05	($52,366.05)	
26	$0.00	$4,032.90	$4,032.90	$2,232.81	($50,133.24)	
27	$0.00	$4,170.02	$4,170.02	$2,256.81	($47,876.43)	
28	$0.00	$4,311.80	$4,311.80	$2,281.08	($45,595.35)	
29	$0.00	$4,458.40	$4,458.40	$2,305.61	($43,289.74)	
30	$0.00	$4,609.98	$4,609.98	$2,330.40	($40,959.34)	

Total Value of Net Savings After 30 Years: $60,125.66 **$101,085.00**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	4,373.77	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$546.72	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$565.31	$565.31	$552.60	($66,973.82)	
2	$0.00	$584.53	$584.53	$558.54	($66,415.27)	
3	$0.00	$604.40	$604.40	$564.55	($65,850.73)	
4	$0.00	$624.95	$624.95	$570.62	($65,280.11)	
5	$0.00	$646.20	$646.20	$576.75	($64,703.35)	
6	$0.00	$668.17	$668.17	$582.96	($64,120.40)	
7	$0.00	$690.89	$690.89	$589.22	($63,531.18)	
8	$0.00	$714.38	$714.38	$595.56	($62,935.62)	
9	$0.00	$738.67	$738.67	$601.96	($62,333.65)	
10	$0.00	$763.79	$763.79	$608.44	($61,725.22)	
11	$0.00	$789.75	$789.75	$614.98	($61,110.24)	
12	$0.00	$816.61	$816.61	$621.59	($60,488.65)	
13	$0.00	$844.37	$844.37	$628.27	($59,860.37)	
14	$0.00	$873.08	$873.08	$635.03	($59,225.34)	
15	$0.00	$902.76	$902.76	$641.86	($58,583.48)	
16	$0.00	$933.46	$933.46	$648.76	($57,934.72)	
17	$0.00	$965.19	$965.19	$655.74	($57,278.99)	
18	$0.00	$998.01	$998.01	$662.79	($56,616.20)	
19	$0.00	$1,031.94	$1,031.94	$669.91	($55,946.29)	
20	$0.00	$1,067.03	$1,067.03	$677.12	($55,269.17)	
21	$0.00	$1,103.31	$1,103.31	$684.40	($54,584.77)	
22	$0.00	$1,140.82	$1,140.82	$691.76	($53,893.01)	
23	$0.00	$1,179.61	$1,179.61	$699.20	($53,193.82)	
24	$0.00	$1,219.72	$1,219.72	$706.71	($52,487.10)	
25	$0.00	$1,261.19	$1,261.19	$714.31	($51,772.79)	
26	$0.00	$1,304.07	$1,304.07	$721.99	($51,050.80)	
27	$0.00	$1,348.41	$1,348.41	$729.76	($50,321.04)	
28	$0.00	$1,394.25	$1,394.25	$737.60	($49,583.44)	
29	$0.00	$1,441.66	$1,441.66	$745.54	($48,837.90)	
30	$0.00	$1,490.67	$1,490.67	$753.55	($48,084.35)	

Total Value of Net Savings After 30 Years: $19,442.07 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	4,434.95	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$554.37	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$573.22	$573.22	$560.33	($66,966.09)	
2	$0.00	$592.71	$592.71	$566.35	($66,399.73)	
3	$0.00	$612.86	$612.86	$572.44	($65,827.29)	
4	$0.00	$633.70	$633.70	$578.60	($65,248.69)	
5	$0.00	$655.24	$655.24	$584.82	($64,663.87)	
6	$0.00	$677.52	$677.52	$591.11	($64,072.76)	
7	$0.00	$700.55	$700.55	$597.47	($63,475.29)	
8	$0.00	$724.37	$724.37	$603.89	($62,871.40)	
9	$0.00	$749.00	$749.00	$610.38	($62,261.02)	
10	$0.00	$774.47	$774.47	$616.95	($61,644.07)	
11	$0.00	$800.80	$800.80	$623.58	($61,020.49)	
12	$0.00	$828.03	$828.03	$630.29	($60,390.21)	
13	$0.00	$856.18	$856.18	$637.06	($59,753.15)	
14	$0.00	$885.29	$885.29	$643.91	($59,109.23)	
15	$0.00	$915.39	$915.39	$650.84	($58,458.40)	
16	$0.00	$946.51	$946.51	$657.83	($57,800.56)	
17	$0.00	$978.70	$978.70	$664.91	($57,135.65)	
18	$0.00	$1,011.97	$1,011.97	$672.06	($56,463.60)	
19	$0.00	$1,046.38	$1,046.38	$679.28	($55,784.31)	
20	$0.00	$1,081.95	$1,081.95	$686.59	($55,097.72)	
21	$0.00	$1,118.74	$1,118.74	$693.97	($54,403.75)	
22	$0.00	$1,156.78	$1,156.78	$701.43	($53,702.32)	
23	$0.00	$1,196.11	$1,196.11	$708.98	($52,993.34)	
24	$0.00	$1,236.78	$1,236.78	$716.60	($52,276.74)	
25	$0.00	$1,278.83	$1,278.83	$724.30	($51,552.44)	
26	$0.00	$1,322.31	$1,322.31	$732.09	($50,820.35)	
27	$0.00	$1,367.27	$1,367.27	$739.96	($50,080.38)	
28	$0.00	$1,413.75	$1,413.75	$747.92	($49,332.46)	
29	$0.00	$1,461.82	$1,461.82	$755.96	($48,576.50)	
30	$0.00	$1,511.52	$1,511.52	$764.09	($47,812.41)	

Total Value of Net Savings After 30 Years: $19,714.01 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	6,506.68	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$813.33	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$840.99	$840.99	$822.08	($66,704.33)	
2	$0.00	$869.58	$869.58	$830.92	($65,873.41)	
3	$0.00	$899.15	$899.15	$839.85	($65,033.56)	
4	$0.00	$929.72	$929.72	$848.89	($64,184.68)	
5	$0.00	$961.33	$961.33	$858.01	($63,326.66)	
6	$0.00	$994.01	$994.01	$867.24	($62,459.42)	
7	$0.00	$1,027.81	$1,027.81	$876.56	($61,582.86)	
8	$0.00	$1,062.76	$1,062.76	$885.99	($60,696.87)	
9	$0.00	$1,098.89	$1,098.89	$895.52	($59,801.35)	
10	$0.00	$1,136.25	$1,136.25	$905.15	($58,896.21)	
11	$0.00	$1,174.88	$1,174.88	$914.88	($57,981.33)	
12	$0.00	$1,214.83	$1,214.83	$924.72	($57,056.61)	
13	$0.00	$1,256.14	$1,256.14	$934.66	($56,121.96)	
14	$0.00	$1,298.84	$1,298.84	$944.71	($55,177.25)	
15	$0.00	$1,343.00	$1,343.00	$954.87	($54,222.38)	
16	$0.00	$1,388.67	$1,388.67	$965.13	($53,257.25)	
17	$0.00	$1,435.88	$1,435.88	$975.51	($52,281.73)	
18	$0.00	$1,484.70	$1,484.70	$986.00	($51,295.73)	
19	$0.00	$1,535.18	$1,535.18	$996.60	($50,299.13)	
20	$0.00	$1,587.38	$1,587.38	$1,007.32	($49,291.81)	
21	$0.00	$1,641.35	$1,641.35	$1,018.15	($48,273.66)	
22	$0.00	$1,697.15	$1,697.15	$1,029.10	($47,244.56)	
23	$0.00	$1,754.86	$1,754.86	$1,040.16	($46,204.39)	
24	$0.00	$1,814.52	$1,814.52	$1,051.35	($45,153.04)	
25	$0.00	$1,876.22	$1,876.22	$1,062.65	($44,090.39)	
26	$0.00	$1,940.01	$1,940.01	$1,074.08	($43,016.31)	
27	$0.00	$2,005.97	$2,005.97	$1,085.63	($41,930.68)	
28	$0.00	$2,074.17	$2,074.17	$1,097.30	($40,833.38)	
29	$0.00	$2,144.69	$2,144.69	$1,109.10	($39,724.27)	
30	$0.00	$2,217.61	$2,217.61	$1,121.03	($38,603.25)	

Total Value of Net Savings After 30 Years: $28,923.17 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	8,832.07	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,104.01	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$1,141.54	$1,141.54	$1,115.88	($66,410.54)	
2	$0.00	$1,180.36	$1,180.36	$1,127.88	($65,282.66)	
3	$0.00	$1,220.49	$1,220.49	$1,140.01	($64,142.65)	
4	$0.00	$1,261.99	$1,261.99	$1,152.26	($62,990.39)	
5	$0.00	$1,304.89	$1,304.89	$1,164.65	($61,825.73)	
6	$0.00	$1,349.26	$1,349.26	$1,177.18	($60,648.55)	
7	$0.00	$1,395.14	$1,395.14	$1,189.84	($59,458.72)	
8	$0.00	$1,442.57	$1,442.57	$1,202.63	($58,256.09)	
9	$0.00	$1,491.62	$1,491.62	$1,215.56	($57,040.53)	
10	$0.00	$1,542.33	$1,542.33	$1,228.63	($55,811.90)	
11	$0.00	$1,594.77	$1,594.77	$1,241.84	($54,570.06)	
12	$0.00	$1,648.99	$1,648.99	$1,255.20	($53,314.86)	
13	$0.00	$1,705.06	$1,705.06	$1,268.69	($52,046.17)	
14	$0.00	$1,763.03	$1,763.03	$1,282.33	($50,763.83)	
15	$0.00	$1,822.97	$1,822.97	$1,296.12	($49,467.71)	
16	$0.00	$1,884.96	$1,884.96	$1,310.06	($48,157.65)	
17	$0.00	$1,949.04	$1,949.04	$1,324.15	($46,833.51)	
18	$0.00	$2,015.31	$2,015.31	$1,338.38	($45,495.12)	
19	$0.00	$2,083.83	$2,083.83	$1,352.78	($44,142.35)	
20	$0.00	$2,154.68	$2,154.68	$1,367.32	($42,775.03)	
21	$0.00	$2,227.94	$2,227.94	$1,382.02	($41,393.00)	
22	$0.00	$2,303.69	$2,303.69	$1,396.88	($39,996.12)	
23	$0.00	$2,382.02	$2,382.02	$1,411.90	($38,584.21)	
24	$0.00	$2,463.01	$2,463.01	$1,427.09	($37,157.13)	
25	$0.00	$2,546.75	$2,546.75	$1,442.43	($35,714.70)	
26	$0.00	$2,633.34	$2,633.34	$1,457.94	($34,256.75)	
27	$0.00	$2,722.87	$2,722.87	$1,473.62	($32,783.14)	
28	$0.00	$2,815.45	$2,815.45	$1,489.46	($31,293.67)	
29	$0.00	$2,911.17	$2,911.17	$1,505.48	($29,788.19)	
30	$0.00	$3,010.15	$3,010.15	$1,521.67	($28,266.53)	

Total Value of Net Savings After 30 Years: $39,259.89 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	10,979.35	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,372.42	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$1,419.08	$1,419.08	$1,387.18	($66,139.24)	
2	$0.00	$1,467.33	$1,467.33	$1,402.09	($64,737.15)	
3	$0.00	$1,517.22	$1,517.22	$1,417.17	($63,319.98)	
4	$0.00	$1,568.80	$1,568.80	$1,432.41	($61,887.57)	
5	$0.00	$1,622.14	$1,622.14	$1,447.81	($60,439.77)	
6	$0.00	$1,677.30	$1,677.30	$1,463.38	($58,976.39)	
7	$0.00	$1,734.32	$1,734.32	$1,479.11	($57,497.28)	
8	$0.00	$1,793.29	$1,793.29	$1,495.02	($56,002.26)	
9	$0.00	$1,854.26	$1,854.26	$1,511.09	($54,491.17)	
10	$0.00	$1,917.31	$1,917.31	$1,527.34	($52,963.83)	
11	$0.00	$1,982.50	$1,982.50	$1,543.76	($51,420.07)	
12	$0.00	$2,049.90	$2,049.90	$1,560.36	($49,859.71)	
13	$0.00	$2,119.60	$2,119.60	$1,577.14	($48,282.57)	
14	$0.00	$2,191.66	$2,191.66	$1,594.10	($46,688.47)	
15	$0.00	$2,266.18	$2,266.18	$1,611.24	($45,077.23)	
16	$0.00	$2,343.23	$2,343.23	$1,628.56	($43,448.66)	
17	$0.00	$2,422.90	$2,422.90	$1,646.08	($41,802.59)	
18	$0.00	$2,505.28	$2,505.28	$1,663.78	($40,138.81)	
19	$0.00	$2,590.46	$2,590.46	$1,681.67	($38,457.15)	
20	$0.00	$2,678.53	$2,678.53	$1,699.75	($36,757.40)	
21	$0.00	$2,769.61	$2,769.61	$1,718.03	($35,039.37)	
22	$0.00	$2,863.77	$2,863.77	$1,736.50	($33,302.87)	
23	$0.00	$2,961.14	$2,961.14	$1,755.17	($31,547.70)	
24	$0.00	$3,061.82	$3,061.82	$1,774.04	($29,773.66)	
25	$0.00	$3,165.92	$3,165.92	$1,793.12	($27,980.54)	
26	$0.00	$3,273.56	$3,273.56	$1,812.40	($26,168.14)	
27	$0.00	$3,384.86	$3,384.86	$1,831.89	($24,336.25)	
28	$0.00	$3,499.95	$3,499.95	$1,851.59	($22,484.67)	
29	$0.00	$3,618.95	$3,618.95	$1,871.50	($20,613.17)	
30	$0.00	$3,741.99	$3,741.99	$1,891.62	($18,721.55)	

Total Value of Net Savings After 30 Years: $48,804.86 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 6 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	12,567.60	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,570.95	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$1,624.36	$1,624.36	$1,587.84	($65,938.57)	
2	$0.00	$1,679.59	$1,679.59	$1,604.92	($64,333.66)	
3	$0.00	$1,736.70	$1,736.70	$1,622.17	($62,711.48)	
4	$0.00	$1,795.74	$1,795.74	$1,639.62	($61,071.87)	
5	$0.00	$1,856.80	$1,856.80	$1,657.25	($59,414.62)	
6	$0.00	$1,919.93	$1,919.93	$1,675.07	($57,739.56)	
7	$0.00	$1,985.21	$1,985.21	$1,693.08	($56,046.48)	
8	$0.00	$2,052.71	$2,052.71	$1,711.28	($54,335.20)	
9	$0.00	$2,122.50	$2,122.50	$1,729.68	($52,605.51)	
10	$0.00	$2,194.66	$2,194.66	$1,748.28	($50,857.23)	
11	$0.00	$2,269.28	$2,269.28	$1,767.08	($49,090.15)	
12	$0.00	$2,346.44	$2,346.44	$1,786.08	($47,304.07)	
13	$0.00	$2,426.22	$2,426.22	$1,805.29	($45,498.78)	
14	$0.00	$2,508.71	$2,508.71	$1,824.70	($43,674.09)	
15	$0.00	$2,594.00	$2,594.00	$1,844.32	($41,829.77)	
16	$0.00	$2,682.20	$2,682.20	$1,864.15	($39,965.62)	
17	$0.00	$2,773.39	$2,773.39	$1,884.19	($38,081.42)	
18	$0.00	$2,867.69	$2,867.69	$1,904.45	($36,176.97)	
19	$0.00	$2,965.19	$2,965.19	$1,924.93	($34,252.03)	
20	$0.00	$3,066.01	$3,066.01	$1,945.63	($32,306.40)	
21	$0.00	$3,170.25	$3,170.25	$1,966.55	($30,339.85)	
22	$0.00	$3,278.04	$3,278.04	$1,987.70	($28,352.15)	
23	$0.00	$3,389.49	$3,389.49	$2,009.07	($26,343.08)	
24	$0.00	$3,504.74	$3,504.74	$2,030.67	($24,312.41)	
25	$0.00	$3,623.90	$3,623.90	$2,052.51	($22,259.90)	
26	$0.00	$3,747.11	$3,747.11	$2,074.58	($20,185.32)	
27	$0.00	$3,874.51	$3,874.51	$2,096.89	($18,088.44)	
28	$0.00	$4,006.24	$4,006.24	$2,119.43	($15,969.00)	
29	$0.00	$4,142.46	$4,142.46	$2,142.22	($13,826.78)	
30	$0.00	$4,283.30	$4,283.30	$2,165.26	($11,661.52)	

Total Value of Net Savings After 30 Years: $55,864.89 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	14,565.23	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,820.65	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$1,882.56	$1,882.56	$1,840.23	($65,686.18)	
2	$0.00	$1,946.56	$1,946.56	$1,860.02	($63,826.17)	
3	$0.00	$2,012.75	$2,012.75	$1,880.02	($61,946.15)	
4	$0.00	$2,081.18	$2,081.18	$1,900.23	($60,045.92)	
5	$0.00	$2,151.94	$2,151.94	$1,920.67	($58,125.25)	
6	$0.00	$2,225.11	$2,225.11	$1,941.32	($56,183.93)	
7	$0.00	$2,300.76	$2,300.76	$1,962.19	($54,221.74)	
8	$0.00	$2,378.98	$2,378.98	$1,983.29	($52,238.45)	
9	$0.00	$2,459.87	$2,459.87	$2,004.62	($50,233.83)	
10	$0.00	$2,543.51	$2,543.51	$2,026.17	($48,207.66)	
11	$0.00	$2,629.98	$2,629.98	$2,047.96	($46,159.70)	
12	$0.00	$2,719.40	$2,719.40	$2,069.98	($44,089.72)	
13	$0.00	$2,811.86	$2,811.86	$2,092.24	($41,997.48)	
14	$0.00	$2,907.47	$2,907.47	$2,114.74	($39,882.74)	
15	$0.00	$3,006.32	$3,006.32	$2,137.47	($37,745.27)	
16	$0.00	$3,108.54	$3,108.54	$2,160.46	($35,584.81)	
17	$0.00	$3,214.23	$3,214.23	$2,183.69	($33,401.12)	
18	$0.00	$3,323.51	$3,323.51	$2,207.17	($31,193.95)	
19	$0.00	$3,436.51	$3,436.51	$2,230.90	($28,963.05)	
20	$0.00	$3,553.35	$3,553.35	$2,254.89	($26,708.16)	
21	$0.00	$3,674.16	$3,674.16	$2,279.14	($24,429.03)	
22	$0.00	$3,799.09	$3,799.09	$2,303.64	($22,125.38)	
23	$0.00	$3,928.26	$3,928.26	$2,328.41	($19,796.97)	
24	$0.00	$4,061.82	$4,061.82	$2,353.45	($17,443.52)	
25	$0.00	$4,199.92	$4,199.92	$2,378.76	($15,064.76)	
26	$0.00	$4,342.71	$4,342.71	$2,404.33	($12,660.43)	
27	$0.00	$4,490.37	$4,490.37	$2,430.19	($10,230.24)	
28	$0.00	$4,643.04	$4,643.04	$2,456.32	($7,773.92)	
29	$0.00	$4,800.90	$4,800.90	$2,482.73	($5,291.19)	
30	$0.00	$4,964.13	$4,964.13	$2,509.43	($2,781.77)	

Total Value of Net Savings After 30 Years: $64,744.65 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Aerogel Strips
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$141,600.85	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$67,526.42	**Study Period (yrs):**	30

Energy Savings:	21,501.73	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$2,687.72	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$67,526.42	$0.00	($67,526.42)	($67,526.42)	($67,526.42)	
1	$0.00	$2,779.10	$2,779.10	$2,716.62	($64,809.80)	
2	$0.00	$2,873.59	$2,873.59	$2,745.83	($62,063.97)	
3	$0.00	$2,971.29	$2,971.29	$2,775.35	($59,288.62)	
4	$0.00	$3,072.31	$3,072.31	$2,805.19	($56,483.42)	
5	$0.00	$3,176.77	$3,176.77	$2,835.36	($53,648.07)	
6	$0.00	$3,284.78	$3,284.78	$2,865.85	($50,782.22)	
7	$0.00	$3,396.47	$3,396.47	$2,896.66	($47,885.56)	
8	$0.00	$3,511.95	$3,511.95	$2,927.81	($44,957.75)	
9	$0.00	$3,631.35	$3,631.35	$2,959.29	($41,998.46)	
10	$0.00	$3,754.82	$3,754.82	$2,991.11	($39,007.35)	
11	$0.00	$3,882.48	$3,882.48	$3,023.27	($35,984.08)	
12	$0.00	$4,014.49	$4,014.49	$3,055.78	($32,928.30)	
13	$0.00	$4,150.98	$4,150.98	$3,088.64	($29,839.66)	
14	$0.00	$4,292.11	$4,292.11	$3,121.85	($26,717.81)	
15	$0.00	$4,438.04	$4,438.04	$3,155.42	($23,562.39)	
16	$0.00	$4,588.94	$4,588.94	$3,189.35	($20,373.04)	
17	$0.00	$4,744.96	$4,744.96	$3,223.64	($17,149.40)	
18	$0.00	$4,906.29	$4,906.29	$3,258.30	($13,891.09)	
19	$0.00	$5,073.10	$5,073.10	$3,293.34	($10,597.75)	
20	$0.00	$5,245.59	$5,245.59	$3,328.75	($7,269.00)	
21	$0.00	$5,423.94	$5,423.94	$3,364.55	($3,904.46)	
22	$0.00	$5,608.35	$5,608.35	$3,400.72	($503.73)	
23	$0.00	$5,799.04	$5,799.04	$3,437.29	$2,933.56	22.1
24	$0.00	$5,996.20	$5,996.20	$3,474.25	$6,407.81	
25	$0.00	$6,200.07	$6,200.07	$3,511.61	$9,919.42	
26	$0.00	$6,410.88	$6,410.88	$3,549.37	$13,468.78	
27	$0.00	$6,628.85	$6,628.85	$3,587.53	$17,056.32	
28	$0.00	$6,854.23	$6,854.23	$3,626.11	$20,682.42	
29	$0.00	$7,087.27	$7,087.27	$3,665.10	$24,347.52	
30	$0.00	$7,328.24	$7,328.24	$3,704.51	$28,052.03	

Total Value of Net Savings After 30 Years: $95,578.45 **$67,526.42**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	2,301.28	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$287.66	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$297.44	$297.44	$290.75	($2,710.42)	
2	$0.00	$307.55	$307.55	$293.88	($2,416.54)	
3	$0.00	$318.01	$318.01	$297.04	($2,119.50)	
4	$0.00	$328.82	$328.82	$300.23	($1,819.27)	
5	$0.00	$340.00	$340.00	$303.46	($1,515.80)	
6	$0.00	$351.56	$351.56	$306.73	($1,209.08)	
7	$0.00	$363.52	$363.52	$310.02	($899.06)	
8	$0.00	$375.88	$375.88	$313.36	($585.70)	
9	$0.00	$388.66	$388.66	$316.73	($268.97)	
10	$0.00	$401.87	$401.87	$320.13	$51.16	9.8
11	$0.00	$415.53	$415.53	$323.57	$374.74	
12	$0.00	$429.66	$429.66	$327.05	$701.79	
13	$0.00	$444.27	$444.27	$330.57	$1,032.36	
14	$0.00	$459.38	$459.38	$334.12	$1,366.48	
15	$0.00	$474.99	$474.99	$337.72	$1,704.20	
16	$0.00	$491.14	$491.14	$341.35	$2,045.55	
17	$0.00	$507.84	$507.84	$345.02	$2,390.57	
18	$0.00	$525.11	$525.11	$348.73	$2,739.30	
19	$0.00	$542.96	$542.96	$352.48	$3,091.78	
20	$0.00	$561.42	$561.42	$356.27	$3,448.05	
21	$0.00	$580.51	$580.51	$360.10	$3,808.15	
22	$0.00	$600.25	$600.25	$363.97	$4,172.12	
23	$0.00	$620.66	$620.66	$367.89	$4,540.01	
24	$0.00	$641.76	$641.76	$371.84	$4,911.85	
25	$0.00	$663.58	$663.58	$375.84	$5,287.69	
26	$0.00	$686.14	$686.14	$379.88	$5,667.57	
27	$0.00	$709.47	$709.47	$383.97	$6,051.54	
28	$0.00	$733.59	$733.59	$388.09	$6,439.63	
29	$0.00	$758.54	$758.54	$392.27	$6,831.90	
30	$0.00	$784.33	$784.33	$396.49	$7,228.38	

Total Value of Net Savings After 30 Years: $10,229.56 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	2,307.83	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$288.48	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$298.29	$298.29	$291.58	($2,709.59)	
2	$0.00	$308.43	$308.43	$294.72	($2,414.88)	
3	$0.00	$318.92	$318.92	$297.88	($2,116.99)	
4	$0.00	$329.76	$329.76	$301.09	($1,815.90)	
5	$0.00	$340.97	$340.97	$304.33	($1,511.58)	
6	$0.00	$352.56	$352.56	$307.60	($1,203.98)	
7	$0.00	$364.55	$364.55	$310.91	($893.08)	
8	$0.00	$376.94	$376.94	$314.25	($578.83)	
9	$0.00	$389.76	$389.76	$317.63	($261.20)	
10	$0.00	$403.01	$403.01	$321.04	$59.84	9.8
11	$0.00	$416.72	$416.72	$324.49	$384.34	
12	$0.00	$430.88	$430.88	$327.98	$712.32	
13	$0.00	$445.53	$445.53	$331.51	$1,043.83	
14	$0.00	$460.68	$460.68	$335.08	$1,378.91	
15	$0.00	$476.35	$476.35	$338.68	$1,717.58	
16	$0.00	$492.54	$492.54	$342.32	$2,059.90	
17	$0.00	$509.29	$509.29	$346.00	$2,405.90	
18	$0.00	$526.60	$526.60	$349.72	$2,755.63	
19	$0.00	$544.51	$544.51	$353.48	$3,109.11	
20	$0.00	$563.02	$563.02	$357.28	$3,466.39	
21	$0.00	$582.16	$582.16	$361.12	$3,827.51	
22	$0.00	$601.96	$601.96	$365.01	$4,192.52	
23	$0.00	$622.42	$622.42	$368.93	$4,561.45	
24	$0.00	$643.59	$643.59	$372.90	$4,934.35	
25	$0.00	$665.47	$665.47	$376.91	$5,311.26	
26	$0.00	$688.09	$688.09	$380.96	$5,692.22	
27	$0.00	$711.49	$711.49	$385.06	$6,077.28	
28	$0.00	$735.68	$735.68	$389.20	$6,466.48	
29	$0.00	$760.69	$760.69	$393.38	$6,859.86	
30	$0.00	$786.56	$786.56	$397.61	$7,257.48	

Total Value of Net Savings After 30 Years: $10,258.65 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	3,420.99	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$427.62	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$442.16	$442.16	$432.22	($2,568.95)	
2	$0.00	$457.20	$457.20	$436.87	($2,132.08)	
3	$0.00	$472.74	$472.74	$441.57	($1,690.52)	
4	$0.00	$488.81	$488.81	$446.31	($1,244.20)	
5	$0.00	$505.43	$505.43	$451.11	($793.09)	
6	$0.00	$522.62	$522.62	$455.96	($337.12)	
7	$0.00	$540.39	$540.39	$460.87	$123.74	6.7
8	$0.00	$558.76	$558.76	$465.82	$589.57	
9	$0.00	$577.76	$577.76	$470.83	$1,060.40	
10	$0.00	$597.40	$597.40	$475.89	$1,536.29	
11	$0.00	$617.71	$617.71	$481.01	$2,017.30	
12	$0.00	$638.72	$638.72	$486.18	$2,503.49	
13	$0.00	$660.43	$660.43	$491.41	$2,994.90	
14	$0.00	$682.89	$682.89	$496.70	$3,491.59	
15	$0.00	$706.11	$706.11	$502.04	$3,993.63	
16	$0.00	$730.11	$730.11	$507.43	$4,501.06	
17	$0.00	$754.94	$754.94	$512.89	$5,013.96	
18	$0.00	$780.60	$780.60	$518.41	$5,532.36	
19	$0.00	$807.15	$807.15	$523.98	$6,056.34	
20	$0.00	$834.59	$834.59	$529.61	$6,585.96	
21	$0.00	$862.96	$862.96	$535.31	$7,121.26	
22	$0.00	$892.31	$892.31	$541.06	$7,662.33	
23	$0.00	$922.64	$922.64	$546.88	$8,209.21	
24	$0.00	$954.01	$954.01	$552.76	$8,761.98	
25	$0.00	$986.45	$986.45	$558.71	$9,320.68	
26	$0.00	$1,019.99	$1,019.99	$564.71	$9,885.40	
27	$0.00	$1,054.67	$1,054.67	$570.79	$10,456.18	
28	$0.00	$1,090.53	$1,090.53	$576.92	$11,033.11	
29	$0.00	$1,127.61	$1,127.61	$583.13	$11,616.24	
30	$0.00	$1,165.94	$1,165.94	$589.40	$12,205.63	

Total Value of Net Savings After 30 Years: $15,206.81 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	4,626.06	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$578.26	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$597.92	$597.92	$584.48	($2,416.70)	
2	$0.00	$618.25	$618.25	$590.76	($1,825.94)	
3	$0.00	$639.27	$639.27	$597.11	($1,228.83)	
4	$0.00	$661.00	$661.00	$603.53	($625.29)	
5	$0.00	$683.48	$683.48	$610.02	($15.27)	
6	$0.00	$706.72	$706.72	$616.58	$601.31	5.0
7	$0.00	$730.74	$730.74	$623.21	$1,224.53	
8	$0.00	$755.59	$755.59	$629.91	$1,854.44	
9	$0.00	$781.28	$781.28	$636.69	$2,491.13	
10	$0.00	$807.84	$807.84	$643.53	$3,134.66	
11	$0.00	$835.31	$835.31	$650.45	$3,785.11	
12	$0.00	$863.71	$863.71	$657.45	$4,442.56	
13	$0.00	$893.08	$893.08	$664.52	$5,107.07	
14	$0.00	$923.44	$923.44	$671.66	$5,778.73	
15	$0.00	$954.84	$954.84	$678.88	$6,457.62	
16	$0.00	$987.30	$987.30	$686.18	$7,143.80	
17	$0.00	$1,020.87	$1,020.87	$693.56	$7,837.36	
18	$0.00	$1,055.58	$1,055.58	$701.02	$8,538.38	
19	$0.00	$1,091.47	$1,091.47	$708.56	$9,246.94	
20	$0.00	$1,128.58	$1,128.58	$716.18	$9,963.12	
21	$0.00	$1,166.95	$1,166.95	$723.88	$10,686.99	
22	$0.00	$1,206.63	$1,206.63	$731.66	$11,418.65	
23	$0.00	$1,247.65	$1,247.65	$739.53	$12,158.18	
24	$0.00	$1,290.07	$1,290.07	$747.48	$12,905.66	
25	$0.00	$1,333.94	$1,333.94	$755.52	$13,661.18	
26	$0.00	$1,379.29	$1,379.29	$763.64	$14,424.82	
27	$0.00	$1,426.19	$1,426.19	$771.85	$15,196.67	
28	$0.00	$1,474.68	$1,474.68	$780.15	$15,976.82	
29	$0.00	$1,524.82	$1,524.82	$788.54	$16,765.36	
30	$0.00	$1,576.66	$1,576.66	$797.02	$17,562.38	

Total Value of Net Savings After 30 Years: $20,563.55 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	5,766.13	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$720.77	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$745.27	$745.27	$728.52	($2,272.66)	
2	$0.00	$770.61	$770.61	$736.35	($1,536.31)	
3	$0.00	$796.81	$796.81	$744.27	($792.04)	
4	$0.00	$823.90	$823.90	$752.27	($39.77)	
5	$0.00	$851.92	$851.92	$760.36	$720.59	4.1
6	$0.00	$880.88	$880.88	$768.53	$1,489.12	
7	$0.00	$910.83	$910.83	$776.80	$2,265.92	
8	$0.00	$941.80	$941.80	$785.15	$3,051.07	
9	$0.00	$973.82	$973.82	$793.59	$3,844.67	
10	$0.00	$1,006.93	$1,006.93	$802.13	$4,646.79	
11	$0.00	$1,041.17	$1,041.17	$810.75	$5,457.54	
12	$0.00	$1,076.57	$1,076.57	$819.47	$6,277.01	
13	$0.00	$1,113.17	$1,113.17	$828.28	$7,105.29	
14	$0.00	$1,151.02	$1,151.02	$837.19	$7,942.48	
15	$0.00	$1,190.15	$1,190.15	$846.19	$8,788.67	
16	$0.00	$1,230.62	$1,230.62	$855.29	$9,643.96	
17	$0.00	$1,272.46	$1,272.46	$864.48	$10,508.45	
18	$0.00	$1,315.72	$1,315.72	$873.78	$11,382.23	
19	$0.00	$1,360.46	$1,360.46	$883.18	$12,265.40	
20	$0.00	$1,406.71	$1,406.71	$892.67	$13,158.07	
21	$0.00	$1,454.54	$1,454.54	$902.27	$14,060.35	
22	$0.00	$1,503.99	$1,503.99	$911.97	$14,972.32	
23	$0.00	$1,555.13	$1,555.13	$921.78	$15,894.10	
24	$0.00	$1,608.00	$1,608.00	$931.69	$16,825.79	
25	$0.00	$1,662.68	$1,662.68	$941.71	$17,767.50	
26	$0.00	$1,719.21	$1,719.21	$951.83	$18,719.33	
27	$0.00	$1,777.66	$1,777.66	$962.07	$19,681.40	
28	$0.00	$1,838.10	$1,838.10	$972.41	$20,653.82	
29	$0.00	$1,900.60	$1,900.60	$982.87	$21,636.69	
30	$0.00	$1,965.22	$1,965.22	$993.44	$22,630.13	

Total Value of Net Savings After 30 Years: $25,631.30 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 6 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	6,588.24	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$823.53	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$851.53	$851.53	$832.39	($2,168.79)	
2	$0.00	$880.48	$880.48	$841.34	($1,327.45)	
3	$0.00	$910.42	$910.42	$850.38	($477.07)	
4	$0.00	$941.37	$941.37	$859.53	$382.45	3.6
5	$0.00	$973.38	$973.38	$868.77	$1,251.22	
6	$0.00	$1,006.47	$1,006.47	$878.11	$2,129.33	
7	$0.00	$1,040.69	$1,040.69	$887.55	$3,016.88	
8	$0.00	$1,076.08	$1,076.08	$897.10	$3,913.98	
9	$0.00	$1,112.66	$1,112.66	$906.74	$4,820.72	
10	$0.00	$1,150.49	$1,150.49	$916.49	$5,737.21	
11	$0.00	$1,189.61	$1,189.61	$926.35	$6,663.56	
12	$0.00	$1,230.06	$1,230.06	$936.31	$7,599.87	
13	$0.00	$1,271.88	$1,271.88	$946.37	$8,546.24	
14	$0.00	$1,315.12	$1,315.12	$956.55	$9,502.79	
15	$0.00	$1,359.84	$1,359.84	$966.84	$10,469.63	
16	$0.00	$1,406.07	$1,406.07	$977.23	$11,446.86	
17	$0.00	$1,453.88	$1,453.88	$987.74	$12,434.60	
18	$0.00	$1,503.31	$1,503.31	$998.36	$13,432.96	
19	$0.00	$1,554.42	$1,554.42	$1,009.10	$14,442.06	
20	$0.00	$1,607.27	$1,607.27	$1,019.95	$15,462.00	
21	$0.00	$1,661.92	$1,661.92	$1,030.91	$16,492.92	
22	$0.00	$1,718.43	$1,718.43	$1,042.00	$17,534.92	
23	$0.00	$1,776.85	$1,776.85	$1,053.20	$18,588.12	
24	$0.00	$1,837.27	$1,837.27	$1,064.53	$19,652.65	
25	$0.00	$1,899.73	$1,899.73	$1,075.97	$20,728.62	
26	$0.00	$1,964.33	$1,964.33	$1,087.54	$21,816.17	
27	$0.00	$2,031.11	$2,031.11	$1,099.24	$22,915.40	
28	$0.00	$2,100.17	$2,100.17	$1,111.06	$24,026.46	
29	$0.00	$2,171.58	$2,171.58	$1,123.00	$25,149.47	
30	$0.00	$2,245.41	$2,245.41	$1,135.08	$26,284.55	

Total Value of Net Savings After 30 Years: $29,285.72 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	7,643.00	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$955.37	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$987.86	$987.86	$965.65	($2,035.53)	
2	$0.00	$1,021.44	$1,021.44	$976.03	($1,059.50)	
3	$0.00	$1,056.17	$1,056.17	$986.53	($72.97)	
4	$0.00	$1,092.08	$1,092.08	$997.13	$924.16	3.1
5	$0.00	$1,129.21	$1,129.21	$1,007.86	$1,932.02	
6	$0.00	$1,167.61	$1,167.61	$1,018.69	$2,950.71	
7	$0.00	$1,207.31	$1,207.31	$1,029.65	$3,980.36	
8	$0.00	$1,248.36	$1,248.36	$1,040.72	$5,021.08	
9	$0.00	$1,290.80	$1,290.80	$1,051.91	$6,072.99	
10	$0.00	$1,334.69	$1,334.69	$1,063.22	$7,136.21	
11	$0.00	$1,380.07	$1,380.07	$1,074.65	$8,210.86	
12	$0.00	$1,426.99	$1,426.99	$1,086.21	$9,297.06	
13	$0.00	$1,475.51	$1,475.51	$1,097.89	$10,394.95	
14	$0.00	$1,525.67	$1,525.67	$1,109.69	$11,504.64	
15	$0.00	$1,577.55	$1,577.55	$1,121.62	$12,626.27	
16	$0.00	$1,631.18	$1,631.18	$1,133.68	$13,759.95	
17	$0.00	$1,686.64	$1,686.64	$1,145.87	$14,905.83	
18	$0.00	$1,743.99	$1,743.99	$1,158.20	$16,064.02	
19	$0.00	$1,803.28	$1,803.28	$1,170.65	$17,234.67	
20	$0.00	$1,864.60	$1,864.60	$1,183.24	$18,417.91	
21	$0.00	$1,927.99	$1,927.99	$1,195.96	$19,613.87	
22	$0.00	$1,993.54	$1,993.54	$1,208.82	$20,822.69	
23	$0.00	$2,061.32	$2,061.32	$1,221.82	$22,044.51	
24	$0.00	$2,131.41	$2,131.41	$1,234.96	$23,279.47	
25	$0.00	$2,203.88	$2,203.88	$1,248.24	$24,527.70	
26	$0.00	$2,278.81	$2,278.81	$1,261.66	$25,789.36	
27	$0.00	$2,356.29	$2,356.29	$1,275.22	$27,064.58	
28	$0.00	$2,436.40	$2,436.40	$1,288.94	$28,353.52	
29	$0.00	$2,519.24	$2,519.24	$1,302.79	$29,656.31	
30	$0.00	$2,604.89	$2,604.89	$1,316.80	$30,973.11	

Total Value of Net Savings After 30 Years: $33,974.29 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Dimpled Flange Stud
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	11,258.95	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,407.37	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$1,455.22	$1,455.22	$1,422.50	($1,578.67)	
2	$0.00	$1,504.70	$1,504.70	$1,437.80	($140.88)	
3	$0.00	$1,555.86	$1,555.86	$1,453.26	$1,312.38	2.1
4	$0.00	$1,608.76	$1,608.76	$1,468.88	$2,781.27	
5	$0.00	$1,663.45	$1,663.45	$1,484.68	$4,265.94	
6	$0.00	$1,720.01	$1,720.01	$1,500.64	$5,766.59	
7	$0.00	$1,778.49	$1,778.49	$1,516.78	$7,283.37	
8	$0.00	$1,838.96	$1,838.96	$1,533.09	$8,816.45	
9	$0.00	$1,901.48	$1,901.48	$1,549.57	$10,366.03	
10	$0.00	$1,966.13	$1,966.13	$1,566.23	$11,932.26	
11	$0.00	$2,032.98	$2,032.98	$1,583.08	$13,515.34	
12	$0.00	$2,102.10	$2,102.10	$1,600.10	$15,115.44	
13	$0.00	$2,173.58	$2,173.58	$1,617.30	$16,732.74	
14	$0.00	$2,247.48	$2,247.48	$1,634.69	$18,367.43	
15	$0.00	$2,323.89	$2,323.89	$1,652.27	$20,019.71	
16	$0.00	$2,402.90	$2,402.90	$1,670.04	$21,689.74	
17	$0.00	$2,484.60	$2,484.60	$1,688.00	$23,377.74	
18	$0.00	$2,569.08	$2,569.08	$1,706.15	$25,083.89	
19	$0.00	$2,656.43	$2,656.43	$1,724.49	$26,808.38	
20	$0.00	$2,746.75	$2,746.75	$1,743.03	$28,551.41	
21	$0.00	$2,840.14	$2,840.14	$1,761.78	$30,313.19	
22	$0.00	$2,936.70	$2,936.70	$1,780.72	$32,093.91	
23	$0.00	$3,036.55	$3,036.55	$1,799.87	$33,893.78	
24	$0.00	$3,139.79	$3,139.79	$1,819.22	$35,713.00	
25	$0.00	$3,246.54	$3,246.54	$1,838.78	$37,551.78	
26	$0.00	$3,356.93	$3,356.93	$1,858.55	$39,410.34	
27	$0.00	$3,471.06	$3,471.06	$1,878.54	$41,288.88	
28	$0.00	$3,589.08	$3,589.08	$1,898.74	$43,187.61	
29	$0.00	$3,711.11	$3,711.11	$1,919.16	$45,106.77	
30	$0.00	$3,837.28	$3,837.28	$1,939.79	$47,046.56	

Total Value of Net Savings After 30 Years: $50,047.73 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	2,530.37	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$316.30	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$327.05	$327.05	$319.70	($7,183.24)	
2	$0.00	$338.17	$338.17	$323.14	($6,860.10)	
3	$0.00	$349.67	$349.67	$326.61	($6,533.49)	
4	$0.00	$361.56	$361.56	$330.12	($6,203.37)	
5	$0.00	$373.85	$373.85	$333.67	($5,869.70)	
6	$0.00	$386.56	$386.56	$337.26	($5,532.44)	
7	$0.00	$399.70	$399.70	$340.89	($5,191.55)	
8	$0.00	$413.29	$413.29	$344.55	($4,847.00)	
9	$0.00	$427.35	$427.35	$348.26	($4,498.75)	
10	$0.00	$441.88	$441.88	$352.00	($4,146.75)	
11	$0.00	$456.90	$456.90	$355.79	($3,790.96)	
12	$0.00	$472.43	$472.43	$359.61	($3,431.35)	
13	$0.00	$488.50	$488.50	$363.48	($3,067.87)	
14	$0.00	$505.11	$505.11	$367.39	($2,700.49)	
15	$0.00	$522.28	$522.28	$371.34	($2,329.15)	
16	$0.00	$540.04	$540.04	$375.33	($1,953.82)	
17	$0.00	$558.40	$558.40	$379.37	($1,574.45)	
18	$0.00	$577.38	$577.38	$383.44	($1,191.01)	
19	$0.00	$597.01	$597.01	$387.57	($803.44)	
20	$0.00	$617.31	$617.31	$391.74	($411.71)	
21	$0.00	$638.30	$638.30	$395.95	($15.76)	
22	$0.00	$660.00	$660.00	$400.20	$384.45	21.0
23	$0.00	$682.44	$682.44	$404.51	$788.95	
24	$0.00	$705.65	$705.65	$408.86	$1,197.81	
25	$0.00	$729.64	$729.64	$413.25	$1,611.07	
26	$0.00	$754.45	$754.45	$417.70	$2,028.76	
27	$0.00	$780.10	$780.10	$422.19	$2,450.95	
28	$0.00	$806.62	$806.62	$426.73	$2,877.68	
29	$0.00	$834.05	$834.05	$431.32	$3,309.00	
30	$0.00	$862.40	$862.40	$435.95	$3,744.95	

Total Value of Net Savings After 30 Years: $11,247.89 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	2,683.41	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$335.43	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$346.83	$346.83	$339.03	($7,163.90)	
2	$0.00	$358.62	$358.62	$342.68	($6,821.22)	
3	$0.00	$370.82	$370.82	$346.36	($6,474.86)	
4	$0.00	$383.42	$383.42	$350.09	($6,124.77)	
5	$0.00	$396.46	$396.46	$353.85	($5,770.92)	
6	$0.00	$409.94	$409.94	$357.66	($5,413.27)	
7	$0.00	$423.88	$423.88	$361.50	($5,051.76)	
8	$0.00	$438.29	$438.29	$365.39	($4,686.38)	
9	$0.00	$453.19	$453.19	$369.32	($4,317.06)	
10	$0.00	$468.60	$468.60	$373.29	($3,943.77)	
11	$0.00	$484.53	$484.53	$377.30	($3,566.47)	
12	$0.00	$501.01	$501.01	$381.36	($3,185.11)	
13	$0.00	$518.04	$518.04	$385.46	($2,799.64)	
14	$0.00	$535.65	$535.65	$389.61	($2,410.04)	
15	$0.00	$553.87	$553.87	$393.79	($2,016.24)	
16	$0.00	$572.70	$572.70	$398.03	($1,618.21)	
17	$0.00	$592.17	$592.17	$402.31	($1,215.91)	
18	$0.00	$612.30	$612.30	$406.63	($809.27)	
19	$0.00	$633.12	$633.12	$411.01	($398.26)	
20	$0.00	$654.65	$654.65	$415.43	$17.16	20.0
21	$0.00	$676.91	$676.91	$419.89	$437.06	
22	$0.00	$699.92	$699.92	$424.41	$861.47	
23	$0.00	$723.72	$723.72	$428.97	$1,290.44	
24	$0.00	$748.32	$748.32	$433.58	$1,724.02	
25	$0.00	$773.77	$773.77	$438.25	$2,162.27	
26	$0.00	$800.07	$800.07	$442.96	$2,605.23	
27	$0.00	$827.28	$827.28	$447.72	$3,052.95	
28	$0.00	$855.40	$855.40	$452.54	$3,505.49	
29	$0.00	$884.49	$884.49	$457.40	$3,962.89	
30	$0.00	$914.56	$914.56	$462.32	$4,425.21	

Total Value of Net Savings After 30 Years: $11,928.15 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	3,764.47	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$470.56	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$486.56	$486.56	$475.62	($7,027.32)	
2	$0.00	$503.10	$503.10	$480.73	($6,546.58)	
3	$0.00	$520.21	$520.21	$485.90	($6,060.68)	
4	$0.00	$537.89	$537.89	$491.13	($5,569.56)	
5	$0.00	$556.18	$556.18	$496.41	($5,073.15)	
6	$0.00	$575.09	$575.09	$501.75	($4,571.40)	
7	$0.00	$594.64	$594.64	$507.14	($4,064.26)	
8	$0.00	$614.86	$614.86	$512.59	($3,551.67)	
9	$0.00	$635.77	$635.77	$518.11	($3,033.56)	
10	$0.00	$657.38	$657.38	$523.68	($2,509.89)	
11	$0.00	$679.74	$679.74	$529.31	($1,980.58)	
12	$0.00	$702.85	$702.85	$535.00	($1,445.58)	
13	$0.00	$726.74	$726.74	$540.75	($904.83)	
14	$0.00	$751.45	$751.45	$546.57	($358.26)	
15	$0.00	$777.00	$777.00	$552.44	$194.18	14.6
16	$0.00	$803.42	$803.42	$558.38	$752.56	
17	$0.00	$830.74	$830.74	$564.39	$1,316.95	
18	$0.00	$858.98	$858.98	$570.46	$1,887.41	
19	$0.00	$888.19	$888.19	$576.59	$2,464.00	
20	$0.00	$918.38	$918.38	$582.79	$3,046.79	
21	$0.00	$949.61	$949.61	$589.06	$3,635.84	
22	$0.00	$981.90	$981.90	$595.39	$4,231.23	
23	$0.00	$1,015.28	$1,015.28	$601.79	$4,833.03	
24	$0.00	$1,049.80	$1,049.80	$608.26	$5,441.29	
25	$0.00	$1,085.49	$1,085.49	$614.80	$6,056.09	
26	$0.00	$1,122.40	$1,122.40	$621.41	$6,677.51	
27	$0.00	$1,160.56	$1,160.56	$628.10	$7,305.60	
28	$0.00	$1,200.02	$1,200.02	$634.85	$7,940.45	
29	$0.00	$1,240.82	$1,240.82	$641.68	$8,582.13	
30	$0.00	$1,283.01	$1,283.01	$648.58	$9,230.71	

Total Value of Net Savings After 30 Years: $16,733.64 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	5,091.40	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$636.42	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$658.06	$658.06	$643.27	($6,859.67)	
2	$0.00	$680.44	$680.44	$650.18	($6,209.48)	
3	$0.00	$703.57	$703.57	$657.18	($5,552.31)	
4	$0.00	$727.49	$727.49	$664.24	($4,888.06)	
5	$0.00	$752.23	$752.23	$671.38	($4,216.68)	
6	$0.00	$777.80	$777.80	$678.60	($3,538.07)	
7	$0.00	$804.25	$804.25	$685.90	($2,852.17)	
8	$0.00	$831.59	$831.59	$693.28	($2,158.90)	
9	$0.00	$859.87	$859.87	$700.73	($1,458.17)	
10	$0.00	$889.10	$889.10	$708.27	($749.90)	
11	$0.00	$919.33	$919.33	$715.88	($34.02)	
12	$0.00	$950.59	$950.59	$723.58	$689.56	11.0
13	$0.00	$982.91	$982.91	$731.36	$1,420.92	
14	$0.00	$1,016.33	$1,016.33	$739.22	$2,160.14	
15	$0.00	$1,050.88	$1,050.88	$747.17	$2,907.31	
16	$0.00	$1,086.61	$1,086.61	$755.21	$3,662.52	
17	$0.00	$1,123.56	$1,123.56	$763.33	$4,425.85	
18	$0.00	$1,161.76	$1,161.76	$771.53	$5,197.38	
19	$0.00	$1,201.26	$1,201.26	$779.83	$5,977.21	
20	$0.00	$1,242.10	$1,242.10	$788.22	$6,765.43	
21	$0.00	$1,284.34	$1,284.34	$796.69	$7,562.12	
22	$0.00	$1,328.00	$1,328.00	$805.26	$8,367.38	
23	$0.00	$1,373.15	$1,373.15	$813.92	$9,181.29	
24	$0.00	$1,419.84	$1,419.84	$822.67	$10,003.96	
25	$0.00	$1,468.12	$1,468.12	$831.51	$10,835.47	
26	$0.00	$1,518.03	$1,518.03	$840.46	$11,675.93	
27	$0.00	$1,569.65	$1,569.65	$849.49	$12,525.42	
28	$0.00	$1,623.01	$1,623.01	$858.63	$13,384.05	
29	$0.00	$1,678.20	$1,678.20	$867.86	$14,251.91	
30	$0.00	$1,735.25	$1,735.25	$877.19	$15,129.10	

Total Value of Net Savings After 30 Years: $22,632.03 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	6,344.23	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$793.03	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$819.99	$819.99	$801.56	($6,701.38)	
2	$0.00	$847.87	$847.87	$810.17	($5,891.21)	
3	$0.00	$876.70	$876.70	$818.89	($5,072.32)	
4	$0.00	$906.51	$906.51	$827.69	($4,244.63)	
5	$0.00	$937.33	$937.33	$836.59	($3,408.04)	
6	$0.00	$969.20	$969.20	$845.59	($2,562.45)	
7	$0.00	$1,002.15	$1,002.15	$854.68	($1,707.77)	
8	$0.00	$1,036.22	$1,036.22	$863.87	($843.90)	
9	$0.00	$1,071.45	$1,071.45	$873.16	$29.25	9.0
10	$0.00	$1,107.88	$1,107.88	$882.55	$911.80	
11	$0.00	$1,145.55	$1,145.55	$892.04	$1,803.84	
12	$0.00	$1,184.50	$1,184.50	$901.63	$2,705.47	
13	$0.00	$1,224.77	$1,224.77	$911.32	$3,616.79	
14	$0.00	$1,266.42	$1,266.42	$921.12	$4,537.91	
15	$0.00	$1,309.47	$1,309.47	$931.03	$5,468.94	
16	$0.00	$1,354.00	$1,354.00	$941.04	$6,409.97	
17	$0.00	$1,400.03	$1,400.03	$951.16	$7,361.13	
18	$0.00	$1,447.63	$1,447.63	$961.38	$8,322.52	
19	$0.00	$1,496.85	$1,496.85	$971.72	$9,294.24	
20	$0.00	$1,547.74	$1,547.74	$982.17	$10,276.41	
21	$0.00	$1,600.37	$1,600.37	$992.73	$11,269.14	
22	$0.00	$1,654.78	$1,654.78	$1,003.41	$12,272.54	
23	$0.00	$1,711.04	$1,711.04	$1,014.19	$13,286.74	
24	$0.00	$1,769.22	$1,769.22	$1,025.10	$14,311.84	
25	$0.00	$1,829.37	$1,829.37	$1,036.12	$15,347.96	
26	$0.00	$1,891.57	$1,891.57	$1,047.26	$16,395.23	
27	$0.00	$1,955.88	$1,955.88	$1,058.52	$17,453.75	
28	$0.00	$2,022.38	$2,022.38	$1,069.91	$18,523.66	
29	$0.00	$2,091.15	$2,091.15	$1,081.41	$19,605.07	
30	$0.00	$2,162.24	$2,162.24	$1,093.04	$20,698.11	

Total Value of Net Savings After 30 Years: $28,201.04 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 6 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	7,248.81	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$906.10	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$936.91	$936.91	$915.84	($6,587.09)	
2	$0.00	$968.76	$968.76	$925.69	($5,661.40)	
3	$0.00	$1,001.70	$1,001.70	$935.65	($4,725.75)	
4	$0.00	$1,035.76	$1,035.76	$945.71	($3,780.05)	
5	$0.00	$1,070.97	$1,070.97	$955.88	($2,824.17)	
6	$0.00	$1,107.39	$1,107.39	$966.15	($1,858.02)	
7	$0.00	$1,145.04	$1,145.04	$976.54	($881.48)	
8	$0.00	$1,183.97	$1,183.97	$987.04	$105.57	7.9
9	$0.00	$1,224.23	$1,224.23	$997.66	$1,103.22	
10	$0.00	$1,265.85	$1,265.85	$1,008.38	$2,111.60	
11	$0.00	$1,308.89	$1,308.89	$1,019.23	$3,130.83	
12	$0.00	$1,353.39	$1,353.39	$1,030.19	$4,161.02	
13	$0.00	$1,399.41	$1,399.41	$1,041.26	$5,202.28	
14	$0.00	$1,446.99	$1,446.99	$1,052.46	$6,254.74	
15	$0.00	$1,496.18	$1,496.18	$1,063.78	$7,318.51	
16	$0.00	$1,547.05	$1,547.05	$1,075.21	$8,393.73	
17	$0.00	$1,599.65	$1,599.65	$1,086.78	$9,480.50	
18	$0.00	$1,654.04	$1,654.04	$1,098.46	$10,578.97	
19	$0.00	$1,710.28	$1,710.28	$1,110.27	$11,689.24	
20	$0.00	$1,768.43	$1,768.43	$1,122.21	$12,811.45	
21	$0.00	$1,828.55	$1,828.55	$1,134.28	$13,945.73	
22	$0.00	$1,890.73	$1,890.73	$1,146.47	$15,092.20	
23	$0.00	$1,955.01	$1,955.01	$1,158.80	$16,251.01	
24	$0.00	$2,021.48	$2,021.48	$1,171.26	$17,422.27	
25	$0.00	$2,090.21	$2,090.21	$1,183.86	$18,606.13	
26	$0.00	$2,161.28	$2,161.28	$1,196.59	$19,802.71	
27	$0.00	$2,234.76	$2,234.76	$1,209.45	$21,012.17	
28	$0.00	$2,310.74	$2,310.74	$1,222.46	$22,234.62	
29	$0.00	$2,389.31	$2,389.31	$1,235.60	$23,470.23	
30	$0.00	$2,470.55	$2,470.55	$1,248.89	$24,719.12	

Total Value of Net Savings After 30 Years: $32,222.05 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	8,412.39	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,051.55	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$1,087.30	$1,087.30	$1,062.86	($6,440.08)	
2	$0.00	$1,124.27	$1,124.27	$1,074.28	($5,365.80)	
3	$0.00	$1,162.49	$1,162.49	$1,085.84	($4,279.96)	
4	$0.00	$1,202.02	$1,202.02	$1,097.51	($3,182.45)	
5	$0.00	$1,242.89	$1,242.89	$1,109.31	($2,073.14)	
6	$0.00	$1,285.15	$1,285.15	$1,121.24	($951.90)	
7	$0.00	$1,328.84	$1,328.84	$1,133.30	$181.40	6.8
8	$0.00	$1,374.02	$1,374.02	$1,145.48	$1,326.88	
9	$0.00	$1,420.74	$1,420.74	$1,157.80	$2,484.68	
10	$0.00	$1,469.04	$1,469.04	$1,170.25	$3,654.93	
11	$0.00	$1,518.99	$1,518.99	$1,182.83	$4,837.77	
12	$0.00	$1,570.64	$1,570.64	$1,195.55	$6,033.32	
13	$0.00	$1,624.04	$1,624.04	$1,208.41	$7,241.72	
14	$0.00	$1,679.26	$1,679.26	$1,221.40	$8,463.12	
15	$0.00	$1,736.35	$1,736.35	$1,234.53	$9,697.66	
16	$0.00	$1,795.39	$1,795.39	$1,247.81	$10,945.47	
17	$0.00	$1,856.43	$1,856.43	$1,261.23	$12,206.69	
18	$0.00	$1,919.55	$1,919.55	$1,274.79	$13,481.48	
19	$0.00	$1,984.81	$1,984.81	$1,288.49	$14,769.97	
20	$0.00	$2,052.30	$2,052.30	$1,302.35	$16,072.32	
21	$0.00	$2,122.07	$2,122.07	$1,316.35	$17,388.68	
22	$0.00	$2,194.23	$2,194.23	$1,330.51	$18,719.18	
23	$0.00	$2,268.83	$2,268.83	$1,344.81	$20,064.00	
24	$0.00	$2,345.97	$2,345.97	$1,359.27	$21,423.27	
25	$0.00	$2,425.73	$2,425.73	$1,373.89	$22,797.16	
26	$0.00	$2,508.21	$2,508.21	$1,388.66	$24,185.82	
27	$0.00	$2,593.49	$2,593.49	$1,403.59	$25,589.42	
28	$0.00	$2,681.66	$2,681.66	$1,418.69	$27,008.11	
29	$0.00	$2,772.84	$2,772.84	$1,433.94	$28,442.05	
30	$0.00	$2,867.12	$2,867.12	$1,449.36	$29,891.41	

Total Value of Net Savings After 30 Years: $37,394.34 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Ridged Flange Stud
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$81,577.37	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$7,502.94	**Study Period (yrs):**	30

Energy Savings:	12,391.89	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,548.99	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$7,502.94	$0.00	($7,502.94)	($7,502.94)	($7,502.94)	
1	$0.00	$1,601.65	$1,601.65	$1,565.64	($5,937.29)	
2	$0.00	$1,656.11	$1,656.11	$1,582.48	($4,354.82)	
3	$0.00	$1,712.42	$1,712.42	$1,599.49	($2,755.32)	
4	$0.00	$1,770.64	$1,770.64	$1,616.69	($1,138.63)	
5	$0.00	$1,830.84	$1,830.84	$1,634.07	$495.44	4.7
6	$0.00	$1,893.09	$1,893.09	$1,651.65	$2,147.09	
7	$0.00	$1,957.45	$1,957.45	$1,669.41	$3,816.49	
8	$0.00	$2,024.01	$2,024.01	$1,687.36	$5,503.85	
9	$0.00	$2,092.82	$2,092.82	$1,705.50	$7,209.35	
10	$0.00	$2,163.98	$2,163.98	$1,723.84	$8,933.18	
11	$0.00	$2,237.55	$2,237.55	$1,742.37	$10,675.56	
12	$0.00	$2,313.63	$2,313.63	$1,761.11	$12,436.67	
13	$0.00	$2,392.29	$2,392.29	$1,780.05	$14,216.71	
14	$0.00	$2,473.63	$2,473.63	$1,799.19	$16,015.90	
15	$0.00	$2,557.73	$2,557.73	$1,818.53	$17,834.43	
16	$0.00	$2,644.70	$2,644.70	$1,838.09	$19,672.52	
17	$0.00	$2,734.62	$2,734.62	$1,857.85	$21,530.37	
18	$0.00	$2,827.59	$2,827.59	$1,877.83	$23,408.20	
19	$0.00	$2,923.73	$2,923.73	$1,898.02	$25,306.22	
20	$0.00	$3,023.14	$3,023.14	$1,918.43	$27,224.64	
21	$0.00	$3,125.93	$3,125.93	$1,939.06	$29,163.70	
22	$0.00	$3,232.21	$3,232.21	$1,959.91	$31,123.61	
23	$0.00	$3,342.10	$3,342.10	$1,980.98	$33,104.59	
24	$0.00	$3,455.73	$3,455.73	$2,002.28	$35,106.87	
25	$0.00	$3,573.23	$3,573.23	$2,023.81	$37,130.68	
26	$0.00	$3,694.72	$3,694.72	$2,045.57	$39,176.25	
27	$0.00	$3,820.34	$3,820.34	$2,067.57	$41,243.82	
28	$0.00	$3,950.23	$3,950.23	$2,089.80	$43,333.62	
29	$0.00	$4,084.54	$4,084.54	$2,112.27	$45,445.89	
30	$0.00	$4,223.41	$4,223.41	$2,134.98	$47,580.88	

Total Value of Net Savings After 30 Years: $55,083.81 **$7,502.94**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 1 - Miami, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	4,144.13	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$518.02	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$535.63	$535.63	$523.59	($2,477.59)	
2	$0.00	$553.84	$553.84	$529.22	($1,948.37)	
3	$0.00	$572.67	$572.67	$534.91	($1,413.47)	
4	$0.00	$592.14	$592.14	$540.66	($872.81)	
5	$0.00	$612.27	$612.27	$546.47	($326.34)	
6	$0.00	$633.09	$633.09	$552.35	$226.01	5.6
7	$0.00	$654.62	$654.62	$558.29	$784.30	
8	$0.00	$676.87	$676.87	$564.29	$1,348.59	
9	$0.00	$699.89	$699.89	$570.36	$1,918.95	
10	$0.00	$723.68	$723.68	$576.49	$2,495.44	
11	$0.00	$748.29	$748.29	$582.69	$3,078.13	
12	$0.00	$773.73	$773.73	$588.95	$3,667.08	
13	$0.00	$800.04	$800.04	$595.29	$4,262.37	
14	$0.00	$827.24	$827.24	$601.69	$4,864.06	
15	$0.00	$855.36	$855.36	$608.16	$5,472.21	
16	$0.00	$884.45	$884.45	$614.70	$6,086.91	
17	$0.00	$914.52	$914.52	$621.31	$6,708.22	
18	$0.00	$945.61	$945.61	$627.99	$7,336.21	
19	$0.00	$977.76	$977.76	$634.74	$7,970.95	
20	$0.00	$1,011.01	$1,011.01	$641.57	$8,612.51	
21	$0.00	$1,045.38	$1,045.38	$648.46	$9,260.98	
22	$0.00	$1,080.92	$1,080.92	$655.44	$9,916.41	
23	$0.00	$1,117.67	$1,117.67	$662.48	$10,578.90	
24	$0.00	$1,155.68	$1,155.68	$669.61	$11,248.51	
25	$0.00	$1,194.97	$1,194.97	$676.81	$11,925.32	
26	$0.00	$1,235.60	$1,235.60	$684.09	$12,609.40	
27	$0.00	$1,277.61	$1,277.61	$691.44	$13,300.84	
28	$0.00	$1,321.05	$1,321.05	$698.88	$13,999.72	
29	$0.00	$1,365.96	$1,365.96	$706.39	$14,706.11	
30	$0.00	$1,412.40	$1,412.40	$713.99	$15,420.10	

Total Value of Net Savings After 30 Years: $18,421.27 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 2 - Gainesville, Florida

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	4,159.33	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$519.92	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$537.59	$537.59	$525.51	($2,475.67)	
2	$0.00	$555.87	$555.87	$531.16	($1,944.51)	
3	$0.00	$574.77	$574.77	$536.87	($1,407.64)	
4	$0.00	$594.31	$594.31	$542.64	($865.00)	
5	$0.00	$614.52	$614.52	$548.48	($316.52)	
6	$0.00	$635.41	$635.41	$554.37	$237.85	5.6
7	$0.00	$657.02	$657.02	$560.33	$798.18	
8	$0.00	$679.36	$679.36	$566.36	$1,364.54	
9	$0.00	$702.45	$702.45	$572.45	$1,936.99	
10	$0.00	$726.34	$726.34	$578.61	$2,515.60	
11	$0.00	$751.03	$751.03	$584.83	$3,100.43	
12	$0.00	$776.57	$776.57	$591.12	$3,691.54	
13	$0.00	$802.97	$802.97	$597.47	$4,289.01	
14	$0.00	$830.27	$830.27	$603.90	$4,892.91	
15	$0.00	$858.50	$858.50	$610.39	$5,503.30	
16	$0.00	$887.69	$887.69	$616.95	$6,120.25	
17	$0.00	$917.87	$917.87	$623.59	$6,743.84	
18	$0.00	$949.08	$949.08	$630.29	$7,374.13	
19	$0.00	$981.35	$981.35	$637.07	$8,011.20	
20	$0.00	$1,014.72	$1,014.72	$643.92	$8,655.12	
21	$0.00	$1,049.22	$1,049.22	$650.84	$9,305.96	
22	$0.00	$1,084.89	$1,084.89	$657.84	$9,963.80	
23	$0.00	$1,121.77	$1,121.77	$664.92	$10,628.72	
24	$0.00	$1,159.92	$1,159.92	$672.06	$11,300.78	
25	$0.00	$1,199.35	$1,199.35	$679.29	$11,980.07	
26	$0.00	$1,240.13	$1,240.13	$686.60	$12,666.67	
27	$0.00	$1,282.29	$1,282.29	$693.98	$13,360.65	
28	$0.00	$1,325.89	$1,325.89	$701.44	$14,062.09	
29	$0.00	$1,370.97	$1,370.97	$708.98	$14,771.07	
30	$0.00	$1,417.59	$1,417.59	$716.61	$15,487.68	

Total Value of Net Savings After 30 Years: $18,488.85 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 3 - Atlanta, Georgia

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	6,164.88	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$770.61	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$796.81	$796.81	$778.90	($2,222.28)	
2	$0.00	$823.90	$823.90	$787.27	($1,435.01)	
3	$0.00	$851.92	$851.92	$795.74	($639.27)	
4	$0.00	$880.88	$880.88	$804.29	$165.02	3.8
5	$0.00	$910.83	$910.83	$812.94	$977.97	
6	$0.00	$941.80	$941.80	$821.68	$1,799.65	
7	$0.00	$973.82	$973.82	$830.52	$2,630.17	
8	$0.00	$1,006.93	$1,006.93	$839.45	$3,469.62	
9	$0.00	$1,041.17	$1,041.17	$848.47	$4,318.09	
10	$0.00	$1,076.57	$1,076.57	$857.60	$5,175.69	
11	$0.00	$1,113.17	$1,113.17	$866.82	$6,042.51	
12	$0.00	$1,151.02	$1,151.02	$876.14	$6,918.65	
13	$0.00	$1,190.15	$1,190.15	$885.56	$7,804.21	
14	$0.00	$1,230.62	$1,230.62	$895.08	$8,699.30	
15	$0.00	$1,272.46	$1,272.46	$904.71	$9,604.00	
16	$0.00	$1,315.72	$1,315.72	$914.44	$10,518.44	
17	$0.00	$1,360.45	$1,360.45	$924.27	$11,442.71	
18	$0.00	$1,406.71	$1,406.71	$934.21	$12,376.92	
19	$0.00	$1,454.54	$1,454.54	$944.25	$13,321.17	
20	$0.00	$1,503.99	$1,503.99	$954.41	$14,275.57	
21	$0.00	$1,555.13	$1,555.13	$964.67	$15,240.24	
22	$0.00	$1,608.00	$1,608.00	$975.04	$16,215.28	
23	$0.00	$1,662.67	$1,662.67	$985.53	$17,200.81	
24	$0.00	$1,719.21	$1,719.21	$996.12	$18,196.93	
25	$0.00	$1,777.66	$1,777.66	$1,006.83	$19,203.76	
26	$0.00	$1,838.10	$1,838.10	$1,017.66	$20,221.42	
27	$0.00	$1,900.59	$1,900.59	$1,028.60	$21,250.02	
28	$0.00	$1,965.21	$1,965.21	$1,039.66	$22,289.69	
29	$0.00	$2,032.03	$2,032.03	$1,050.84	$23,340.53	
30	$0.00	$2,101.12	$2,101.12	$1,062.14	$24,402.67	

Total Value of Net Savings After 30 Years: $27,403.84 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 4 - Seattle, Washington

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	8,362.74	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,045.34	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$1,080.88	$1,080.88	$1,056.58	($1,944.59)	
2	$0.00	$1,117.63	$1,117.63	$1,067.94	($876.65)	
3	$0.00	$1,155.63	$1,155.63	$1,079.43	$202.78	2.8
4	$0.00	$1,194.92	$1,194.92	$1,091.03	$1,293.81	
5	$0.00	$1,235.55	$1,235.55	$1,102.76	$2,396.58	
6	$0.00	$1,277.56	$1,277.56	$1,114.62	$3,511.20	
7	$0.00	$1,321.00	$1,321.00	$1,126.61	$4,637.81	
8	$0.00	$1,365.91	$1,365.91	$1,138.72	$5,776.53	
9	$0.00	$1,412.35	$1,412.35	$1,150.97	$6,927.49	
10	$0.00	$1,460.37	$1,460.37	$1,163.34	$8,090.84	
11	$0.00	$1,510.03	$1,510.03	$1,175.85	$9,266.69	
12	$0.00	$1,561.37	$1,561.37	$1,188.49	$10,455.18	
13	$0.00	$1,614.45	$1,614.45	$1,201.27	$11,656.46	
14	$0.00	$1,669.34	$1,669.34	$1,214.19	$12,870.65	
15	$0.00	$1,726.10	$1,726.10	$1,227.25	$14,097.89	
16	$0.00	$1,784.79	$1,784.79	$1,240.44	$15,338.34	
17	$0.00	$1,845.47	$1,845.47	$1,253.78	$16,592.12	
18	$0.00	$1,908.22	$1,908.22	$1,267.26	$17,859.38	
19	$0.00	$1,973.10	$1,973.10	$1,280.89	$19,140.27	
20	$0.00	$2,040.18	$2,040.18	$1,294.66	$20,434.93	
21	$0.00	$2,109.55	$2,109.55	$1,308.58	$21,743.52	
22	$0.00	$2,181.27	$2,181.27	$1,322.65	$23,066.17	
23	$0.00	$2,255.44	$2,255.44	$1,336.88	$24,403.05	
24	$0.00	$2,332.12	$2,332.12	$1,351.25	$25,754.30	
25	$0.00	$2,411.41	$2,411.41	$1,365.78	$27,120.08	
26	$0.00	$2,493.40	$2,493.40	$1,380.47	$28,500.55	
27	$0.00	$2,578.18	$2,578.18	$1,395.31	$29,895.86	
28	$0.00	$2,665.84	$2,665.84	$1,410.31	$31,306.17	
29	$0.00	$2,756.47	$2,756.47	$1,425.48	$32,731.65	
30	$0.00	$2,850.19	$2,850.19	$1,440.81	$34,172.45	

Total Value of Net Savings After 30 Years: $37,173.63 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 5 - Chicago, Illinois

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	10,398.76	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,299.85	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$1,344.04	$1,344.04	$1,313.82	($1,687.35)	
2	$0.00	$1,389.74	$1,389.74	$1,327.95	($359.40)	
3	$0.00	$1,436.99	$1,436.99	$1,342.23	$982.83	2.3
4	$0.00	$1,485.85	$1,485.85	$1,356.66	$2,339.49	
5	$0.00	$1,536.37	$1,536.37	$1,371.25	$3,710.74	
6	$0.00	$1,588.60	$1,588.60	$1,385.99	$5,096.73	
7	$0.00	$1,642.61	$1,642.61	$1,400.90	$6,497.63	
8	$0.00	$1,698.46	$1,698.46	$1,415.96	$7,913.59	
9	$0.00	$1,756.21	$1,756.21	$1,431.19	$9,344.77	
10	$0.00	$1,815.92	$1,815.92	$1,446.57	$10,791.35	
11	$0.00	$1,877.66	$1,877.66	$1,462.13	$12,253.48	
12	$0.00	$1,941.50	$1,941.50	$1,477.85	$13,731.33	
13	$0.00	$2,007.51	$2,007.51	$1,493.74	$15,225.07	
14	$0.00	$2,075.77	$2,075.77	$1,509.80	$16,734.87	
15	$0.00	$2,146.35	$2,146.35	$1,526.04	$18,260.91	
16	$0.00	$2,219.32	$2,219.32	$1,542.45	$19,803.36	
17	$0.00	$2,294.78	$2,294.78	$1,559.03	$21,362.39	
18	$0.00	$2,372.80	$2,372.80	$1,575.80	$22,938.19	
19	$0.00	$2,453.48	$2,453.48	$1,592.74	$24,530.93	
20	$0.00	$2,536.90	$2,536.90	$1,609.87	$26,140.79	
21	$0.00	$2,623.15	$2,623.15	$1,627.18	$27,767.97	
22	$0.00	$2,712.34	$2,712.34	$1,644.67	$29,412.64	
23	$0.00	$2,804.56	$2,804.56	$1,662.36	$31,075.00	
24	$0.00	$2,899.91	$2,899.91	$1,680.23	$32,755.23	
25	$0.00	$2,998.51	$2,998.51	$1,698.30	$34,453.53	
26	$0.00	$3,100.46	$3,100.46	$1,716.56	$36,170.10	
27	$0.00	$3,205.87	$3,205.87	$1,735.02	$37,905.11	
28	$0.00	$3,314.87	$3,314.87	$1,753.68	$39,658.79	
29	$0.00	$3,427.58	$3,427.58	$1,772.53	$41,431.32	
30	$0.00	$3,544.12	$3,544.12	$1,791.59	$43,222.91	

Total Value of Net Savings After 30 Years: $46,224.09 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 5 - Helena, Montana

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	11,901.27	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,487.66	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$1,538.24	$1,538.24	$1,503.66	($1,497.52)	
2	$0.00	$1,590.54	$1,590.54	$1,519.82	$22.31	2.0
3	$0.00	$1,644.62	$1,644.62	$1,536.17	$1,558.47	
4	$0.00	$1,700.54	$1,700.54	$1,552.68	$3,111.16	
5	$0.00	$1,758.35	$1,758.35	$1,569.38	$4,680.53	
6	$0.00	$1,818.14	$1,818.14	$1,586.25	$6,266.79	
7	$0.00	$1,879.95	$1,879.95	$1,603.31	$7,870.10	
8	$0.00	$1,943.87	$1,943.87	$1,620.55	$9,490.65	
9	$0.00	$2,009.96	$2,009.96	$1,637.98	$11,128.63	
10	$0.00	$2,078.30	$2,078.30	$1,655.59	$12,784.22	
11	$0.00	$2,148.97	$2,148.97	$1,673.39	$14,457.61	
12	$0.00	$2,222.03	$2,222.03	$1,691.38	$16,148.99	
13	$0.00	$2,297.58	$2,297.58	$1,709.57	$17,858.56	
14	$0.00	$2,375.70	$2,375.70	$1,727.95	$19,586.52	
15	$0.00	$2,456.47	$2,456.47	$1,746.53	$21,333.05	
16	$0.00	$2,539.99	$2,539.99	$1,765.31	$23,098.36	
17	$0.00	$2,626.35	$2,626.35	$1,784.30	$24,882.66	
18	$0.00	$2,715.65	$2,715.65	$1,803.48	$26,686.14	
19	$0.00	$2,807.98	$2,807.98	$1,822.87	$28,509.02	
20	$0.00	$2,903.45	$2,903.45	$1,842.47	$30,351.49	
21	$0.00	$3,002.17	$3,002.17	$1,862.29	$32,213.78	
22	$0.00	$3,104.24	$3,104.24	$1,882.31	$34,096.09	
23	$0.00	$3,209.78	$3,209.78	$1,902.55	$35,998.64	
24	$0.00	$3,318.92	$3,318.92	$1,923.01	$37,921.65	
25	$0.00	$3,431.76	$3,431.76	$1,943.69	$39,865.33	
26	$0.00	$3,548.44	$3,548.44	$1,964.59	$41,829.92	
27	$0.00	$3,669.09	$3,669.09	$1,985.71	$43,815.63	
28	$0.00	$3,793.84	$3,793.84	$2,007.06	$45,822.69	
29	$0.00	$3,922.83	$3,922.83	$2,028.64	$47,851.33	
30	$0.00	$4,056.20	$4,056.20	$2,050.46	$49,901.79	

Total Value of Net Savings After 30 Years: $52,902.96 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 7 - Minot, North Dakota

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	13,793.52	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$1,724.19	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$1,782.81	$1,782.81	$1,742.73	($1,258.44)	
2	$0.00	$1,843.43	$1,843.43	$1,761.47	$503.02	1.7
3	$0.00	$1,906.10	$1,906.10	$1,780.41	$2,283.43	
4	$0.00	$1,970.91	$1,970.91	$1,799.55	$4,082.99	
5	$0.00	$2,037.92	$2,037.92	$1,818.90	$5,901.89	
6	$0.00	$2,107.21	$2,107.21	$1,838.46	$7,740.35	
7	$0.00	$2,178.86	$2,178.86	$1,858.23	$9,598.58	
8	$0.00	$2,252.94	$2,252.94	$1,878.21	$11,476.79	
9	$0.00	$2,329.54	$2,329.54	$1,898.41	$13,375.20	
10	$0.00	$2,408.74	$2,408.74	$1,918.82	$15,294.02	
11	$0.00	$2,490.64	$2,490.64	$1,939.45	$17,233.47	
12	$0.00	$2,575.32	$2,575.32	$1,960.31	$19,193.77	
13	$0.00	$2,662.88	$2,662.88	$1,981.38	$21,175.16	
14	$0.00	$2,753.42	$2,753.42	$2,002.69	$23,177.85	
15	$0.00	$2,847.04	$2,847.04	$2,024.22	$25,202.07	
16	$0.00	$2,943.84	$2,943.84	$2,045.99	$27,248.06	
17	$0.00	$3,043.93	$3,043.93	$2,067.99	$29,316.05	
18	$0.00	$3,147.42	$3,147.42	$2,090.23	$31,406.28	
19	$0.00	$3,254.43	$3,254.43	$2,112.70	$33,518.98	
20	$0.00	$3,365.08	$3,365.08	$2,135.42	$35,654.40	
21	$0.00	$3,479.50	$3,479.50	$2,158.38	$37,812.78	
22	$0.00	$3,597.80	$3,597.80	$2,181.59	$39,994.37	
23	$0.00	$3,720.12	$3,720.12	$2,205.05	$42,199.42	
24	$0.00	$3,846.61	$3,846.61	$2,228.76	$44,428.17	
25	$0.00	$3,977.39	$3,977.39	$2,252.72	$46,680.90	
26	$0.00	$4,112.62	$4,112.62	$2,276.95	$48,957.84	
27	$0.00	$4,252.45	$4,252.45	$2,301.43	$51,259.27	
28	$0.00	$4,397.04	$4,397.04	$2,326.17	$53,585.44	
29	$0.00	$4,546.54	$4,546.54	$2,351.19	$55,936.63	
30	$0.00	$4,701.12	$4,701.12	$2,376.47	$58,313.10	

Total Value of Net Savings After 30 Years: $61,314.27 **$3,001.17**

LIFE CYCLE COST ANALYSIS
Slit Web Stud
Zone 8 - Nome, Alaska

Baseline Initial Cost:	$74,074.43	**Discount Rate:**	2.3%
Alternate Cost:	$77,075.61	**Energy Inflation Rate:**	3.4%
Additional Initial Cost:	$3,001.17	**Study Period (yrs):**	30

Energy Savings:	20,358.44	kWh
Average Energy Cost:	$0.125	per kWh
Annual Savings:	$2,544.81	

Year	Payment	Energy Savings	Net Savings	PV Net Savings	Accrued Savings	Breakeven Year?
0	$3,001.17	$0.00	($3,001.17)	($3,001.17)	($3,001.17)	
1	$0.00	$2,631.33	$2,631.33	$2,572.17	($429.00)	
2	$0.00	$2,720.79	$2,720.79	$2,599.83	$2,170.82	1.2
3	$0.00	$2,813.30	$2,813.30	$2,627.78	$4,798.60	
4	$0.00	$2,908.95	$2,908.95	$2,656.04	$7,454.64	
5	$0.00	$3,007.86	$3,007.86	$2,684.60	$10,139.24	
6	$0.00	$3,110.13	$3,110.13	$2,713.46	$12,852.70	
7	$0.00	$3,215.87	$3,215.87	$2,742.64	$15,595.34	
8	$0.00	$3,325.21	$3,325.21	$2,772.13	$18,367.48	
9	$0.00	$3,438.27	$3,438.27	$2,801.94	$21,169.41	
10	$0.00	$3,555.17	$3,555.17	$2,832.07	$24,001.48	
11	$0.00	$3,676.04	$3,676.04	$2,862.52	$26,864.00	
12	$0.00	$3,801.03	$3,801.03	$2,893.30	$29,757.30	
13	$0.00	$3,930.26	$3,930.26	$2,924.41	$32,681.71	
14	$0.00	$4,063.89	$4,063.89	$2,955.86	$35,637.57	
15	$0.00	$4,202.06	$4,202.06	$2,987.64	$38,625.21	
16	$0.00	$4,344.93	$4,344.93	$3,019.76	$41,644.97	
17	$0.00	$4,492.66	$4,492.66	$3,052.24	$44,697.21	
18	$0.00	$4,645.41	$4,645.41	$3,085.05	$47,782.26	
19	$0.00	$4,803.36	$4,803.36	$3,118.23	$50,900.49	
20	$0.00	$4,966.67	$4,966.67	$3,151.76	$54,052.25	
21	$0.00	$5,135.54	$5,135.54	$3,185.65	$57,237.90	
22	$0.00	$5,310.15	$5,310.15	$3,219.90	$60,457.80	
23	$0.00	$5,490.69	$5,490.69	$3,254.52	$63,712.32	
24	$0.00	$5,677.37	$5,677.37	$3,289.52	$67,001.84	
25	$0.00	$5,870.41	$5,870.41	$3,324.89	$70,326.73	
26	$0.00	$6,070.00	$6,070.00	$3,360.64	$73,687.37	
27	$0.00	$6,276.38	$6,276.38	$3,396.78	$77,084.15	
28	$0.00	$6,489.78	$6,489.78	$3,433.30	$80,517.45	
29	$0.00	$6,710.43	$6,710.43	$3,470.22	$83,987.67	
30	$0.00	$6,938.58	$6,938.58	$3,507.53	$87,495.20	

Total Value of Net Savings After 30 Years: $90,496.37 **$3,001.17**

LIST OF REFERENCES

ASHRAE. (2009). *Handook: Fundamentals.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

ASHRAE. (2010). *Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Building*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

Ben-Nakhi, A. E. (2003). "Development of an integrated dynamic thermal bridging assessment environment." *Energy and Buildings,* 35, 375-382.

Brock, L. (2005). *Designing the Exterior Wall: An Architectural Guide*. John Wiley & Sons, Hoboken, NJ.

Christian, J. E. & Kosny, J. (1996). "Thermal performance and wall ratings." *ASHRAE Journal-American Society of Heating Refrigerating and Air-Conditioning Engineers,* 38, 56-58.

Clarke, J. A. (2001). *Energy Simulation in Building Design*. Butterworh-Heinemann, Woburn, MA.

Coats, P. (2007). "Modeling and design approach for treatment of highly thermally conductive architectural elements in high performance buildings in mixed climates." *ASHRAE Journal-American Society of Heating Refrigerating and Air-Conditioning Engineers,* 47, 44-48..

Code of Federal Regulations. (2010). Title 10 - Energy, Volume 3, Chapter 2 – Department of Energy, Part 434 – Energy Code for New Commercial and Multi-Family High-Rise Residential Buildings.

Department of Energy (DOE). (2010). *Buildings Energy Data Book*. US Government Printing Office, Washington, DC.

Elhajj, N. (2006). "Development of cost-effective, energy efficient steel framing: Thermal performance of slit-web steel wall studs." NAHB Research Center, Upper Marlboro, MD.

Enermodal, (2001). "Modeling two- and three-dimensional heat transfer through composite wall and roof assemblies in hourly energy simulation programs." *1145-RP*, ASHRAE, Atlanta, GA.

Graf, T. (2008). "Portland architect rethinks the stud." *Daily Journal of Commerce*. Portland, OR. March 17, 2008.

Hoglund, T. & Burstrand, H. (1998). "Slotted steel studs to reduce thermal bridges in insulated walls." *Thin-Walled Structures*. Volume 32, Number 1, September 1998 , pp. 81-109(29)

Hugens, P. & Mipenz, B. E. (2010). "Thermal performance comparisons of timber stud and steel walls." *GreenBeing for Sustainable Building.* August 2010.

Kosny, J. & Christian, J. E. (1995). “Thermal evaluation of several configurations of insulation and structural materials for some metal stud walls.” *Energy and Buildings*, 22, 157-163.

Kosny, J. & Christian, J. E. (1997). “Metal stud wall systems: Thermal disaster, or modern wall systems with highly efficient thermal insulation?” ASTM. Insulation Materials, Testing and Application, v. 3, 1997.

Kosny, J. & Yarbrough, D. (1998). “Steel-framed buildings: Impacts of wall detail configurations on the whole wall thermal performance.” *ASHRAE Transactions* 1998, v.104 pt 2.

Kosny, J. (2001). “Steel stud walls: Breaking a thermal bridge.” *Home Energy*, July, 2001.

Kosny, J. & Desjarlais, A. (2001). “Energy performance of steel stud walls: Steel framing can perform as well as wood.” *Roofs + Walls*, October, 2001.

Kosny, J. & Kossecka, E. (2002). “Multi-dimensional heat transfer through complex building envelope assemblies in hourly energy simulation programs.” *Energy and Buildings*, 34, 445-454.

Kosny, J. & Yarbrough, D. (2007). “How the same wall can have several different r-values: Relations between amount of framing and overall thermal performance in wood and steel framed walls.” *Thermal Performance of the Exterior Envelopes of Buildings X*, proceedings of ASHRAE THERM X, Clearwater, FL.

Kosny, J. & Yarbrough, D. (2007). “Nano-scale insulation at work: Thermal performance of thermally bridged wood and steel structures insulated with local aerogel insulation”. *Thermal Performance of the Exterior Envelopes of Buildings X*, proceedings of ASHRAE THERM X.

Kosny, J., Biswas, K. & Childs, P. (2010). “Steady-state thermal performance evaluation of steel-framed wall assembly with local foam insulation. ASHRAE.

Kossecka, E. & Kosny, J. (1996). “Relations between structural and dynamic thermal characteristics of building walls.” Proceedings of 1996 International Symposium of CIB W67 *Energy and Mass Flows in the Life Cycle of Buildings*, Vienna, 4-10 August, pp. 627-632.

Kossecka E. & Kosny, J. (1997). “Equivalent wall as a dynamic model of a complex thermal structure.” *Journal of Thermal Insulation and Building Envelopes*, vol. 20, January 1997.

Kossecka, E. & Kosny, J. (2002). “Influence of insulation configuration on heating and cooling loads in a continuously used building.” *Energy and Buildings*, 34, 321-331.

Kossecka, E. & Kosny, J. (2005). “Three-dimensional conduction z-transfer function coefficients determined from the response factors.” *Energy and Buildings*, 37, 301-310.

Kossecka, E. & Kosny, J. (2008). “Hot-box testing of building envelope assemblies: A simplified procedure for estimation of minimum time of the test. *Journal of Testing and Evaluation,* 36, 242-249.

McDermott, J. F. (1975). “Load tests on steel-stud Walls.” *Proceedings of the 3rd International Specialty Conference on Cold-Formed Steel Structures*. University of Missouri-Rolla, Nov. 1975.

Mumovic, D. & Santamouris, M. (2009*). A Handbook of Sustainable Building Design & Engineering*. MPG Books, Ltd, Bodmin, England.

National Science & Technology Council (NSTC). (2008). “Final report: Federal research and development agenda for net-zero energy, high-performance green buildings.”

O’Brien, S. (2006). “Thermal bridging in the building envelope: Maximizing insulation effectiveness through careful design. *The Construction Specifier*. October 2006.

Petrie, T. & Childs, P. (1997). “Radiation control coatings installed on federal buildings at Tyndall Air Force Base: Pre-coating monitoring and fresh coating results.” *ORNL/CON-439/V1*, Oak Ridge National Laboratory.

Petrie, T. & Childs, P. (1997). “Radiation control coatings installed on federal buildings at Tyndall Air Force Base: Long-term monitoring and modeling. *ORNL/CON-439/V2*, Oak Ridge National Laboratory.

Straube, J. F. & Burnett, E. F. F. (2005). *Building Science for Building Enclosures*. Building Science Press, Westford, CT.

Strzepek, W.R. (1990). “Thermal resistances of metal frame wall constructions incorporating various combinations of insulating materials.” *Insulation Materials, Testing and Applications, ASTM/STP 1030, 1990.*

Strohl, Fred. (1995). “New type of steel stud tested at ORNL”. Oak Ridge National Laboratory, in press.

Syed A. M. & Kosny, J. (2006). “Effect of framing factor on clear wall r-value for wood and steel framed walls.” *Journal of Building Physics,* 30, 163-180.

BIOGRAPHICAL SKETCH

Brian Kevin Bennett was born in 1968 in Perry, Florida. He is the third child of Olen and Evelyn Bennett. He graduated from Gainesville High School in the spring of 1986. After graduating high school, Kevin attended the University of Florida until December of 1998 when he joined the US Army for a four 4 year enlistment. Kevin was stationed in Germany and served in the Gulf War. Kevin returned to the University of Florida in August of 1991 and received his Bachelor of Science from the M.E. Rinker, Sr. School of Building Construction in December of 1994.

While in the industry, Kevin worked primarily on hospitality projects but has experience in the retail, theme park, assisted living, and office sectors. During his career, Kevin has worked for several general contractors and has diverse experience in both pre-construction and operations. Additionally, Kevin has experience in owner and architect representation.

In May of 2010, Kevin returned to the University of Florida to pursue master's and PhD degrees in construction management. He is currently enrolled in the M.E. Rinker, Sr. School of Building Construction and is expected to graduate in the summer of 2011.

Kevin is divorced and has two sons. His older son, Kyle, was born in September of 2000 and his younger son, Michael, was born in July of 2002. Kevin currently resides in both Gainesville, Florida and Orlando, Florida.