BERG White Paper 1601

MEASURING AND VERIFYING THE EFFECTIVENESS OF STATE ENERGY OFFICE PROGRAMS

A Report for the Wyoming Business Council,
State Energy Office

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EXECUTIVE SUMMARY

UW–BERG, the University of Wyoming Building Energy Research Group, was asked to perform Measurement and Verification (M&V) for energy efficiency grant programs administered by the Wyoming State Energy Office. The State of Wyoming and its citizens would like to know: Do these grant programs work? Is the money being spent wisely?

BERG examined 4 projects completed with grants awarded by the State Energy Office:

ABC Seamless (Cheyenne), which was awarded a $5,000 grant from the Small Business Energy Audit Program in 2013, completed a lighting retrofit. The total cost of the project was $10,578.21. It achieved the following results:

Electricity Savings per year:	**10,086.9 kWh**	**22% savings**
Cost Savings per year:	**$1,286.73**	
Simple Payback	**8.2 years**	

The Powder River Basin Resource Council (Sheridan), which was awarded a $5,000 grant from the Small Business Energy Audit Program in 2013, completed a retrofit of windows and a furnace replacement. The total cost of the project was $7,059.82. It achieved the following results:

Natural Gas Savings per year:	**91.6 Therms**	**11% savings**
Cost Savings per year:	**$80.51**	
Simple Payback	**87.7 years**	

Goshen County, which was awarded a grant from the WYECIP Program in 2010, completed a variety of building upgrades, varying from building to building. The total cost of the project was $1,461,064.00. It achieved the following results:

Electricity Savings per year:	**281,757.9 kWh**	**11% savings**
Cost Savings per year:	**$21,174.13**	
Simple Payback	**67.4 years**	

Niobrara County Library, which was awarded a $20,000 grant from the WYLite Program in 2014, completed an upgrade of windows and asbestos abatement. The total cost of the project was $28,835.87, with a total energy-related cost of $12,612.28. It achieved the following results:

Electricity Savings per year:	**3,195.1 kWh**	**8% savings**
Cost Savings per year:	**$295.11**	
Natural Gas Savings per year:	**228.2 Therms**	
Cost Savings per year:	**$301.60**	
Simple Payback	**21.1 years**	

Based on these examples, we conclude the grant programs generally work as intended, and that the money has been put to beneficial use. Some more detailed conclusions are found in Sections 7 and 8.

1. INTRODUCTION

The Wyoming State Energy Office and Wyoming Business Council has awarded grants to a number of counties and small businesses in order to implement energy conservation and efficiency measures within their buildings. The Wyoming Energy Efficiency Energy Audit and Renewable Energy Development Assessment Program, the Wyoming Energy Conservation Improvement Program (WYECIP), and the WYLite Program (a scaled down version of WYECIP) are all examples of the programs with grants from the Wyoming Business Council, State Energy Office.

In general, the program structure consists of a building energy audit, then installation of suggested energy conservation and efficiency measures.

In this project, Building Energy Research Group (BERG) at the University of Wyoming has performed measurement and verification of four energy efficiency projects that were a part of these programs.

These projects include two Small Business Energy Audit Program projects, one WYECIP project and one WYLite project. The four projects are ABC Seamless, Powder River Basin Resource Council, Goshen County, and the Niobrara County Library. A total of twelve buildings were evaluated.

2. BACKGROUND

The Wyoming State Energy Office (SEO) is "charged with promoting energy efficiency and conservation throughout Wyoming. The assistance can be summarized as:

- Promoting energy efficiency and conservation to residents, businesses and local government
- Providing information on in-state and national efforts toward clean energy
- Coordinating with statewide partners to advance the energy efficiency effort" (SEO 2016a)

The SEO administers three programs which are the subject of this report:

2.1 Small Business Energy Audit Program

According to the SEO: "The purpose of this program is to encourage energy efficiency improvements. The program funds 75% of cost of an energy audit and energy efficiency retrofits identified in the energy audit. SEO will work in unison with USDA Rural Development." (SEO 2016b).

$125,000 was budgeted for this program in FY 15-16 (SEO 2016c). The maximum award is $5,000 with a 25% required cash match.

2.2 WYECIP

The Wyoming Energy Conservation Improvement Program (WYECIP) supports Energy Performance Contracting, which is a:

> Process through which energy efficiency and capital upgrade improvements are funded (fully or partially) by the energy and maintenance cost savings generated by the improvements themselves when the cost savings are formally "captured" and used to pay back the funding source. (SEO 2013).

The program requires applicants to partner with an Energy Service Company (ESCo). The SEO says it has "rigorously evaluated" and pre-qualified 9 ESCos to work within the WYECIP.

2.3 WYLite

WYLite is a scaled down version of WYECIP, intended to offer services to smaller local governments. The WYLite approach incorporates a no-cost energy audit/feasibility assessment performed as part of the process (SEO 2016d).

$125,000 was budgeted for WYECIP/ WYLite in FY 15-16 (SEO 2016c). Additionally $80,000 was budgeted for the Local Government Energy Audit/Retrofit program, which requires each applicant to sign up for WYECIP/ WYLite. For the Local Government Energy Audit/Retrofit program, the maximum award is $20,000 with a 10% required cash match.

3. NATIONAL CONTEXT

In 2013, the most recent year data is available, Wyoming was #3 of 51 (states plus District of Columbia) in highest energy use per capita in the Residential and Commercial Sectors (see Figure 1. Energy Use per Capita Data).

2013 ENERGY USE PER CAPITA
RESIDENTIAL AND COMMERCIAL SECTORS
in MMBtu

1	District of Columbia	228.4	26	Louisiana	132.3
2	North Dakota	219.4	27	Delaware	131.8
3	Wyoming	192.5	28	South Carolina	128.1
4	South Dakota	164	29	Alabama	127.3
5	Nebraska	162.7	30	North Carolina	126.7
6	Montana	159.8	31	Washington	125.9
7	Missouri	157	32	Texas	124.3
8	West Virginia	154.5	33	Mississippi	124.2
9	Kansas	154.1	34	Colorado	123.8
10	Kentucky	152.2	35	New Hampshire	123.4
11	Iowa	151.8	36	Pennsylvania	122.2
12	Alaska	151.7	37	Georgia	121.9
13	Oklahoma	150.8	38	Connecticut	121.8
14	Virginia	149.8	39	New Mexico	119.6
15	Tennessee	147.8	40	Utah	116.7
16	Indiana	145.3	41	Oregon	114.3
17	Maryland	144.2	42	Arizona	112.2
18	Minnesota	143	43	New York	112
19	Wisconsin	141.8	44	Massachusetts	110.9
20	Arkansas	141.3	45	Rhode Island	109.5
21	Illinois	140.9	46	Vermont	109.5
22	Ohio	139	47	Florida	109
23	Michigan	138.9	48	Maine	108.7
24	New Jersey	134.7	49	Nevada	101.6
25	Idaho	133.5	50	California	77.1
			51	Hawaii	53

Figure 1. Energy Use per Capita Data (EIA, 2016)

Wyoming was ranked #50 out of 51 (states plus District of Columbia) in the *2015 State Energy Efficiency Scorecard* (ACEEE, 2015). This report considers the six policy areas in which states typically pursue energy efficiency:

- Utility and public benefits programs and policies
- Transportation policies
- Building energy codes and compliance
- Combined heat and power (CHP) policies
- State government-led initiatives around energy efficiency
- Appliance and equipment standards

The report recommends the following strategies states can pursue to improve energy efficiency:

- Put in place and adequately fund an EERS or similar energy savings target.
- Adopt updated, more stringent building energy codes, improve code compliance, and involve efficiency program administrators in code support.
- Set quantitative targets for reducing vehicle miles traveled, and integrate land use and transportation planning.
- Treat cost-effective and efficient CHP as an energy efficiency resource equivalent to other forms of energy efficiency.
- Expand state-led efforts—and make them visible.

4. METHODOLOGY (summary)

For this report we studied four example projects in detail in order to assess the programs. The four projects are:

- ABC Seamless, Cheyenne (Small Business Energy Audit Program)
- Powder River Basin Resource Council, Sheridan (Small Business Energy Audit Program)
- Goshen County; multiple buildings, Torrington (WYECIP)
- Niobrara County Library, Lusk (WYLite)

These four example projects were selected by the State Energy Office. These specific projects were chosen because a high level of detail could be assured to be available. We do not believe these projects were 'cherry-picked' to show positive results. Nevertheless, this method of selection has some significant limitations:

- Four is a very small sample size
- The projects were not chosen by random sample
- There is not a control group

According to the National Renewable Energy Laboratory (NREL), the best Evaluation Protocol for Energy Efficiency retrofit programs is to conduct a randomized controlled trial (RCT).

> "RCT experimental design is essentially the standard approach used across the experimental sciences to (1) isolate treatment (program) effects and (2) establish a causal link between the treatment and the effect."
>
> "For an RCT, a sampling of eligible participants is randomly assigned to one of two groups before the program installations (treatment). This assures that the two groups—treatment and control—are probabilistically similar in every respect except for the offer of program treatment." (NREL 2013)

Whether or not these four example projects are representative is unknown. Broad claims cannot be made with confidence based on this evidence.

To analyze the actual savings from building system retrofits for each building, we used ASHRAE Guideline 14: 2014 –Measurement of Energy, Demand, and Water Savings (ASHRAE 2014) and Measurement and Verification Protocol (EVO 2012). We employed the "Whole Building Approach" which involves the use of monthly utility bills for pre-retrofit and post-retrofit periods. For more detail, see Appendix A.

5. RESULTS (summary)

Results of the four projects are summarized in this section. For regression model analysis and detailed energy saving calculation, see Appendix B.

5.1 Small Business Energy Audit Program: ABC Seamless

Figure 2. ABC Seamless warehouse, Cheyenne, after lighting retrofit

a. Project Summary

ABC Seamless applied for a Small Business Energy Audit Program Grant and was awarded a grant of $5,000 with a starting date of October 13, 2013 and an ending date of June 30, 2014. With this money, ABC Seamless was able to complete a lighting retrofit, replacing lights in the shop and installing new exterior lights. They were also able to add two lighting fixtures.

b. Results of Audit

An energy assessment (audit) was performed for ABC Seamless on November 9, 2013 by Beaudin Ganze Consulting Engineers, Inc. (now known as BG Buildingworks). Eleven items of improvement were recognized within the audit. Recommendations for Energy Conservation Measures (ECMs) include many lighting upgrades, with some space and water heating suggestions. These suggestions are as follows (BGCE 2013):

1. Replace existing (15) metal halide exterior wall packs with new LED wall packs and reconnect to existing photocell on/time clock off lighting controls or replace with new for lighting control.
2. Replace existing (12) 400 watt metal halide high bay lights in warehouse with new T8 fluorescent high bay lights.
3. Have dual-level switching for the new warehouse lights and consider occupancy sensors to reduce hours of operation when lights are not needed.

4. Replace existing (9) 8–foot 2–lamp T12 fluorescent strip lights with 4–foot single lamp T8 fluorescents and re–space to provide maximum lighting coverage.
5. Replace (1) 2–foot 2–lamp fluorescent surface mounted light in office area with new LED or compact fluorescent fixture.
6. Replace controls for all showroom and office area lighting (45 fixtures) with dual–level switching and rewire fixtures as needed to permit dual–level switching control.
7. Consider replacing all showroom and office area lights with new LED fixtures, occupancy sensors, and daylight sensor controls.
8. Replace lighting controls in break room and offices with occupancy sensor switches.
9. When existing 50–gallon 9kW water heater fails, replace with smaller 20–gallon tank with (4) 5 kW heater coils.
10. When existing greater than 90% efficient condensing furnace fails, replace with another high–efficiency condensing furnace.
11. If and when tubes for existing infrared heaters in the warehouse crack due to age, replace with similar equipment.

Projected Savings were not defined by the audit company.

c. Work Performed

Energy Conservation Measures (ECMs) implemented consist of all lighting improvements (Figure 2). A breakdown of ECMs and implementation costs can be found in Table 1.

Table 1. ABC Seamless, Energy Conservation Measures

Energy Conservation Measure	Date Implemented (Date of Invoice)	Company	Cost	Amount Paid through Grant
Energy assessment (audit)	November 9, 2013	Beaudin Ganze Consulting Engineers, Inc. (now BG Buildingworks)	$750.00	$562.50
Replaced (12) high bay metal halide fixtures with (12) new T5 high bay fixtures Installed (2) additional T5 high ay fixtures in locations with no lights and extended wiring for (2) additional fixtures New junction boxes and receptacles (2)	February 21, 2014	Signature Electric	$4,005.21	$3,003.91
Installed 15 LED wall packs	March 6, 2014	Accurate Construction & Electrical Services, Inc.	$5,823.00	$1,433.59

d. Results

A cumulative total of 18,492.65 kWh were saved from the period of March 18, 2014 to January 14, 2016. Using the average cost per kWh found on ABC Seamless utility bills for post-retrofit months, 12.757 cents/kWh, a total project savings of $2,359.01 has occurred from the period March 18, 2014 to January 14, 2016. The total project cost was $10,578.21, and the yearly average saving of $1,286.73 was calculated. Thus, a simple payback period of 8.22 years was found.

5.2 Small Business Energy Audit Program: Powder River Basin Resource Council

a. Project Summary

Powder River Basin Resource Council applied for a Small Business Energy Audit Program Grant and was awarded a grant of $5,000 with a starting date of November 19, 2013 and an ending date of June 30, 2014. With this money, Powder River Basin Resource Council was able to complete building upgrades, including window replacements and replacement of the furnace.

b. Results of Audit

An audit was performed for Powder River Basin Resource Council on January 23, 2014 by Manufacturing–Works. Three areas of improvement were recognized within the audit: windows, furnace/AC unit, and lighting. Recommendations for Energy Conservation Measures (ECMs) include the following (Manufacturing–Works 2014):

1. Replace (8) windows with higher efficiency thermopane units that are tight fitting and insulated in the two offices on the main floor and the two offices on the second floor, north end.
2. Replace the large single pane windows in the rear porch, with consideration of the amount of use of the area.
3. Replace the gas furnace with a unit of at least 90% AFUE.
4. Service (purge and recharge) or replace the AC unit.
5. Replace fixture or globe that allows greater transmittance of light for lighting fixtures.
6. Replace all screw in light bulbs with compact fluorescent bulbs in all fixtures with normal office hour use.
7. Replace older style fluorescent fixtures in rear porch with T8 type fluorescent bulbs and ballasts.

Projected Savings were not defined by the energy audit company, however it was estimated that replacing the gas furnace would save approximately 10% of gas and electricity use.

c. Work Performed

Energy Conservation Measures (ECMs) implemented consist of window and furnace replacements (Figure 3). A breakdown of ECMs and implementation costs can be found in Table 2.

Table 2. Powder River Basin Resource Council, Energy Conservation Measures

Energy Conservation Measure	Date Implemented (Date of Invoice)	Company	Cost	Amount Paid through Grant
Energy audit	January 23, 2014	Manufacturing-Works	$1,000.00	$750.00
Window material (4 – 24"x53" and 2 – 28"x61")	May 12, 2014	The Home Depot	$874.82	$656.12
Window replacements Replacement of lumber as needed Insulation Installation, trim and caulking Repair of one downstairs window	June 9–June 13, 2014	RS Painting and Repairs	$1,185.00	$593.88
Install new Trane 80,000 Btu 95% furnace	May 27, 2014	Kosma Heating, A.C. & Roofing, Inc.	$4,000.00	$3,000.00

(a)

(b)

Figure 3. (a) Window replacement; (b) new furnace for Powder River Basin Resource Council, Sheridan, WY

d. Results

A cumulative total of 61.07 therms were saved from the period of May 22, 2015 to January 22, 2016. For this project, a price of 87.9 cents/therm was used, which was found as the April 2016 national average price for natural gas on the Bureau of Labor Statistics webpage (BLS 2016). A total project savings for natural gas of $53.68 has occurred from the period May 22, 2015 to January 22, 2016. The total project cost was $7,059.82, and the yearly average savings was $80.51. Thus, a total payback period of 87.68 years was calculated.

5.3 WYECIP: Goshen County

Project Summary

An Investment Grade Audit (IGA) was completed April 7, 2010 for selected buildings of Goshen County, Wyoming. These buildings include the Courthouse, the Detention Center, the Library, the Care Center, Evergreen Court, Public Health, the Extension Office, the Weed and Pest Office and Storage, the Road Department Office and Storage, and the Fairgrounds.

Recommendations for Energy Conservation Measures (ECMs) are grouped by ECM and by individual buildings. Many areas of improvement, or "observations," were lighting upgrades and HVAC equipment replacement and control system upgrades (Custom Energy 2010). These observations are included for buildings selected to receive upgrades. There are nine buildings in Goshen County that received upgrades through the WYECIP project. Between these buildings, a total of $1,426,064.00 were spent on upgrades.

Goshen County Care Center

Results of Audit

Observations by Custom Energy (2010) for the Care Center include:

1. Lighting uses recent technology, however, converting to more efficient fixtures because of hours of operation of building would yield energy savings.
2. The facility is controlled by an automated control system. Minor improvements would provide some savings, but major changes are not likely needed.
3. Due to utilization of commercial washers and dryers, modifying laundry equipment could allow the reuse of rinse water as the initial wash water in the next load.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Care Center consist of lighting upgrades (Figure 4) and the installation of programmable thermostats. A breakdown of ECMs and implementation costs can be found in Table 3.

Results

A cumulative total of 12,896.73 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 7.43 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $958.23 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $44,556.00, and the yearly average saving was $459.95. Thus, a simple payback period of 96.87 years was found.

Table 3. Goshen County Care Center, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$44,556.00
Install Programmable Thermostats	Brice's Refrigeration, Inc.	$ Not Available

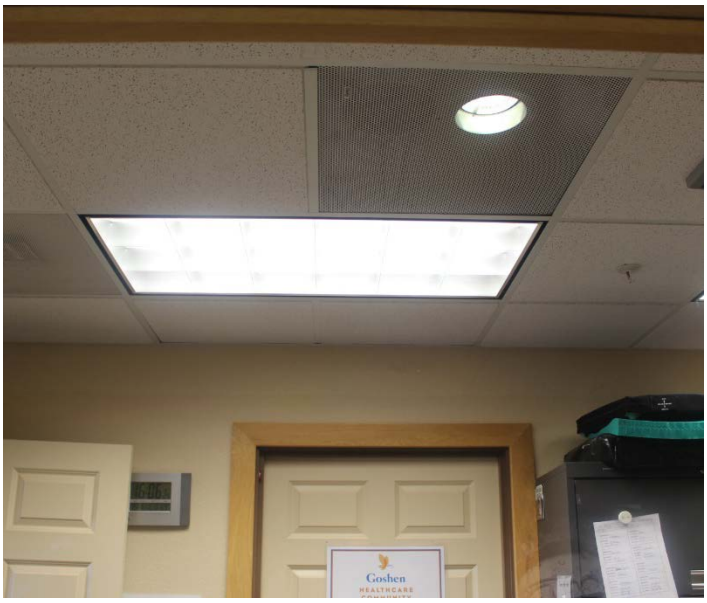

Figure 4. Goshen County Care Center interior, Torrington, post retrofit

Goshen County Courthouse

Figure 5. Goshen County Courthouse exterior, Torrington

Results of Audit

Observations by Custom Energy (2010) for the Courthouse include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. Replacing high-flow water fixtures would be of benefit.
3. Replacing existing heat pumps, which are nearing the end of useful life, would have minor energy savings but a major improvement on maintenance.
4. Existing steam system in the original building needs replacing. Expanding the existing water-source heat pump would increase occupant comfort and save energy.
5. There is no night setback for the heat pumps. Adding an energy management system would save energy.
6. Repairing the make-up air unit that has been abandoned would use more energy, but as it is the only source of fresh air in the building, is recommended.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Courthouse consist of lighting upgrades, vending machine controls, HVAC upgrades and expansion, and a control system upgrade. A breakdown of ECMs and implementation costs can be found in Table 4.

Table 4. Goshen County Courthouse, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$193,593.00
Lighting Occupancy Sensors	Xcel Energy Group	$26,341.00
Vending Machine Controls	Xcel Energy Group	$1,188.00
Heat Pump Replacement	Brice's Refrigeration, Inc.	$313,085.00
Heat Pump System Expansion	Brice's Refrigeration, Inc.	$264,223.00
Controls System Upgrade	Brice's Refrigeration, Inc.	$38,018.00

Results

A cumulative total of 287,345.31 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 7.43 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $21,349.76 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $836,448.00, and the yearly average saving was $10,247.88. Thus, a simple payback period of 81.62 years was found.

Goshen County Detention Center

Figure 6. Goshen County Detention Center exterior, Torrington

Results of Audit

Observation by Custom Energy (2010) for the Detention Center include:

1. Lighting uses recent technology, however, converting to more efficient fixtures because of hours of operation of building would yield energy savings.
2. Photocells controlling exterior lights have failed and staff want brighter fixtures. Replacing fixtures would save energy and improve security issues.
3. The facility is controlled by manual thermostats. The office areas could be set back at night with the installation of a programmable thermostat.
4. Part of the roof is leaking. Replacing the roof would help and could have energy savings (taken care of outside this project).
5. Many HVAC units are nearing end of useful life and replacing units would have some energy savings and relieve maintenance.
6. The kitchen exhaust fan is manually controlled and an automated control fan would have energy savings.
7. Installing laundry equipment that reuses rinse water in the next wash cycle would save water.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Detention Center consist of lighting upgrades, vending machine controls, HVAC additions, and a control system upgrade. A breakdown of ECMs and implementation costs can be found in Table 5.

Table 5. Goshen County Detention Center, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$38,032.00
Lighting Occupancy Sensors	Xcel Energy Group	$6,001.00
Vending Machine Controls	Xcel Energy Group	$1,783.00
Add Basement Cooling	Brice's Refrigeration, Inc.	$22,435.00
Controls System Upgrades	Brice's Refrigeration, Inc.	$27,098.00

Results

A cumulative total of 222,633.09 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 7.43 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $16,541.64 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $95,349.00, and the yearly average saving was $7,939.99. Thus, a simple payback period of 12.01 years was found.

Goshen County Evergreen Court

Figure 7. Goshen County Evergreen Court exterior, Torrington

Results of Audit

Observations by Custom Energy (2010) for Evergreen Court include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. Replacing high-flow water fixtures would be of benefit.
3. Existing water-source heat pumps are aged. Replacement of units would save some energy and mitigate the issue of maintenance having to find replacement parts.

4. Installing laundry equipment that reuses rinse water in the next wash cycle would save water.

Work Performed

Energy Conservation Measures (ECMs) implemented in Evergreen Court consist of a lighting upgrade (Figure 8). A breakdown of ECMs and implementation costs can be found in Table 6.

Table 6. Goshen County Evergreen Court, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$26,404.00

Figure 8. Goshen County Evergreen Court hallway, Torrington, after lighting retrofit

Results

A cumulative total of 44,072.81 kWh were saved from the period of December 15, 2013 to December 14, 2015. Using the value of 7.43 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $3,274.61 has occurred from the period of December 15, 2013 to December 14, 2015. The total project cost was $26,404.00, and the yearly average saving was $1,637.30. Thus, a simple payback period of 16.13 years was found.

Goshen County Extension

Results of Audit

Observations by Custom Energy (2010) for the Extension Office include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. The facility is controlled by manual thermostats. The building could be set back at night with the installation of programmable thermostats and energy could be saved.

3. Radiant heat is not a good system for this type of facility. Installing residential–style furnaces and drop ceilings in all spaces would save energy and increase occupant comfort. Adding a cooling system would increase occupant comfort, but would increase energy use.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Extension Office consist of lighting upgrades, installation of lighting occupancy sensors (Figures 10–11), vending machine controls, and a replacement of a heating system (Figure 9). A breakdown of ECMs and implementation costs can be found in Table 7.

Table 7. Goshen County Extension, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$64,828.00
Lighting Occupancy Sensors	Xcel Energy Group	$6,209.00
Vending Machine Controls	Xcel Energy Group	$595.00
Replace Radiant with Three Split System	Brice's Refrigeration, Inc.	$160,145.00

Figure 9. Goshen County Extension Office, Torrington, after HVAC upgrade

Figure 10. Goshen County Extension Office, Torrington, wall-mounted occupancy sensor

Figure 11. Goshen County Extension Office, Torrington, ceiling mounted occupancy sensor

Results

A cumulative total of 17,144.80 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 10.17 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $1,743.63 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $231,777.00, and the yearly average saving was $836.94. Thus, a simple payback period of 276.93 years was found.

Goshen County Fairgrounds

Figure 12. Goshen County Fairgrounds Rendezvous Center exterior, Torrington

Results of Audit

Observations by Custom Energy (2010) for the Fairgrounds Rendezvous Center include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. The facility is controlled by manual thermostats and installing programmable thermostats would save energy.
3. The HVAC system is nearing end of useful life and replacing would save energy, avoid future costs, and decrease maintenance costs.

Observations by Custom Energy (2010) for the Fairgrounds Pavilion include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. Existing photocells have had issues and maintenance staff requested exterior lights be put on a timer. Energy can be saved, however it would depend on the number of failed photocells.
3. The facility is controlled by manual thermostats and installing programmable thermostats would save energy, but since temperature is already kept low, there is limited potential.
4. Humidity issues arise in the summer due to wetting of the arena floor and little can be done to remedy the issue without having to wet the arena more often.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Fairgrounds consist of lighting upgrades (Figures 13–14) and weatherization. A breakdown of ECMs and implementation costs can be found in Table 8.

Table 8. Goshen County Fairgrounds, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$163,118.00
Lighting Occupancy Sensors	Xcel Energy Group	$4,265.00
Weatherization	Brice's Refrigeration, Inc.	$1,213.00 (Pavilion)

Figure 13. Goshen County Fairgrounds Rendezvous Center interior, Torrington

Figure 14. Goshen County Fairgrounds Rendezvous Center interior, Torrington

Results

A cumulative total of 18,585.67 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 10.17 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $1,890.16 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $168,596.00, and the yearly average saving was $907.28. Thus, a simple payback period of 185.83 years was found.

Goshen County Library

Figure 15. Goshen County Library exterior, Torrington

Results of Audit

Observations by Custom Energy for the Library include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. Many areas have sufficient natural light and installing sensors to automatically shut off lights when natural lighting is adequate would lead to savings.
3. The facility is controlled by manual thermostats. The building could be set back at night with the installation of programmable thermostats and would energy could be saved.
4. Rooftop units are nearing the end of useful life and replacing units would save some energy and reduce maintenance costs.
5. The roof is leaking and replacing the roof would help and could save energy.

Work Performed

Energy Conservation Measures (ECMs) implemented in the Library consist of lighting upgrades (Figure 16). A breakdown of ECMs and implementation costs can be found in Table 9.

Results

A cumulative total of 32,872.25 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 10.17 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of $3,343.11 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $21,149.00, and the yearly average saving was $1,604.69. Thus, a simple payback period of 13.18 years was found.

Table 9. Goshen County Library, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$16,892.00
Lighting Occupancy Sensors	Xcel Energy Group	$4,257.00

Figure 16. Goshen County Library interior, Torrington, post retrofit

Goshen County Public Health

Figure 17. Goshen Public Health exterior, Torrington

Results of Audit

Observations by Custom Energy (2010) for Public Health include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. Replacing high-flow water fixtures would be of benefit.

3. The facility is controlled by manual thermostats. Due to current zoning, installing programmable thermostats would not yield significant changes. Rezoning the systems and having programmable thermostats would yield energy savings.

Work Performed

Energy Conservation Measures (ECMs) implemented in Public Health consist of lighting upgrades (Figure 18) and the installation of programmable thermostats (Figure 19). A breakdown of ECMs and implementation costs can be found in Table 10.

Table 10. Goshen County Public Health, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$6,605.00
Install Programmable Thermostats	Brice's Refrigeration, Inc.	$4,683.00

Figure 18. Goshen County Public Health interior, Torrington, lighting post-retrofit

Figure 19. Goshen County Public Health, Torrington, programmable thermostat

Results

A cumulative total of –31,313.90 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 10.17 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of –$3,184.62 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $11,288.00, and the yearly average savings was –$1,528.62. Because of the negative values of electricity savings, a simple payback period could not be found.

Goshen County Road and Bridge

Figure 20. Goshen County Road and Bridge exterior, Torrington, post lighting retrofit

Results of Audit

Observations by Custom Energy for the Road Department Office and Storage include:

1. Lighting technology has progressed since installation. Retrofitting of fixtures to newer technology would save energy.
2. The facility is controlled by manual thermostats and installing programmable thermostats would save energy.
3. Unit heaters in storage building were on while doors open. Installing radiant heaters and sensors to shut off units when doors are open would save energy.
4. The HVAC unit for the office area is nearing end of useful life and replacement would have some energy savings and relieve maintenance issues.

Work Performed

Energy Conservation Measures (ECMs) implemented for the Road and Bridge project consist of lighting upgrades (Figures 20–22) and the replacement of unit heaters in the storage area. A breakdown of ECMs and implementation costs can be found in Table 11.

Table 11. Goshen County Road and Bridge, Energy Conservation Measures

Energy Conservation Measure	Company	Proposed Cost
Lighting	Xcel Energy Group	$12,296.00 Rd. Dept. Office +$4,294.00 Rd. Dept. Storage
Lighting Occupancy Sensors	Xcel Energy Group	$1,165.00 Rd. Dept. Office
Replace Unit Heaters	Brice's Refrigeration, Inc.	$24,478.00 Rd. Dept. Storage

Figure 21. Goshen County Road and Bridge shop interior, Torrington, post lighting retrofit

Figure 22. Goshen County Road and Bridge office, Torrington, wall-mounted occupancy sensor

Results

A cumulative total of -19,077.56 kWh were saved from the period of December 15, 2013 to January 14, 2016. Using the value of 10.17 cents/kWh, as reported in the Energy Performance Contract (2010), a total project savings of -$1,940.19 has occurred from the period of December 15, 2013 to January 14, 2016. The total project cost was $42,233.00, and the yearly average savings is -$931.29. Due to the negative values of electricity savings, a simple payback period could not be found.

5.4 WyLITE: Niobrara County Library

Figure 23. Niobrara County Library exterior, Lusk, window

Figure 24. Niobrara County Library, Lusk, new furnace

a. Project Summary

The Niobrara County Library applied for and was awarded a grant of $20,000 with a starting date of April 9, 2014 and an ending date of June 30, 2015. With this money, Niobrara County Library was able to complete a variety of building upgrades including asbestos abatement, architectural consulting, and, HVAC and control upgrades, lighting upgrades, and window improvements.

b. Results of Audit

A WYLite Energy Engineering Study (audit) was performed for Niobrara County Library in September 2013 by the Wyoming Business Council, Wyoming State Energy Office and Trident Energy Services, Inc.. Recommendations for Energy Conservation Measures (ECMs) include lighting upgrades, window/door replacement/restoration, and HVAC and controls upgrades. These suggestions are as follows (SEO and Trident Energy Services 2013):

1. Upgrades in lighting
2. Replacing main door (including sidelights)
3. Restoring windows
4. Install natural gas DHW heater
5. HVAC upgrades
6. Installing thermostat controllers on radiators and installing programmable thermostats
7. Replacing the boiler

Projected Savings were estimated as $1,386.97 annually if all ECMs are implemented (SEO and Trident Energy Services 2013).

c. Work Performed

Energy Conservation Measures (ECMs) implemented consist of many different improvements. A breakdown of ECMs and implementation costs can be found in Table 12.

Table 12. Niobrara County Library, Energy Conservation Measures

Energy Conservation Measure	Date Implemented (Date of Invoice)	Company	Cost	Amount Paid through Grant
Window sampling and report for lead and asbestos samples	May 14, 2014	Enviro Engineering, Inc.	$743.50	$669.15
Architectural Consulting (design development, construction documents, bidding and negotiations)	June 30, 2014	Dubbe Moulder	$10,514.59	$9,463.13
Asbestos removal and waste disposal	July 22, 2014	Enviro Engineering, Inc.	$4,965.00	$4,468.50
Historic window restoration, HVAC and control upgrades, lighting upgrades	August 26, 2014	Spiegelberg Lumber	$12,612.28	$11,351.05

d. Results

A cumulative total of 4,792.61 kWh of electricity were saved from the period of July 15, 2014 to January 14, 2016. Using the value of 9.2365 cents/kWh, averaged from the Niobrara County Library utility summary, a total project savings of $442.67 has occurred from the period of July

15, 2014 to January 14, 2016. The total project cost, excluding non-energy work, was $12,612.28, and the yearly average savings is $295.11.

Additionally, a cumulative total of 342.36 therms of natural gas were saved from the period of July 15, 2014 to January 14, 2016. Using the value of $1.321/therm, averaged from the Niobrara County Library utility summary, a total project savings of $452.40 has occurred from the period of July 15, 2014 to January 14, 2016. The total project cost was $12,612.28, and the yearly average savings is $301.60.

Together, with a total project cost of $12,612.28, and the yearly combined average savings of $596.71, a simple payback period of 21.14 years was found.

5.5 Limitations

Some Limitations are discussed in Section 4 above, and in Section 8 below.

Additionally, in this study, a Simple Payback period was calculated for each building and project.

Simple Payback is not the best tool to use for this analysis. "The simple payback calculation ignores several critical investment characteristics, including: the time value of money, energy price escalation, variable rate electricity pricing, alternative investment options, and what happens after payback" (UW Extension, 2013). Net Present Value is a better metric for evaluation.

This study assumed that the energy saving was consistent throughout the payback periods, but this is also a limitation which may affect the results.

6. OTHER BENEFITS

The results described above are directly measureable. It is also likely that the State Energy Office Programs are producing other benefits which we are not able to measure directly. We offer the following information to suggest some other benefits which are probable outcomes.

Building retrofits for energy efficiency are very likely to deliver improved conditions for the building occupants. For retrofits involving HVAC systems, modern systems offer a high degree of control, while modern equipment can delivers a higher quality and quantity of air. For retrofits involving lighting systems, modern fixtures and bulbs deliver a higher quality of light.

One anecdote from this project speaks to the presence of qualitative benefits: When we visited ABC Seamless, a worker in the warehouse mentioned that the quality of light was much-improved after the retrofit.

6.1 Operations & Maintenance

Energy Efficiency retrofits should result in lower costs for Operations and Maintenance (O&M). For example, energy-saving light fixtures have a much longer bulb lifetime compared with previous-generation light fixtures. This was specifically mentioned as a benefit by the manager of Goshen County Evergreen Court Mention when BERG visited.

6.2 Occupant Health and Comfort

It is well established that energy-efficient retrofits will lead to benefits for Occupant Health and Comfort. Some examples are listed here. These are all based on reputable studies.

- Building retrofits which improved the indoor environment of a building resulted in:
  - reductions of communicable respiratory diseases of 9-20%
  - reductions of allergies and asthma of 18-25%
  - reductions of non-specific health and discomfort effects of 20-50% (USGBC, 2015).
- General health in adults improved from 59% to 67% after green improvements at a low-income housing development (Breysse, 2014).
- Indoor pollution is estimated to cause thousands of cancer deaths and hundreds of thousands of respiratory health problems each year. In addition, hundreds of thousands of children have experienced elevated blood lead levels resulting from their exposure to indoor pollutants (EPA, 2001).

6.3 Productivity

Some examples of Productivity benefits are listed here.

- Low-CO_2 environments (more fresh air) leads to higher cognitive performance scores for office workers (Allen, et.al., 2016).
- Improved ventilation creates up to 11% gains in productivity (WorldGBC, 2013).
- Individual temperature control for each worker creates up to 3% gains in productivity (WorldGBC, 2013).

- Improved lighting design creates up to 23% gains in productivity (WorldGBC, 2013).
- Improved lighting design reduces incidence of headaches 27% (Loftness, 2000).
- In the context of K–12 School buildings, over 70% of organizational leaders said green schools reduced student absenteeism and improved student performance (Turner, 2005).
- OSHA calculated a three percent loss of productivity from poor Indoor Air Quality (OSHA, 1994).
- U.S. employers lose $15 billion annually due to poor Indoor Air Quality leading to worker inefficiency and sick leave (OSHA, 1994).

To an employer, the productivity benefits may be significantly more important than the lower utility bills in the long term. This presumes that energy efficiency measures will lead to reduced absenteeism, reduced turnover and the associated benefits of reduced recruiting and training efforts. The large relative importance of these benefits can be seen in the high proportion of Personnel Costs (compared to Operations and Maintenance Costs) in the 30–Year Cost of a Building (see Figure 25).

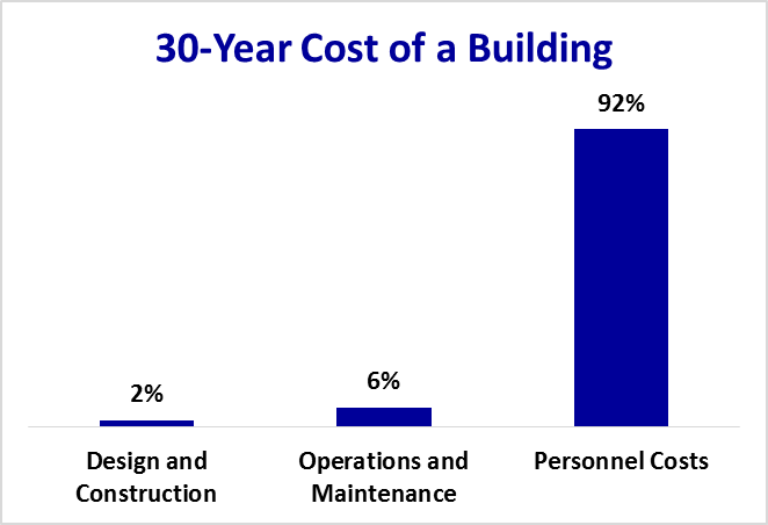

Figure 25. 30–Year Cost of a Building, Data from (WBDG, 2010)

6.4 Real Estate

Some examples of Real Estate benefits are listed here.

- Owners of green buildings reported that their ROI improved by 19.2% on average for existing building green projects (USGBC 2015).
- Green building retrofits of existing buildings increase building values by 6.8% (USGBC 2015).
- Lease–up rates for green buildings typically range from average to 20% above average (USGBC 2015).

7. OTHER OBSERVATIONS

BERG offers some additional observations related to this project and the Energy Efficiency programs administered by the SEO.

7.1 Energy Modeling

Energy Modeling is the use of computer simulation tools to evaluate the energy performance of various architectural and systems options during the design phase. These tools are mature and they work very well. Most Wyoming architects do not include this service in their normal design practices.

The SEO should consider offering grants specifically to support Energy Modeling, both for new construction and significant remodels. Current programs do not appear to incentivize this activity.

Energy Modeling is very effective; the payback period is typically 1 or 2 months (DOE, 2016).

7.2 Education for Building Operators and Maintenance (O&M) Personnel

How do buildings waste energy? Operational factors can dwarf the impact of design features. Building operation is the main factor in the energy under-performance of buildings (Turner and Frankel 2008). Another study found poor practice in building operations results in an increase in energy use of 49–79% (Wang, Mathew, et. al., 2012).

Because O&M personnel play such an important role, the SEO should consider sponsoring educational programs for them. BERG could organize and manage training and certification programs for facility managers, building operators and technicians to close skills/knowledge gaps and to achieve new levels of skills and knowledge. ASHRAE Guideline 32 would serve as foundation for such training (ASHRAE 2012).

7.3 Monitoring-based Commissioning

Monitoring-based commissioning is a method for ensuring that building systems are performing as intended, using "smart building" information systems and diagnostic tools. This is considered a low-cost, high-return energy efficiency strategy (Mills and Mathew, 2009). A cyclic process of monitoring-based building commissioning for existing buildings is illustrated in Figure 26.

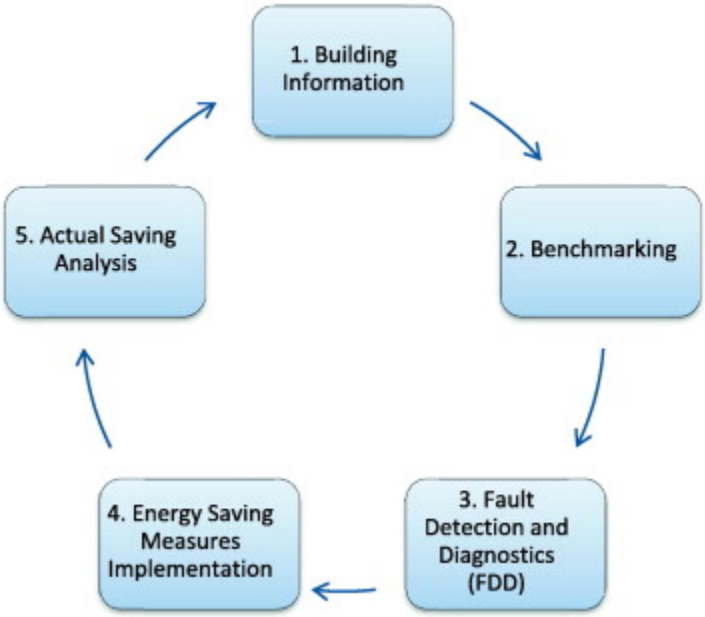

Figure 206. Monitoring-based commissioning flow chart (Wang, Greenberg et al. 2013).

The SEO should consider offering grants to support Monitoring-based commissioning for Wyoming buildings. The payback period is about 2.3 years (Brown, et. al., 2006).

8. CONCLUSIONS

The simplified results are as follows:

ABC Seamless (Cheyenne), which was awarded a $5,000 grant from the Small Business Energy Audit Program in 2013, completed a lighting retrofit. The total cost of the project was $10,578.21. It achieved the following results:

Electricity Savings per year:	**10,086.9 kWh**
Cost Savings per year:	**$1,286.73**
Simple Payback	**8.2 years**

The Powder River Basin Resource Council (Sheridan), which was awarded a $5,000 grant from the Small Business Energy Audit Program in 2013, completed a retrofit of windows and a furnace replacement. The total cost of the project was $7,059.82. It achieved the following results:

Natural Gas Savings per year:	**91.6 Therms**
Cost Savings per year:	**$80.51**
Simple Payback	**87.7 years**

Goshen County, which was awarded a grant from the WYECIP Program in 2010, completed a variety of building upgrades, varying from building to building. The total cost of the project was $1,461,064.00. It achieved the following results:

Electricity Savings per year:	**281,757.9 kWh**
Cost Savings per year:	**$21,174.13**
Simple Payback	**67.4 years**

Niobrara County Library, which was awarded a $20,000 grant from the WYLite Program in 2014, completed an upgrade of windows and asbestos abatement. The total cost of the project was $28,835.87, with a total energy-related cost of $12,612.28. It achieved the following results:

Electricity Savings per year:	**3,195.1 kWh**
Cost Savings per year:	**$295.11**
Natural Gas Savings per year:	**228.2 Therms**
Cost Savings per year:	**$301.60**
Simple Payback	**21.1 years**

We offer the following conclusions.

1. The grant programs generally work as intended. When investments are made in Energy Efficiency Measures, energy savings follow.

2. There is likely to be a lot of 'noise' in the data due to externalities. We know this because some projects exhibited very long payback periods, or negative energy savings, and we followed up to understand the unexpected results.

- Goshen County Public Health exhibited an increase in energy use after the improvements. We learned:
    a) the staff does not know how to operate the programmable thermostats
    b) the staff began using a significant amount of personal-comfort equipment (portable fans and space heaters) after the retrofit work.
    c) the staff acquired a commercial-grade medical refrigerator between the pre- and post- periods of data collection. They kept the old refrigerators online. This is certainly a major contributor to increased energy use not related to the project.

- Goshen County Road and Bridge exhibited an increase in energy use after the improvements. We were not able to find a reason for these results.

- Goshen County Fairgrounds Rendezvous Center exhibited an extraordinarily-long 96.9 year payback period. We believe:
    a) The building has a very low intensity of use in general. It is used for special events only, and sits dormant (with the lights off) for a vast majority of time (Figure 13). The auditor's forecasted savings was based upon the lighting being used 2555 hours per year---30% of all hours---way off.
    b) The use increased (from very low to low) after the retrofit. More events were scheduled because the space became more functional and pleasant. This was mentioned by Torrington residents familiar with the project.

- Powder River Basin Resource Council exhibited an extraordinarily-long 80.5 year payback period. We learned:
    a) the staff increased by 33% (3 people to 4 people) at the time of the project. Plug loads likely increased proportionally.
    b) the new staff member required heavy use of a space heater.
    c) a new computer server was added at about the time of the project.

In short, user behavior is a major factor in building energy use. This is well-known in research and in practice. Future evaluations would be more accurate if the 'noise' of user behavior could be eliminated from the data.

3. The simpler the project, the more predictable the energy savings. Particularly, in projects which only involved lighting upgrades, the energy savings were very predictable:

    - ABC Seamless: 8.2 year payback period
    - Goshen County Library: 13.2 year payback period
    - Goshen County Evergreen Court: 16.1 year payback period

4. Wyoming's lower-than-average energy prices lead to longer-than-average payback periods. In 2014 the average price of electricity in Wyoming was 7.78 cents/kWh, whereas the National Average was 10.45 cents/kWh (74.44%). If a National Average project has a payback period of 1.00 years, the same Wyoming project would have a payback period of 1.34 years.

    Put another way, the Goshen County Evergreen Court project pays back in 16.1 years with Wyoming electricity rates, but it would pay back in 12.0 years with 'normal' electricity rates. This means Wyoming energy efficiency projects are relatively more difficult to justify.

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APPENDIX A: METHODOLOGY (in detail)

In this study, we analyzed the actual savings from building system retrofits for each building based on ASHRAE Guideline 14: 2014 –Measurement of Energy, Demand, and Water Savings (ASHRAE 2014) and Measurement and Verification Protocol (EVO 2012). We employed the "Whole Building Approach" which involves the use of monthly utility bills for pre-retrofit and post-retrofit periods. We conducted statistical linear regression analysis to correlate building energy use to the independent variable weather data. In general, the linear regression model is in the format as follows.

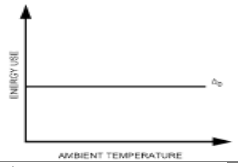
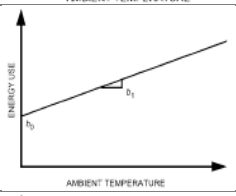
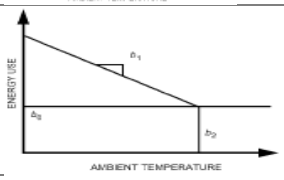
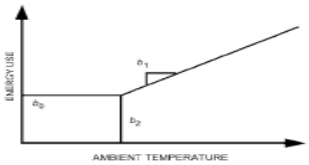
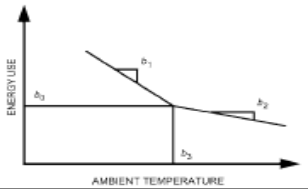
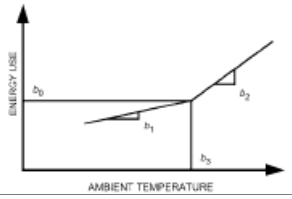
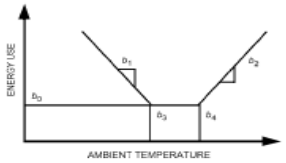
$$\mathrm{E} = \mathrm{C} + B_1 V_1 + B_2 V_2 + B_3 V_3 + \cdots$$

Where *E* is energy use per day or energy use per billing period; *C* is a constant, B_n refers to the coefficient of independent variable V_n. The actual energy savings equals to the projected baseline energy use for pre-retrofit period minus the actual energy use for post-retrofit period.

We used the average dry bulb temperature for each billing period as the independent variable for the regression models in this study. We obtained the historical daily average temperature for each building site from the National Climatic Data Center's (NCDC) (NCDC 2016), and we used quality controlled local climatological data (QCLCD). Average dry bulb temperatures for each billing period were attained from averaging daily average temperatures from NCDC for each location. Because dry bulb temperature data for Lusk, WY was not available, we used the dry bulb temperature data from Torrington, WY instead for the Niobrara County Library project. For projects in which billing periods were not specified, an assumption that billing period starts and ends in the middle of the month (15th to the 14th of the following month) was made.

The regression models commonly used (Table App.A.1) in the Whole Building Approach are: one-parameter or constant model, two-parameter model, three-parameter model, four-parameter model and five-parameter model.

Table App.A.1 Sample Models for Whole Building Approach (revised from ASHRAE Guideline 14 (ASHRAE 2014)

Model Type	Independent Variables	Form	Illustration
Constant Model (non-weather sensitive)	None	$E = C$	
Two-Parameter Model	Temperature	$E=C+B_1(T)$	
Three-Parameter Change Point Heating Model	Temperature	$E=C+B_1(B_2-T)^+$	
Three-Parameter Change Point Cooling Model	Temperature	$E=C+B_1(T-B_2)^+$	
Four-Parameter Change Point Heating Models	Temperature	$E=C+B_1(B_3-T)^+ - B_2(T- B_3)^+$	
Four-Parameter Change Point Cooling Models	Temperature	$E=C -B_1(B_3-T)^+ + B_2(T- B_3)^+$	
Five-Parameter Model for both heating and cooling	Temperature	$E=C +B_1(B_3-T)^+ + B_2(T- B_4)^+$	

Normalized energy uses based on actual local weather data for the two time periods, before and after retrofit, were analyzed to evaluate the effectiveness of each of the four identified projects. The normalization of energy uses with weather data eliminates the energy use differences due to weather fluctuations in the years prior to and after the installation of energy conservation and efficiency measures. Linear regression analysis was employed to develop an inverse regression model to fit the weather data and energy use data.

In this project, we used the Inverse Model Toolkit (IMT) (Kissock, Haberl et al. 2004) developed by Texas A&M University for the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) to fit weather data and energy usage to an inverse model. The Inverse Model Toolkit was widely used in industry as a tool to evaluate energy savings. We developed a Matlab code, as shown in Figure App.A.1, to streamline the process from preparing weather data and energy use, preparing input data file for Inverse Model Toolkit, running the Inverse Model Toolkit, and post-processing the results.

Cumulative energy savings were calculated by finding differences between the regression model before retrofits and the regression model after retrofits. The sum of each month's energy savings were totaled for the available months post-retrofit.

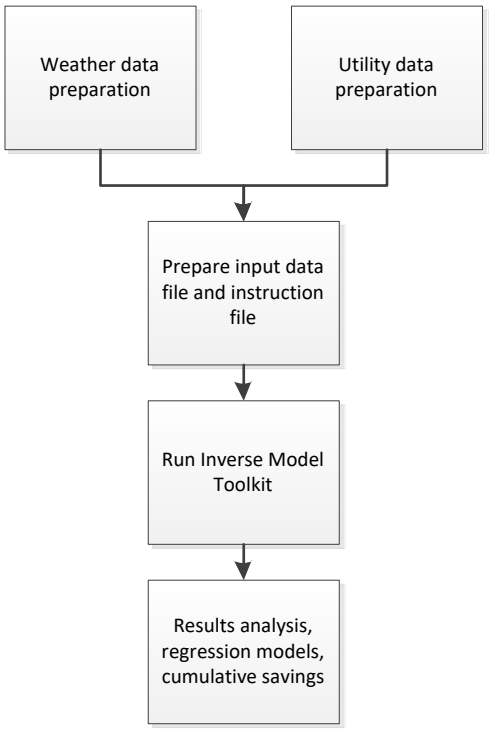


Figure App.A.1. Automated Energy Saving Analysis for Measurement and Verification

APPENDIX B: RESULTS (in detail)

Quality of fit is determined both by R^2 value and the Coefficient of Variation of the Root Mean Square Error (CV-RMSE) value. An R^2 value of 1.0 means the model fits the data perfectly. In other words, the closer an R^2 value is to 1.0, the better the fit. In addition, the CV-RMSE value should not exceed 20% for a post retrofit savings report period of less than 12 months and should not exceed 25% for a post retrofit savings report period between 12 and 60 months (ASHRAE 2014). Cumulative electricity savings were calculated by summing the difference between pre- and post-retrofit data for each monthly billing period.

B.1 Small Business Energy Audit Program: ABC Seamless

Regression Model Analysis

One-parameter, or mean, models were used to estimate the energy usage for the ABC Seamless building. The two models, as shown in Figure App.B.1, estimated the average energy usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly billing period electricity data from ABC Seamless utility bills.

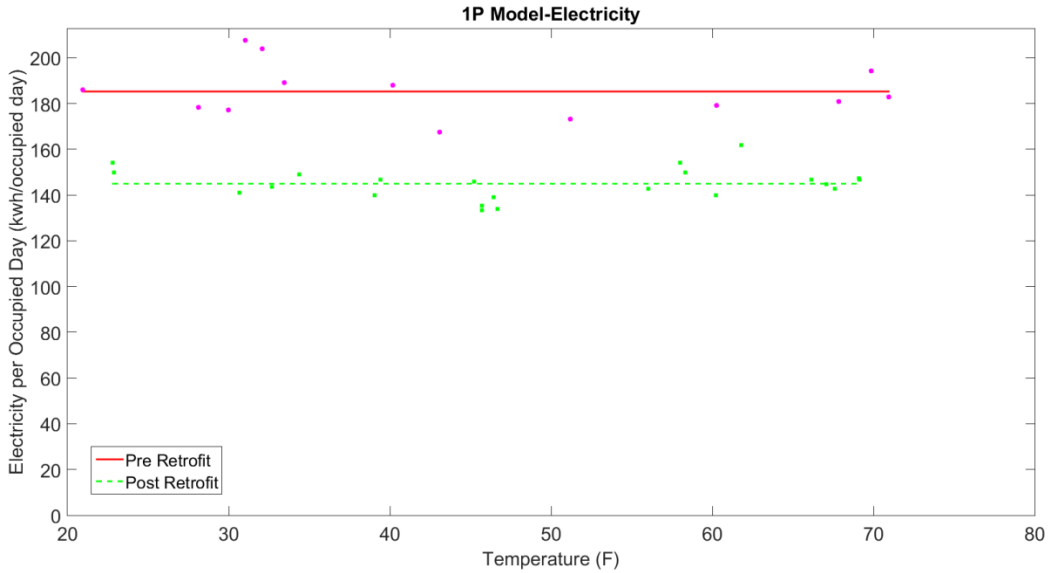


Figure App.B.1. ABC Seamless One-Parameter Model, Electricity Usage

The one-parameter models demonstrated electricity savings from before and after the retrofits. The uppermost line, the pre-retrofit line, showed more energy usage than the lower, or post-retrofit, line. Values of standard deviation and CV-St. Dev were shown in Table App.B.1.

Table App.B.1. ABC Seamless Electricity Usage Quality of Fit

	Pre-Retrofit	Post-Retrofit
Std. Dev.	11.502	6.881
CV-StDev	6.209%	4.747%

Energy Savings

A total cumulative saved energy value of 18,492.65 kWh was found for the period of March 18, 2014 to January 14, 2016. Figure App.B.2 showed the progression of the cumulative savings.

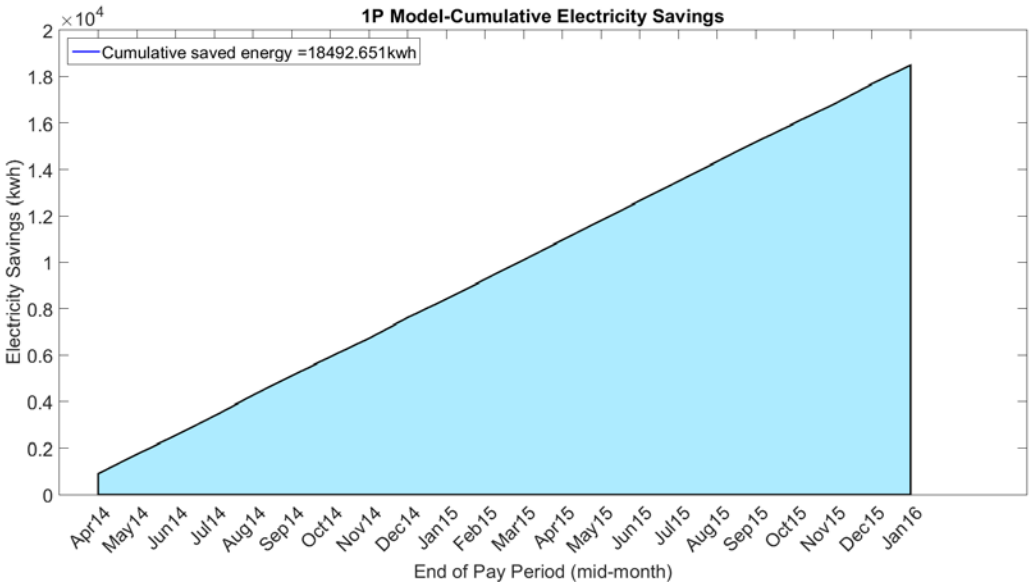


Figure App.B.2. Cumulative Electricity Savings for ABC Seamless

B.2 Small Business Energy Audit Program: Powder River Basin Resource Council

Regression Model Analysis

Three-parameter heating models were used to simulate natural gas usage for the Powder River Basin Resource Council building. The two models, as shown in Figure App.B.3, estimated the natural gas usage prior to retrofit and post-retrofit, respectively. Natural gas usage per occupied day was calculated using monthly billing period natural gas data obtained from the utility bills.

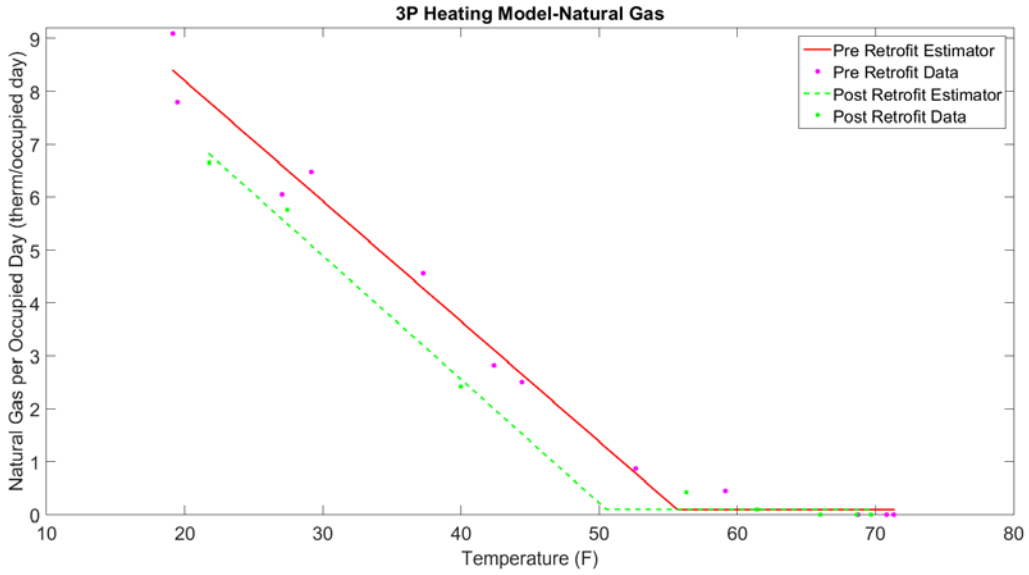


Figure App.B.3. Three-Parameter Model for Powder River Basin Resource Council, Natural Gas Usage

As shown in Table App.B.2, the R^2 values of both three-parameter models are 0.987 and 0.995, respectively. The CV-RMSE values of both models met the 20% limit required by ASHRAE Guideline 14 (ASHRAE 2014).

Table App.B.2. Powder River Basin Resource Council Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.987	0.995
CV-RMSE	11.642%	10.694%

Energy Savings

A cumulative total of 61.07 therms of natural gas were saved from the period of May 22, 2015 to January 22, 2016. Figure App.B.4 showed the progression of the cumulative savings.

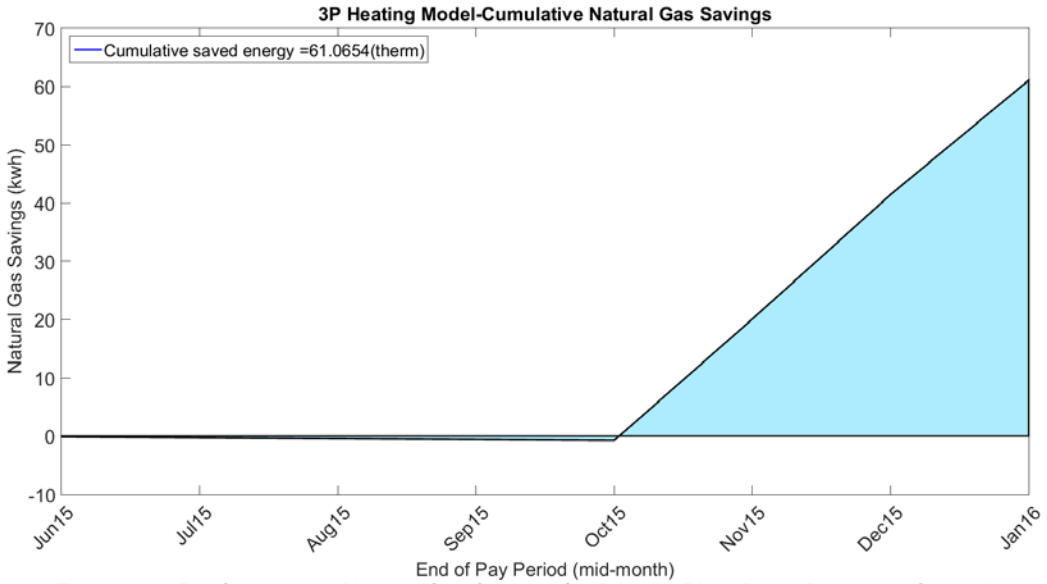


Figure App.B.4 Cumulative Natural Gas Savings for Powder River Basin Resource Council

B.3 WYECIP: Goshen County

Care Center

Regression model analysis

Four-parameter models were used to simulate electricity usage of the Care Center project. The two four-parameter models (as shown in Figure App.B.5) estimate the energy usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

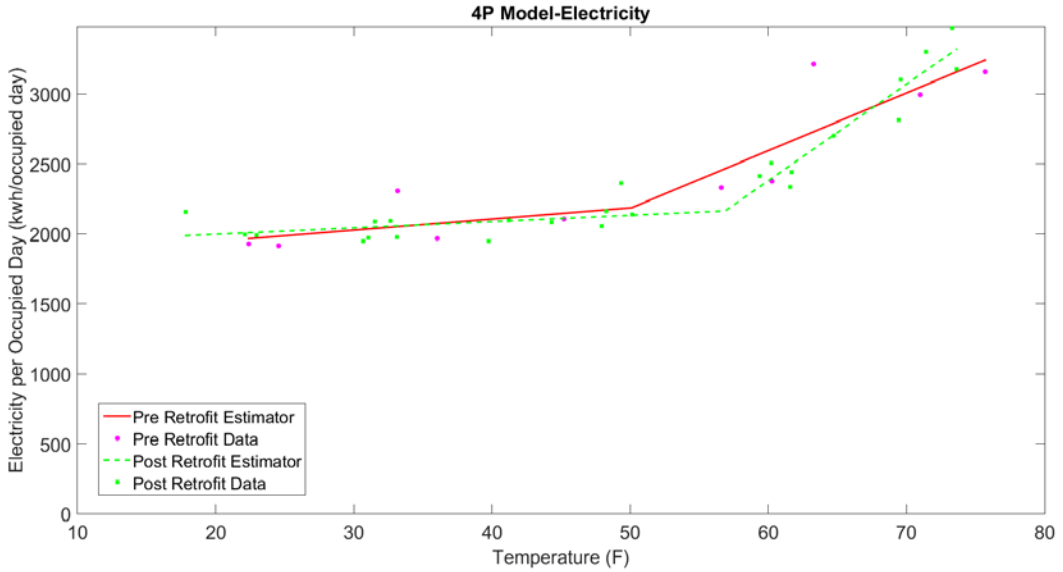


Figure App.B.5. Goshen County Care Center Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Care Center post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Care Center project were shown in Table App.B.3.

Table App.B.3. Goshen County Care Center Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.829	0.942
CV-RMSE	9.824%	4.903%

Energy Savings

A total cumulative saved energy value of 12,896.73 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.6 showed the progression of the cumulative savings.

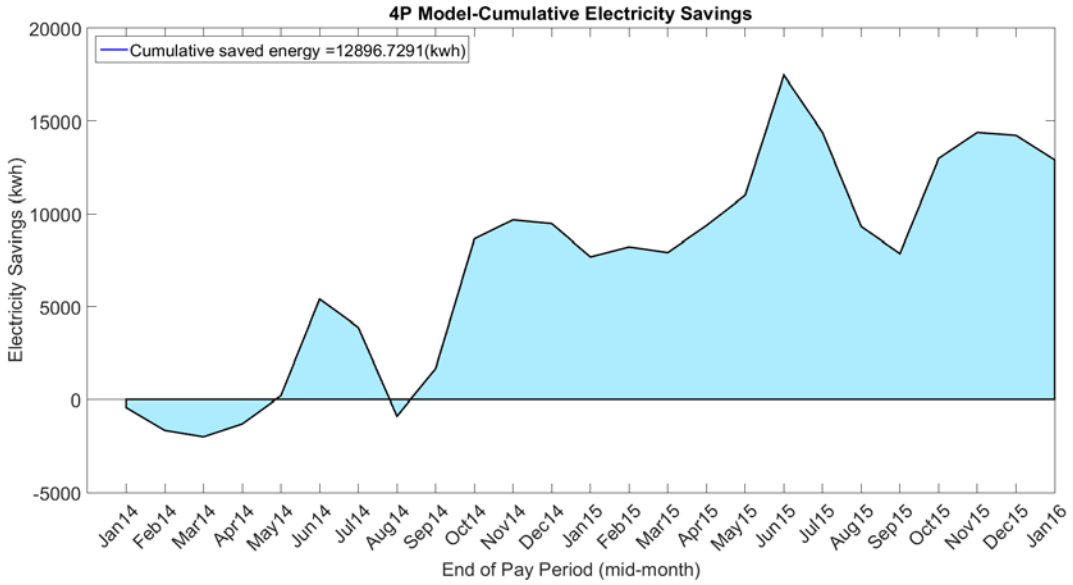


Figure App.B.6. Goshen County Care Center Cumulative Electricity Savings

Courthouse

Regression Model Analysis

Four-parameter models were used to simulate electricity usage of the Courthouse project. The two models, as shown in Figure App.B.7, estimated the energy usage prior to retrofit and post-retrofit. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

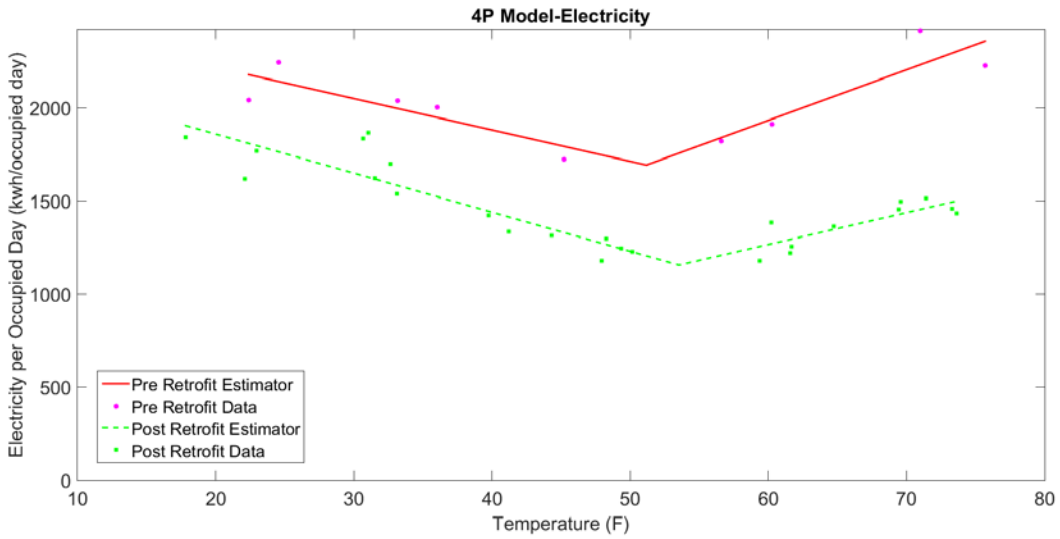


Figure App.B.7. Goshen County Courthouse Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Courthouse post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Courthouse project are shown in Table App.B.4.

Table App.B.4. Goshen County Courthouse Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.761	0.808
CV-RMSE	6.006%	6.715%

Energy Savings

A total cumulative saved energy value of 287,345.31 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.8 showed the progression of the cumulative savings.

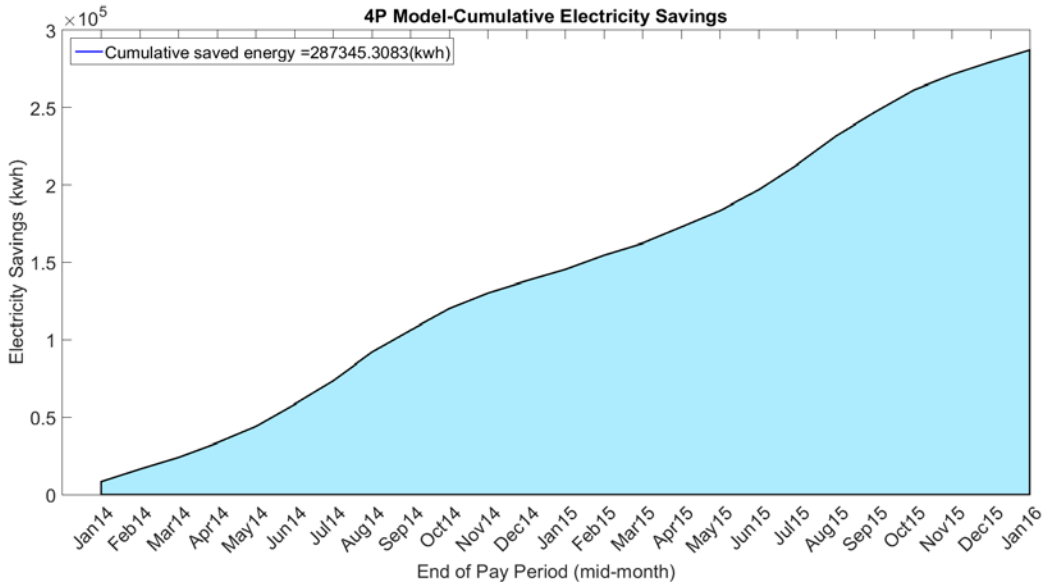


Figure App.B.8. Goshen County Courthouse Cumulative Electricity Savings

Detention Center

Regression Model Analysis

Three-parameter cooling models were used to simulate electricity usage of the Detention Center project. Two models, as shown in Figure App.B.9, estimated the energy usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

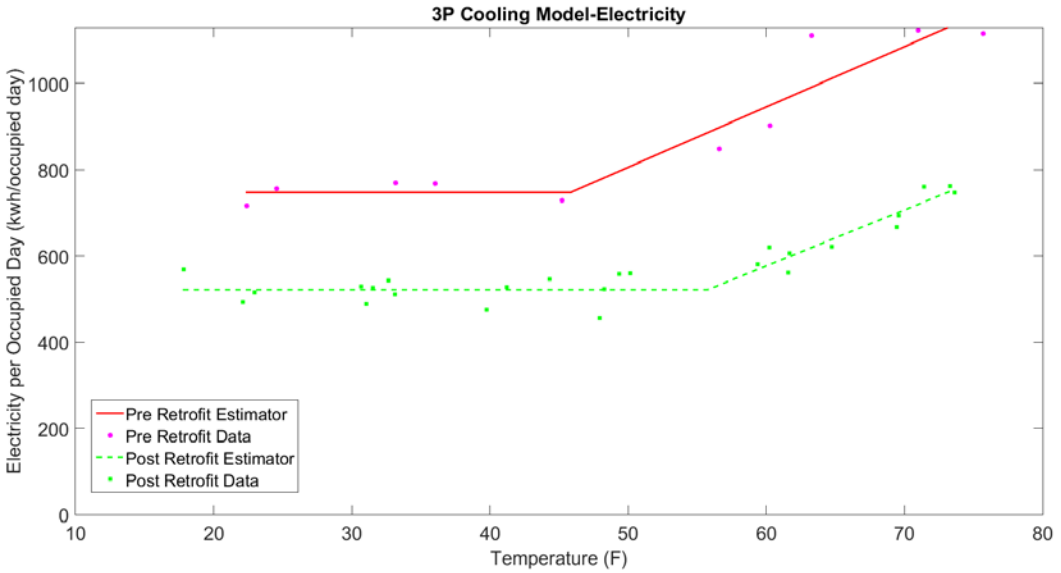


Figure App.B.9. Goshen County Detention Center Three-Parameter Cooling Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Detention Center post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Detention Center project were shown in Table App.B.5.

Table 13. Goshen County Detention Center Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.906	0.889
CV-RMSE	6.253%	5.165%

Energy Savings

A total cumulative saved energy value of 222,633.09 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.10 showed the progression of the cumulative savings.

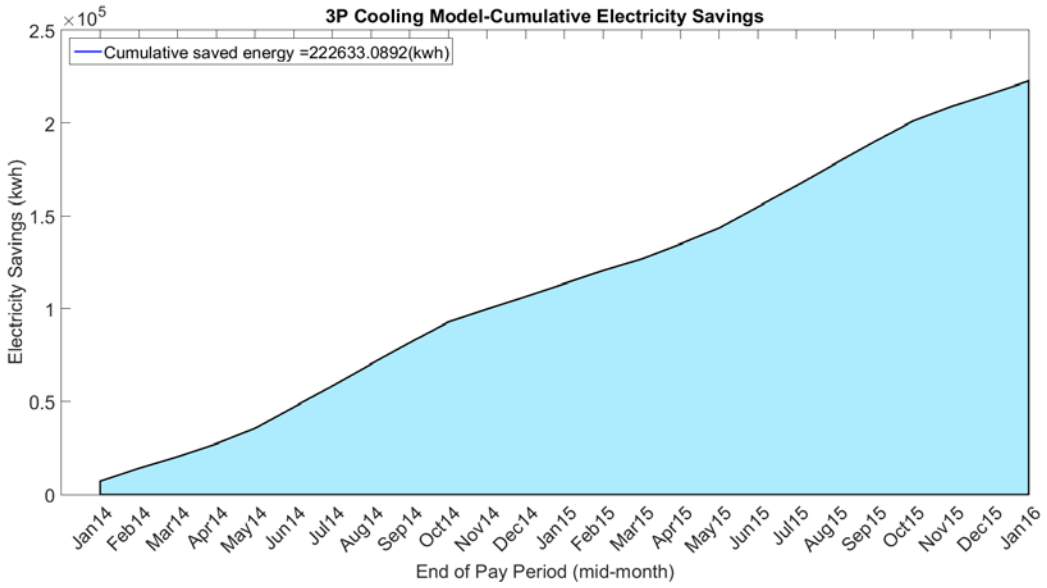


Figure 21. Goshen County Detention Center Cumulative Electricity Savings

Evergreen Court

Regression Model Analysis

Five-parameter models were applied to simulate the electricity usage of Evergreen Court. The two models, as shown in Figure App.B.11, estimated the energy usage prior to retrofit and post-retrofit. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

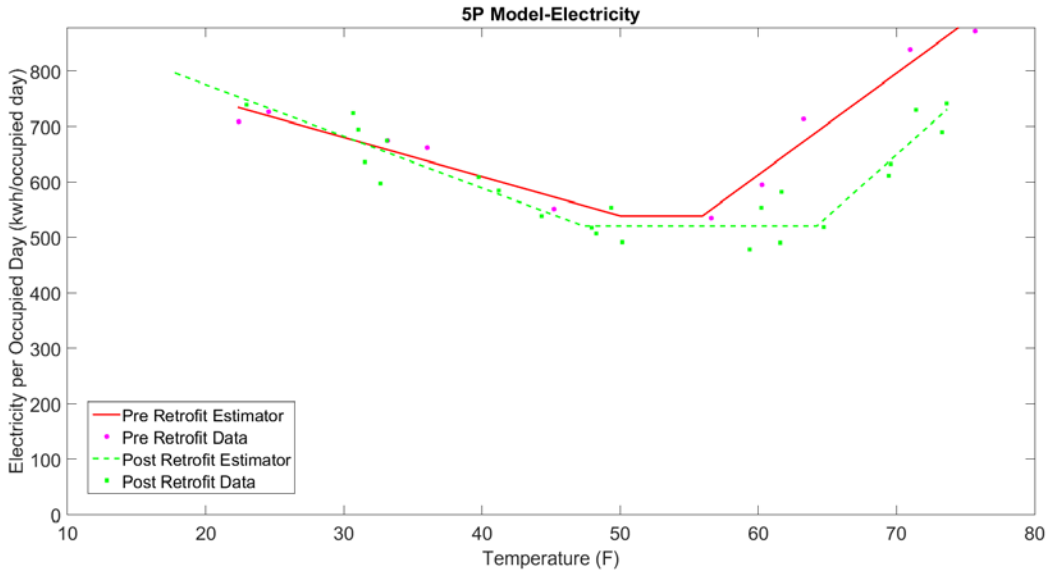


Figure App.B.11. Goshen County Evergreen Court Five-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Evergreen Court post retrofit savings report period is 24 months, a CV(RMSE) value under 25% is acceptable. These two values for Evergreen Court project were shown in Table App.B.6.

Table App.B.6. Goshen County Evergreen Court Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.947	0.865
CV-RMSE	4.218%	5.537%

Energy Savings

A total cumulative saved energy value of 44,072.81 kWh was found for the period of December 15, 2013 to December 14, 2015. Figure App.B.12 showed the progression of the cumulative savings.

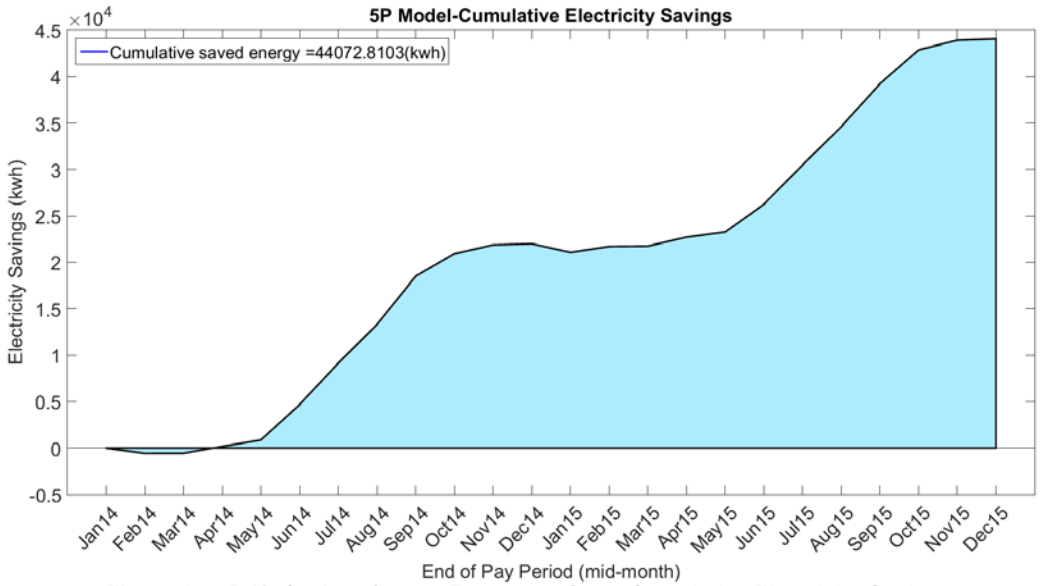


Figure App.B.12. Goshen County Evergreen Court Cumulative Electricity Savings

Extension

Regression Model Analysis

Three-parameter cooling models were applied to simulate electricity usage of the Extension building. The two models, as shown in Figure App. B.13, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County Extension.

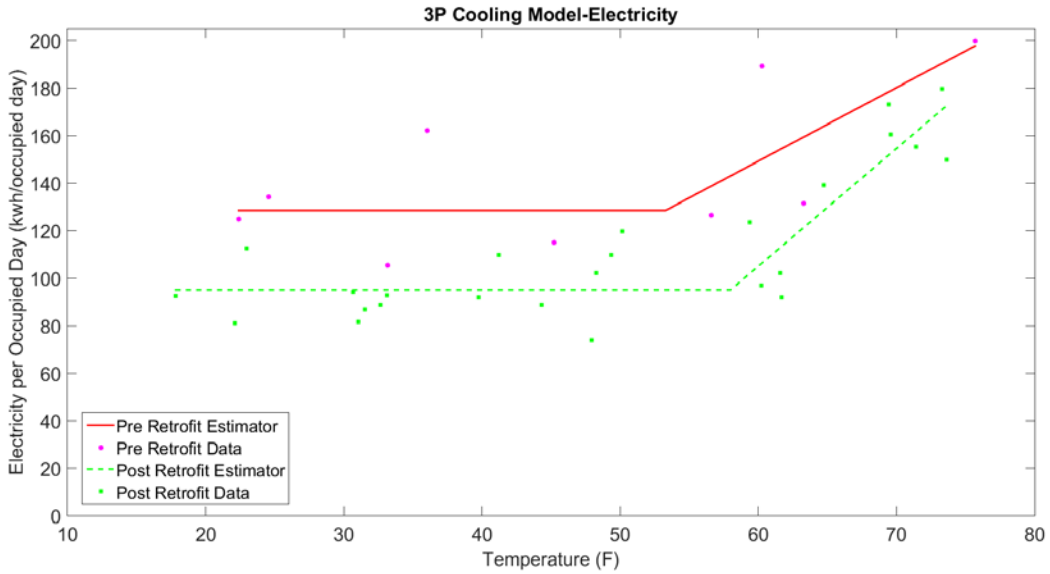


Figure App.B.13. Goshen County Extension Three-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Extension Office post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Extension project were shown in Table App.B.7.

Table App.B.7. Goshen County Extension Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.501	0.786
CV-RMSE	17.455%	12.878%

Energy Savings

A total cumulative saved energy value of 17,144.80 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.14 showed the progression of the cumulative savings.

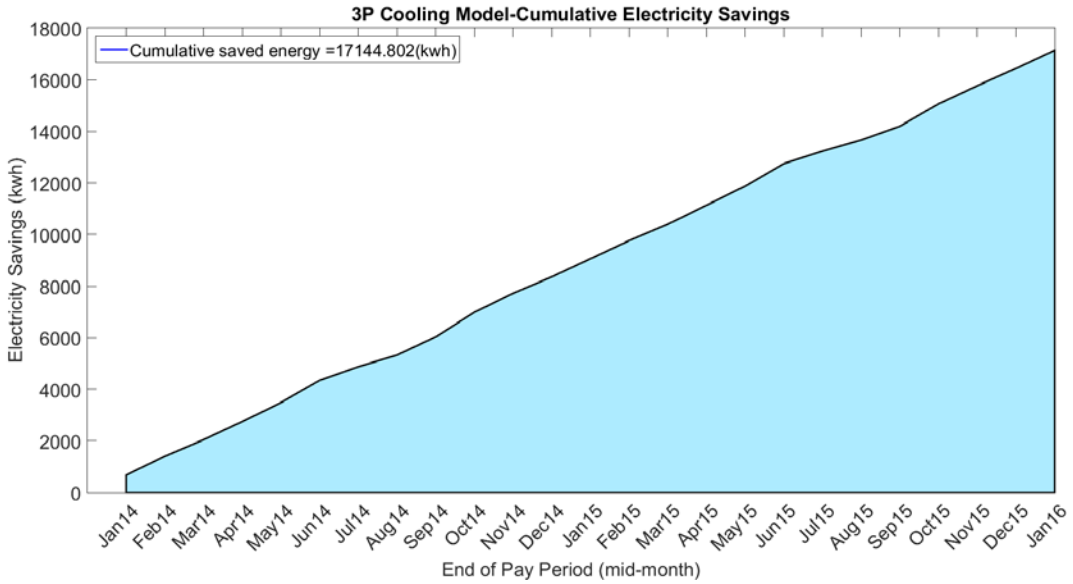


Figure App.B.14. Goshen County Extension Cumulative Electricity Savings

Fairgrounds

Regression Model Analysis

Four-parameter models were applied to simulate electricity usage of the Fairground buildings. The two models, as shown in Figure App.B.15, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

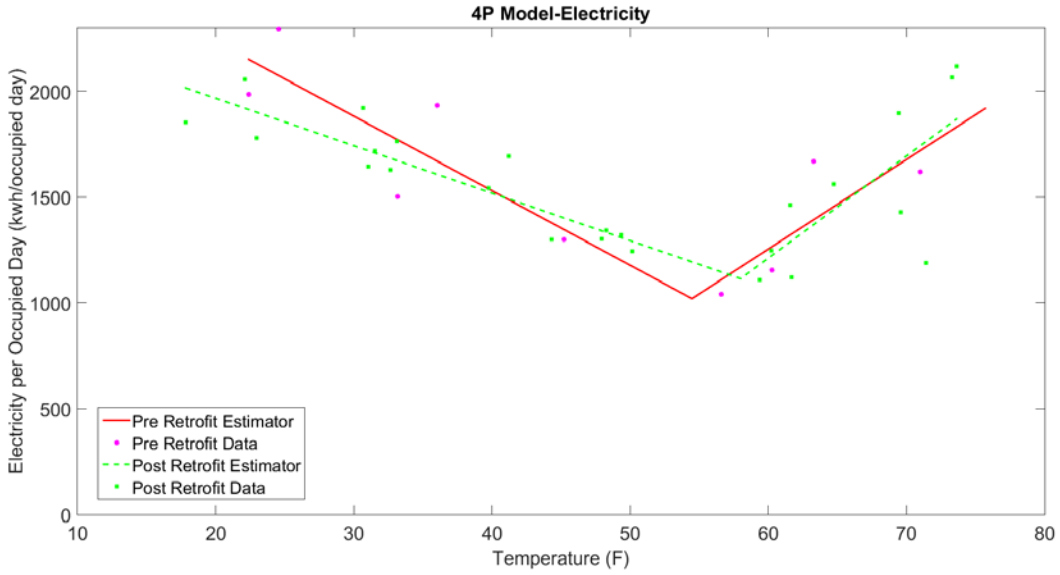


Figure App.B.15. Goshen County Fairgrounds Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Fairgrounds post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Fairgrounds project were shown in Table App.B.8.

Table App.B.8. Goshen County Fairgrounds Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.763	0.647
CV-RMSE	14.362%	12.177%

Energy Savings

A total cumulative saved energy value of 18,585.67 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.16 showed the progression of the cumulative savings.

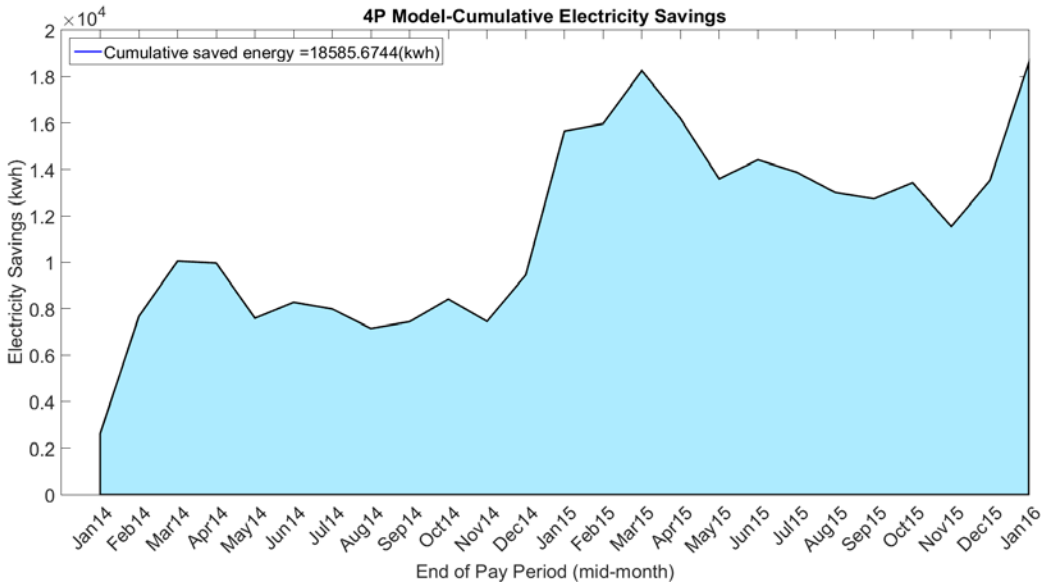


Figure App.B.16. Goshen County Fairgrounds Cumulative Electricity Savings

Library

Regression Model Analysis

Four-parameter models were applied to simulate electricity usage of the Library building. The two models, as shown in Figure App.B.17, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

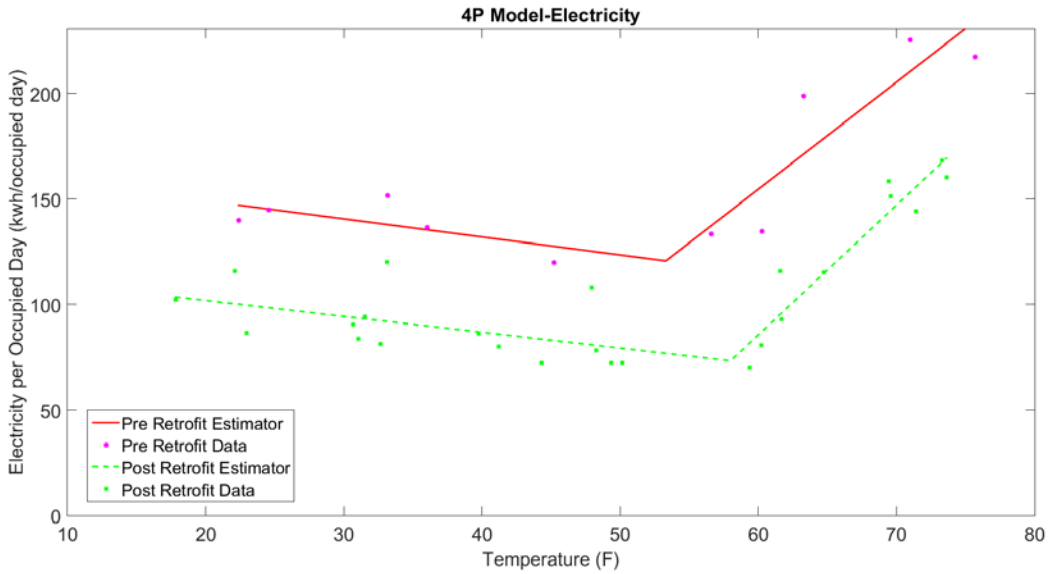


Figure App.B.17 Goshen County Library Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Courthouse post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Care Center project are shown in Table App.B.9.

Table 149. Goshen County Library Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.846	0.845
CV-RMSE	10.669%	12.176%

Energy Savings

A total cumulative saved energy value of 32,872.25 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.18 showed the progression of the cumulative savings.

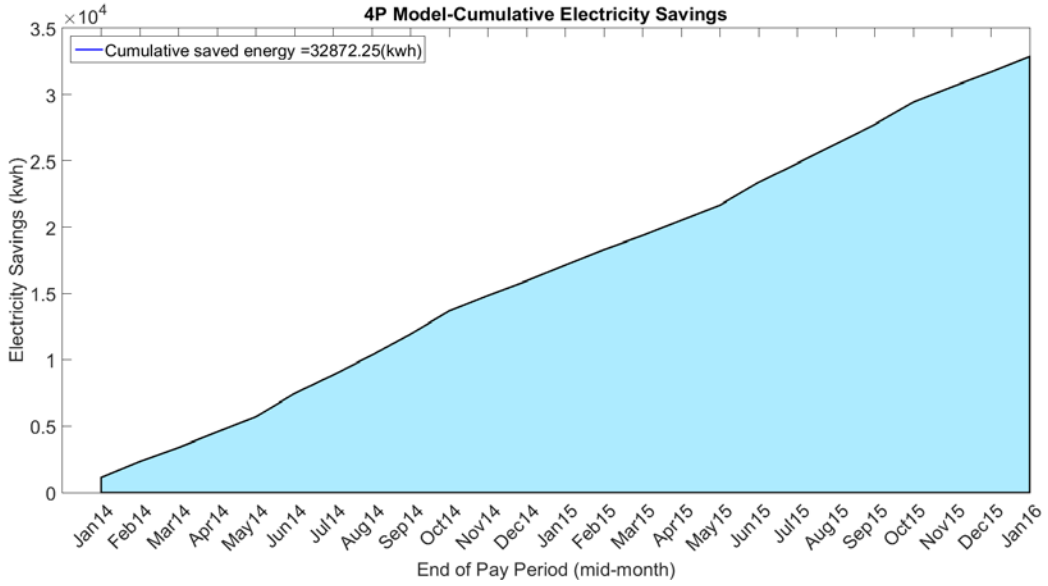


Figure App.B.18. Goshen County Library Cumulative Electricity Savings

Public Health

Regression Model Analysis

Four-parameter models were applied to simulate electricity usage of the Public Health building. The two models, as shown in Figure App.B.19, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

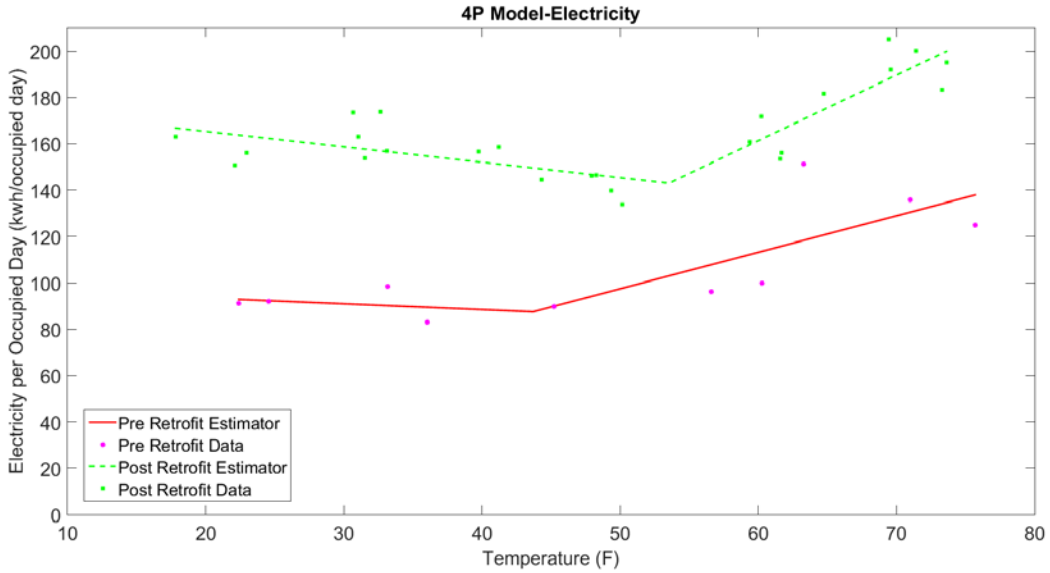


Figure 22. Goshen County Public Health Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Public Health post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Public Health project were shown in Table App.B.10.

Table App.B.1015. Goshen County Public Health Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.633	0.766
CV-RMSE	14.762%	5.879%

Energy Savings

A total cumulative saved energy value of -31,313.89 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.20 showed the progression of the cumulative savings.

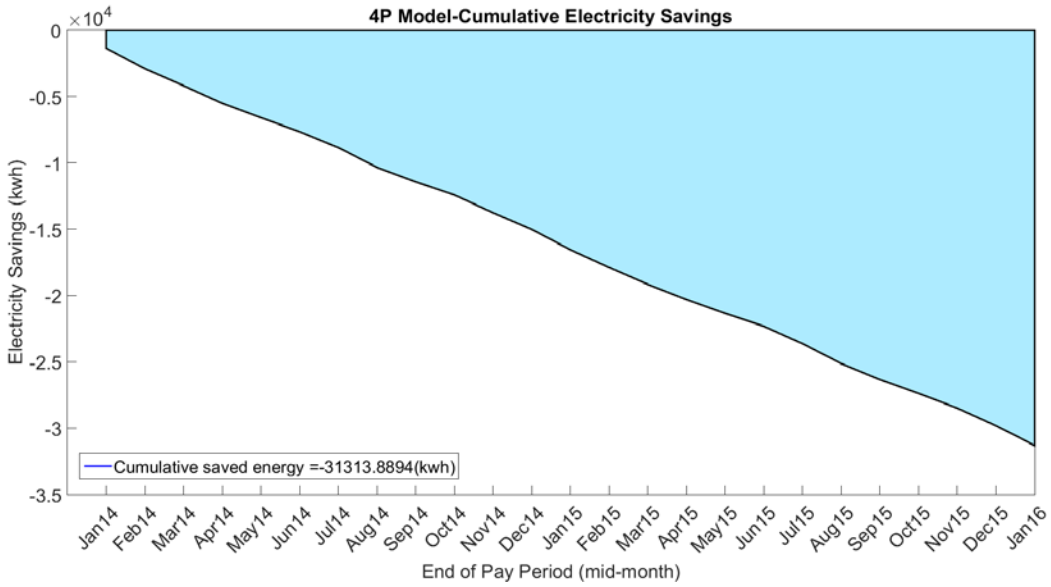


Figure App.B.20. Goshen County Public Health Cumulative Electricity Savings

Road and Bridge

Regression Model Analysis

Four-parameter models were applied to simulate electricity usage of the Road and Bridge buildings. The two models, as shown in Figure App.B.21, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Goshen County.

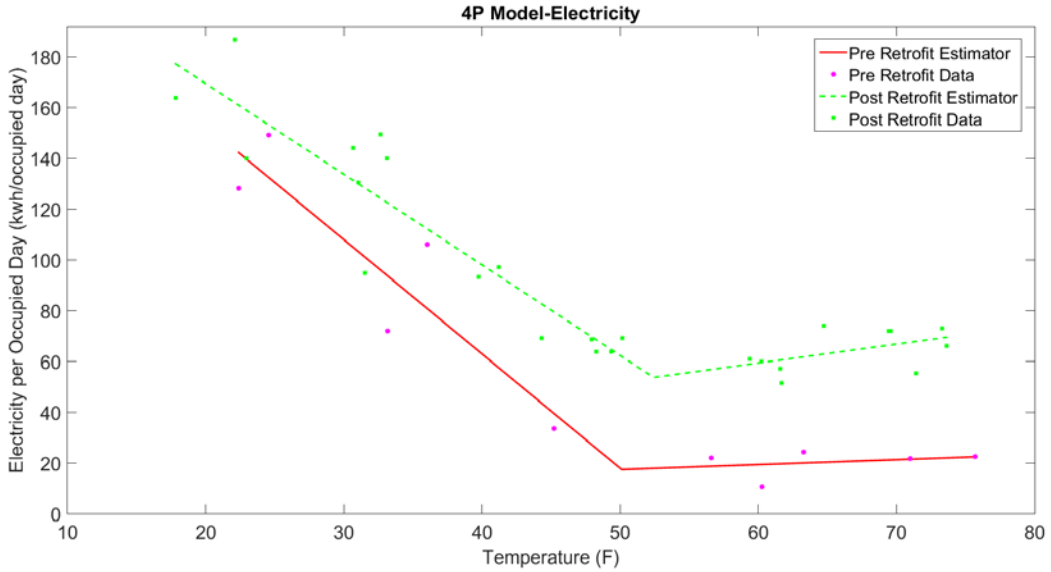


Figure App.B.21. Goshen County Road and Bridge Four-Parameter Model, Electricity Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Goshen County Road and Bridge post retrofit savings report period is 25 months, a CV(RMSE) value under 25% is acceptable. These two values for the Road and Bridge project are shown in Table App.B.11.

Table App.B.11. Goshen County Road and Bridge Quality of Fit

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.927	0.890
CV-RMSE	26.665%	14.842%

Energy Savings

A total cumulative saved energy value of -19,077.56 kWh was found for the period of December 15, 2013 to January 14, 2016. Figure App.B.22 showed the progression of the cumulative savings.

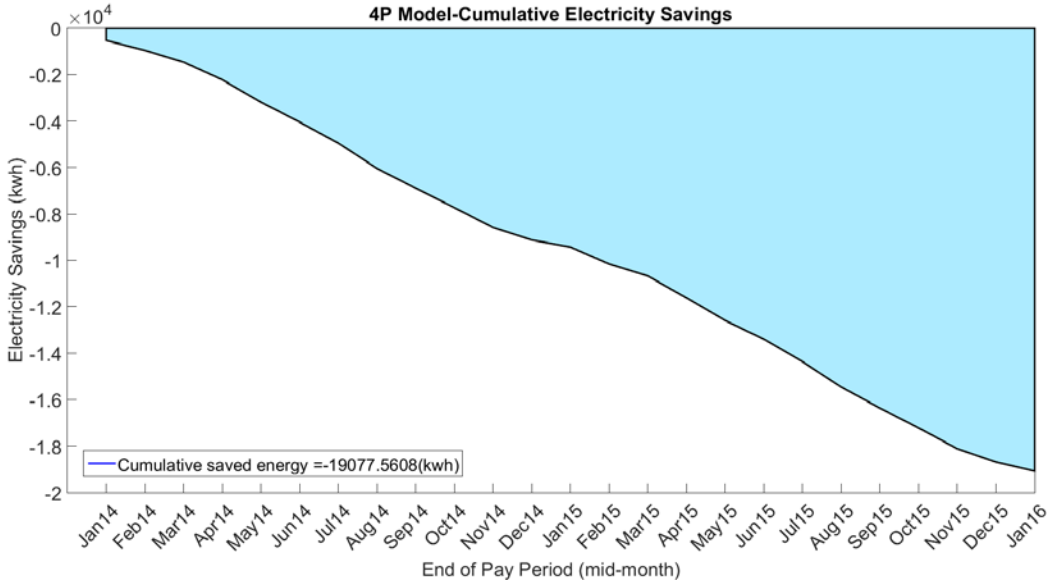


Figure App.B.22. Goshen County Road and Bridge Cumulative Electricity Savings

B.4 WyLITE: Niobrara County Library

Regression Model Analysis

Four-parameter models were applied to simulate electricity usage for the Niobrara County Library building. The two models, as shown in Figure App.B.23, estimated the electricity usage prior to retrofit and post-retrofit, respectively. Electricity per occupied day was calculated using monthly electricity data provided by Niobrara County Library.

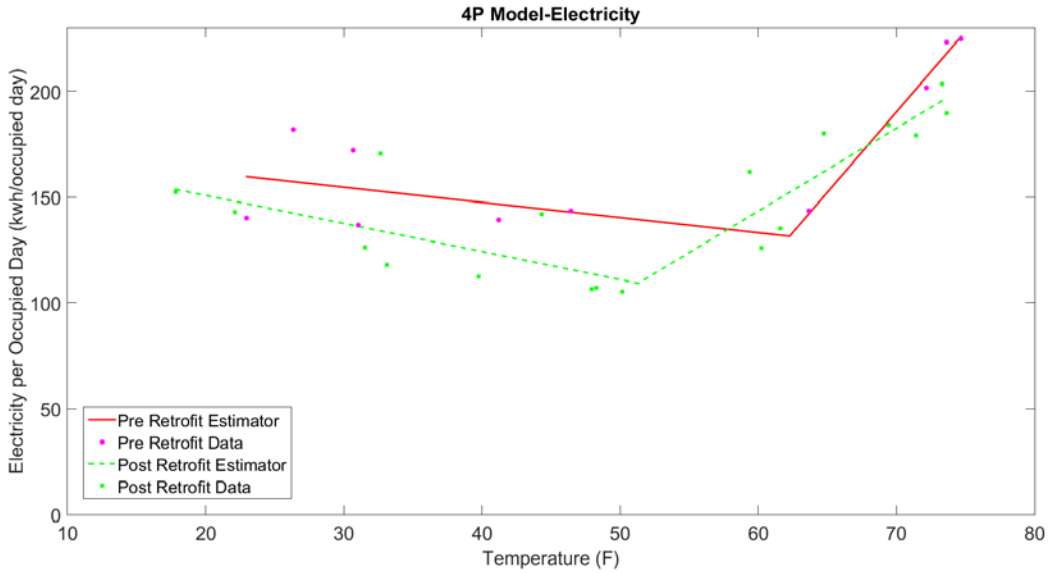


Figure App.B.23 Niobrara County Library Four Parameter Model, Electricity Usage

Three-parameter heating models were used to simulate natural gas usage for the Niobrara County Library building. The two models, as shown in Figure App.B.24, estimated the natural gas usage prior to retrofit and post-retrofit, respectively. Natural gas usage per occupied day was calculated using monthly natural gas data provided by Niobrara County Library.

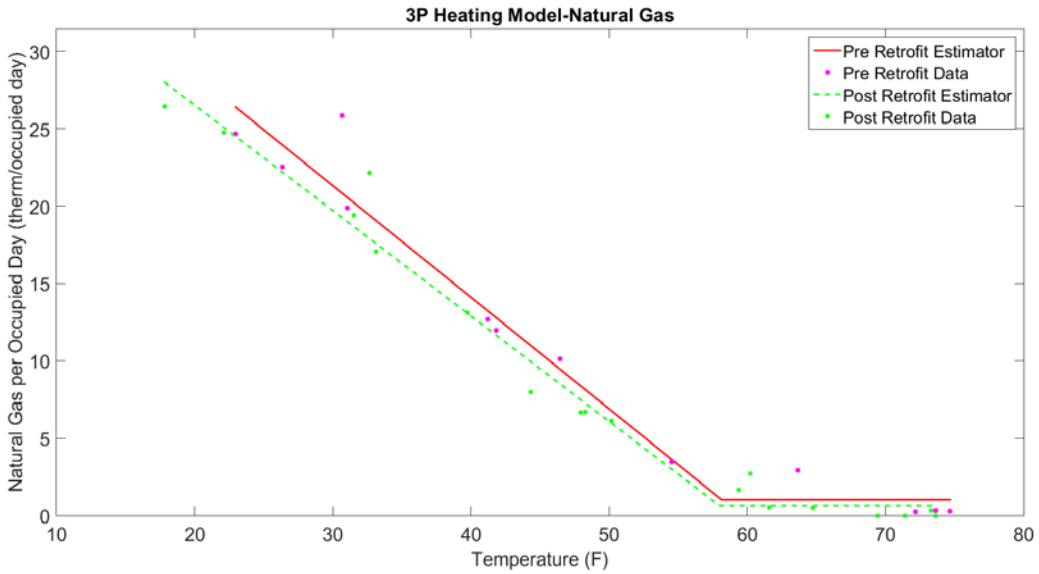


Figure App.B.24 Niobrara County Library Four Parameter Model, Natural Gas Usage

Both R^2 value and CV(RMSE) were used to determine whether a model's fit is acceptable. An R^2 value closer to 1.0 is more acceptable. Additionally, because the Niobrara County Library post retrofit savings report period is 18 months, a CV(RMSE) value under 25% is acceptable. These

two values for the electricity and natural gas models developed for Niobrara County Library were shown in Tables App.B.12–13, respectively.

Table App.B.12. Niobrara County Library Quality of Fit, Electricity

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.848	0.768
CV-RMSE	9.190%	11.139%

Table App.B.13. Niobrara County Library Quality of Fit, Natural Gas

	Pre-Retrofit	Post-Retrofit
R^2 Value	0.966	0.978
CV-RMSE	17.164%	16.626%

Energy Savings

A cumulative total of 4,792.61 kWh of electricity were saved from the period of July 15, 2014 to January 14, 2016. A cumulative total of 342.36 Therms of Natural Gas were saved from the period of July 15, 2014 to January 14, 2016. The cumulative savings were shown in Figures App.B.25–26 for electricity and natural gas, respectively.

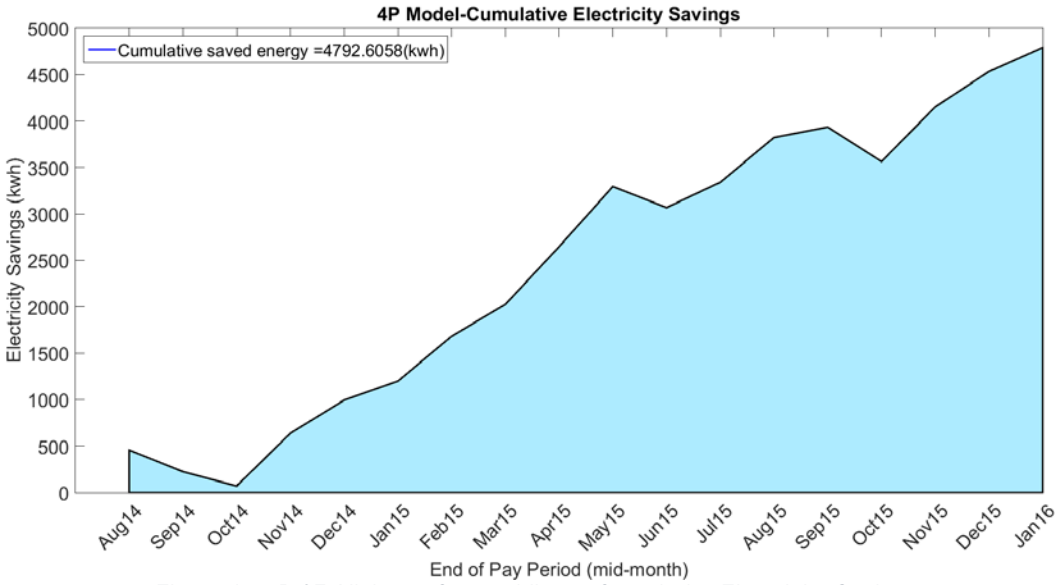


Figure App.B.25. Niobrara County Library Cumulative Electricity Savings

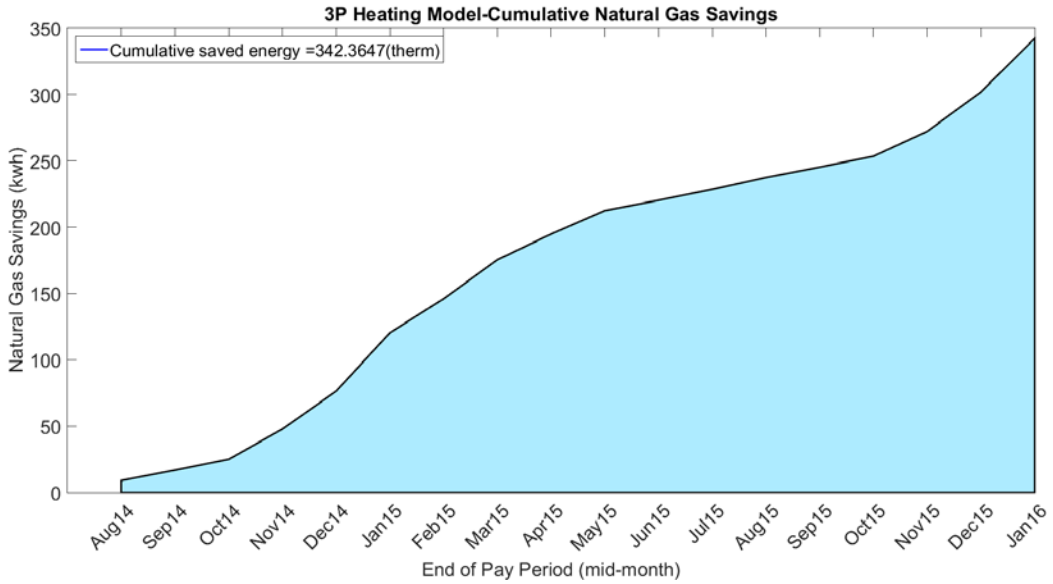


Figure App.B.26 Niobrara County Library Four Parameter Model, Natural Gas Usage

APPENDIX C: ABOUT BERG

BERG, the Building Energy Research Group at the University of Wyoming, is an academic research unit with unique capabilities. The faculty leadership consists of:

- 2 Architects
- 2 Engineers
- 2 Economists

And we include graduate students and professional consultants when necessary.

BERG does not have a political agenda. We are dedicated to offering sensible solutions to all types of real-world problems related to energy efficiency, and building design and performance. We do not accept projects which are only commercial in nature and can be performed by Wyoming professionals. We accept projects which involve academic research, or become class projects, or engage unique expertise which is not offered by Wyoming professionals.

www.uwberg.org

PEOPLE

1. **Liping Wang** Ph.D., P.E.
   Liping is Assistant Professor of Architectural Engineering, with expertise in: Energy systems design; Building energy simulation and model calibration; Commissioning; Fault detection, Control sequence modeling, and optimization for HVAC systems.

2. **Anthony Denzer** Ph.D., M.Arch., LEED-AP
   Tony is Associate Professor of Architectural Engineering, with expertise in architectural design and energy efficiency. He is the author of *The Solar House: Pioneering Sustainable Design* (2013).

3. **Milton Geiger** M.S., LEED GA, REP, CEM
   Milt is the energy extension coordinator for UW Extension and the School of Energy Resources. He has a broad expertise in feasibility analysis for energy efficiency and renewable energy projects.

4. **Jon Gardzelewski** AIA, M.Arch., LEED-AP
   Jon is a licensed architect and Lecturer in Architectural Engineering. His expertise is in architectural design, energy efficiency, and computer modeling and simulation tools. He also leads student teams in performing home energy audits.

5. **Gang Tan** Ph.D., P.E., LEED-AP
   Gang is Assistant Professor of Architectural Engineering, with expertise in HVAC systems, Commissioning and Retro-commissioning, Level III energy audits, and large-scale benchmarking studies.

6. **Ben Gilbert** Ph.D.
   Ben is Assistant Professor in the Department of Economics & Finance. He specializes in Environmental and Natural Resource Economics and Applied Microeconomics, focusing on decision-making.