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REPORT #E15-319

Existing Building Renewal

Montana and Idaho Savings Validation

2014 Results

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Acknowledgment

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Executive Summary

This report summarizes research conducted for the Northwest Energy Efficiency Alliance (NEEA) as part of the evaluation of four Existing Building Renewal (EBR) pilot projects. This evaluation involved a review of the energy efficiency efforts undertaken at the NEEA EBR participating owner demonstration buildings in Missoula, Montana and in Boise, Idaho during the period of 2013 through 2014 in order to validate savings. These are the first two of four buildings to pilot the EBR initiative, which is designed to achieve whole-building deep energy efficiency retrofits of existing assets through the integration of savings strategies across building systems. The specific objectives of this evaluation study are to validate the energy savings estimated as a part of the Integrated Measure Packages (IMP) deployed in 2014 for each building. The IMP is being deployed in phases and this review deals with Phase 2 measures which included:

Montana Building:

1. HVAC – Variable Refrigerant Volume HVAC System
2. HVAC – Installing Direct Digital Controls System
3. HVAC - Testing and Balancing
4. HVAC - Recommissioning Flow Rate
5. HVAC - Decommissioning Main Exhaust Fan
6. Lighting - Delamping
7. Lighting - Energy Efficient Lighting
8. Lighting - Occupancy Sensors
9. Lighting - Re-circuiting Lighting
10. Water Heating - 50 gallon Domestic Hot Water Heater

Idaho Building:

1. Infiltration Reduction – envelope sealing around the smoke relief dampers in the elevator shaft

Montana Building:

Project staff reports that measures installation was completed as of December 31, 2013. Navigant Consulting, Inc. (Navigant) used whole building energy use simulation modeling to estimate the gas and electric savings from these measures. The model simulated the energy consumption of the building after these measures were installed and compared it to the baseline model and to actual energy consumption meter data. Navigant calibrated the baseline model using two years of meter data and normalized the usage data using weather data (typical meteorological year or TMY data) for this area of Montana[1].

Per Navigant's recommendation from the Phase 1 report, the building owner installed submeters to the data center floors in the beginning of spring 2014. The goal was to generate nine months of useful post retrofit data in order to calibrate the Phase 2 model and also to true up the savings from Phase 1 as this would have provided six more months of data for Phase 1 calibration. However, Navigant discovered

[1] Missoula International Airport Weather Station Data

that the submeters were installed incorrectly and the readings from the submeters did not represent the data center energy consumption. The variance in the consumption was over acceptable limits and after discussing with the Integrated Design Lab (IDL) and the building owner, Navigant determined the building energy consumption data could not be used for any calibration purposes until the issue was addressed. The issue was fixed during the summer of 2014 by rewiring the submeters. This resulted in only 4 months of available electric data for the post-retrofit case.

After multiple interviews with the building owner and the IDL, it became apparent that the building was also not running as designed until September 2014, which is directly after the meter issue was fixed. According to the follow-up test, adjust, and balance report[2] that was conducted in May 2014, the contractors who installed the HVAC system to the building did not do air balancing properly, did not put the fan coil units in the correct locations per the design, and did not set dampers correctly. So, for the period of time where meter data was not available, Navigant concluded that the building was operating at a less efficient state than intended based on design, resulting in saving less energy than would have been the case had the installed systems worked according to design.

However, to demonstrate both the true savings potential of NEEA's initiative and the validated savings, Navigant created two scenarios; Scenario 1 details savings that would have happened if malfunctioning had not occurred; Scenario 2 is the validated savings after Navigant's evaluation of final savings based on actual conditions. Due to the absence of savings in Scenario 1, the negative impact of the malfunction in the HVAC system does not show up in Scenario 2. Navigant presents each scenario in Table 1, below.

Table 1: Montana Phase 2 Scenario Savings

Savings Metric	Scenario 1	Scenario 2
Electric Savings	0%	0%
Natural Gas Savings	98%	98%
Electric Savings (MWh)	1.3	0
Natural Gas Savings (MMBtu)	1,997.9	1,997.9
Natural Gas Savings (Therms)	19,979.0	19,979.0
Electric Savings (AMW)	0	0

Note: Annual Average MW (AMW) = (MWh annual saved) / 8760 hours

After a "shake-out" period with negative electric savings in 2014, the building owner realized the cost of commissioning was really worth it. In the long term, commissioning EBR buildings could help ensure that projects sustain savings at expected levels and that new measures function properly.
Navigant believes the building is now operating as designed and the submeters are installed correctly. As next steps to true-up the savings from 2014 and realize more electric savings from this building, Navigant recommends that NEEA should implement the following:

[2] Test, Adjust, and Balance Report, AirCommander, May 2014.

- Ensure the submeters are working correctly and any additional data center load has submeters connected
- Install lighting measures to the remaining 1st and 6th floors and conduct another lighting survey with fixture count by each floor at the end of 2015
- Keep track of the occupancy by each floor and keep track of the electric heaters used on the 4th floor
- Educate the building owner and manager to optimize the HVAC controls and occupancy sensors used in the conditioned area

Idaho Building:
This evaluation report quantifies the additional savings realized from the infiltration reduction measures undertaken in 2014, relative to the savings baseline inclusive of the efficient boiler retrofit from Phase 1 of the project. Navigant also presents the savings realized over the entire course of the demonstration project from 2013 through 2014.

Navigant used the same approach with the Montana Building for whole-building energy simulation modeling to estimate the marginal gas and electric savings from the infiltration reduction measure. Navigant calibrated the baseline model using two years of meter data (2011 and 2012) provided by IDL, and normalized the annual usage data using typical meteorological year 3 (TMY 3) weather data for Boise, Idaho[3].

Table 2 presents an overview of savings estimates for Phase 2 of the demonstration project, as well as the total savings for Phase 1 and Phase 2 of the project combined.

Table 2: Idaho Phase 2 Project Savings

Savings Metric	Phase 2 Incremental*	Phase 1 and Phase 2 Total
Electric Savings	1.0%	1.0%
Natural Gas Savings	21.9%	27.7%
Electric Savings (MWh)	5.4	5.4
Natural Gas Savings (MMBtu)	59.3	80.8
Natural Gas Savings (Therms)	593	808
Electric Savings (AMW)	0.0006	0.0006

Note: Annual Average MW (AMW) = (MWh annual saved) / 8760 hours

**Phase 2 Incremental Project Savings represent the savings of Phase 2 relative to Phase 1.*

As next steps to true-up the electric and gas savings from 2014 and to validate the savings for Phase 3 measures, Navigant recommends that NEEA implement the following:

[3] Boise Airport Weather Station Data

- For infiltration reduction measures, NEEA should repeat the blower door air leakage tests pre and post retrofit to inform evaluation of measure savings.
- Utilize end-use sub-metering as applicable for future efficiency measure

The following section describes details of the methodology Navigant used to validate savings.

Montana Building

1. Methodology

1.1 Data Collection

Navigant utilized five different channels of sources for information to input into the energy models:

- Energy audit reports/drawings[4,5,6,7]
- Integrated Design Lab's (IDL) energy models
- IDL's building visits
- Building commissioning report[8]
- Building owner interviews[9]

Information provided from energy audit reports informed Navigant about the baseline and post-Phase 2 condition of the building. The IDL's energy models helped to fill gaps in the information that Navigant was not able to extract from the audit reports. Interviews with the building owner and the manager confirmed some of Navigant's hypotheses about the building operations. For most of the data collection, Navigant collaborated with Gunnar Gladics and Brad Acker from the Idaho IDL, who played a major role and acted as facilitator acquiring the necessary data.

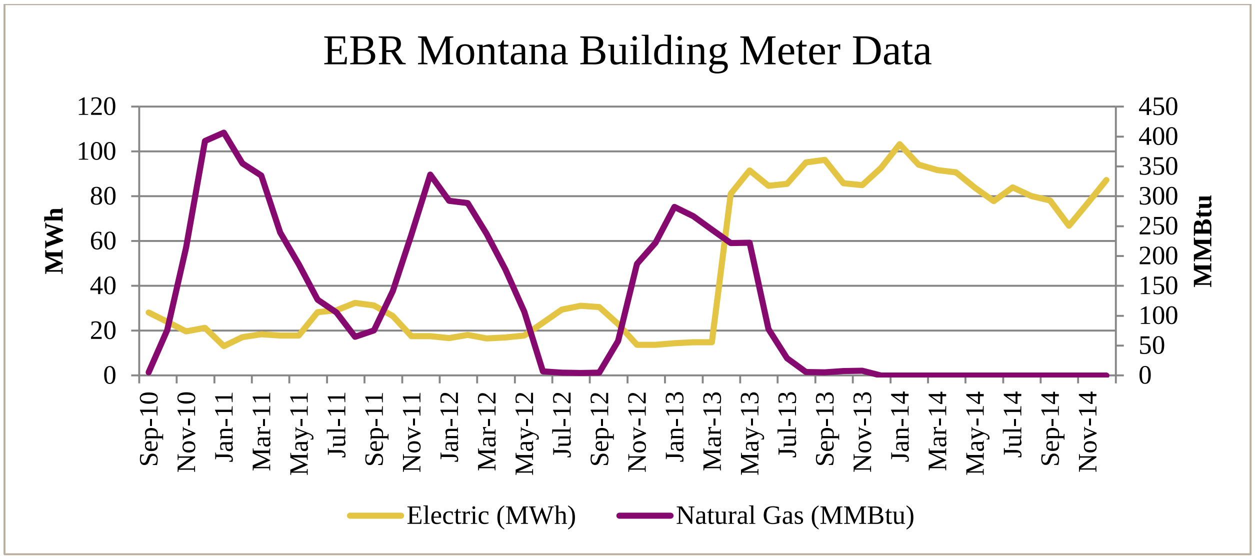
Navigant received four years' worth of monthly gas and electric utility meter data for the period September 2010 through December 2014 as charted in Figure 1. This meter data provided Navigant with 2 years of pre-retrofit billing data and 1 year of post-retrofit billing data for Phase 1 retrofits and 1 year of post-retrofit billing data for Phase 2. This data were used to validate the energy savings due to NEEA's initiative, which were completed in December 2013.

However, as mentioned in the Phase 1 report[10] of this two phase evaluation study, Navigant discovered that pre-March 2013, the building had two separate electric meters; one for the building (main meter), and one for the data center located on the 4th and 5th floors of the building. The building owner used the separate meter to bill the data center owners separately from the rest of the tenants. In March 2013,

[4] Walk Through Audit Report, June 2011.
[5] Pilot Project Assessment, IDL, June 2012.
[6] Preliminary Savings and Costs Estimates, IDL, December 2012.
[7] Deep Energy Retrofit, BetterBricks, February 2013.
[8] Test, Adjust, and Balance Report, AirCommander, May 2014.
[9] Interview with the building owner by Brad Acker, February 2014.
[10] Existing Building Renewal Report: Montana Savings Validation 2013 Results, Navigant Consulting, March 2014.

unbeknownst to the owner, the electric contractor and utility company unified these two meters into one meter resulting in the dramatic change in the usage trend.

Figure 1: EBR Montana Monthly Building Meter Data



Because NEEA's initiative excluded the data center floors from the building, it was imperative for Navigant to isolate the data center energy consumption from the remainder of the building's energy consumption to ascertain that the final savings estimate representing the savings due to the initiative. The obvious solution would have been to subtract the data center meter data from the main meter data. However, as noted, the data center meter data was not available due to the fact that during the remodel, the data center meter was disconnected from the data center, making this approach untenable. Another approach would have been to extrapolate the historic data center energy usage data to forecast the data center energy usage after the meter was disconnected. Navigant decided this approach would not be appropriate for two reasons: 1) the size of the data center load compared to building electricity load was very large; and 2) the data center could have added or removed servers over the period of the analysis, making this approach problematic.

Per Navigant's recommendation from the Phase 1 report, the building owner installed submeters to the data center floors in the beginning of spring 2014. The goal was to generate nine months of useful post retrofit data in order to calibrate the Phase 2 model and also to true up the savings from Phase 1 as this would have provided six more months of data for Phase 1 calibration. However, after discussing with IDL and the building owner, Navigant discovered that the submeters were installed incorrectly and the readings from the submeters did not represent the data center energy consumption. The variance in the consumption was over acceptable limits[11] and Navigant determined the building energy consumption data could not be used for any calibration purposes until the issue was addressed. The issue was fixed during the summer of 2014 when the facility operator had the submeters rewired. This resulted in only 4

[11] The data center load was more than twice the whole building electricity load. The variance in the data center consumption was as much as the whole building electricity load.

months of available electric data for the post-retrofit case, as seen in Figure 1, which Navigant was able to utilize to calibrate its Phase 2 energy model. Because of this, Navigant utilized calibrated simulation models (IPMVP: Option D[12]) to validate the savings achieved from Phase 2 measures in 2014.

1.2 eQuest Inputs

Navigant used detailed site specific inputs and created baseline and post-Phase-2 whole building calibrated energy use simulation models using eQuest 3.65[13] to verify savings from the measures installed in Phase 2. Navigant used the information from the sources described in the previous section and later adjusted some inputs based on the feedback from IDL and NEEA.

1.2.1 Baseline Model

The building located in Montana is a six-story structure built in 1952. The south elevation faces approximately 24 degrees west of true south in Missoula. The ground level south elevation is comprised of double glazed glass storefront in an aluminum frame which is the lobby for a bank. The upper five stories of the south elevation is an aluminum curtain wall system with a horizontal band of ribbon windows and spandrel panels along the floor lines. The north elevation is a blank wall of concrete and brick. The east elevation is a blank brick wall with approximately four foot square glass block windows at each of the interior exit stair landings. The full height elevator, rest rooms, and a mechanical space are also located at the east end of the building. Louvers for the mechanical room are in the horizontal lines of the east end brick component of the south elevation. The lobby for the upper floors is also located in the southeast corner of the building and the main elevator is in this lobby. The west elevation is a blank brick wall with the exception of a three-panel double-glazed unit at the ground level. At the west end of the building there is an electric elevator that travels between the basement and second floor. The floor plates above the first floor are typically single-loaded corridors along the north wall that provide access between the north fire stair and the east fire stair. Office spaces are then located along the south curtainwall[5].

The fifth floor houses a data center and the fourth floor is currently being renovated into a data center. The data center on the fifth floor has a separate HVAC system than the main building HVAC system and conditioned air is served by three air handling units compared to four single zone air handling units on other floors. As described above, the building used to have a separate meter attached to the fifth floor data center servers and HVAC system.

To mimic the main meter data pre-integration of the data center meter to the main meter, Navigant excluded the fifth floor HVAC system and the data center load from the model, meaning Navigant modeled it as an unconditioned space with no occupants. This way the baseline model consumption results were analogous with the main meter data, which allowed Navigant to calibrate model results to meter data. The fourth floor is still under renovation, therefore Navigant modeled it in the same way as

[12] Per IPMVP 2012, Volume 1, p. 29, Option D is useful where: "Reporting-period energy data are unavailable or obscured by factors that are difficult to quantify."

[13] eQuest is an 8760 hour whole building energy model based on the DOE 2 building energy simulation engine developed in collaboration with Lawrence Berkeley National Laboratory (LBNL) .

it modelled the rest of the floors as conditioned space as for the period of analysis it was occupied and connected to the main meter.

Below, Navigant describes the inputs from various resources described in the Data Collection section of this report that Navigant used to create the baseline model. Navigant used the window and wall types described in the energy audit reports, and the final average U-values and window to wall area ratios for each face of the building as listed in Table 2. Navigant modeled the building to be approximately 22,000 square feet gross with approximately 19,000 square feet conditioned. As mentioned earlier, due to the data center, Navigant modeled the fifth floor as unconditioned. For occupancy, Gunnar Gladics provided Navigant with a timeline showing floor by floor tenancy over the period of the analysis based on his interview with the building owner. For lighting and equipment densities, Navigant utilized the field measurement results for each floor from the Pilot Project Assessment[5] report. The occupancy, lighting density, and equipment density levels are listed in Table 3.

The baseline HVAC system included six multi-zone constant air volume systems with ducted return air; however the system on the 4th floor had been dismantled. Each system contained four zones generally distributed linearly along the length of the building. The HVAC exhaust system was central, while each zone had an individual air intake through a grille in the building wall. A single zone heating and ventilation unit served the basement. Navigant found that the existing controls systems were pneumatic, and cooling was direct expansion air-cooled system and heating was a natural gas steam boiler system. Navigant leveraged the system efficiencies and maximum supply temperatures used in IDL's energy models, and adjusted cooling system size to 54 tons and sized the heating system to 2.1MMBtu/hr based on audit reports. The inputs for the HVAC system are listed in Table 4.

Navigant estimated the baseline HVAC setpoints given that results from the audit reports revealed that thermostats were problematic and the HVAC system was not able to satisfy the supply air temperature setpoints for conditioned air. Navigant compared the energy model results to meter data to determine a reasonable estimate for the average thermostat setpoints for the baseline case. Navigant used the same technique to determine the infiltration rate for the building. Infiltration is the introduction of outside air into a building, typically through gaps in the building envelope and through use of doors for passage. Infiltration was significant for this building, especially because the building had significant gaps, cracks and holes in the envelope, damage in window gaskets and great deal of leakage through gaps in the curtain wall on the south façade.

The baseline fan system consisted of constant volume fans with approximately 6000 cfm cooling capacity per floor. The outdoor air damper positions on all of the air handling units were closed or broken. The building operator mentioned that the outdoor air dampers were shut during the winter and summer, and opened only during the shoulder seasons. The dampers were manually operated and Navigant assumed that this schedule may be unpredictable. Therefore, Navigant modeled outside air flow to be low. Audit reports also indicated both the building exhaust and bathroom fans were operating 24/7[5], which is particularly important as all of the building's outdoor air dampers were shut, the exhaust fans were negatively pressurizing the building, meaning air was being pulled into the building.

For building operations, Navigant modeled the building HVAC system to be on 24/7 including weekends and holidays, except during summer months the boiler is assumed to be disconnected from the system. Navigant modeled the rest of the building operations in line with standard office building operation schedules as defined in eQuest.

1.2.2 Phase 1 Model

Navigant developed a Phase 1 model to estimate the energy consumption of the building after the following measures were installed:

- Building Envelope - Seal existing leaks in south curtain wall and other areas of the envelope
- HVAC - Add time clocks to exhaust fans and air handling units in the ventilation system
- HVAC - Test and repair broken dampers
- HVAC - Improve air flow through conditioning system with cleaner filters
- Building Envelope - Insulate behind the spandrel panels at the south façade

These measures typically are specified as operations and maintenance (O&M) measures and usually do not require significant changes to the existing mechanical system. These measures primarily targeted building operations and building envelope. Navigant incorporated the impact of these measures into the calibrated baseline model by adjusting the following fields:

- <u>Fan schedule</u>: Navigant changed the ventilation schedule from continuous (24 hours/day) to 14 hours/day due to installation of time clocks to air handling units.
- <u>Fan system total efficiency</u>: Navigant improved the total efficiency of fan system due to filter change. Navigant expects building operators to change filters on a regular schedule.
- <u>Fan system static pressure</u>: Navigant increased the static pressure of the fan system to exhibit the effects of adding time clocks to exhaust fans.
- <u>Outside air flow</u>: Navigant increased the outside air flow rates per person since dampers that were broken and in closed state were repaired to operate as expected. Opening the damper allows outdoor air to enter the building.
- <u>Infiltration</u>: Navigant decreased the infiltration rate of the building envelope to incorporate the impact of insulation and sealing of the envelope.

1.2.3 Phase 2 Model

Navigant developed a Phase 2 model to estimate the energy consumption of the building after the following measures were installed in addition to all the applicable measures that were installed during Phase 1 which are already incorporated in the Phase 2 model:

- HVAC - Variable refrigerant volume (VRV) with three condenser units with a total cooling capacity of 44 tons and 17 indoor fan coils and strip heats
- HVAC - Direct digital controls (DDC) system with HVAC schedule and setpoint controls and user interface
- HVAC - Test and balance HVAC system, duct pressure, outside air intake

» HVAC - Recommission flow rate at each fan unit
» HVAC - Decommission malfunctioning main exhaust fan
» Lighting - Delamp T8s to reduce the lighting power density at basement, 2nd, and 3rd floors
» Lighting – Install energy efficient lighting to basement, 2nd, and 3rd floors
» Lighting – Install occupancy sensors to basement, 2nd, and 3rd floors
» Lighting - Re-circuiting lighting
» Water Heating – Install 50 gallon domestic hot water heater to replace 120 gallon

These measures represent the majority of the proposed IMP and are significant updates to the existing building equipment and system. These measures primarily targeted HVAC and lighting. One of the critical changes to the building was the change from fuel-based heating to electricity- based heating. This resulted in significant change in the building energy consumption trend and made it difficult to recognize the real value of the energy efficient measures from decreased electricity consumption because it introduced a new load to the electricity usage. Nevertheless, Navigant incorporated the impact of these measures into the calibrated baseline model by adjusting the following fields:

» HVAC system: Navigant changed the HVAC system to a high efficiency VRV system with direct digital controls and with supplemental strip heating and baseboards in some zones.

» HVAC schedules and setbacks: Navigant adjusted the HVAC setpoints to 74F for cooling and 72F for heating and HVAC setbacks to 78F for cooling and 70F for heating during the unoccupied hours.

» Fan schedule: Navigant changed back the fan schedule to always on status again but with setback temperatures during the unoccupied hours.

» Fan system: Navigant updated the fan system to a variable volume system with lower cfm capacities.

» Fan system static pressure: Navigant decreased the fan system static pressure as the exhaust fan was no longer negatively pressurizing the fan system and all dampers were working as designed after the commissioning was completed and air balancing was done.

» Lighting power density: Navigant decreased the lighting power density of the basement, 1st, 2nd, 3rd, and 5th floors based on the new T8 lamp counts provided by the IDL labs after delamping was completed and revised the lighting densities of rest of the floors based on more recent data.

» Water heater: Navigant changed the capacity of the 120 gallon domestic hot water heater to 50 gallons.

Also, as part of the Phase 2 retrofits, the building owner decided to decommission the 4th floor HVAC system and not install a new one as this floor will be retrofitted into a data center in the future and it will require a separate and different HVAC system. Therefore, Navigant accounted for this change to the IMP plan by changing this floor from conditioned status to unconditioned status in its post model while keeping the baseline same as previously modeled. The reason Navigant used this approach was based on the fact that in the absence of NEEA's initiative the building owner wouldn't have disconnected the HVAC system on the 4th floor in 2014 as there were still tenants living on this floor and it would have operated throughout the year. This could have resulted in significant savings for 2014, but in hindsight,

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this did not contribute to building-level energy savings, as according to the building owner, Navigant discovered that in 2014, tenants on the 4th floor used seven electric heaters at a rated total capacity of approximately 9000W for heating. This resulted in increased equipment usage as shown in Table 3.

In addition to building retrofits, Navigant received new tenant occupancy information and adjusted both baseline and post models to reflect this change in the occupancy. This means Navigant did not favor either pre or post retrofit models based on different occupancy inputs because occupancy is considered as an exogenous variable and not an endogenous variable.

Navigant lists all these inputs to model in the following tables.

Table 4: Building Characteristics

	Average U-Value/ Windows (Btu/hr-sqft-F)	Average U-Value/Wall (Btu/hr-sqft-F)	Window to Wall Area Ratio
North	0.000	0.238	0%
East	1.003	0.238	4%
South	0.977	0.238	58%
West	0.980	0.238	4%
Roof	0.000	0.044	0%
Building	0.978	0.182	11%

Table 3: HVAC System

	Cooling		Heating	
	Base	Post[14]	Base	Post[14]
System Type	Air Cooled DX Cooling	Variable Refrigerant Volume (VRV)	Boiler	Heat Pump with Strip Heating
System Sizing	Adjust Load	Adjust Load	Adjust Load	Adjust Load

[14] http://www.daikinac.com/content/assets/DOC/SubmittalDataSheets/IndoorUnitAndVentilation/SDS-FXTQ30PAVJU.pdf

System Capacity (per unit)	Autosized to Design Day	30,000 Btu/hr	2.1 MBtu/hr	34,000 Btu/hr
System Efficiency	0.4 EIR[15]	0.23 EIR	1.5 HIR[16]	0.21 EIR

[15] EIR: Electric-input-ratio

[16] HIR: Heat-input-ratio

Table 4: Modeled Thermostat SetPoints

	Occupied (°F)				Unoccupied (°F)			
	Cool		Heat		Cool		Heat	
	Base	Post	Base	Post	Base	Post	Base	Post
Winter Season[17]	76	74	71	72	76	74	71	72
Summer Season[18]	74	74	60	72	74	74	60	72

Table 5: Air Barrier System

	Baseline Condition	Phase-2 Condition
Infiltration (cfm/ft2)	0.16	0.04

Table 6: Fan Schedule

	Baseline Condition	Phase-2 Condition
Weekdays	12:00AM – 12:00AM	12:00AM – 12:00AM
Weekends/Holidays	12:00AM – 12:00AM	12:00AM – 12:00AM

Table 7: Fan System

	Baseline Condition	Phase-2 Condition
Total Efficiency (η)	0.6	0.6
Fan Control	Constant Volume	Variable Volume
Design Flow (cfm/ft2)	1.0	1.2
Static Pressure (WG)	1.0	0.5
OA Flow (cfm/person)	5.0	20.0

1.3 Model Calibration

Navigant used detailed site specific inputs to create Baseline and Post-Phase 2 whole building energy models using eQuest. The use of site specific inputs, such as actual weather data and equipment schedules, capacities, and setpoints based on known information about how the building operates, ensures that the energy use of the computer based models closely resembles the actual building energy use.

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17 Winter Season: October 1st – April 30th

18 Summer Season: May 1st – September 30th

The calibration process for the Baseline and Post-Retrofit models is as follows:

- **Information Gathering:** Collect site specific inputs for Baseline and Post-Phase 2 models including:
  - » Building geometry, composition, and orientation
  - » Actual regional weather data for dates aligned with the billing data
    - dry bulb temperature
    - percent relative humidity
  - » Equipment types and capacities
  - » Heating and cooling setpoints
  - » Building occupancy and use
  - » Weekly, seasonal, and annual equipment operational schedules
- **Develop Whole Building Energy Models**[19]**:** use the inputs above to generate the following 8760 hour energy models in eQuest
  - » Baseline
  - » Post-Phase 1 or Post-Phase 2
- **Calibrate Whole Building Energy Models by Refining Inputs:** calibrate models according to the procedures in Guideline 14:[20]
  - » Compare monthly modeled annual energy and gas use to actual billing data on a monthly and yearly basis.
  - » Adjust inputs[21] iteratively until the recommended Guideline 14 metrics are satisfied[22], using an appropriate level of effort relative to the magnitude of the savings being evaluated:
    - Coefficient of Variation of the Root Mean Square Error
      - CVRMSE ≤ 15%
    - Normalized Mean Bias Error
      - NMBE ≤ 5%

Navigant calibrated the Baseline demonstration model to 21 months of monthly electric and gas billing data, and calibrated the Post-Phase 2 model to 4 months[23] of monthly electric and gas data, resulting in

[19] Described in eQuest Inputs Section above.
[20] ASHRAE Guideline 14-2002, Section 6.3.2, p. 33.
[21] ASHRAE Guideline 14-2002, Section 6.3.3.3.9, p. 37.
[22] ASHRAE Guideline 14-2002, p. 18.
[23] See Data Collection Section for more information on availability of post retrofit billing data.

calibrated models with metrics of 14 percent CV(RMSE) and 2 percent NMBE, which are within acceptable limits required by ASHRAE Guideline 14[24].

The relative effect of calibrating to 4 months of post-Phase 2 data rather than 12 months can be seen in Figure 2[25] below to be relatively small. This resulted in additional uncertainty estimated at 10 percent in the calculated energy savings, compared to the case where 12 months of Post-Phase 2 data is available.

Figure 2: Impact of 4 Months vs. 12 Months Post-Retrofit Calibration

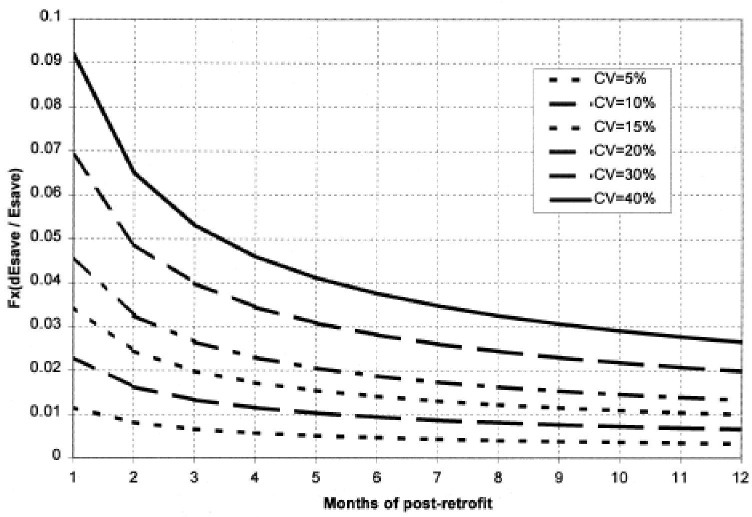

Figure B-1 Fractional uncertainty in savings with varying CVs and months of post-retrofit data.

Navigant then replaced the historical weather data used to calibrate the models with typical meteorological year (TMY3) weather data[26] for Missoula, Montana, in order to subject building components to identical weather load conditions in the pre and post case that are representative of a typical year, and calculate first year annualized energy savings for Phase 2 measures. The savings reported in eQuest Results Section are the annualized electric and gas energy savings for Phase 2 measures, calculated as the difference between the Baseline and Post-Phase 2 annual calibrated eQuest model utilizing typical weather data (TMY3) for Missoula, Montana.

1.4 *Savings Calculation*

This section discusses the annual energy savings calculation approach, including considerations regarding code requirements.

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[24] ASHRAE Guideline 14-2002, Measurement of Energy and Demand Savings, p. 18.

[25] ASHRAE Guideline 14-2002, p. 108.

[26] National Renewable Energy Lab (NREL), http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

The International Performance Measurement and Verification Protocol (IPMVP[27]) provides a framework for quantifying total savings attributable to energy conservation measures (ECMs). In cases where it is desirable to calculate the individual impacts of multiple individual ECMs within a facility, where billing data may be incomplete in either the baseline or post-retrofit case, or where the savings may be low, the IPMVP recommends Option D Calibrated Simulation Modeling.[28] Navigant developed the reported total savings for Phase 2 based on Option D using Calibrated Simulation Modeling in eQuest. Total savings results are reported in eQuest Results Section below.

Total savings are the focus of this report (see Figure 5 below), and net to gross research (NTG) was not in the scope of this evaluation. Navigant nonetheless interviewed several parties involved in the decision making process to understand what would have happened absent NEEA's initiative in order to determine the percent of savings that are attributable to NEEA's intervention. Navigant determined the building owner had no retrofit plans prior to NEEA influencing the owner. Therefore, it is Navigant's position that all the validated savings reported herein are attributable to NEEA's initiative.

For some utility programs, it may also not be permissible to report savings that would have occurred due to code compliance for a major renovation, even for an early replacement project, due to the fact that applicable codes and standards, including applicable federal rules, would have been in effect. The Phase 2 measures were extensive enough that a professional engineer designed and stamped the new HVAC system design drawings. As such, the savings should consider the minimum requirements of the state energy code in effect at the time of the project (ASHRAE 90.1-2007), as discussed in Section 2.3 Code Savings below.

The Phase 2 analysis of code savings focused on the state energy code in Montana in effect during the project: ASHRAE 90.1-2007, and assumes that the program acknowledges the requirement of engineering design professionals to respect the state energy code in their work supporting program-sponsored energy efficiency upgrades. Navigant is not asserting that the retrofit would have occurred anyway absent the program, but that the program supports the use of the state energy code where it applies. The analysis quantifies the savings relative to the minimally code compliant systems the engineer could legally have designed under the code.

[27] Reference International Performance Measurement and Verification Protocol (IPMVP)—Concepts and Options for Determining Energy and Water Savings, Volume 1, EVO 1000-1:2012.
[28] IPMVP P1:2012, p. 33.

2. Findings

2.1 *eQuest Results*

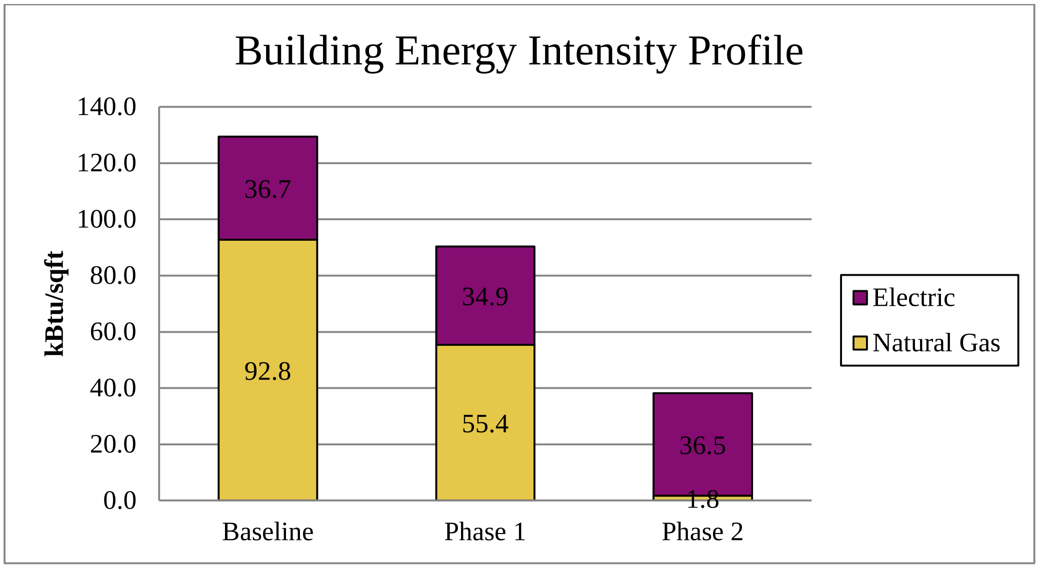
This section discusses the annualized electric and gas energy savings for Phase 2 measures, calculated as the difference between the Baseline and Post-Phase 2 annual calibrated eQuest model utilizing typical weather data (TMY3) for Montana, and referred as the Scenario 1 savings in this report. Navigant calculated the total electric savings to be negligible (~0%) and the total gas savings to be 98 percent (1997.9 MMBtu) over the baseline energy consumption. The building total savings is equal to 68.5 percent (1.3 MWh and 1997.9 MMBtu) which translates into 91.2 kBtu/sq.ft. reduction in the total building energy intensity for gross building area[29]. The chart below illustrates the drop in the building energy intensity due to Phase 1 and Phase 2 measures.

One of the critical changes to the building during Phase 2 was the change from fuel-based heating to electricity-based heating. This resulted in significant change in the building energy consumption trend because it introduced a new load to the electricity usage. For this reason, while the building has undergone significant energy efficiency improvements in most of its end-uses such as lighting and cooling, the building electric usage remained high relative to baseline on an annual basis.

Moreover, Navigant discovered that in 2014, tenants on the 4th floor, where HVAC was decommissioned during Phase 2, used seven electric heaters at a rated total capacity of approximately 9,000W for heating and this resulted in increased equipment usage that was not expected or accounted for in the IMP plan. Navigant expects significant reduction in the electricity usage once this floor turns into a data center, but it is still unknown when this floor will become a data center. For this reason, Navigant included this extra load in its model even for Scenario 1 analysis, which ended up negatively impacting electricity savings realized from the building.

[29] Gross building area (conditioned and unconditioned) is 21,952 sq.ft. Conditioned space area is 18,816 sq.ft.

Figure 3: Building Energy Intensity Profiles



Navigant calculated the uncertainty in the gross Phase 2 savings based on the equation expressed in the ASHRAE Guideline 14[30]. The uncertainty in the final Phase 2 savings is approximately 23 percent of the calculated savings at 68 percent confidence, including the uncertainty due to limited number of months of available billing data, which is significantly better than the maximum allowed uncertainty of 50 percent at the 68 percent confidence interval[32] per ASHRAE Guideline 14.

2.2 *Validated Savings*

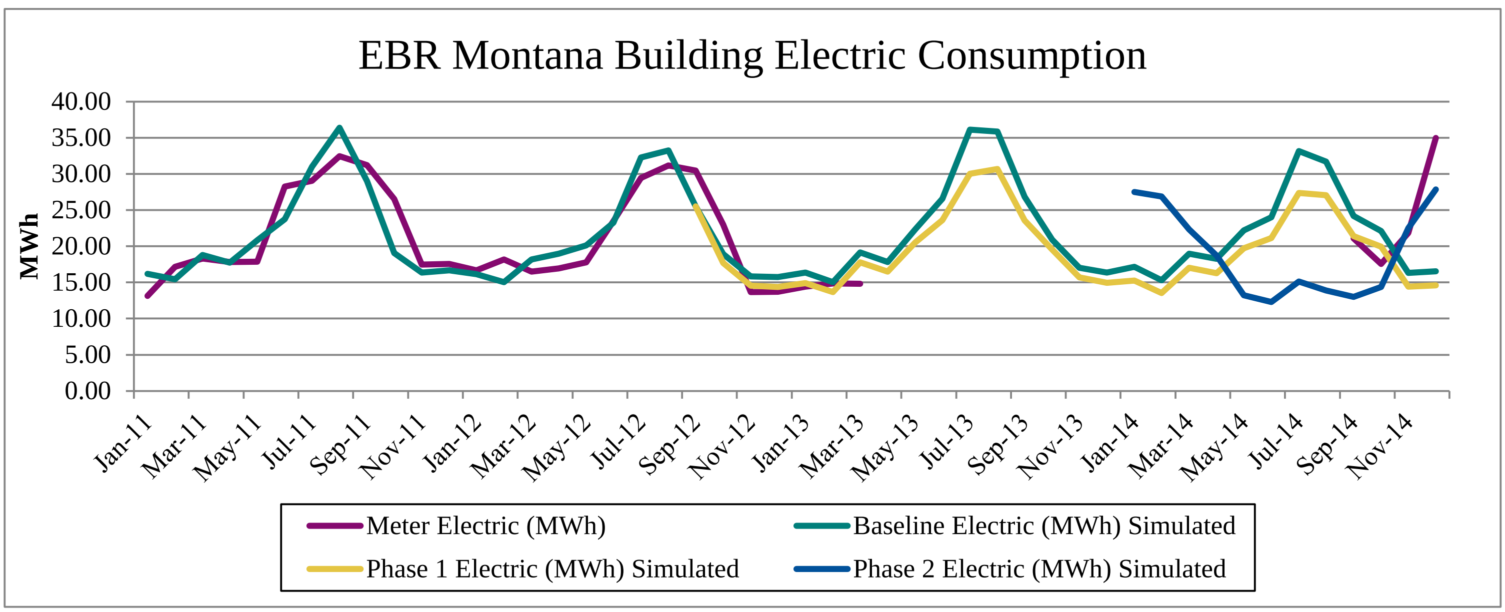
Navigant compared the calibrated model energy usage to meter energy usage to further validate savings where possible throughout the course of Phase 2 (January 2013 – December 2014).

On the electric consumption chart (Figure 6), the electricity consumptions for the meter data, the baseline modeled energy data, the post-Phase 1 modeled energy data, and the post-Phase 2 modeled energy data are shown. This graph provides a visual of the ASHRAE 14 statistical analysis discussed in the previous section by demonstrating how closely the calibrated baseline model shadows the meter data and demonstrates how the addition of heating load to electricity usage during winter months may offset the total savings from other energy efficiency measures on an annual basis. However, due to the addition of the data center meter into main electric meter on March 2013, the meter data is only available until March 2013 and after September 2014 when the issue was fixed. To validate savings for the course of Phase 2 measures, the meter situation led Navigant to use the Phase 2 simulation model in place of meter data. Since Navigant calibrated the baseline data to twenty-one moths and the Phase 2 model to four months, Navigant can report validated savings with only an additional 10 percent uncertainty compared to savings that would have been validated with traditional IPMVP Option D approach, which requires twelve months of post-retrofit data[30].

[30] ASHRAE 14 Guideline, Equation B-13a, p. 107.

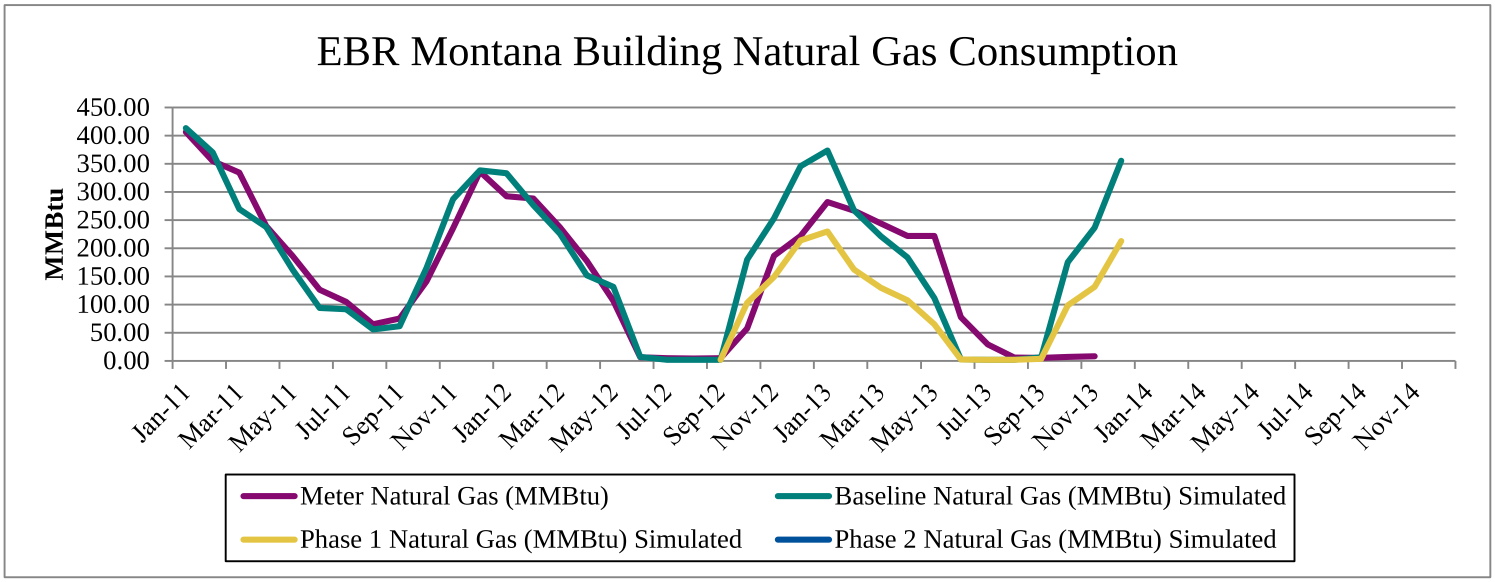
After multiple interviews with the building owner and the IDL lab, it became apparent that the building was not running as designed until September 2014, which is right after the meter issue was fixed. According to the commissioning report that was conducted in May 2014, the contractors who installed the HVAC system to the building did not do air balancing properly, did not put the fan coil units in the correct locations per the design, and did not set dampers correctly. Due to the issues with dampers and damper controls, the building outdoor temperature lockout was also not working as designed, and as a result strip heaters were trying to come back from deep setbacks. Therefore, for the period of time where meter data is not available, Navigant concluded that the building was running worse than designed and ended up saving even less energy than what would have occurred if everything was working according to design. The building owner also suggested on occasion that the building electricity bills have been significantly higher than the pre-retrofit case. Based on all these facts, Navigant calculated validated electricity savings to be less than the Scenario 1 electricity savings, which were already less than zero, so Navigant concluded that there is no electricity savings realized from Phase 2 measures for this building.

Figure 4: Building Electric Consumption



On the natural gas consumption chart (Figure 7), the natural gas consumptions for the meter data, the baseline modeled energy data, the post-Phase 1 modeled energy data, and the post-Phase 2 modeled energy data are shown. This graph also provides a visual of the ASHRAE 14 statistical analysis discussed in the previous section by demonstrating how closely the calibrated baseline model follows the meter data. For natural gas usage, adequate pre and post-meter data is available and plotted on the chart.

Figure 5: Building Natural Gas Consumption



Since the boiler, which was the main source of the natural gas consumption of the building, decommissioned in September 2013, the natural gas consumption has gone down almost to zero. The only natural gas usage remained for the domestic water heating, which was also retrofitted to a smaller size of 50 gallons. Water heater retrofit only saved about 15.2 MMBtu in 2014. Navigant concluded all the savings are realized on the natural gas side and calculated the validated savings to be 98%.

As a result, Navigant created two scenarios, where Scenario 1 is savings that would have happened if HVAC system was working as designed; Scenario 2 is the validated savings after Navigant's evaluation. Due to negative electric savings in the Scenario 1, the negative impact of the malfunction in the HVAC system does not show up in the Scenario 2. Final savings for each scenario are shown in table 9.

Table 8: Montana Phase 2 Scenario Savings

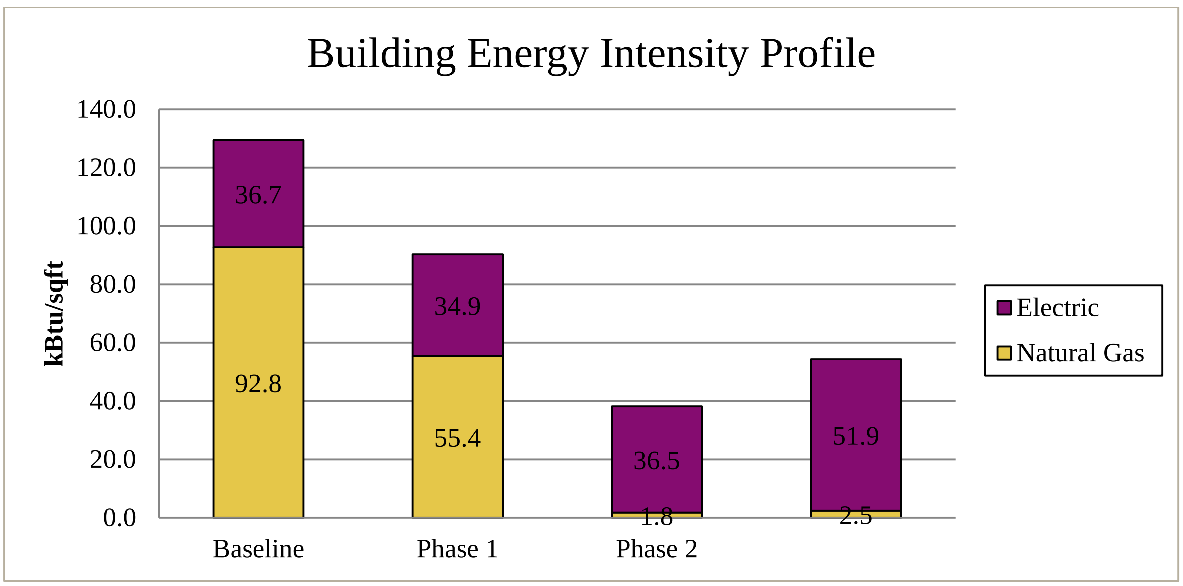
	Scenario 1	Scenario 2
Electric Savings	0%	0%
Natural Gas Savings	98%	98%
Electric Savings (MWh)	1.3	0
Natural Gas Savings (MMBtu)	1,997.9	1,997.9
Natural Gas Savings (Therms)	19,979.0	19,979.0
Electric Savings (AMW)	0	0

Note: Annual Average MW (AMW) = (MWh annual saved) / 8760 hours

2.3 Code Savings

The section focuses on the savings relative to the minimally code compliant the engineer could legally have designed under the code considering Phase 2 retrofits. During Phase 2, the HVAC system was completely gutted and redesigned by a professional engineer in Montana. Since it is reasonable to expect that the engineer would respect the state energy code, Navigant modeled an alternative baseline building utilizing minimally code compliant systems that the engineer had the option to use according to Section 6—Heating, Ventilating, and Air Conditioning of ASHRAE 90.1-2007[31]. The ASHRAE 90.1-2007 code requirement for a new VRV installation of this type is air cooled 10.4 EER (cooling mode) and 3.2 COP (heating mode) rated electrically operated heat pump units, which suggests a change from fuel-based heating to electric-based heating system compared to the baseline case. Based on the alternative baseline, Navigant estimated savings of 99.5 MWh electric and 15.2 MMBtu for Phase 2 measures, resulting in an alternate total savings of 29.7% over the code baseline and a 16.2 kBtu/sq.ft. reduction in the building energy intensity.

Figure 6: Building Energy Intensity Profiles with Code



The change from natural gas based to electric based heating in the alternative baseline case increased the electric energy consumption of the building to a level that is higher than the existing baseline, which made the existing baseline appear as better (more efficient) than the alternative baseline used for code savings considering only electric savings. However, in reality, the alternative baseline is more efficient because the amount of natural gas heating load offset in the alternative baseline case when converted into electric load is more than the amount of electric heat load introduced in the alternative baseline. In no instances, where the building is this old and has not gone under any major retrofits, the code should

[31] Navigant determined that since the program design does not require the building upgrades to exceed code, Appendix G of ASHRAE 90.1-2007 is not applicable.

make the building less efficient than the existing case. As such, it is important to understand that when a change from fuel-based heating to electric-based heating system is taken into account properly these electricity savings are "paper savings," meaning they do not exist and would not have existed in any scenario when the building is considered as a whole. In fact, Navigant found no electricity savings in 2014 from Phase 2 measures and, therefore, *Navigant does not recommend these savings be part of any claims to the utilities.*

2.4 Caveats and Limitations

Since the reported uncertainties above are limited to the quantified uncertainty attainable in savings calculated using a calibrated modeling approach, it is important to note the various other sources of uncertainty that have not been addressed in the modeling uncertainty, and which may in fact have a larger impact on the savings.

Examples of additional uncertainties are measure persistence issues and unforeseen changes in load, such as those Navigant discovered by comparing the expected results from the post-retrofit calibrated model, to what the billing data showed for the whole building. While the errors in building operation were discovered eventually and building commissioning was done during 2014, in some cases, particularly for less dramatic changes, these errors may never be discovered. The impact of this is potentially reduced customer participation, since if the energy bills stay the same, or even inexplicably increase, a customer may conclude that the effort and expense of energy efficiency 'is not worth it'. The impact of this type of error is difficult to quantify.

Additional sources of uncertainty[32] in energy efficiency savings calculation include sampling uncertainty (U_s), uncertainty associated with the utility meter accuracy ($RE_{instrument}$), and uncertainty in independent variables (U_{iv}). A sensitivity analysis on independent variables was not performed as part of this evaluation scope.

[32] ASHRAE Guideline 14-2002, p.15.

3. Conclusions

This project demonstrates the significance of commissioning building operations and other measures installed in buildings. In the first report of the two, due to malfunction, the projected natural gas savings realization rate appeared to be as low as 15 percent; approximately 700 MMBtu natural gas savings were wiped out. In this report, although the electricity savings remained zero percent, the impact to the building owner was much more drastic and the electricity bills were too high. Not only were no electricity savings realized, but also electricity consumption went up until the commissioning was done to the building, and all the issues were fixed. After a shake-out year 2014, the building owner realized the cost of commissioning was really worth it. In the long term, commissioning EBR buildings could help ensure NEEA that projects sustain savings at expected levels and that new measures function properly.

4. Recommendations

Navigant believes the building is now operating as designed and the submeters are installed correctly. For 2015, Navigant recommends that NEEA should implement the following next steps to true-up the savings from 2014 and realize more electric savings from this building:

» Ensure the submeters are working correctly and any additional data center load has submeters connected

» Install lighting measures to the remaining 1st and 6th floors and conduct another lighting survey with fixture count by each floor at the end of 2015

» Keep track of the occupancy by each floor and keep track of the electric heaters used on the 4th floor

» Educate the building owner and manager to optimize the HVAC controls and occupancy sensors use in the conditioned area

Finally, Navigant recommends NEEA to include commissioning as a requirement as part of the EBR effort and in the future to be eligible for a rebate. The value of commissioning for this kind of deep retrofit projects is undeniable and this project has been a living proof of it.

Idaho Building

5. Methodology

5.1 Data Collection

Navigant based evaluated savings on project information and utility data provided by Integrated Design Labs (IDL) and NEEA. Navigant used the following sources of information to inform input assumptions to the building energy models:

» Integrated Design Lab's (IDL) baseline energy models[33]

» Integrated Design Lab's (IDL) "Scorecard" sheets with baseline and measure input assumptions[34]

» Air leakage (blower door) tests[35]

» Monthly electric and natural gas billing (meter) data – January 2011 through December 2014

» Post-installation walk-through audit report

Navigant utilized the baseline building models provided by IDL as a starting point for this analysis. In addition, Navigant referenced the IDL "Scorecards" for the Idaho building, which provided various building characteristic values for the pre-retrofit model. The assumptions in the "Scorecard" files are based on audit walkthroughs and interviews with building staff. Navigant also referenced post-installation walk-through audit reports from IDL to inform modeling assumptions.

Navigant used electric and gas meter data provided by IDL to calibrate the baseline building model to actual energy consumption in the building. Phase 1 of the project was completed in February 2013 and Phase 2 of the project was completed in September 2014.

For Phase 2 of the project, the building owners implemented infiltration reduction measures. As part of this initiative, the owners sealed the smoke relief dampers on the top of the elevator shaft; they were previously open year-round and allowed conditioned air to escape from the building through the door seals around the elevator. The building owners indicate that this was a major source of overall infiltration for the building, and that the building was fairly "leaky" for the baseline case. IDL provided Navigant pre-retrofit blower door test results, which Navigant used to inform infiltration reduction input assumptions for the building model.

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[33] "CG_Calibrated_Baseline.idf" - EnergyPlus input file

[34] "Code_Base_Scorecard.xls" and "EBR_Light_Scorecard.xls"

[35] Building Envelope Air Leakage Test in Compliance with ASTM E-779-03, feltsHOUSE engineering, March, 2012.

Infiltration reduction is a weather-sensitive measure. The savings from reduced air exchange between the interior and exterior of the building is dependent on indoor and outdoor temperature, as well as exterior variables such as wind speed. Navigant utilized calibrated simulation models (IPMVP: Option D) to validate the savings achieved from Phase 2 from this project[36].

5.2 *Baseline Model Development*

The Idaho demonstration building is a three-story structure built in 1955, located in Boise, Idaho. To evaluate savings for Phase 2 of the EBR project, Navigant first calibrated the IDL baseline energy model to the pre-retrofit billing data for the building. Navigant chose to utilize the existing baseline building model developed by IDL[37] in EnergyPlus v7.0[38].

Table 10 provides an overview of baseline building characteristics for the Idaho building.

Table 9: Baseline Building Characteristics

Building Characteristic	Assumption
Vintage (Year)	1955
Location	Boise, Idaho
Building Type	Office
Total Floor Area (sq. ft.)	31,821
Number of Floors	3
Heating Type	Water-to-Air Heat Pumps, Boiler
Cooling Type	Water-to-Air Heat Pumps
Distribution and Terminal Units	Zonal Heat Pumps

Source: IDL Calibrated Baseline Scorecard sheet

[36] Per IPMVP 2012, Volume 1, p. 28: "Option D simulation tool allows you to also estimate the savings attributable to each ECM within a multiple-ECM project."

[37] IDL provided Navigant a "code baseline" model in addition to the "calibrated baseline model". The "code baseline" model modified the ventilation rates in the baseline building to bring them up to code minimum requirements. The building was previously not using the code minimum outdoor air, instead relying on the leakiness of the building to provide ventilation. In discussions with Brad Acker at IDL and a review of the project walkthrough document provided by IDL, it appears that the building ventilation rates were not re-commissioned in 2014 after infiltration measure was implemented. For this reason, Navigant decided to use the "calibrated baseline model" as the starting point for the building modeling exercise, and to forego the "code baseline model" to calculate savings for Phase 2 of the project in 2014. The pilot EBR program is designed to encourage deep energy retrofits for existing buildings which are not expected to be up to code. Thus the program design does not assume a code baseline, code minimum baseline should only be used when the retrofit is comprehensive enough that the state energy code should be respected by the implementer (ie. if an entire system is gut-renovated, or the use of the space changes).

[38] EnergyPlus is an advanced whole-building energy simulation program developed by the US Department of Energy (DOE). Energy Plus is an hourly simulation tool that models heating, cooling, lighting, ventilation, and other energy flows within the building.

Navigant used the following process to finalize the baseline model calibration:

- Run baseline building simulation for 2011 and 2012 using actual meteorological year (AMY) weather files for Boise, Idaho.
    - Utilize baseline EnergyPlus model provided by IDL

- Compare simulated energy consumption to actual gas and electric meter readings for the Idaho building in 2011 and 2012.

- Calibrate building energy model by refining inputs: calibrate models according to the procedures in ASHRAE Guideline 14:[39]
    » Compare monthly simulated energy and gas use to actual billing data
    » Adjust inputs[40] iteratively until the recommended Guideline 14 metrics are satisfied[41], using an appropriate level of effort relative to the magnitude of the savings being evaluated:
        - Coefficient of Variation of the Root Mean Square Error
            ▪ CVRMSE ≤ 15%
        - Normalized Mean Bias Error
            ▪ NMBE ≤ 5%

Navigant used the procedure outlined above to calibrate the baseline model for the Idaho building. Navigant calibrated the baseline demonstration model to 24 months of monthly electric and gas billing data in 2011 and 2012. Figure 9 and Figure 10 illustrate the results of the calibration process for electric and gas consumption, respectively.

[39] ASHRAE Guideline 14-2002, Section 6.3.2, p. 33.
[40] ASHRAE Guideline 14-2002, Section 6.3.3.3.9, p. 37.
[41] ASHRAE Guideline 14-2002, p. 18.

Figure 7: Calibration Results – Electric Meter Data Compare to Simulated Data (MWh)

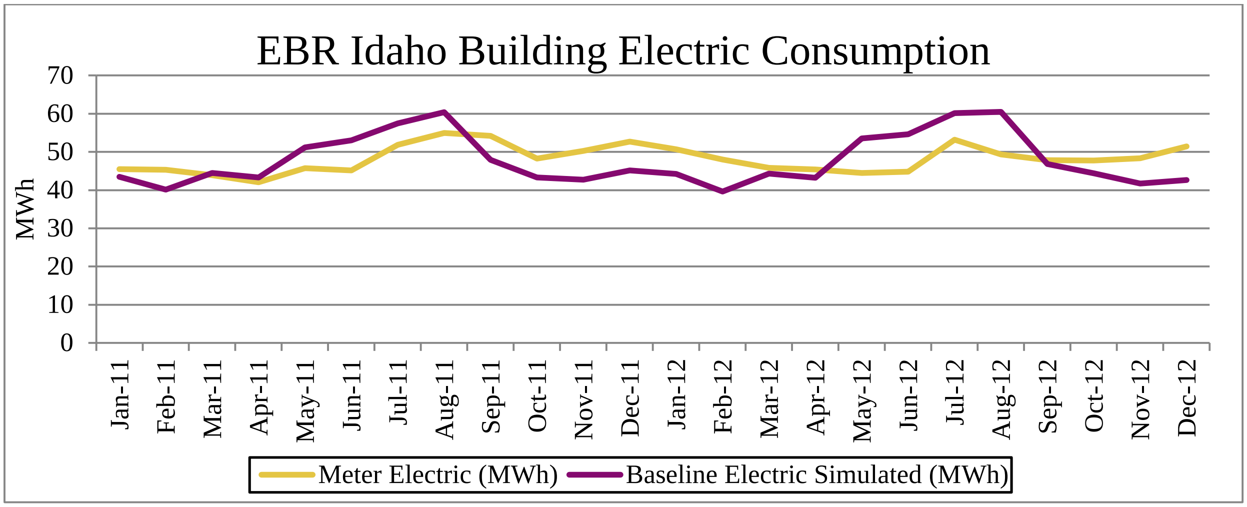
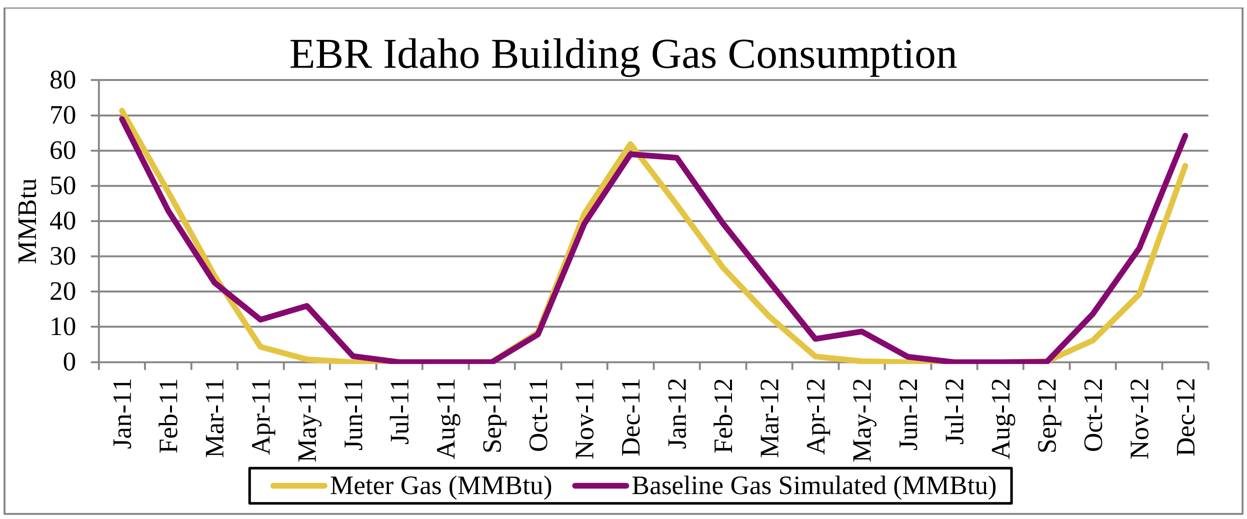


Figure 8: Calibration Results - Gas Meter Data Compare to Simulated Data (MMBtu)



The Guideline 14 CVRMSE and NMBE metrics for electric and gas consumption calibration are shown in Table 11.

Table 10: Guideline 14 Metrics for Calibrated Model – CVRMSE and NMBE

Calibration Metric	Percentage
Electric CVRMSE	13.5%
Natural Gas CVRMSE	40.1%
Electric NMBE	0.8%
Natural Gas NMBE	-21.4%

Electric consumption metrics are within the Guideline 14 tolerances (CVRMSE ≤ 15% and NMBE ≤ 5%). However, gas consumption metrics are outside of the required tolerances. Navigant iterated on the EnergyPlus model several times in attempts to bring gas consumption CVRMSE and NMBE within bounds. However, in Navigant's estimation, gas savings calculated using this calibrated baseline model are representative of the actual gas savings due to the installed measures.

5.3 Phase 1 and Phase 2 Model Development

This section details Navigant's approach in creating the Phase 1 and Phase 2 versions of the EnergyPlus models. The Phase 1 model incorporates the boiler retrofit, which was completed in February 2013. The Phase 2 model incorporates the boiler and infiltration reduction measures. The infiltration reduction measures were completed in September 2014.

Phase 1:

Navigant first developed a Phase 1 model to incorporate all efficiency measures implemented at the building in 2013. The building owners retrofit the existing boiler to a new condensing boiler in February 2013. The efficiency of the new condensing boiler is assumed to be 95% based on specification sheets from the manufacturer. Navigant incorporated the impact of these measures into the calibrated baseline model by adjusting the following input fields:

- Phase 1 Efficient Case - Nominal Thermal Efficiency = 0.95
    - Phase 1 Baseline Case - value was 0.88

Phase 2:

Next, Navigant developed a Phase 2 model to incorporate the efficiency measures implemented at the building in 2014. In September, 2014, the building owners began implementing infiltration reduction measures at the facility. The owners sealed the smoke relief dampers on the top of the elevator shaft. IDL notes that dampers were previously open and contributed significantly to the overall "leakiness" of the building. Navigant assumed that the boiler operational schedule and setpoints, and the building occupancy schedules, did not change between Phase 1 and Phase 2, such that all savings was attributable to the infiltration reduction. Navigant incorporated the impact of these measures to the Phase 2 model by adjusting the following fields:

- Phase 2 Efficient Case - Flow per Exterior Surface Area ($m^3/s\text{-}m^2$) = 0.000178
    - Phase 1 Baseline Case - value was 0.000302

This is a 41% reduction in infiltration for the building compared to the baseline condition in the Phase 1 building model. Navigant estimated the infiltration reduction in the building using pre and post effective leakage area (ELA) estimates for the building. The steps in this calculation include:

- Navigant sourced blower door results from the Building Envelope Air Leakage Report provided for the building[42]
    - The report provided pressure readings and CFM measurements from the blower door test at various fan speeds.
- Navigant used the pressure and airflow readings to calculate ELA for the baseline Idaho building.
    - ELA for the post-retrofit building is 5.8 sq. ft.
- Navigant added the approximate square footage of the smoke relief dampers on the top of the elevator shaft from the post-retrofit ELA.
    - Approximate square footage of smoke relief damper is 4.0 sq. ft.
- Pre-retrofit ELA is 5.8 sq. ft. + 4.0 sq. ft = 9.8 sq. ft.
    - There is a 41% reduction in infiltration for the building compared to the baseline condition.[43]

Navigant applied the 41% infiltration reduction to the Phase 2 building model to estimate savings for the project in Phase 2.

5.4 *Savings Calculations*

This section discusses Navigant's annual energy savings approach for Phase 2. In order to calculate annualized energy savings for Phase 2 of the project, Navigant used typical meteorological year 3 (TMY3) weather data for Boise, Idaho[44]. Navigant ran the Phase 1 model as the baseline, pre-retrofit model and the Phase 2 model as the post-retrofit model. The Phase 1 model used the calibrated baseline model and incorporated the efficient boiler that was part of the Phase 1 measures implemented at the building in 2013. The Phase 2 model used the Phase 1 model and added the infiltration reduction measure. By taking the difference in annual energy consumption between the Phase 2 and Phase 1 model, Navigant was able to isolate the marginal savings attributable to the infiltration reduction measure implemented in 2014.

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[42] Building Envelope Air Leakage Test in Compliance with ASTM E-779-03, feltsHOUSE engineering, March, 2012.

[43] Based on discussions with IDL, Navigant assumed the elevator door seals and elevator shaft are located within conditioned space. Therefore, the entire 4 sq. ft. of damper sealing was added to the overall building effective leakage area. (5.8 sq. ft. + 4.0 sq. ft = 9.8 sq. ft.) This is an impactful assumption that has a large effect on overall measure savings.

[44] National Renewable Energy Lab (NREL), http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

6. Findings

6.1 Phase 2 Savings Calculations

This section discusses the annualized electric and gas energy savings for Phase 2 measures, calculated as the difference between the Phase 1 and Phase 2 EnergyPlus models[45] utilizing typical meteorological year 3 (TMY3) for Boise, Idaho. Navigant also presents the total Phase 1 and Phase 2 savings over the course of the demonstration project.

The total electric savings for Phase 2 of the project relative to Phase 1 of the project is 1.0 percent (5.4 MWh) and the total gas savings is 21.9 percent (59.3 MMBtu). The building total savings is equal to 3.6 percent (77.7 MMBtu), which translates into 2.4 kBtu/sqft reduction in the total building energy intensity for gross building area[46].

Electric savings for Phase 1 and Phase 2 of the project is 1.0 percent (5.4 MWh) and the total gas savings is 27.7 percent (80.8 MMBtu). The building total savings for Phase 1 and Phase 2 of the project is equal to 4.5 percent (99.2 MMBtu), which translates into 3.1 kBtu/sqft reduction in the total building energy intensity for gross building area.

The building realized both electric and natural gas savings throughout the course of the project. The natural gas savings are substantial, and are attributed to the installation of a condensing boiler with a higher thermal efficiency than the pre-existing boiler. In addition, the infiltration reduction measure reduces heat transfer with indoor and outdoor air, decreasing heating loads to the building in the winter. Electric savings are likely due to reduced run-time of fans and pumps due to the decreased heating loads in Phase 2.

[45] Phase 1 and Phase 2 models are based off the calibrated baseline model for this project. The Phase 1 model incorporates the efficient boiler, installed in 2013. The Phase 2 model adds the infiltration reduction measure to the Phase 2 model, which was implemented in 2014.
[46] Gross building area (conditioned and unconditioned) is 31,821 sq.ft.

Figure 9 illustrates the savings in the building energy intensity for the baseline, Phase 1, and Phase 2 scenarios.

Figure 9: Phase 1 (Baseline) vs. Phase 1 Building Energy Intensity

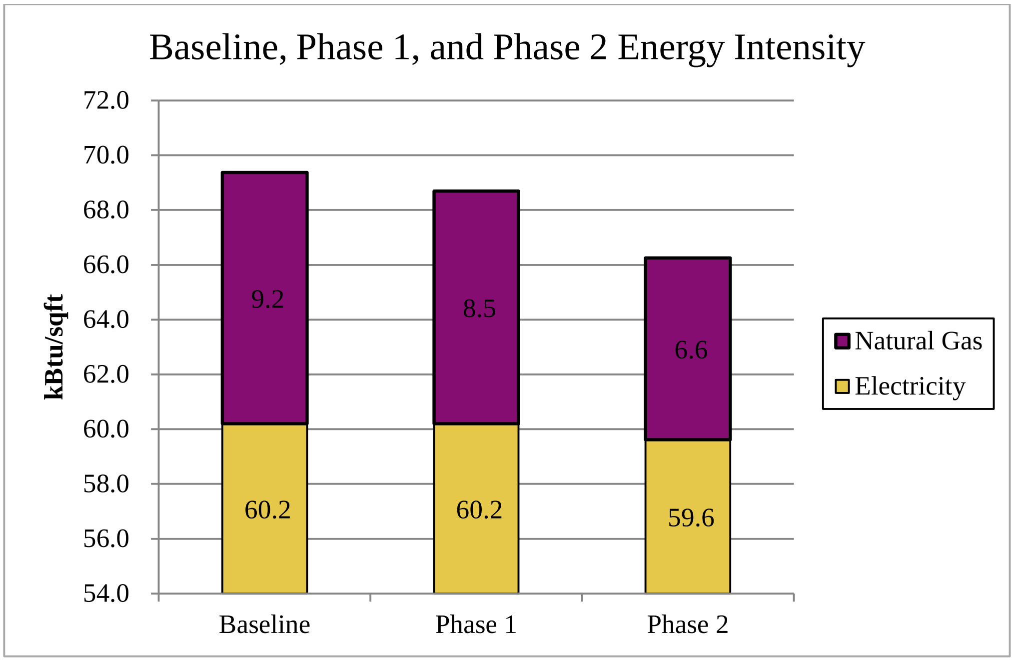


Table 13 presents the Phase 2 electric and gas savings in tabular format, as well as the total Phase 1 and Phase 2 savings over the course of the demonstration project.

Table 11: Idaho Phase 2 Project Savings

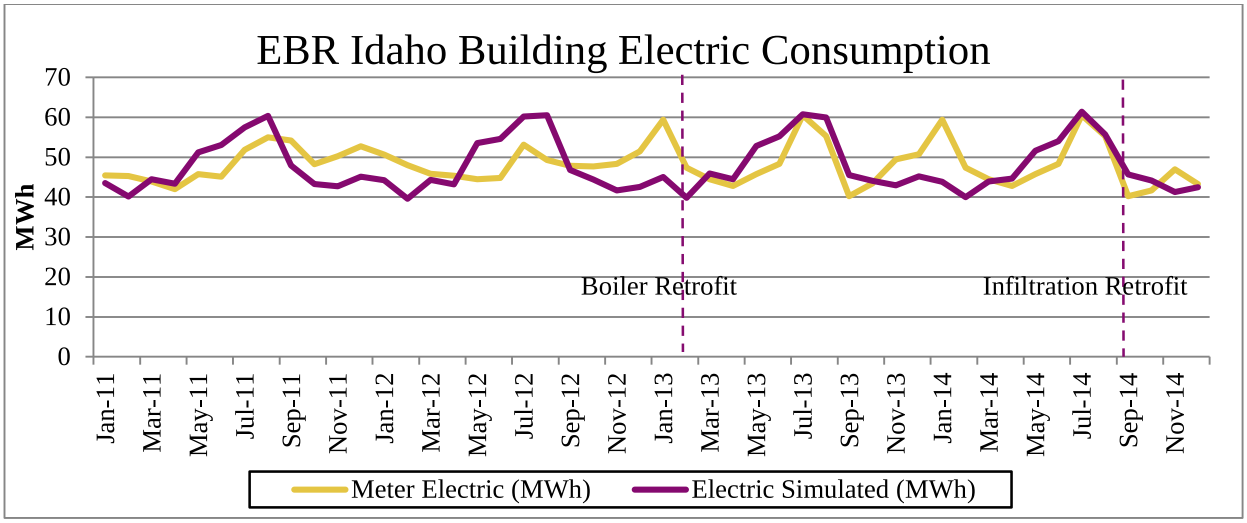
Savings Metric	Phase 2 Incremental*	Phase 1 and Phase 2 Total
Electric Savings	1.0%	1.0%
Natural Gas Savings	21.9%	27.7%
Electric Savings (MWh)	5.4	5.4
Natural Gas Savings (MMBtu)	59.3	80.8
Natural Gas Savings (Therms)	593	808
Electric Savings (AMW)	0.0006	0.0006

Note: Annual Average MW (AMW) = (MWh annual saved) / 8760 hours
**Phase 2 Project Savings represent the savings of Phase 2 relative to Phase 1.*

6.2 *Validated Savings*

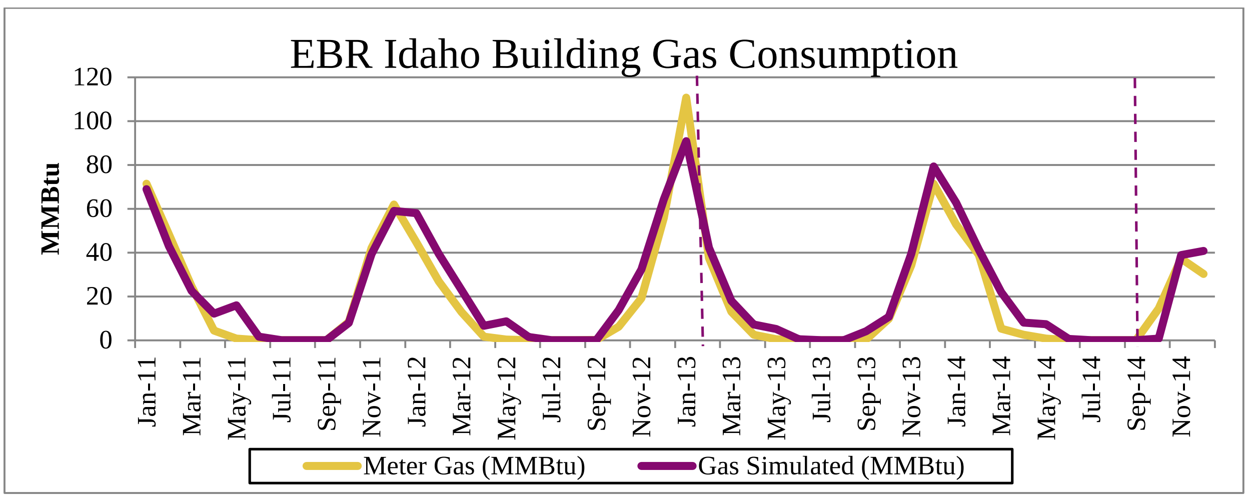
Navigant compared the simulated building energy data to meter energy data to validate savings where possible throughout the course of Phase 1 and Phase 2 of the project. Figure 10 and Figure 11 show the simulated and meter electric and natural gas consumption, respectively.

Figure 10: Comparison of Building Electric Consumption (Meter vs. Simulated)



Note: For simulation data, baseline model is used Jan-11 through Jan-13, Phase 1 model is used Feb-13 through Aug-14, and Phase 2 model is used Sept-14 through Dec-14.

Figure 11: Comparison of Building Natural Gas Consumption (Meter vs. Simulated)



Note: For simulation data, baseline model is used Jan-11 through Jan-13, Phase 1 model is used Feb-13 through Aug-14, and Phase 2 model is used Sept-14 through Dec-14.

The Phase 1 and Phase 2 measures primarily influenced the natural gas consumption of the building. The building owners installed an efficient boiler in February 2013 and implemented infiltration reduction measures in September 2014. Figure 11 shows that simulated natural gas consumption compares favorably with meter natural gas consumption from 2011 through 2014. This further validates the modeling input assumptions used in the Phase 1 and Phase 2 building energy models.

7. Recommendations

As next steps to true-up the electric and gas savings from 2014 and to validate the savings for Phase 3 measures, Navigant recommends that NEEA implement the following:

- For infiltration reduction measures, NEEA should repeat the blower door air leakage tests pre and post retrofit to inform evaluation of measure savings.
- Utilize end-use sub-metering as applicable for future efficiency measure

References

ASHRAE Guideline 14-2002. *Measurement of Energy and Demand Savings*, American Society of Heating, Ventilating, and Air Conditioning Engineers, Atlanta, Georgia.

International Performance Measurement and Verification Protocol (IPMVP). *Concepts and Options for Determining Energy and Water Savings*, Volume 1, EVO 1000-1:2012.

Appendix A. Montana Building Simulation Results

TMY3 Baseline, Phase 1, Post-Retrofit Phase 2, and Code Results

Electric Consumption (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Baseline Model	15,517	14,885	17,278	17,008	19,969	23,524	26,842	29,493	21,814	18,553	15,572	15,355	235,812
Phase 1 Model	14,833	14,412	16,844	16,509	19,239	22,265	24,580	26,986	21,140	18,211	14,984	14,614	224,616
Phase 2 Model	30,824	23,765	22,775	19,413	14,112	12,321	13,242	13,792	12,984	16,840	21,470	32,918	234,455
Code Model	44,934	31,991	29,417	23,710	21,524	19,369	19,527	22,241	19,111	24,175	31,151	46,777	333,927

Gas Consumption (therms)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Baseline Model	3,638	2,604	2,419	1,845	1,382	23	21	22	47	1,838	2,698	3,830	20,367
Phase 1 Model	2,245	1,535	1,412	1,091	786	55	21	22	24	1,028	1,582	2,370	12,171
Phase 2 Model	35	32	36	36	34	32	31	30	29	31	29	34	388
Code Model	47	44	51	46	48	45	42	44	41	43	43	45	540

Appendix B. Idaho Building Simulation Results

TMY3 Phase 1 (Baseline) and Post-Retrofit Phase 2 Results

Electric Consumption (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Phase 1 (Baseline) Model	43,518	39,404	44,887	43,919	50,637	53,629	56,060	55,913	45,068	43,386	41,966	43,019	561,405
Phase 2 Model	42,608	38,790	44,258	43,527	50,380	53,479	55,996	55,786	44,769	42,857	41,290	42,265	556,006

Gas Consumption (therms)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Phase 1 (Baseline) Model	773	376	297	85	86	13	-	7	13	117	395	542	2,706
Phase 2 Model	662	289	209	47	64	7	-	4	7	79	304	440	2,112