# ENGINEERING AND CONSTRUCTION BULLETIN

**No.** 2023-1 **Issuing Office:** CECW-EC **Issued:** 23 Jan 23 **Expires:** 23 Jan 25

**SUBJECT:** Meet the Requirements of ASHRAE 90.1-2019 to Optimize Energy Performance

**CATEGORY:** Directive and Policy

1. **References:**

a. Unified Facilities Criteria (UFC) 1-200-02 with Change 2, High Performance And Sustainable Building Requirements, 1 June 2022

b. 10 CFR Part 433, Energy Efficiency Standards For The Design And Construction Of New Federal Commercial And Multi-Family High-Rise Residential Buildings, 7 April 2022

c. PUBLIC LAW 109–58, Energy Policy Act of 2005 (EPACT 05), 8 August 2005

d. PUBLIC LAW 117–81 s.2843, Amendment of Unified Facilities Criteria to Promote Energy Efficient Military Installations, 27 December 2021

e. ANSI/ASHRAE/IES Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, 2019

2. **Background:** Per EPACT 05, Section 109, Federal Building Performance Standards, if life-cycle cost-effective for new Federal buildings, the buildings are to be designed to achieve energy consumption levels that are at least 30 percent below the levels established in the effective version of the ASHRAE Standard. Sustainable design principles are to be applied to the siting, design, and construction of all new and replacement buildings. If water is used to achieve energy efficiency, water conservation technologies shall be applied to the extent that the technologies are life-cycle cost-effective.

Per the National Defense Authorization act 2022, DOD is to: “incorporate the latest consensus-based codes and standards for energy efficiency and conservation, including the 2021 International Energy Conservation Code and the ASHRAE Standard 90.1-2019.” UFC 1-200-02 states, “For commercial and multi-family high-rise buildings with design starts on or after 7 April 2023, meet the requirements of ASHRAE 90.1-2019.” ASHRAE 90.1 2019 increases difficulty of meeting energy reduction goals in a Life Cycle Cost Effective manner for the Army.

Per 10 CFR 433 and UFC 1-200-02 High Performance and Sustainable Building Requirements, DoD projects must meet the requirements of ASHRAE 90.1 Energy Standard and achieve at least 30% energy consumption reduction from the ASHRAE 90.1 baseline. Per 10 CFR Part 433, ASHRAE 90.1-2019 will replace 90.1-2013 as the current design standard starting April 2023.

3. **Guidance:** Per UFC 1-200-02, commercial and multi-family high-rise buildings with design starting on or after 7 April 2023 must meet the requirements of ASHRAE 90.1-2019. For low-rise residential buildings with design starting on or after 5 April 2023, meet the requirements of 2021 IECC.

To the extent practicable, based on LCCA and DoD policy, meet the following:

a. Meet the requirements of ASHRAE 90.1-2019.

b. Design the building to achieve at least 30% energy consumption reduction from ASHRAE 90.1 baseline.

c. Determine energy consumption levels for both the ASHRAE Baseline Building 2019 and proposed building alternatives by using the Performance Rating Method found in Appendix G of ASHRAE 90.1-2019.

Between ASHRAE 90.1 versions 2013 to 2019, there are a total of 209 changes. The updates to ASHRAE 90.1 make revisions to provide more potential for energy savings, resolve limiting or conflicting issues, and offer an alternative compliance path called The Performance Rating Method. Changes to modeling rules, verification and testing, and recording and reporting requirements may affect labor costs. Changes that will affect building costs include lowering or adding U-factor criteria for building envelope materials, adding the new climate zone 0 for extremely hot climates, and raising the thresholds for energy and lighting. More impactful changes include moving the location of controls, adding requirements for control systems, increasing requirements for certain room types, and raising the criteria for replacement equipment to meet the requirements formerly only for new equipment.

ASHRAE 90.1 2019 offers three different compliance paths: Prescriptive Method, Energy Cost Budget Method (ECB), and Performance Rating Method (PRM). The Federal Government is required by Code of Federal Regulations (CFR) Title 10 Part 433 to determine energy consumption levels for both the ASHRAE Baseline Building and the proposed building using the Performance Rating Method (PRM). CFR Title 10 Part 433 requires a 30% improvement over the ASHRAE 90.1 Baseline if it is life cycle cost effective (LCCE). If a 30% reduction is not LCCE, the design is to be modified to achieve the highest level of energy efficiency that is LCCE.

Additionally, Unregulated Energy Costs, such as receptacle and process loads, are now included in the percentage improvement calculation. Although previously modeled, these costs were subtracted out when calculating the percentage improvement. This inclusion has a significant impact on meeting a 30% improvement over baseline. These loads have highly variable energy costs that are often difficult to determine for the types of projects common to the Federal Government. However, lowering the Unregulated Energy Costs for the modeled building may produce a small improvement in the percentage over baseline.

Per ASHRAE, the 2019 edition includes various modifications and clarifications to improve internal consistency and to standardize the structure and language of the document. Significant changes to requirements include the following:

Administration and Enforcement

- New commissioning requirements in accordance with ASHRAE/IES Standard 202

Building Envelope

- Combined categories of “nonmetal framed” and “metal framed” products for vertical fenestration
- Upgraded minimum criteria for SHGC and U-factor across all climate zones
- Revised air leakage section to clarify compliance
- Refined exceptions related to vestibules, added new option and associated criteria for using air curtains

Lighting

- Modified lighting power allowances for Space-by-Space Method and the Building Area Method
- New simplified method for lighting for contractors and designers of renovated office buildings and retail buildings up to 25,000 ft2 (2300 m2).
- Updated lighting control requirements for parking garages to account for the use of LEDs
- Updated daylight responsive requirements, added definition for “continuous dimming” based on NEMA LSD-64-2014
- Clarified side-lighting requirements and associated exceptions

Mechanical

- New requirements to allow the option of using ASHRAE Standard 90.4 instead of ASHRAE Standard 90.1 in computer rooms that have an IT equipment load larger than 10 kW
- Added pump definitions, requirements, and efficiency tables to the standard for the first time
- New equipment efficiency requirement tables and changes to existing tables
- Replaced fan efficiency grade (FEG) efficiency metric with fan energy index (FEI)
- New requirements for reporting fan power for ceiling fans and updated requirements for fan motor selections to increase design options for load-matching variable-speed fan applications
- New energy recovery requirements for high-rise residential building
- New requirement for condenser heat recovery for acute care inpatient hospitals

Performance Rating Method (Appendix G)

- Clarified Appendix G rules and corresponding baseline efficiency requirement when combining multiple thermal zones into a single thermal block
- New explicit heating and cooling COPs without fan for baseline packaged cooling equipment
- New rules for modeling impact of automatic receptacle controls
- Set more specific baseline rules for infiltration modeling
- Clarified how plant and coil sizing should be performed
- Updated building performance factors
- Clearer, more specific rules for treatment of renewables

- New updates to rules for lighting modeling

4. **Update.** All new requirements will be included in the next appropriate policy document update prior to the expiration of this ECB.

5. **Enclosures.**

a. "Analysis of ASHRAE 90.1: 2013 VS. 2019." U.S. Army Corps of Engineers, Savannah District.

b. "Analysis of 2013 vs. 2019: ASHRAE Standard 90.1. Energy Standard for Buildings Except Low-Rise Residential Buildings." U.S. Army Corps of Engineers, Mobile District.

6. **Point of Contact.** HQUSACE point of contact for this ECB is Ryan R Murphy, AIA, CECW-CE, (202) 236-0670.

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Encl.
Attachment A- Analysis of ASHRAE 90.1: 2013 VS. 2019
Attachment B- Analysis of 2013 vs. 2019: ASHRAE Standard 90.1. Energy Standard for Buildings Except Low-Rise Residential Buildings.

**ATTACHMENT A: Analysis of ASHRAE 90.1: 2013 VS. 2019**

# ANALYSIS OF ASHRAE 90.1

## 2013 VS. 2019


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## EXECUTIVE SUMMARY

Under direction from HQ USACE, the Savannah District (SAS) Center of Standardization (CoS) team reviewed and analyzed ASHRAE Standard 90.1-2013 against ASHRAE 90.1-2019 to evaluate its impact on new federal projects. Example Company Operations Facility (COF) and Battalion Headquarters (BN HQ) standard design projects were used to both develop energy models and assess the cost effects of implementing the newer version of 90.1. The energy models of the designs were compared against the 90.1 baselines to quantify expected changes in energy performance and estimate broad costs. Building envelope, HVAC, and electrical costs were also examined and contrasted during this process.

Results from the energy modeling analysis in both the COF and BN HQ determined that designs performed significantly better than the 2013 baseline versus the 2019 baseline using the method detailed in the CFR. For the COF, the design energy consumption showed a 35% improvement over the 2013 baseline and 1% worse than the 2019 baseline. The BN HQ design showed similar results: energy consumption was 31% lower than the 2013 baseline and 6% more than the 2019 baseline. These findings indicate that most projects as designed currently may meet ASHRAE 90.1-2019 (and ultimately UFC 1-200-02 and 10 CFR Part 433) requirements but will likely not achieve 30% energy consumption less than the baseline.

Cost per square foot was understandably higher for compliance with the 90.1-2019 prescriptive method versus 2013 but may vary considerably based on building type and project scope. For the COF, the unit cost increased by an estimated 2-4% (or $5-10 per square foot) in meeting the minimum prescriptive requirements for 2019 over 2013. Cost information for BN HQ is not available at this time.

# INTRODUCTION

Per 10 CFR Part 433 and UFC 1-200-02 High Performance & Sustainable Building Requirements, DoD projects must meet the requirements of ASHRAE 90.1 Energy Standard via any of three compliance methods and achieve at least 30% energy consumption reduction from the ASHRAE 90.1 baseline if life cycle cost effective (LCCE) as measured by the Performance Rating Method (PRM) calculation. Starting April 7, 2023, ASHRAE 90.1-2019 will replace version 2013 as the applicable design standard in accordance with the CFR. To investigate how new projects may be affected with the change, the SAS team worked with Mobile District (SAM) in determining approximate energy and cost differences associated with moving from the 2013 to 2019 version of ASHRAE 90.1.

# SUMMARY OF CHANGES

## Performance Rating Method (PRM)

The most impactful revision between the two versions of ASHRAE 90.1 is the energy consumption calculation process, which was overhauled in ASHRAE 90.1-2016 and carried through to the 2019 version. For 2013, the baseline was modeled with the 2013 Prescriptive Method values and compared against the design. The calculation in Appendix G of 90.1 has been traditionally used to rate a building's performance that exceeds the requirements of Standard 90.1 and was not an official method of compliance with ASHRAE 90.1. For 2019, this became the Performance Rating Method (PRM), which <u>is</u> a compliance method for 90.1 starting in April and is the required method per the CFR and UFC for determining energy consumption. The PRM uses ASHRAE 90.1-2004 prescriptive values for baseline and a new building performance factor (BPF) to calculate the energy cost savings versus the design.

## Prescriptive Method

As to be expected, the prescriptive requirements for the building envelope, HVAC efficiencies, and electrical power and lighting were made more stringent in 2019 to improve energy performance. The execution process for meeting the requirements of the Prescriptive Method is consistent between 2013 and 2019 versions of ASHRAE 90.1 and remains a path of compliance.

## Energy Cost Budget Method

In addition to the new Performance Rating Method and Prescriptive paths of compliance, the Energy Cost Budget (ECB) method of compliance was added between versions 2013 and 2019 in the new Chapter 11. This method is another simulation method that compares the proposed design against a baseline building. Unlike the PRM baseline, the ECB baseline is essentially a clone of the proposed design with building envelope values, HVAC equipment efficiencies, and lighting densities taken from the minimum prescriptive requirements of 90.1-2019. Thus, a building is expected to perform better than the ECB baseline if the design meets or exceeds the minimum prescriptive requirements.

## Other Notable Changes

Lighting power density allowances became more stringent in version 2019 and will likely be the biggest impact on lighting design. Also, insulation values (i.e. mostly U-values) for some building envelope systems and components increased, including most exterior fenestration, as well as some duct insulation values. These changes, along with revisions to solar heat gain coefficient (SHGC) values and receptacle control requirements, will affect the project costs. Many other changes are evident in 2019 that designers must become familiar with and consider during design that may not affect project costs.

# ANALYSIS

## Energy Model

To quantify the overall changes between 90.1-2013 and 2019, two building types in two climate zones were used. A COF building at JB San Antonio, TX, in climate zone 2A and a BN HQ building at Fort Benning, GA, in climate zone 3A were modeled in Trane Trace 700 with typical room geometries and internal loads (occupants, lighting, and receptacle and process loads such as computers and kitchen appliances). These internal loads were estimated from architectural floor plans as well as standard practices and designs (e.g., a typical office is modeled with one sitting person and one computer). For each building, the HVAC systems and plants were modeled as designed. Baselines were then generated based on the ASHRAE 90.1-2013 and 2019 guidelines and compared against each design model. While this is not a one-to-one comparison between the two versions, it provides a reasonable comparison for measuring energy efficiency and compliance with each standard. The tables below reflect the numbers and values used for running the energy models per Chapters 5 and 9 as well as Appendix G.

*Table 1: Building Envelope U-Values – COF*

| JBSA COF | | | |
|---|---|---|---|
| | **Design*** | **2013** | **2019** |
| Roofs | U-0.039 | U-0.039 | U-0.063 |
| Walls | U-0.084 | U-0.084 | U-0.124 |
| SOG Floors | F-0.730 | F-0.730 | F-0.730 |
| Swinging Doors | U-0.370 | U-0.700 | U-0.700 |
| Entrance Doors | U-0.83 / SHGC-0.25 | U-0.83 / SHGC-0.25 | U-0.77 / SHGC-0.23 |
| Fixed Metal Windows | U-0.45 / SHGC-0.25 | U-0.57 / SHGC-0.25 | U-0.57 / SHGC-0.25 |
| Skylights | U-0.65 / SHGC-0.35 | U-0.65 / SHGC-0.35 | U-0.69 / SHGC-0.39 |

**Design values are 2019 Prescriptive*

*Table 2: Building Envelope U-Values – BN HQ*

| Ft. Benning BN HQ | | | |
|---|---|---|---|
| | **Design*** | **2013** | **2019** |
| Roofs | U-0.039 | U-0.039 | U-0.063 |
| Walls | U-0.123 | U-0.077 | U-0.124 |
| SOG Floors | F-0.730 | F-0.730 | F-0.730 |
| Swinging Doors | U-0.370 | U-0.700 | U-0.700 |
| Entrance Doors | U-0.77 / SHGC-0.25 | U-0.77 / SHGC-0.25 | U-0.68 / SHGC-0.23 |

| | | | |
|---|---|---|---|
| Fixed Metal Windows | U-0.42 / SHGC-0.25 | U-0.50 / SHGC-0.25 | U-0.57 / SHGC-0.25 |

**Design values are 2019 Prescriptive*

*Table 3: Lighting Power Densities (baselines)*

| JBSA COF / Ft. Benning BN HQ | | |
|---|---|---|
| | **2013** | **2019** |
| Conference Room (W/ft$^2$) | 1.23 | 1.30 |
| Corridor (W/ft$^2$) | 0.66 | 0.50 |
| Electrical/Mechanical (W/ft$^2$) | 0.42 | 1.50 |
| Breakroom (W/ft$^2$) | 0.73 | 1.20 |
| Office enclosed (W/ft$^2$) | 1.11 | 1.10 |
| Office open (W/ft$^2$) | 0.98 | 1.10 |
| Restroom (W/ft$^2$) | 0.98 | 0.90 |
| Stairwell (W/ft$^2$) | 0.69 | 0.60 |
| Storage Room (W/ft$^2$) | 0.63 | 0.80 |

*Table 4: HVAC Systems*

| JBSA COF / Ft. Benning BN HQ | |
|---|---|
| **Design** | **ASHRAE Baseline** |
| Water Source Heat Pump | Packaged Rooftop Heat Pump |
| DX Heat Pump | Packaged Rooftop Heat Pump |
| Electric Unit Heater | Warm Air Furnace, Electric |

*Table 5: Local Energy Rates*

| Utility Rates | | |
|---|---|---|
| | **JBSA** | **Ft. Benning** |
| Natural Gas ($/therm) | 0.492 | 0.567 |
| Electricity ($/kWh) | 0.073 | 0.098 |

## Energy Costs and Formula Input

Local energy rates (Table 5 above) were used to convert the modeled energy usage into estimated annual energy costs for each design. The design energy costs were compared against the baselines using the respective cost improvement formulas. When using ASHRAE 90.1-2013, the energy savings formula from the CFR is:

*Percentage improvement = 100 x ((Baseline building consumption – Receptacle and process loads) – (Proposed building consumption – Receptacle and process loads)) / (Baseline building consumption – Receptacle and process loads)*

However, with 90.1-2019, the cost improvement is calculated for the CFR using the following formula:

*Percentage Improvement = 100 x (1 – PCI / $PCI_t$)*

Where:
*PCI (Performance Cost Index) = Proposed building / Baseline building performance*

*$PCI_t$ (Performance Cost Index Target) =*
*(Baseline building unregulated energy cost + (Building performance factor x Baseline building regulated energy cost)) / Baseline building performance*

The building performance factor (BPF) is defined in ASHRAE 90.1-2019 Chapter 4 by the building type and climate zone. Using a BPF is intended to standardize the PRM for current and future versions of ASHRAE 90.1 by using set 2004 baseline prescriptive values and continuing to revise the BPF to make compliance more or less stringent. For the JBSA COF, the BPF is 0.50 and for the Ft. Benning BN HQ, the BPF is 0.53.

## Performance for Criteria

Per the CFR and UFC, designs are required to achieve 30% cost savings (energy consumption) over the baseline if LCCE. If achieving this is not LCCE, designs must meet the requirements of ASHRAE 90.1 to achieve an "energy consumption level at or better than the maximum level of energy efficiency that is LCCE". To do this, the building envelope, lighting / communication / electrical systems, and HVAC equipment must continue to improve and consequently, increase project costs.

To determine whether the 30% improvement over baseline was possible, on-site energy generation was generically analyzed. ASHRAE 90.1-2019 Chapter 4 includes a separate Percentage Improvement (PCI) equation to use when projects have on-site renewable energy generation systems of a certain amount but limits how much credit for on-site energy can be counted. Thus, any on-site renewable energy generation beyond this amount is not counted in the percent improvement equation. This was introduced to promote direct energy use reduction rather than offsetting energy efficiency with renewable energy. This new equation is used when the following is met.

$$\frac{PBP_{nre} - PBP}{BBP} > 0.05$$

In the above equation, *$PBP_{nre}$* is the *proposed building performance* without any credit for reduced annual energy costs from on-site renewable energy generation systems; *PBP* is the *proposed building performance* including energy costs associated with on-site *renewable energy* generation systems; and BBP is the *baseline building performance*. When this amount of on-site energy is generated (typically 5-10% of the total electric energy consumption), the new Percentage Improvement (PCI) formula used is below.

$$Percentage\ Improvement\ =\ 100\ x\ (1 - \frac{PCI + \frac{(PBP_{nre} - PBP)}{BBP} - 0.05}{PCI_t})$$

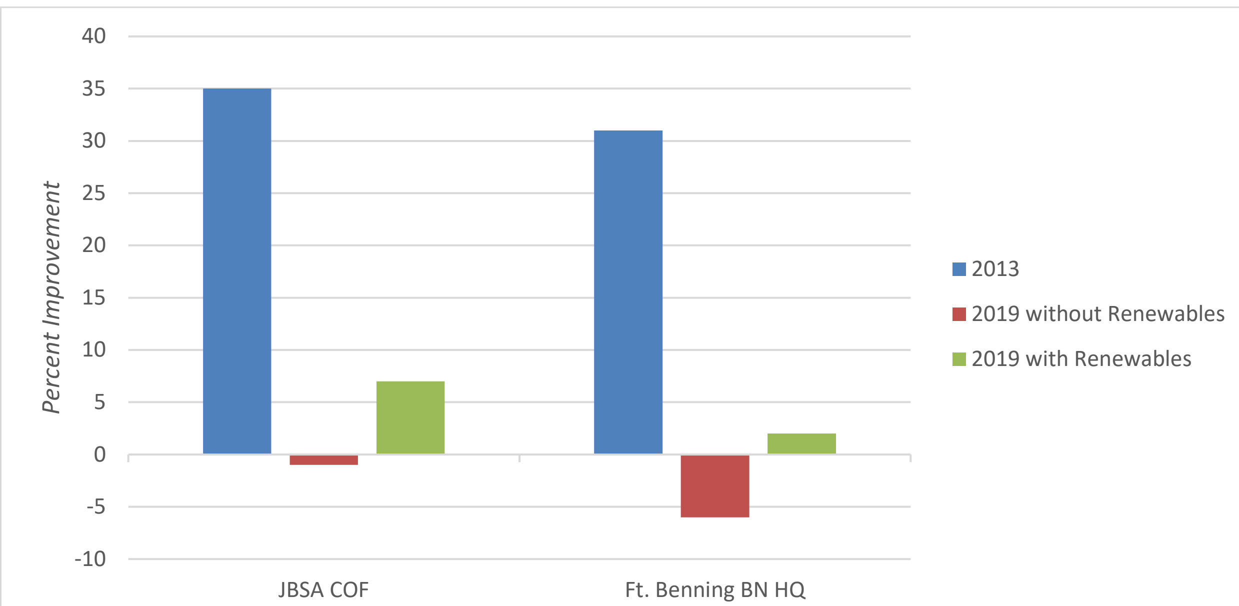
Although neither design includes on-site renewable energy production, this option was included in the analysis to assess its impact.

# RESULTS

## Overall

Compared to the 2013 baselines, the COF design performed 35% better and the BN HQ design performed 31% better using the PRM calculation. Against the 90.1-2019 baselines with the overhauled formula, the COF design was 1% below and the BN HQ was 6% below. When applying estimated on-site renewable energy generation in the proposed designs (as discussed further below), the COF design performed 7% better than the 2019 baseline and the BN HQ design performed 2% better. Both the COF and BN HQ models showed less than a 30% improvement over the 2019 baselines using the updated PRM, and neither model even met ASHRAE 90.1-2019 minimums as designed (i.e. without on-site energy).

*Figure 1 – Percentage Improvement of Design vs. ASHRAE Baselines*




To calculate the percent improvement for the design over the baselines, the annual energy consumption costs are used. These costs are the results of the energy models converted by the local electric and natural gas rates. The annual energy consumption costs of the designs and baselines are in the tables below.

*Table 6: Annual Energy Costs - COF*

| JBSA COF | | | |
|---|---|---|---|
| | **Design** | **2013** | **2019** |

| | | | |
|---|---|---|---|
| Natural Gas | $1,686.24 | - | - |
| Electricity | $14,554.45 | $21,051.59 | $25,029.73 |
| Unregulated Energy Load | $7,174.15 | $7,174.15 | $7,174.15 |
| Total | $16,240.69 | $21,051.59 | $25,029.73 |

*Table 7: Annual Energy Costs – BN HQ*

| Ft. Benning BN HQ | | | |
|---|---|---|---|
| | **Design** | **2013** | **2019** |
| Natural Gas | $974.42 | - | - |
| Electricity | $15,436.06 | $21,429.73 | $24,616.12 |
| Unregulated Energy Load | $5,116.90 | $5,116.90 | $5,116.90 |
| Total | $16,410.48 | $21,429.73 | $24,616.12 |

## Energy Generation

The calculations using on-site renewable energy generation would determine if the new Percentage Improvement on-site energy equation was needed; if implementing renewable energy would achieve better energy performance over the baseline; and if this option would be life cycle cost effective. For the JBSA COF, roughly 17,144 kWh of renewable energy (9% of total electric energy) is needed to reach the maximum credit limit using the altered PCI equation, which would result in a 7% improvement over the 2019 baseline. For the Ft. Benning BN HQ, an estimated 12,499 kWh of renewable energy (8% of total electric energy) is needed to use the revised equation and achieves a 2% improvement over the 2019 baseline.

Although both projects showed compliance with the PRM by including renewables, neither were life cycle cost effective. The estimated installation costs for correctly sized solar panel arrays were $47,850 for the JBSA COF and $35,090 for the Ft. Benning BN HQ. At the electric rates for each location, the annual cost of electric energy needed in lieu of solar energy is $1,251 for the COF and $1,231 for the BN HQ. Thus, the estimated payback time for solar panel systems would be at least 38 years for the COF and 29 years for the BN HQ. Since the expected lifespan of solar panels is typically 25 to 30 years, on-site solar energy is not life cycle cost effective at both locations.

## Costs

Cost changes and overall difference between the COF design using ASHRAE 90.1-2013 requirements and 2019 requirements were estimated by SAS Cost Engineers. Recent bid data for a similar new COF designed using 90.1-2013 was used to establish an initial cost estimate. Scope changes based on 90.1-2019 requirements were identified and then incorporated into the cost data via the cost estimating process. The JBSA COF design cost-per-square-foot was estimated to increase by a range of $5 to $10 per square foot when meeting ASHRAE 90.1-2019 (without on-site energy generation), which equates to roughly 2%

to 4% unit cost increase. Cost analysis for the BN HQ was not performed.

### Conclusion

As the Performance Rating Method in ASHRAE 90.1-2019 is written, this analysis found it essentially impossible to meet a 30% improvement over the baseline even with on-site renewable energy generation. It is recommended that the CFR be revised to make the mandated energy performance requirements attainable. Removing the 30% ‘beyond code’ improvement mandate is the simplest and most future-proof change, as this mark was much more achievable with the older energy performance methodology.

## DESIGN IMPACTS AND CHALLENGES

### Energy Modeling

With the drastic shift in the PRM calculation, additional challenges exist when modeling the designs. The main impacts are the change in baseline values and the formula to find the percent improvement. Although the intent of ASHRAE 90.1 is to standardize the PRM process by using the prescriptive values from the 2004 version for baseline, most modeling software used by USACE has not populated these values in their libraries yet. As more codes adopt versions of the ASHRAE 90.1 standard past 2013 in the coming months and years, it is assumed that energy modeling software programmers will add these baseline values as an option. In modeling the 2013 baseline, Trane Trace 700 and Carrier HAP (the two most common energy modeling programs) automatically generate the 2013 baselines, requiring minimal project-specific changes. However, at this time designers must manually create the 2019 baselines based on the 2004 prescriptive requirements until software programs provide these values.

Further, Trane Trace 700 will soon be retired and replaced by Trace 3D Plus, a newer program frequently used by SAS designers. Being a new program, the software has a multitude of known bugs and operating quirks, leading to extra time needed to model with potentially less accurate results.

Designers must also be aware that the Percent Improvement calculation now includes Unregulated Energy Consumption loads (i.e., receptacle and process loads) so it will become even more crucial to model with accurate receptacle and process loads. Although the previous version of ASHRAE 90.1 also required inputting estimated unregulated energy loads in the energy model, receptacle and process loads were subtracted from the building energy consumption in the Percent Improvement Equation. Since these loads are estimates, designers are urged to request historic or measured energy usage from DPWs, facility managers, and other government entities for the building type of each project to achieve more accurate results. In the case that these values are not available, it is recommended to refer to similar recently constructed projects or Standard Designs for unregulated energy loads. ASHRAE provides estimates for specific internal loads in the ASHRAE Fundamentals handbook, which is updated every three years.

### Insulation

Designers will need to perform additional initial research to provide higher U-Value and SHGC envelope products, particularly fenestration including doors, windows, and glazing. Along with this, designers must ensure at least three (3) manufacturers have compliant products or provide a J&A early in design if products are not available or fit with project design strategy. Project cost may be impacted if the facility has a large amount of exterior doors or windows.

### Lighting

Changes to the lighting power density requirements may require designers to re-evaluate and select alternative fixtures and systems to their ‘typical’ or regular-use components. However, it appears relatively straightforward to meet this revised performance.

## OPERATIONAL IMPACTS

The team is unaware of operational impacts from buildings designed using ASHRAE 90.1-2019. However, DPWs and users may have challenges with newer equipment types, controls, and technologies that are necessary for facilities to become more energy efficient.

**ATTACHMENT B: Analysis of 2013 vs. 2019: ASHRAE Standard 90.1. Energy Standard for Buildings Except Low-Rise Residential Buildings.**

# Analysis of 2013 vs. 2019 ASHRAE Standard 90.1

## Energy Standard for Buildings Except Low-Rise Residential Buildings

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# 1 EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE) Mobile District (SAM) was tasked by USACE HQ with comparing the effects of adopting the 2019 edition of ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings. In April 2023, the 2019 edition will replace the 2013 edition currently in effect. This report focuses on a single building type in a hot-humid climate. Therefore, it may not be representative of all projects that will be affected by the adoption of the 2019 edition of ASHRAE 90.1. The Center of Standardization (CoS) Adapt-Build 7-Module Hangar was used for the comparison effort.

For the project analyzed, the proposed design performed 43.75% better than the 2013 Performance Rating Method (PRM) baseline. Using the 2019 PRM, the proposed design performed 12.5% better than the baseline, without any changes or cost increase to the proposed design.

Overall, the 2019 Edition of ASHRAE 90.1 was found to be a welcome update to the standard. However, the method in which the Federal Government is required to determine percentage improvement over the ASHRAE Baseline Building was found to be excessively stringent. The regular expected improvement in building performance for a building minimally compliant with ASHRAE 90.1, coupled with the unintended stringency of the new percentage improvement calculation methodology of the Performance Rating Method makes the 30% improvement over baseline required by 10 CFR Part 433 exceedingly difficult.

# 2 BACKGROUND

ASHRAE 90.1 2019 offers three different compliance paths: Prescriptive Method, Energy Cost Budget Method (ECB), and Performance Rating Method (PRM). The Federal Government is required by Code of Federal Regulations (CFR) Title 10 Part 433 to determine energy consumption levels for both the ASHRAE Baseline Building and the proposed building using the Performance Rating Method (PRM). CFR Title 10 Part 433 requires a 30% improvement over the ASHRAE 90.1 Baseline if it is life cycle cost effective (LCCE). If a 30% reduction is not LCCE, the design is to be modified to achieve the highest level of energy efficiency that is LCCE.

All three compliance paths are intended to represent a design minimally compliant with the current edition of Standard 90.1. The ECB and PRM paths are performance paths, intended to allow trade-offs during design by showing better performance via an energy model. For example, the design team could design a building with lower U-values for a component of the building, if the building performs better than a baseline building when modeled in an approved energy modeling software.

## 2.1 PROJECT DESCRIPTION AND ENERGY COSTS

Energy modeling for SAM was performed on the Center of Standardization for Army Aviation Facilities' 7-Module Adapt-Build Hangar in Savannah, GA (ASHRAE Climate Zone 2A). This facility is a 7-module medium hangar attached to two stories of shop and general office space. The building area is approximately 112,000 SF. The space types in the facility are a mix of office space, conference rooms, storage rooms, workshops, repair rooms, sleeping rooms, and a 7-module hangar bay. The occupant load is approximately 353 people. For building envelope requirements, the hangar bay is considered a Conditioned Space by ASHRAE 90.1 definition due to having more than 5 BTU/h-ft^2 of heating. Current design is 9 BTU/h-ft^2.

*Table 1: Energy Costs – Hunter AAF, GA*

| | |
|---|---|
| Electricity Cost | $0.12199/kWh* |
| Natural Gas Cost | $0.92408/Therm* |

*1 kWh = 3412.14 BTU/hr

**1 Therm = 100 MBH = 100,000 BTU/hr

# 3 KEY TAKEAWAYS

The 2019 edition of ASHRAE 90.1 incorporates many significant updates and changes, some of which were introduced in the 2016 edition. Energy modeling for 3rd party modeling requirements is now easier due to changes in percentage improvement calculation methodology, however, meeting 30% improvements over baseline are much more difficult.

The changes in percentage improvement calculation methodology make it difficult to make direct comparisons between 2013 and 2019 editions. Unregulated energy costs, such as receptacle loads, are now included in the percentage improvement calculation.

This analysis includes the Prescriptive path in addition to the PRM path to compare the stringency of the new standard. This analysis found the PRM path to be excessively stringent for our specific project. ASHRAE has recognized this excessive stringency with the publication of Addendum bv. This addendum replaces the Building Performance Factor (BPF) table used when determining performance with the Performance Rating Method. The BPF factors for hot-humid climates were made less stringent. Building Performance Factors provide a quick and easy way to modify the target performance for a baseline building. Building Performance Factors are discussed in the next section.

ASHRAE 90.1 will continue to push towards net-zero. As such, achieving 30% energy savings over 90.1 will soon start to become exceedingly difficult. Removing the 30% improvement requirement from the CFR with continued adoption of new editions of ASHRAE 90.1 will meet the intent of pushing toward more energy efficient buildings.

At first glance it seems increasing on-site energy generation could offset energy usage to achieve net energy savings, however, 2019 ASHRAE 90.1 limits credit for on-site renewable energy to 5% when calculating percentage improvement.

## 3.1 CHANGES TO PERFORMANCE RATING METHOD

### 3.1.1 Percentage Improvement Calculation Methodology

The intent of the changes to the ASHRAE 90.1 Performance Rating Method (Appendix G) is to make it easier for modelers to meet 3rd party modeling requirements, such as LEED, which uses a 2010 ASHRAE baseline. With the 2019 edition of 90.1, the ASHRAE Baseline for the PRM was reset to the baseline of the 2004 edition. For future iterations of 90.1, the baseline will remain the same and a target improvement over this baseline will be implemented. The equation for the $PCI_t$ given in chapter 4 of 90.1 2019 edition is as follows:

$$PCI_t = [BBUEC + (BPF \times BBREC)] / BBP$$

*Where:*

*$PCI_t$ = Performance Cost Index Target calculated by formula in section 4.2.1.1 of ASHRAE 90.1-2019*

*BBUEC = baseline building unregulated energy cost, the portion of the annual energy cost of a baseline building design that is due to unregulated energy use (Primarily receptacle loads).*

*BBREC = baseline building regulated energy cost, the portion of the annual energy cost of a baseline building design that is due to regulated energy use (HVAC, lighting, etc).*

*BPF = building performance factor from Table 4.2.1.1. For building area types not listed in Table 4.2.1.1 use “All others.” Where a building has multiple building area types, the required BPF shall be equal to the area-weighted average of the building area types.*

*BBP = Baseline Building Performance ($/yr)*

To adjust the target Performance Cost Index ($PCI_t$), a Building Performance Factor (BPF) will be updated with each new edition of ASHRAE 90.1 to set the baseline building performance. This factor is given by table 4.2.1.1 in ASHRAE 90.1. For 2016, the BPF for “All others” and climate zone “2A” for the COS Hangar is 0.55, for 2019, the BFP was reduced to 0.50.

Addendum bv to ASHRAE 90.1 2019 was published to revise the building performance factor tables. Language from the addendum stated that BPFs represent the savings of a design minimally compliant with the current edition of Standard 90.1, and that 2019 BPFs were excessively stringent for some building types and not stringent enough for others. The BPF applicable to this analysis increased from 0.50 to 0.55.

The formula for determining the percentage improvement in the 2019 edition is:

*Percentage Improvement = 100 x (1-PCI/$PCI_t$)*

*Where:*

*PCI = Performance Cost Index = Proposed Building Performance ($/yr) / Baseline Building Performance($/yr) (from section G1.2)*

*$PCI_t$ = Performance Cost Index Target calculated by formula in section 4.2.1.1 of ASHRAE 90.1-2019*

For previous editions of ASHRAE 90.1 adopted by the Federal Government, the formula for calculating percentage improvement was:

*Percentage improvement = 100 × ((Baseline building consumption − Receptacle and process loads) − (Proposed building consumption − Receptacle and process loads)) / (Baseline building consumption − Receptacle and process loads)*

A direct comparison between 2013 and 2019 using this the PRM path is not feasible due to the difference in calculation methodology. To compare the two editions, the Prescriptive Method was modeled in a similar fashion to the ECB path and evaluated in addition to the PRM.

Unregulated Energy Costs, such as receptacle and process loads, are now included in the percentage improvement calculation. Although previously modeled, these costs were subtracted out when calculating the percentage improvement. This has a significant impact on meeting a 30% improvement over baseline. These are highly variable energy costs that are difficult to determine for the types of projects common to the Federal Government. It was found during the analysis that lowering the Unregulated Energy Costs for the modeled building produced a small improvement in the percentage over baseline, but only by a small amount.

### 3.1.2 On-Site Energy Generation

ASHRAE 90.1 places a 5% limit on credit for on-site renewable energy generation for calculating percent improvement. Because of the 5% limitation, on-site renewable energy generation cannot offset very much of the yearly energy cost. This contributes to making the 30% improvement difficult.

When $(PBP_{nre} - PBP)/BBP > 0.05$ the following equation is to be used:

$$PCI + \left[\frac{PBP_{nre} - PBP}{BBP}\right] - 0.05 < PCI_t$$

*Where:*

*PBP = Proposed Building Performance, including the reduced, annual purchased energy cost associated with all on-site renewable energy generation systems.*

*$PBP_{nre}$ = Proposed Building Performance without any credit for reduced annual energy costs from on-site renewable energy generation systems.*

When the threshold for on-site renewables triggers the PCI equation above, the equation can be rearranged to determine the percentage improvement as follows:

$$\%_{improvment} = 100 \times (1 - \frac{PCI + \frac{PBP_{nre} - PBP}{BBP} - 0.05}{PCI_t})$$

Using the above equation to calculate the percentage improvement over baseline will limit credit for on-site renewable energy generation to 5%.

Addenda by, ck, and cp add the requirement for on-site renewable energy in the prescriptive path and update the ECB and PRM paths to reflect the addition.

### 3.1.3 Changes to Modeling Inputs

Prior editions of ASHRAE 90.1 required the energy modeler to input many variables from the prescriptive section of the referenced edition of the standard for whichever 3rd party they were creating an energy model for. Because each program referenced different editions of standard 90.1, the energy modeler would spend large amounts of time developing separate models to show compliance.

With the updates to the 2019 edition, the inputs required for any 3rd party program are from the 2004 edition. This greatly shortens the modeling time. However, the new methods for showing compliance are not yet incorporated in energy modeling software requiring the energy modeler to make these calculations manually.

## 3.2 Changes to Applicable Prescriptive Requirements

The following sections describe a few notable changes to the prescriptive requirements between 2013 and 2019 editions.

### 3.2.1 Envelope

While the thermal insulation requirements for roofs and walls did not change, the maximum u value for doors was reduced by 38 percent. In the 2013 edition of the Standard, a U-0.700 is allowed on swinging doors and a U-1.450 is allowed on non-swinging (hangar bay) doors. The 2019 edition of the Standard reduces these values to U-0.370 and U-0.310

respectively. Given our hangar doors are currently designed with a U-0.059 insulation, they provided a significant improvement over both the 2013 and 2019 editions.

#### 3.2.2 Lighting

Prescriptive Lighting Power Densities (LPD) were reduced for all space types in the modeled project except bedrooms. The reduction averages about 40% lower LPD when compared to 2013.

#### 3.2.3 HVAC Systems

Both editions of ASHRAE 90.1 include requirements for fan performance based on selection relative to flow and pressure added to the airstream and the fan's performance. The 2013 edition included a Fan Efficiency Grade (FEG) based on performance testing of AMCA (The Air Movement and Control Association) Standard 205. The 2019 edition introduces the Fan Efficiency Index from AMCA 208. In either of these requirements, the manufacturer will be mostly responsible for providing fans that comply with the requirements, but it will result in product lines that have more distinct sizes that handle narrower ranges of flow requirements. In either case, it requires the designer/specifier to consult the manufacturer and select fans for a specific rating as close to the best efficiency point on the performance curves to meet the standard. The difference between the two rating systems appears to be that the 2019 edition rates a fans performance relative to a standard efficient fan using the index where a value of 1.0 is the minimum and higher values are desired and achieved based on the fan design and the selection of the correct fan size for the flow and pressure requirements. While it is likely that additional costs may result from the change in the Standard, there is no means to quantify the expected increase.

# 4 ENERGY MODEL

## 4.1 PERFORMANCE RATING METHOD ENERGY MODEL INPUTS

#### 4.1.1 Envelope

Envelope values for the 2013 PRM Baseline are given in ASHRAE 90.1 2013 Table 5.5-2. Envelope values for the 2019 PRM baseline are given in ASHRAE 90.1 2019 Table G3.4-2. The Envelope systems were selected by a Life Cycle Cost Analysis.

*Table 2: Assembly Maximum U-Values (lower is better)*

| | **Proposed Design** | **2013** | **2019** |
|---|---|---|---|
| Roofs | U-0.032 | U-0.039 | U-0.063 |
| Walls | U-0.066 | U-0.084 | U-0.124 |
| Floors | U-0.107 | U-0.107 | U-0.052 |
| Swinging Doors | U-0.400 | U-0.700 | U-0.700 |
| Nonswinging Doors | U-0.059 | U-0.500 | U-1.450 |
| Fenestration | U-0.350 | U-0.57 | U-1.22 |
| Skylight | U-0.350 | U-0.65 | U-1.36 |

### 4.1.2 Lighting

Lighting Power Densities (LPD) for the 2013 PRM baseline are given in ASHRAE 90.1 2013 Table 9.6.1. LPD's for the 2019 PRM baseline are given in ASHRAE 90.1 2019 Table G3.7.

*Table 3: Lighting Power Density (W/ft^2) (lower is better)*

| | **Proposed Design** | **2013 PRM Baseline** | **2019 PRM Baseline** |
|---|---|---|---|
| Active Storage | 0.59 | 0.63 | 0.80 |
| Classroom | 0.67 | 1.24 | 1.40 |
| Conference | 0.67 | 1.23 | 1.30 |
| Corridor | 0.24 | 0.66 | 0.50 |
| Bedroom | 0.90 | 0.38 | 1.07 |
| Electrical/Mechanical | 0.76 | 0.42 | 1.50 |
| Inactive Storage | 0.59 | 0.63 | 0.80 |
| Lounge | 0.50 | 0.73 | 1.20 |
| Enclosed Office | 0.91 | 1.11 | 1.10 |
| Open Office | 0.68 | 0.98 | 1.10 |
| Restrooms | 0.48 | 0.98 | 0.90 |
| Workshop | 0.70 | 1.59 | 1.90 |

### 4.1.3 HVAC System Types

Between 2013 and 2019 editions, the HVAC system types were the same for the PRM Baseline. The thermal zones in the proposed design and baseline are identical. The HVAC systems for the Proposed Design were selected by a Life Cycle Cost Analysis.

*Table 4: HVAC System Selection*

| | **Proposed Design** | **2013 and 2019 baseline** |
|---|---|---|
| Office Space | VAV with chilled water coils, hot water reheat. Air cooled chiller, natural gas boiler. | System 6 – Packaged rooftop VAV with parallel fan power boxes and reheat, Direct expansion, electric resistance |
| Hangar Bay | Natural gas fired low-intensity overheat heaters. Exhaust make-up air provided by hot water heating only air handler. | System 10 – Heating and ventilation, electric resistance |
| Shop Space | 100% Outside Air unit, chilled water coil, hot water heating coil, with cross-flow fixed plate energy recovery. Air cooled chiller, natural gas boiler | System 6 – Packaged rooftop VAV with parallel fan power boxes and reheat, Direct expansion, electric resistance |

When using the PRM method, the actual air conditioning equipment efficiencies are to be used when modeling the proposed design. Due to the designers not being allowed to select the final equipment, the actual equipment efficiency and performance curves needed to do a performance-based model is not known. For modeling purposes, the Trace 700 default air-cooled chiller equipment that is most like the one selected for the design was used for the proposed design and compared with the PRM baseline efficiencies of systems 6 and 10. The efficiency values given below do not include fan power.

*Table 5: Minimum Efficiency*

| | **Proposed Design** | **2013 PRM Baseline** | **2019 PRM Baseline** |
|---|---|---|---|
| Office and Shops Efficiency | 10.1 EER (Air Cooled Chiller) | 11.2 EER (dx, compressor only) | 3.4 COP (dx, compressor only)* |
| Hangar Bay Efficiency | 77% (Gas-Fired) | 100% (electric resistance) | 100% (electric resistance) |

*EER = 3.41 X COP

## 4.2 Prescriptive Method Energy Model Inputs

### 4.2.1 Envelope

Envelope values for the 2013 Prescriptive Baseline are given in ASHRAE 90.1 2013 Table 5.5-2. Envelope values for the 2019 Prescriptive baseline are given in ASHRAE 90.1 2019 Table 5.5-2.

*Table 6: Assembly Maximum U-Values (lower is better)*

| | **Proposed Design** | **2013** | **2019** |
|---|---|---|---|
| Roofs | U-0.032 | U-0.039 | U-0.039 |
| Walls | U-0.066 | U-0.084 | U-0.084 |
| Floors | U-0.107 | U-0.107 | U-0.107 |
| Swinging Doors | U-0.370 | U-0.700 | U-0.370 |
| Nonswinging Doors | U-0.310 | U-0.500 | U-0.310 |
| Fenestration | U-0.350 | U-0.57 | U-0.45 |
| Skylight | U-0.350 | U-0.65 | U-0.65 |
| Hangar Bay Door | U-0.059 | 0.500 | U-0.310 |

### 4.2.2 Lighting

Lighting Power Densities (LPD) for the 2013 Prescriptive baseline are given in ASHRAE 90.1 2013 Table 9.6.1. LPDs for the 2019 Prescriptive baseline are given in ASHRAE 90.1 2019 Table 9.6.1. The LPDs in Table 7 below in bold were lowered from those used for the Performance Rating Path to meet the requirements of the prescriptive path, which does not allow trade-offs. These changes will have a negligible cost effect.

*Table 7: Lighting Power Density (W/ft^2) (lower is better)*

| | Proposed Design | 2013 | 2019 |
|---|---|---|---|
| Active Storage | **0.38** | 0.63 | 0.38 |
| Classroom | 0.67 | 1.24 | 0.71 |
| Conference | 0.67 | 1.23 | 0.97 |
| Corridor | 0.24 | 0.66 | 0.41 |
| Bedroom | **0.50** | 0.38 | 0.50 |
| Electrical/Mechanical | **0.43** | 0.42 | 0.43 |
| Inactive Storage | **0.38** | 0.63 | 0.38 |
| Lounge | 0.50 | 0.73 | 0.59 |
| Enclosed Office | **0.66** | 1.11 | 0.66 |
| Open Office | **0.61** | 0.98 | 0.61 |
| Restrooms | 0.48 | 0.98 | 0.63 |
| Workshop | 0.70 | 1.59 | 1.26 |

### 4.2.3 HVAC System Types

Between 2013 and 2019 editions, the HVAC system types were the same for the Prescriptive Method Baseline. The thermal zones in the proposed design and baseline are identical. The HVAC system types modeled were the same for the PRM baselines and the Prescriptive baselines for the purposes of this analysis.

*Table 10: HVAC System Selection*

| | Proposed Design | 2013 and 2019 baseline |
|---|---|---|
| Office Space | VAV with chilled water coils, hot water reheat. Air cooled chiller, natural gas boiler. | System 6 – Packaged rooftop VAV with parallel fan power boxes and reheat, Direct expansion, electric resistance |
| Hangar Bay | Natural gas fired low-intensity overheat heaters. Exhaust make-up air provided by hot water heating only air handler. | System 10 – Heating and ventilation, electric resistance |
| Shop Space | 100% Outside Air unit, chilled water coil, hot water heating coil, with cross-flow fixed plate energy recovery. Air cooled chiller, natural gas boiler | System 6 – Packaged rooftop VAV with parallel fan power boxes and reheat, Direct expansion, electric resistance |

# 5 Results

## 5.1 Overall Results

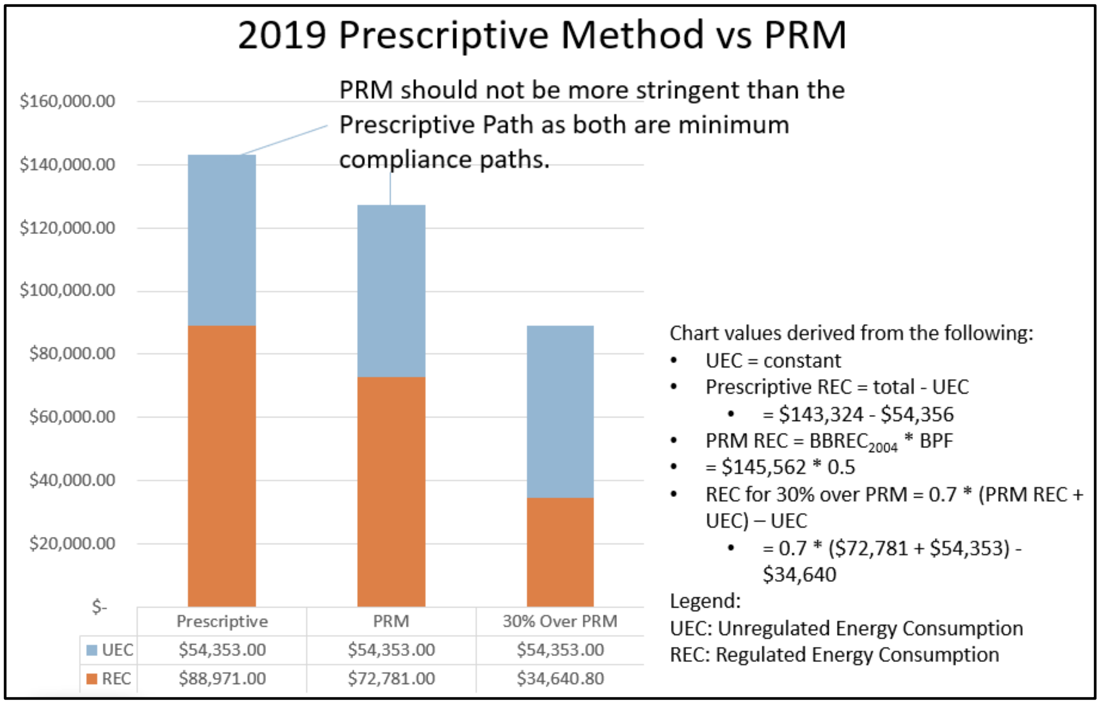


*Figure 1: 2019 Prescriptive Method vs PRM*

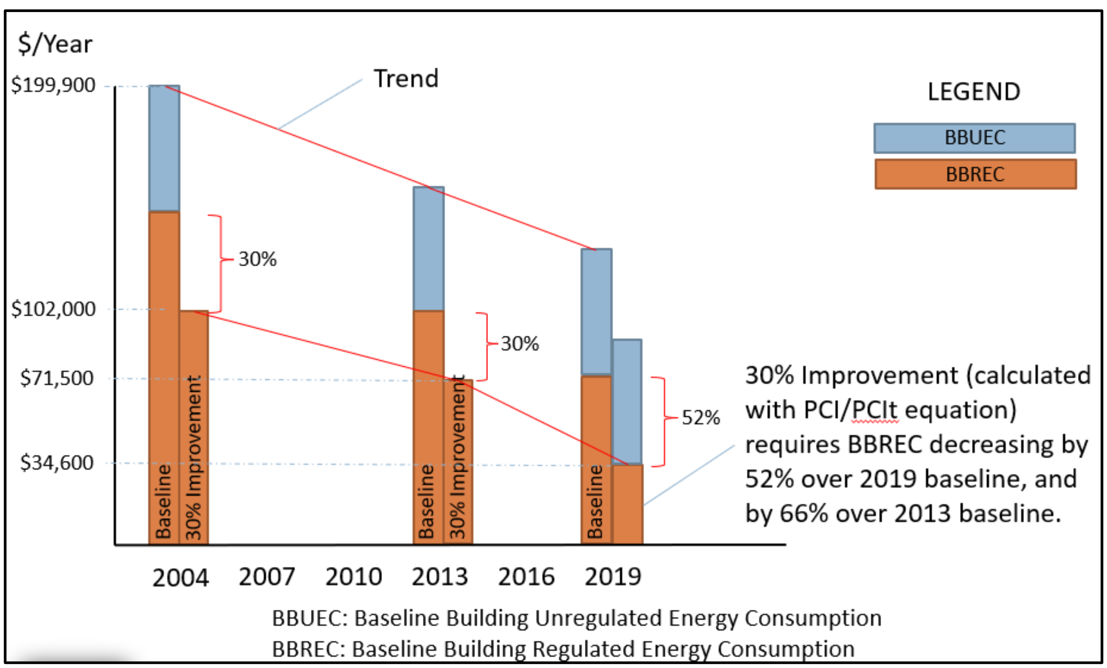


*Figure 2: PRM Stringency*

## 5.2 Performance Rating Method (PRM) Results

PRM baseline energy usage increases from 2013 to 2019. This is because the 2019 baseline was reset to match the 2004 baseline for the Performance Rating Method. Using the 2019 Performance Rating Method, the proposed design performed 12.5% better than the baseline. Using the 2013 Performance Rating Method, the proposed design performed 43.75% better than the baseline.

The simulated building is in Savannah, GA, ASHRAE Climate zone 2A. 8760-hour weather data for Hunter AAF, GA was imported into Trace 700 for a full-year analysis.

*Table 8: Energy Usage*

| | **Proposed Design** | **2013 PRM Baseline** | **2019 PRM Baseline** |
|---|---|---|---|
| **Total Energy Costs** | $111,808/yr | $156,491/yr | $199,915/yr |
| BBUEC (Receptacles) | $54,353/yr (1520.4E6 BTU/yr) | $54,353/yr (1520.4E6 BTU/yr) | $54,353/yr (1520.4E6 BTU/yr) |
| BBREC (Total – Receptacles) | $57,455/yr | $102,138/yr | $145,562/yr |

### 5.2.1 2019 Performance Rating Method (PRM)

*PCI = $111,808/$199,915 = 0.56*
*PCIt = [BBUEC + (BPF X BBREC)] / BBP*
*PCIt = [$54,353 + (0.50 X $145,562)] / $199,915 = 0.64*
*Percentage Improvement = 100 X (1-PCI/PCIt)*
*100 X (1-(0.56/0.64)) = 12.5%*

### 5.2.2 2013 Performance Rating Method (PRM)

*Percentage improvement = 100 × ((Baseline building consumption − Receptacle and process loads) − (Proposed building consumption − Receptacle and process loads)) / (Baseline building consumption − Receptacle and process loads)*

*= 100 * (($156,491 - $54,353) - ($111,808- $54,353)) / ($156,491 - $54,353) = 43.75%*

## 5.3 Prescriptive Method Results

At a minimum, upgrading to ASHRAE 90.1 2019 from 2013 will require meeting the standard. One compliance path to meet the standard is the prescriptive method. An energy analysis comparing the proposed design, 2013 prescriptive baseline, and 2019 prescriptive baseline was performed to compare the effects of minimum compliance with ASHRAE 90.1. This analysis was conducted in a similar fashion to the Energy Cost Budget Method, except for the HVAC system types. The HVAC system types modeled were the same for the PRM baselines and the Prescriptive baselines for this analysis. The proposed design was 45.96% better than the

2013 prescriptive baseline. The proposed design was 37.76% better than the 2019 prescriptive baseline. The 2019 prescriptive baseline was 13.18% better than the 2013 prescriptive baseline.

*Table 9: Energy Usage*

| | **Proposed Design** | **2013 Prescriptive Baseline** | **2019 Prescriptive Baseline** |
|---|---|---|---|
| **Total Energy Costs** | $109,732/yr | $156,831/yr | $143,324/yr |
| BBUEC (Receptacles) | $54,353/yr (1520.4E6 BTU/yr) | $54,353/yr (1520.4E6 BTU/yr) | $54,353/yr (1520.4E6 BTU/yr) |
| BBREC (Total – Receptacles) | $55,379/yr | $102,478/yr | $88,971/yr |

To compare each alternative, percentage improvement is calculated using the equation below:

*Percentage improvement = 100 × (((Baseline building consumption − Receptacle and process loads) − (Proposed building consumption − Receptacle and process loads)) / (Baseline building consumption − Receptacle and process loads))*

*Proposed design vs 2013 prescriptive baseline = 100 * (($156,831 - $54,353) - ($109,732 - $54,353)) / ($156,831 - $54,353) = 45.96%*

*Proposed design vs 2019 prescriptive baseline = 100 * (($143,324 - $54,353) - ($109,732 - $54,353)) / ($143,324 - $54,353) = 37.76%*

*2019 prescriptive baseline vs 2013 prescriptive baseline = 100 * (($156,831 - $54,353) - ($143,324 - $54,353)) / ($156,831 - $54,353) = 13.18%*

# 6 CONCLUSION

The 2019 Edition of ASHRAE 90.1, specifically the Performance Rating Method, contains some of the most significant changes to date. Since the Performance Rating Method must be used for Federal Government projects, there will be a significant hurdle for designers to overcome to ensure compliance when adopting the 2019 Edition in April of 2023.

All three compliance paths are intended to represent a design minimally compliant with the current edition of Standard 90.1. As the 2019 ASHRAE 90.1 Performance Rating Method currently stands, it was found to be excessively stringent for the project studied. The regular expected improvement in building performance for a building minimally compliant with ASHRAE 90.1, coupled with the unintended stringency of the new percentage improvement calculation methodology of the Performance Rating Method makes the 30% improvement over baseline required by 10 CFR Part 433 exceedingly difficult. As ASHRAE 90.1 will continue to trend towards net-zero, a 30% improvement will eventually become impossible. It is recommended that the 30% improvement language be removed from the CFR, or the Building Performance Factor Tables be modified to resemble the types of buildings common to federal projects.

# 7 REFERENCES

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# 8 APPENDIX

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## LCCA - Envelope Alternatives

Minimums based on ASHRAE 90.1 2013 building envelopes

- **Alt 1** – Total Building Energy Cost $/yr = $113,337
  - Walls:
    - OUTSIDE AIR LAYER-R0.17
    - CLAY BRICK VENEER-R0.44
    - AIR SPACE-R1.00
    - 1" RIGID INSULATION (POLYISO)- R7.20
    - 5/8" EXTERIOR SHEATHING-R0.5625
    - R-10 BATT INSULATION W/6" METAL STUD @ 16" O.C.-R5.50
    - INSIDE AIR LAYER-R0.68
    - TOTAL R-VALUE = 15.5525 (17.54 MODELED)
  - Roof:
    - PVC ROOF
    - ½: GLASS MAT GYP PROTECTION BD
    - R33 RIGID INSULATION
    - TOTAL R-VALUE = 34.4828 (34.977 MODELED)
  - Glazing:
    - U-0.54, SHGC-0.25, VTISHGC-1.10
  - Doors
    - ASHRAE MIN ZONE 2A

- **Alt 2** – Total Building Energy Cost $/yr = $113,386
  - Walls:
    - OUTSIDE AIR LAYER-R0.17
    - PRECAST CONCRETE PANEL @ 90 LBS PER CUBIC FOOT-R.26 PER INCH=R2.08
    - 3" RIGID INSULATION-R7.20 PER INCH=R21.6
    - INSIDE AIR LAYER-R0.68
    - TOTAL R-VALUE= 24.53 (25 MODELED)
  - Roof:
    - PRECAST ROOF PANEL
    - SPRAY FOAM INSULATION R-30
    - TOTAL R-VALUE = 33.3333 (33.113 MODELED)
  - Glazing:
    - U-0.54, SHGC-0.25, VTISHGC-1.10
  - Doors
    - ASHRAE MIN ZONE 2A

- **Alt 3** – Total Building Energy Cost $/yr = $113,290
  - Walls:
    - OUTSIDE AIR LAYER-R0.17
    - STUCCO-R.94
    - 5/8" EXTERIOR SHEATHING-R0.5625
    - 2" RIGID INSULATION (POLYISO)-R14.40

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        - CMU 8"-R1.11
        - 1 5/8" METAL STUD-R0.003
        - 5/8" GYPSUM WALL BOARD-R0.5625
        - INSIDE AIR LAYER-R0.68
        - TOTAL R-VALUE=18.428 (17.54 MODELED)
    - Roof:
        - MULTI-PLY MODIFIED BUTUMEN ROOF SYSTEM
        - ½" EXTERIOR GLASS MAT GYPSUM SHEATING ROOF BOARD
        - RIGID INSULATION R-30
        - TOTAL R-VALUE = 32.2580 (31.876 MODELED)
    - Glazing:
        - U-0.54, SHGC-0.25, VTISHGC-1.10
    - Doors
        - ASHRAE MIN ZONE 2A

- **Alt 4** – Total Building Energy Cost $/yr = $112,943
    - Walls: ASHRAE MIN ZONE 2A (ASHRAE 90.1 App A steel-framed wall, standard framing 3.5" depth)
        - OUTSIDE AIR LAYER-R0.17
        - STUCCO
        - GYPSUM BOARD
        - 3.5 INCH THICK R-13 INSULATION
        - GYPSUM BOARD
        - INSIDE AIR LAYER-R0.68
        - TOTAL R-VALUE=11.90 MODELED
    - Roof: ASHRAE MIN ZONE 2A (ASHRAE 90.1 APP A roof with insulation above deck table A2.2)
        - OUTSIDE AIR LAYER-R0.68
        - METAL DECK
        - INSULATION ABOVE DECK R-25
        - INSIDE AIR LAYER-R0.17
        - TOTAL R-VALUE = 25 MODELED
    - Glazing:
        - ASHRAE MIN ZONE 2A
    - Doors
        - ASHRAE MIN ZONE 2A

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## LCCA – HVAC Cooling System Alternatives

Minimums based on ASHRAE 90.1 2013

**COST IS NOT FOR A COMPLETE SYSTEM. ADDITIONAL MAINTENANCE AND REPLACEMENT COSTS WILL NOT CHANGE THE RESULTS OF THE LCCA.**

- **ALT 1** – VAV AHUS, AIR COOLED CHILLER ***MOST LCCE**
    - TOTAL BUILDING ENERGY COST $/YR = 115,474
    - INITIAL COST = $288,471 (YR2011), $361,667 (YR2023)
    - ELECTRICITY USAGE = 3,219.4 E 6 BTU/YR
    - GAS USAGE 43.8 E 6 BTU/YR
- **ALT 2** – VAV AHUS, DOAS, AIR COOLED CHILLER
    - TOTAL BUILDING ENERGY COST $/YR = 116,209
    - INITIAL COST = $330,633, $414,528 (YR2023)
    - ELECTRICITY USAGE = 3,212.3 E 6 BTU/YR
    - GAS USAGE = 150.8 E 6 BTU/YR
- **ALT 3** – VAV AHU, WATER COOLED CHILLER, GROUND SOURCE HEAT EXCHANGER
    - TOTAL BUILDING ENERGY COST $/YR = 115,060
    - INITIAL COST = $485,928 (YR2011), $609,227 (YR2023)
    - ELECTRICITY USAGE = 3212.3 E 6 BTU/YR
    - GAS USAGE = 0 BTU/YR
- **ALT 4** – ASHRAE 90.1 BASELINE
    - TOTAL BUILDING ENERGY COST $/YR = 120,256
    - INITIAL COST = $288.471 (YR2011), $361,667 (YR2023)
    - ELECTRICITY USAGE = 3,364.5 E 6 BTU/YR
    - GAS USAGE = 0 BTU/YR

Project Notes
7-Bay Medium Hangar
Hunter AAF, GA
MHY23001

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2/3/2022 1:35 AM

**COS Hangar ALT 1** — Page 1 of 1 — Lines 1 - 4 of 4

| Qty | Line Number | Description | Crew | Unit | Labor Hours | Daily Output | Extended Material | Extended Labor | Extended Equipment | Extended Total | Extended Total O&P | Labor Type | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 232123135190 | Pump, circulating, cast iron, base mounted, coupling gua | Q1 | Ea. | 8.889 | 1.80 | $6,775.00 | $260.58 | | $7,035.58 | $7,837.84 | Standard Unio | |
| 1.00 | 236426100120 | Water chiller, screw liquid chiller, air cooled, insulated ev | Q7 | Ea. | 228.000 | 0.14 | $83,500.00 | $7,091.80 | | $90,591.80 | $102,577.60 | Standard Unio | |
| 3.00 | 237313202350 | Central station air handling unit, packaged indoor, variab | Q6 | Ea. | 48.000 | 0.50 | $103,800.00 | $4,372.29 | | $108,172.29 | $120,835.89 | Standard Unio | |
| 1.00 | 237313202360 | Central station air handling unit, packaged indoor, variab | Q6 | Ea. | 60.000 | 0.40 | $49,500.00 | $1,818.03 | | $51,318.03 | $57,219.53 | Standard Unio | |
| | | | | | | | $243,575.00 | $13,542.70 | | $257,117.70 | $288,470.86 | | |

**COS Hangar ALT 2** — Page 1 of 1 — Lines 1 - 7 of 7

| Qty | Line Number | Description | Crew | Unit | Labor Hours | Daily Output | Extended Material | Extended Labor | Extend | Extended Total | Extended Total O&P | Labor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 237313201550 | Central station air handling unit, packaged indoor, constant volume, 10,000 CFM, cooling co | Q6 | Ea. | 44.444 | 0.54 | $32,400.00 | $1,352.25 | | $33,752.25 | $37,613.35 | Stan |
| 2.00 | 237313202350 | Central station air handling unit, packaged indoor, variable air volume, 10,000 CFM, cooling | Q6 | Ea. | 48.000 | 0.50 | $69,200.00 | $2,914.86 | | $72,114.86 | $80,557.26 | Stan |
| 1.00 | 237313202360 | Central station air handling unit, packaged indoor, variable air volume, 15,000 CFM, cooling | Q6 | Ea. | 60.000 | 0.40 | $49,500.00 | $1,818.03 | | $51,318.03 | $57,219.53 | Stan |
| 1.00 | 237313202340 | Central station air handling unit, packaged indoor, variable air volume, 5000 CFM, cooling cc | Q6 | Ea. | 34.286 | 0.70 | $18,000.00 | $1,036.73 | | $19,036.73 | $21,347.58 | Stan |
| 1000.00 | 233113165500 | Metal Ductwork, spiral preformed, steel, galvanized, straight lengths, max. 10" S.P.W.G., 20' | Q10 | L.F. | 0.369 | 65.00 | $6,600.00 | $10,700.00 | | $17,300.00 | $23,480.00 | Stan |
| 1.00 | 232123135190 | Pump, circulating, cast iron, base mounted, coupling guard, bronze impeller, flanged joints, | Q1 | Ea. | 8.889 | 1.80 | $6,775.00 | $260.58 | | $7,035.58 | $7,837.84 | Stan |
| 1.00 | 236426100120 | Water chiller, screw liquid chiller, air cooled, insulated evaporator, 130 ton, includes standarc | Q7 | Ea. | 228.000 | 0.14 | $83,500.00 | $7,091.80 | | $90,591.80 | $102,577.60 | Stan |
| | | | | | | | $265,975.00 | $25,174.25 | | $291,149.25 | $330,633.16 | |

**COS Hangar Alt 3** — Page 1 of 1 — Lines 1 - 7 of 7

| Qty | Line Number | Description | Crew | Unit | Labor Hours | Daily Output | Extended Material | Extended Labor | Exten | Extended Total | Extended Total O&P | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 232123135300 | Pump, circulating, cast iron, base mounted, coupling guard, bronze impeller, flanged joints, 5 H.P., to 225 | Q1 | Ea. | 10.000 | 1.60 | $7,775.00 | $293.91 | | $8,068.91 | $9,011.32 | |
| 1.00 | 236419101180 | Water chiller, reciprocating, multiple compressor, semi-hermetic, water cooled, 125 ton cooling, includes s | Q7 | Ea. | 196.000 | 0.16 | $66,500.00 | $6,070.10 | | $72,570.10 | $82,075.10 | |
| 1130.00 | 221113742470 | Pipe, plastic, PVC, 3/4" diameter, schedule 80, includes couplings 10' OC, and hangers 3 per 10' | 1 Plun | L.F. | 0.170 | 47.00 | $4,474.80 | $6,226.30 | | $10,701.10 | $14,226.70 | |
| 100.00 | 221113742530 | Pipe, plastic, PVC, 3" diameter, schedule 80, includes couplings 10' OC, and hangers 3 per 10' | Q1 | L.F. | 0.320 | 50.00 | $1,240.00 | $936.00 | | $2,176.00 | $2,759.00 | |
| 36000.00 | 332113100105 | Public Water Supply Wells, wells domestic water, drilled, drill geothermal well 4"-6" dia, not to exceed 400 | B23 | L.F. | 0.050 | 800.00 | | $49,680.00 | $112,: | $162,000.00 | $199,800.00 | |
| 3.00 | 237313202350 | Central station air handling unit, packaged indoor, variable air volume, 10,000 CFM, cooling coils may be c | Q6 | Ea. | 48.000 | 0.50 | $103,800.00 | $4,372.29 | | $108,172.29 | $120,835.89 | |
| 1.00 | 237313202360 | Central station air handling unit, packaged indoor, variable air volume, 15,000 CFM, cooling coils may be c | Q6 | Ea. | 60.000 | 0.40 | $49,500.00 | $1,818.03 | | $51,318.03 | $57,219.53 | |
| | | | | | | | $233,289.80 | $69,396.63 | $112 | $415,006.43 | $485,927.54 | |

**COS Hangar ALT 4** — Page 1 of 1 — Lines 1 - 4 of 4

| Qty | Line Number | Description | Crew | Unit | Labor Hours | Daily O | Extended Mate | Extended La | Extend | Extended Total | Extended Total O&P | Labo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.00 | 237313202350 | Central station air handling unit, packaged indoor, variable air volume, 10,000 CFM, cooling coils may be chilled w | Q6 | Ea. | 48.000 | 0.50 | $103,800.00 | $4,372.29 | | $108,172.29 | $120,835.89 | Sta |
| 1.00 | 237313202360 | Central station air handling unit, packaged indoor, variable air volume, 15,000 CFM, cooling coils may be chilled w | Q6 | Ea. | 60.000 | 0.40 | $49,500.00 | $1,818.03 | | $51,318.03 | $57,219.53 | Sta |
| 1.00 | 232123135190 | Pump, circulating, cast iron, base mounted, coupling guard, bronze impeller, flanged joints, 3 H.P., to 150 GPM, 2- | Q1 | Ea. | 8.889 | 1.80 | $6,775.00 | $260.58 | | $7,035.58 | $7,837.84 | Sta |
| 1.00 | 236426100120 | Water chiller, screw liquid chiller, air cooled, insulated evaporator, 130 ton, includes standard controls | Q7 | Ea. | 228.000 | 0.14 | $83,500.00 | $7,091.80 | | $90,591.80 | $102,577.60 | Sta |
| | | | | | | | $243,575.00 | $13,542.70 | | $257,117.70 | $288,470.86 | |

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# NIST BLCC 5.3-20: Summary LCC

**Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A**

## General Information

| | |
|---|---|
| **File Name:** | C:\Users\k5endjbp\Desktop\MHY23001_COOLING_LCCA.xml |
| **Date of Study:** | Fri Dec 10 16:45:59 CST 2021 |
| **Analysis Type:** | MILCON Analysis, Energy Project |
| **Project Name:** | COS 7-BAY MEDIUM HANGAR - COOLING |
| **Project Location:** | Georgia |
| **Analyst:** | JP |
| **Comment:** | MHY23001 ADAPT-BUILD 7 BAY HANGAR, HUNTER AAF, GA. HVAC LCCA |
| **Base Date:** | April 1, 2023 |
| **Beneficial Occupancy Date:** | April 1, 2023 |
| **Study Period:** | 40 years 0 months (April 1, 2023 through March 31, 2063) |
| **Discount Rate:** | 3% |
| **Discounting Convention:** | Mid-Year |

**Discount and Escalation Rates are REAL (exclusive of general inflation)**

# Alternative: ALT 1

### LCC Summary

| | Present Value | Annual Value |
|---|---|---|

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| | | |
|---|---|---|
| **Initial Cost Paid By Agency** | $361,667 | $15,647 |
| **Energy Consumption Costs** | $2,645,008 | $114,433 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$29,756 | -$1,287 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $2,976,920 | $128,793 |

# Alternative: ALT 2

## LCC Summary

| | **Present Value** | **Annual Value** |
|---|---|---|
| **Initial Cost Paid By Agency** | $414,528 | $17,934 |
| **Energy Consumption Costs** | $2,747,961 | $118,888 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$34,105 | -$1,475 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $3,128,385 | $135,346 |

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# Alternative: ALT 3

## LCC Summary

| | Present Value | Annual Value |
|---|---|---|
| **Initial Cost Paid By Agency** | $609,227 | $26,358 |
| **Energy Consumption Costs** | $2,628,539 | $113,721 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$31,824 | -$1,377 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $3,205,941 | $138,702 |

# Alternative: ALT 4

## LCC Summary

| | Present Value | Annual Value |
|---|---|---|
| **Initial Cost Paid By Agency** | $361,667 | $15,647 |
| **Energy Consumption Costs** | $2,753,080 | $119,109 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |

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| | | |
|---|---|---|
| **Less Remaining Value** | -$29,756 | -$1,287 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $3,084,992 | $133,469 |

Project Notes
7-Bay Medium Hangar
Hunter AAF, GA
MHY23001

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## LCCA – HVAC HEATING System Alternatives

Minimums based on ASHRAE 90.1 2013

**COST IS NOT FOR A COMPLETE SYSTEM. ADDITIONAL MAINTENANCE AND REPLACEMENT COSTS WILL NOT CHANGE THE RESULTS OF THE LCCA.**

- **Alt 1** – HOT WATER HEATING COILS, HW REHEAT
  - **Present Value: $2,996,245**
  - Total Building Energy Cost $/yr = $121,831
  - INITIAL COST = $175,696 (YR2011), $ 220,277(YR2023)
  - ELECTRICITY USAGE = 3,396.8 E 6 BTU/YR
  - GAS USAGE = 45.6 E 6 BTU/YR
- **Alt 2** – ELECTRIC HEATING COILS, ELECTRIC REHEAT ***MOST LCCE**
  - **Present Value: $2,982,951**
  - Total Building Energy Cost $/yr = $122,578
  - INITIAL COST = $151,227 (YR2011), $189,599 (YR2023)
  - ELECTRICITY USAGE = 3429.4 E 6 BTU/YR
  - GAS USAGE = 0 BTU/YR

INITIAL COSTS:

**COS Hangar Heating Alt 1** — Page 1 of 1 — Lines 1 - 14 of 14

| Qty | Line Number | Description | Unit | Extended To | Extended Total ( | Labor Type | Notes |
|---|---|---|---|---|---|---|---|
| 700.00 | 22071910432 | Insulation, pipe (price copper tube one size less than I.P.S.), cellular glass, closed cell foam, all service jacket, sealant, 0 water vapor transmission, working temperature (-450 | L.F. | $8,085.00 | $11,025.00 | Standard Union | |
| 1200.00 | 22071910432 | Insulation, pipe (price copper tube one size less than I.P.S.), cellular glass, closed cell foam, all service jacket, sealant, 0 water vapor transmission, working temperature (-450 | L.F. | $18,060.00 | $24,120.00 | Standard Union | |
| 700.00 | 22111323120 | Pipe, copper, tubing, solder, 1" diameter, type K, includes coupling & clevis hanger assembly 10' O.C. | L.F. | $12,810.00 | $15,890.00 | Standard Union | |
| 1200.00 | 22111323126 | Pipe, copper, tubing, solder, 2" diameter, type K, includes coupling & clevis hanger assembly 10' O.C. | L.F. | $47,040.00 | $57,000.00 | Standard Union | |
| 1.00 | 23212010004 | Air control, air separator, 2" diameter, includes strainer | Ea. | $995.00 | $1,144.00 | Standard Union | |
| 10.00 | 23212018006 | Automatic air vent, cast iron body, stainless steel internals, float type, 300 psi, 1/2" NPT inlet | Ea. | $1,265.00 | $1,535.00 | Standard Union | |
| 2.00 | 23212313404 | Pump, circulating, cast iron, close coupled, end suction, bronze impeller, flanged joints, 1-1/2 H.P., to 40 GPM, 1-1/2" size | Ea. | $4,264.00 | $4,920.00 | Standard Union | |
| 12.00 | 23361610561 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 200 CFM | Ea. | $9,510.00 | $10,824.00 | Standard Union | |
| 16.00 | 23361610562 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 400 CFM | Ea. | $12,952.00 | $14,672.00 | Standard Union | |
| 23.00 | 23361610563 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 600 CFM | Ea. | $18,618.50 | $21,091.00 | Standard Union | |
| 8.00 | 23361610564 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 800 CFM | Ea. | $6,784.00 | $7,768.00 | Standard Union | |
| 1.00 | 23361610565 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 1000 CFM | Ea. | $848.00 | $971.00 | Standard Union | |
| 2.00 | 23361610567 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 1500 CFM | Ea. | $1,898.00 | $2,194.00 | Standard Union | |
| 2.00 | 23361610568 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 2000 CFM | Ea. | $2,172.00 | $2,542.00 | Standard Union | |
| | | | | $145,301.5 | $175,696.00 | | |

**COS Hangar Heating Alt 2** — Page 1 of 1 — Lines 1 - 11 of 11

| Qty | Line Number | Description | Unit | Extended Total | Extended Total O&I | Labor Type | Notes |
|---|---|---|---|---|---|---|---|
| 20.00 | 260519503400 | Mineral insulated cable, 4 conductor, 600 volt, #8 | C.L.F. | $40,000.00 | $46,900.00 | Standard Union | |
| 4.00 | 262413101400 | Switchboards, no main disconnect, 4 wire, 277/480 V, 1000 amp, incl CT compartment, excl CT's or PT's | Ea. | $24,500.00 | $28,500.00 | Standard Union | |
| 23.00 | 233616105630 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 600 CFM | Ea. | $18,618.50 | $21,091.00 | Standard Union | |
| 16.00 | 233616105620 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 400 CFM | Ea. | $12,952.00 | $14,672.00 | Standard Union | |
| 1.00 | 261219100110 | Transformer, oil-filled, 15 kV with taps, 480 V secondary 3 phase, 225 kVA, pad mounted | Ea. | $12,235.00 | $14,133.00 | Standard Union | |
| 12.00 | 233616105610 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 200 CFM | Ea. | $9,510.00 | $10,824.00 | Standard Union | |
| 8.00 | 233616105640 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 800 CFM | Ea. | $6,784.00 | $7,768.00 | Standard Union | |
| 2.00 | 233616105680 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 2000 CFM | Ea. | $2,172.00 | $2,542.00 | Standard Union | |
| 2.00 | 233616105670 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 1500 CFM | Ea. | $1,898.00 | $2,194.00 | Standard Union | |
| 64.00 | 233616105560 | Duct accessories, mixing box, variable air volume, cool only, pneumatic pressure independent, for electric with thermostat, pressure dependent, add | Ea. | $1,472.00 | $1,632.00 | Standard Union | |
| 1.00 | 233616105650 | Duct accessories, mixing box, variable air volume, cool and hot water coils, damper, actuator and thermostat, 1000 CFM | Ea. | $848.00 | $971.00 | Standard Union | |
| | | | | $130,989.50 | $151,227.00 | | |

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# NIST BLCC 5.3-20: Summary LCC

**Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A**

## General Information

| | |
|---|---|
| **File Name:** | C:\Users\k5endjbp\Desktop\MHY23001_HEATING_LCCA.xml |
| **Date of Study:** | Fri Dec 10 16:38:55 CST 2021 |
| **Analysis Type:** | MILCON Analysis, Energy Project |
| **Project Name:** | COS 7-BAY MEDIUM HANGAR - COOLING |
| **Project Location:** | Georgia |
| **Analyst:** | JP |
| **Comment:** | MHY23001 ADAPT-BUILD 7 BAY HANGAR, HUNTER AAF, GA. HVAC LCCA |
| **Base Date:** | April 1, 2023 |
| **Beneficial Occupancy Date:** | April 1, 2023 |
| **Study Period:** | 40 years 0 months (April 1, 2023 through March 31, 2063) |
| **Discount Rate:** | 3% |
| **Discounting Convention:** | Mid-Year |

**Discount and Escalation Rates are REAL (exclusive of general inflation)**

# Alternative: ALT 1 - HW HEAT

### LCC Summary

| | **Present Value** | **Annual Value** |
|---|---|---|
| **Initial Cost Paid By Agency** | $220,277 | $9,530 |
| **Energy Consumption Costs** | $2,790,879 | $120,744 |

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| | | |
|---|---|---|
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$14,911 | -$645 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $2,996,245 | $129,629 |

# Alternative: ALT 2 - ELEC HEAT

### LCC Summary

| | **Present Value** | **Annual Value** |
|---|---|---|
| **Initial Cost Paid By Agency** | $189,599 | $8,203 |
| **Energy Consumption Costs** | $2,806,186 | $121,407 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$12,834 | -$555 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $2,982,951 | $129,054 |

Project Notes
7-Bay Medium Hangar
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MHY23001

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## LCCA – HVAC HANGAR BAY HEATING SYSTEM ALTERNATIVES

Minimums based on ASHRAE 90.1 2013

**COST IS NOT FOR A COMPLETE SYSTEM. ADDITIONAL MAINTENANCE AND REPLACEMENT COSTS WILL NOT CHANGE THE RESULTS OF THE LCCA.**

- **Alt 1** –GAS FIRED INFRARED HEAT IN HANGAR ***MOST LCCE**
    - Total Annual Cost $/yr = $8,308
    - INITIAL COST = $69,580 (YR2011), $87,235 (YR2023)
    - ELECTRICITY USAGE = 0 BTU/YR
    - GAS USAGE = 4440.4 THERMS
- **Alt 2** – ELECTRIC HEATERS IN HANGAR
    - Total Annual Cost $/yr = $15,681
    - INITIAL COST = $70,804 (YR2011), $88,770 (YR2023)
    - ELECTRICITY USAGE = 100,178.8 kW
    - GAS USAGE = 0 THERMS

COS Hangar Bay Heating Alt 1 — Page 1 of 1 — Lines 1 - 3 of 3

| Qty | Line Number | Description | Unit | Extended Total | Extended Total O&P | Labor Type |
|---|---|---|---|---|---|---|
| 16.00 | 238227100240 | Infra-red unit, gas fired, unvented, electric ignition, input, 100% shutoff, 120 MBH, excludes piping and wiring | Ea. | $37,840.00 | $43,680.00 | Standard Union |
| 600.00 | 221113440610 | Pipe, steel, black, threaded, 2" diameter, schedule 40, Spec. A-53, includes coupling and clevis hanger assembly sized | L.F. | $14,100.00 | $18,360.00 | Standard Union |
| 400.00 | 221113440580 | Pipe, steel, black, threaded, 1" diameter, schedule 40, Spec. A-53, includes coupling and clevis hanger assembly sized | L.F. | $5,700.00 | $7,540.00 | Standard Union |
| | | | | **$57,640.00** | **$69,580.00** | |

COS Hangar Bay Heating Alt 2 — Page 1 of 1 — Lines 1 - 2 of 2

| Qty | Line Number | Description | Unit | Extended Total | Extended Total O&P | Labor Type |
|---|---|---|---|---|---|---|
| 23.00 | 238227102150 | Infra-red unit, electric, single or three phase, 24 kW, 81,912 BTU | Ea. | $35,673.00 | $41,354.00 | Standard Union |
| 1.00 | 261219100400 | Transformer, oil-filled, 15 kV with taps, 480 V secondary 3 phase, 750 kVA, pad mounted | Ea. | $25,865.00 | $29,450.00 | Standard Union |
| | | | | **$61,538.00** | **$70,804.00** | |

# NIST BLCC 5.3-20: Summary LCC

**Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A**

## General Information

| | |
|---|---|
| **File Name:** | C:\Users\k5endjbp\Desktop\MHY23001_BAYHEATING_LCCA.xml |

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| | |
|---|---|
| **Date of Study:** | Fri Dec 17 14:22:43 CST 2021 |
| **Analysis Type:** | MILCON Analysis, Energy Project |
| **Project Name:** | COS 7-BAY MEDIUM HANGAR - BAY HEATING |
| **Project Location:** | Georgia |
| **Analyst:** | JP |
| **Comment:** | MHY23001 ADAPT-BUILD 7 BAY HANGAR, HUNTER AAF, GA. HVAC LCCA |
| **Base Date:** | April 1, 2023 |
| **Beneficial Occupancy Date:** | April 1, 2023 |
| **Study Period:** | 40 years 0 months (April 1, 2023 through March 31, 2063) |
| **Discount Rate:** | 3% |
| **Discounting Convention:** | Mid-Year |

**Discount and Escalation Rates are REAL (exclusive of general inflation)**

# Alternative: ALT 1 - NG HEAT

## LCC Summary

| | Present Value | Annual Value |
|---|---|---|
| **Initial Cost Paid By Agency** | $87,235 | $3,774 |
| **Energy Consumption Costs** | $110,702 | $4,789 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |

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| | | |
|---|---|---|
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$5,905 | -$255 |
| | ------------ | ------------ |
| **Total Life-Cycle Cost** | $192,032 | $8,308 |

# Alternative: ALT 2 - ELEC HEAT

## LCC Summary

| | Present Value | Annual Value |
|---|---|---|
| **Initial Cost Paid By Agency** | $88,770 | $3,841 |
| **Energy Consumption Costs** | $279,678 | $12,100 |
| **Energy Demand Costs** | $0 | $0 |
| **Energy Utility Rebates** | $0 | $0 |
| **Water Usage Costs** | $0 | $0 |
| **Water Disposal Costs** | $0 | $0 |
| **Routine Annually Recurring OM&R Costs** | $0 | $0 |
| **Routine Non-Annually Recurring OM&R Costs** | $0 | $0 |
| **Major Repair and Replacement Costs** | $0 | $0 |
| **Less Remaining Value** | -$6,009 | -$260 |
| | ------------ | ------------ |

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| | | |
|---|---|---|
| **Total Life-Cycle Cost** | $362,439 | $15,681 |

# Energy Cost Budget / PRM Summary

By USACE

| Project Name: COS ADAPT BUILD MEDIUM HANGAR | Date: December 19, 2022 |
|---|---|
| City: HUNTER AAF, GA | Weather Data: Hunter AAF, GA |

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

* Denotes the base alternative for the ECB study.

| | | * Alt-2 2013 ASHRAE Baseline | | | Alt-1 Proposed Design | | | Alt-3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh |
| **Lighting - Conditioned** | Electricity | 1,185.6 | 27 | 459 | 741.0 | 63 | 287 | 1,226.5 | 103 | 475 |
| **Space Heating** | Electricity | 734.1 | 17 | 1,109 | 20.9 | 3 | 41 | 1,873.3 | 255 | 2,072 |
| | Gas | 0.0 | 0 | 0 | 205.1 | 0 | 780 | 0.0 | 0 | 0 |
| **Space Cooling** | Electricity | 878.5 | 20 | 440 | 681.1 | 78 | 347 | 909.8 | 104 | 472 |
| **Pumps** | Electricity | 0.0 | 0 | 0 | 17.9 | 0 | 5 | 0.0 | 0 | 0 |
| **Heat Rejection** | Electricity | 57.7 | 1 | 30 | 93.7 | 162 | 42 | 58.2 | 101 | 33 |
| **Fans - Conditioned** | Electricity | 2.0 | 0 | 10 | 0.0 | 0 | 0 | 4.9 | 248 | 10 |
| **Receptacles - Conditioned** | Electricity | 1,520.4 | 35 | 174 | 1,520.4 | 100 | 174 | 1,520.4 | 100 | 174 |
| **Total Building Consumption** | | **4,378.3** | | | **3,280.2** | | | **5,593.2** | | |

| | | * Alt-2 2013 ASHRAE Baseline | Alt-1 Proposed Design | Alt-3 |
|---|---|---|---|---|
| **Total** | **Number of hours heating load not met**<br>**Number of hours cooling load not met** | 441<br>0 | 333<br>0 | 546<br>0 |

| | * Alt-2 2013 ASHRAE Baseline | | Alt-1 Proposed Design | | Alt-3 | |
|---|---|---|---|---|---|---|
| | Energy 10^6 Btu/yr | Cost/yr $/yr | Energy 10^6 Btu/yr | Cost/yr $/yr | Energy 10^6 Btu/yr | Cost/yr $/yr |
| **Electricity** | 4,378.3 | 156,491 | 3,075.1 | 109,913 | 5,593.2 | 199,915 |
| **Gas** | 0.0 | 0 | 205.1 | 1,896 | 0.0 | 0 |
| **Total** | **4,378** | **156,491** | **3,280** | **111,808** | **5,593** | **199,915** |

# Energy Cost Budget / PRM Summary

By USACE

| Project Name: COS ADAPT BUILD MEDIUM HANGAR | Date: December 20, 2022 |
|---|---|
| City: HUNTER AAF, GA | Weather Data: Hunter AAF, GA |

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

* Denotes the base alternative for the ECB study.

| | | * Alt-2 2013 ASHRAE Prescripti | | | Alt-1 Proposed Design | | | Alt-3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh | Energy 10^6 Btu/yr | Proposed / Base % | Peak kBtuh |
| **Lighting - Conditioned** | Electricity | 1,185.6 | 27 | 459 | 682.6 | 58 | 265 | 782.1 | 66 | 303 |
| **Space Heating** | Electricity | 734.1 | 17 | 1,109 | 21.0 | 3 | 41 | 804.1 | 110 | 1,086 |
| | Gas | 0.0 | 0 | 0 | 220.0 | 0 | 778 | 0.0 | 0 | 0 |
| **Space Cooling** | Electricity | 887.9 | 20 | 424 | 678.0 | 76 | 344 | 845.8 | 95 | 394 |
| **Pumps** | Electricity | 0.0 | 0 | 0 | 17.8 | 0 | 5 | 0.0 | 0 | 0 |
| **Heat Rejection** | Electricity | 57.8 | 1 | 30 | 93.3 | 161 | 42 | 55.9 | 97 | 28 |
| **Fans - Conditioned** | Electricity | 2.0 | 0 | 10 | 0.0 | 0 | 0 | 1.5 | 78 | 6 |
| **Receptacles - Conditioned** | Electricity | 1,520.4 | 35 | 174 | 1,520.4 | 100 | 174 | 1,520.4 | 100 | 174 |
| **Total Building Consumption** | | **4,387.8** | | | **3,233.2** | | | **4,009.9** | | |

| | | * Alt-2 2013 ASHRAE Prescripti | Alt-1 Proposed Design | Alt-3 |
|---|---|---|---|---|
| **Total** | **Number of hours heating load not met** | 441 | 332 | 407 |
| | **Number of hours cooling load not met** | 0 | 0 | 0 |

| | * Alt-2 2013 ASHRAE Prescripti | | Alt-1 Proposed Design | | Alt-3 | |
|---|---|---|---|---|---|---|
| | Energy 10^6 Btu/yr | Cost/yr $/yr | Energy 10^6 Btu/yr | Cost/yr $/yr | Energy 10^6 Btu/yr | Cost/yr $/yr |
| **Electricity** | 4,387.8 | 156,831 | 3,013.2 | 107,699 | 4,009.9 | 143,324 |
| **Gas** | 0.0 | 0 | 220.0 | 2,033 | 0.0 | 0 |
| **Total** | **4,388** | **156,831** | **3,233** | **109,732** | **4,010** | **143,324** |