Historical Net Zero Building Renovation: Wayne N. Aspinall Federal Building and US Courthouse

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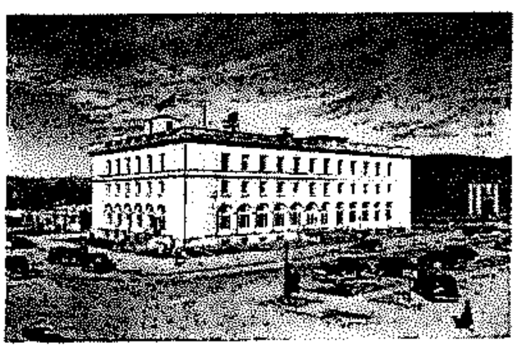
ABSTRACT

The $15 million high performing green modernization of the Wayne N. Aspinall Federal Building and U.S. Courthouse in Grand Junction, CO, preserves the 41,562 square foot building's historic character, while transforming the landmark structure into one of the most energy efficient, sustainable historic buildings in the country. Executed through a design-build contract, the Wayne N. Aspinall Federal Building & US Courthouse showcases through an integrated project delivery method how innovative technology and building preservation can work hand-in-hand to create award winning, sustainable design.

HISTORY

The Wayne N. Aspinall Federal Building and US Courthouse is a long-held General Services Administration (GSA) (owner) managed property, located in Grand Junction, CO. The building was constructed in 1918 under the supervision of the Architect of the Treasury, James Wetmore. Originally designed as a Post Office and US Courthouse, the building served as an architecturally significant example of a Second Renaissance Revival style federal building, and the first permanent post office constructed in the region. In 1938, under the supervision of Louis A. Simon, the building was expanded to the east, maintaining the building's symmetry, true to its original design. *Figure 1 and 2*



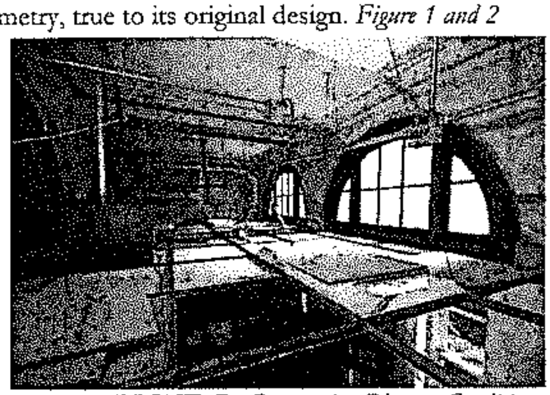


Figure 1 (LEFT) Building in 1938; *Figure 2 (RIGHT) Pre-Renovation Plenum Condition*

The building is a three-story steel, concrete, and wood structure with an Indiana limestone façade and parapet balustrade. A basement level on the south and west sides of the building in the area of the 1938 expansion, have window

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wells, which allow daylight to infiltrate occupied spaces of the basement floor. The window well was the primary disruption to the building's symmetry on the south façade. As part of the 1938 expansion, an elevator was placed in the building's main lobby. The 1st floor postal workroom located on the north side of the building, was daylight through large windows spanning a significant portion of the first floor's 14'4" (4.37m) ceiling height. In addition, the building's 2nd and 3rd floors were recessed above the first floor on the north side, creating a light well, with the first floor roof penetrated by a skylight. The main postal lobby was located on the building's prominent south façade. The lobby spanned from the building's west entrance and original southwest staircase, to the elevator lobby located in the eastern expansion.

In the 1960's, the Post Office permanently relocated out of the building. The GSA took ownership of the property, and leased the space associated with the Post Office to federal agencies within the region. The building's first floor plan was significantly altered by the new space configuration which created a "U" shaped circulation path centered on the first floor to allow for offices to be located against the windows. The building's HVAC system was introduced at that time as well, impacting the interior special volumes with dropped acoustical ceilings to mask the systems. In 2009, the building was considered for disposal as the owner did not have the funds to upgrade all of the building's systems which were well over 40 years old, and upgrade the building to meet current codes.

PROCUREMENT

The Wayne N. Aspinall Federal Building and US Courthouse modernization project was funded through the American Recovery & Reinvestment Act (ARRA) 2009. A request for funding was issued by the region in October 2009 to upgrade all of the building's systems, modernize the building's tenant interior, renovate to meet current code, and preserve areas of significance. In January 2010, the region received $15M to fund all contracts supporting the modernization. Stipulations on these funds required that all contracts be awarded within five (5) months, or funding would be rescinded and reallocated. As a result of this expedited award time-frame, the owner's project team looked to the Design-Build (DB) Delivery method to assure on-time award.

Design-Build is not common on historic federal buildings, as the government is required to adhere to the Section 106 process for compliance with the Secretary of Interior Standards for Historic Preservation. Award prior to that process presents significant risk to the owner, as the review process which will most likely initiate changes in the design is conducted post award to the design-builder. Financial risk was high based on this delivery method.

In addition to a quick award, ARRA funding required compliance with a minimum performance criteria which mandated aggressive energy targets for building systems, water reduction targets, and sustainable material choices. The design-build delivery method is becoming increasingly common on projects which aggressive energy targets as it allows for more collaboration throughout the life of the project, and targets can be better incorporated into contracts. Targets can include specific Energy Use Intensity (EUI) goals, stretch EUI goals, and goals specifically stating zero net energy. Using a single contract which allows the designer and the builder to work hand-in-hand reduces owner risk of "finger pointing" between multiple owner contracts if targets are not met.

The proposal which the contract was awarded included multiple innovative options. The options included energy production from photovoltaic (PV) which was elevated above the building's roof on a flat canopy which extended beyond the building's edge. The estimated PV production was approximately 140 kW or the estimated building energy use. Another option included radiant panels with indirect cooling and hot water generated using solar heating panels.

DELIVERY

Upon award the project began the Section 106 review process, in addition to the GSA Peer Review process as part of the Design Excellence Program. The consistent comment out of both reviews was that for the historic building, the visibility of the PV canopy should be reduced from the pedestrian view.

The GSA team worked closely with the City of Grand Junction, Downtown Development Authority, Central Business

District groups, and the Grand Junction Historic Preservation Board early in the project to help gain community support for the project and the project's energy goals. As a result of the relationships built with the City, the Historic Preservation Board wrote a letter to the State Historic Preservation Office in support of a PV canopy design which eliminated the canopy from the pedestrian view at the south façade from across the street; and eliminated the canopy view from the property line on the east and west facades.

However, as a result of the changes to the original design, the Project Team looked at other means to reduce overall building use to accommodate the reduced energy production capabilities. Changes to the HVAC approach, building enclosure, lighting, and metering concept were incorporated into the project through a change order, which also reduced the canopy to the approved design. The Project Team was able to remain close to the original budget through a collaborative approach which addressed energy efficiency, preservation, scope, and budget. Preservation and energy efficiency needed to be woven together for this project to be a success. Decisions about building systems had to address preservation, much like how decisions regarding preservation treatments had to address enhanced energy efficiency. Both aspects of the project had to support one-another. What the team realized is that historic buildings inherently support energy efficient design. The design decisions made in 1918 and 1938 addressed thermal comfort and day-lighting inherently through the architectural design. These architectural elements were used to support the renovation's energy goals.

Buy-in from building occupants related to the project's energy goals was necessary to address building loads, and especially plug loads. Sessions were held with the building occupants throughout the design and construction process which discussed ways to reduce energy use and how they could expect the building to operate post-construction. The project team focused heavily on daytime energy use. Post construction energy evaluations indicate the daytime energy use is very low. The team did not focus on night-time and weekend energy use as part of these sessions. Post construction energy evaluations indicate a much higher than expected energy use by all of the building occupants. By in large, the agencies within the building have been very supportive of the project and the project's energy goals.

One lesson learned is that owner's should broaden their view of their HVAC and lighting investment to include desktop concepts. Including items such as USB powered fans and solar powered task lighting may allow for changes to space conditioning temperatures and overhead lighting levels to reduce system energy use. As part of this modernization, a portion of the project's electrical budget did include desktop devices to assist in addressing plug loads.

RENOVATION

The high performing green building renovation of the Wayne N. Aspinall Federal Building and US Courthouse in Grand Junction, CO exemplifies the successful balance of preservation and sustainability. The project preserves an anchor in the community and the building's historic character, and converts the 1918 landmark into one of the most energy efficient, sustainable historic buildings in the country. The design has achieved LEED® Platinum certification and aims to be GSA's first site net-zero energy facility on the National Register. In 2014, the project was awarded an AIA Top 10 COTE Award and a GSA Design Citation Award for Engineering.

ENERGY EFFICIENCY

The DB procurement approach was utilized to deliver a high-performance project within budget and with an aggressive schedule. The approach acknowledged the federal government's goal to be carbon-neutral by 2030, and creates a "*green proving ground*" demonstrating how to potentially make an existing historic building perform at net-zero energy, 15 years ahead of schedule.

To meet aggressive performance goals, including energy independence and energy efficiency (68.7% more efficient than ASHRAE Standard 90.1-2007), design included: a roof canopy-mounted 123 kW PV array (generating electricity on-site to power 15 average homes), addition of spray foam and rigid insulation to building shell; storm windows with solar control film to reduce demand on HVAC; variable-refrigerant flow heating and cooling systems tied to a 32-well Geo-

Exchange loop; a dedicated outdoor air system with evaporative cooling and heat recovery; wireless controls and fluorescent and LED lighting upgrades; and post occupancy monitoring capability.

Building physics simulation was utilized prior to award of contract through an 18-month post-occupancy measurement and verification process. The following tools were utilized:

- Trane Trace 700: whole building energy analysis, with a focus on systems optimization.
- IES-VE: dynamic thermal simulation and daylighting analysis. *Figure 3*
- WUFI: dynamic hygrothermal modeling was utilized to review the impact of new wall insulation.
- THERM/WINDOW: 2D-heat transfer modeling was performed to evaluate the assembly U-value of existing windows improved with a new interior storm window system with solar control film. *Figure 4*
- Autodesk Ecotect: this tool was utilized to optimize the design of the photo-voltaic canopy
- Autodesk Revit / Navisworks: Revit was utilized to improve export of geometrical data to the other modeling tools described. Navisworks was utilized during the construction phase to optimize the layout of ductwork and piping systems, to minimize elbows and other fittings that would increase fan and pump power requirements.
- UCLA Climate Consultant: this tool was utilized to better understand the climate of Grand Junction and identify the best initial blend of passive and active strategies to achieve comfort with low energy consumption.
- NIST BLCC: this tool was utilized for life-cycle cost analysis. Five different HVAC schemes were evaluated, including a four-pipe fan coil unit system, VAV system, radiant cooling and heating system, active chilled beam system, and VRF system (air and water-source types).

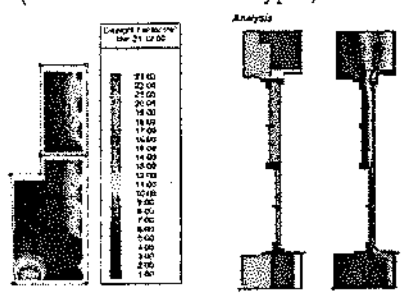


Figure 3 (LEFT) Daylighting analysis; *Figure 4 (RIGHT) THERM analysis of storm window*

ASHRAE 90.1-2007 was utilized as the reference energy standard. The whole building energy model was updated at each major design phase. The ASHRAE Advanced Energy Design Guide was utilized as a source for prescriptive information for achieving a 68.7% reduction in energy cost compared to ASHRAE 90.1-2007 Appendix G.

The actual energy use intensity in the first year of building operation (March 2013 to February 2014) was 21 kBTU/yr-gsf (4kW/yr-m2), prior to the contribution of on-site renewable energy or renewable energy credits. The EUI for a median building of similar type is 67.5 kBTU/yr-gsf (12.78 kW/yr-m2).

The lighting power density prior to renovation was approximately 2 W/sf (0.02 W/m2). The post-modernization peak lighting power is between 0.3 (0.003 W/m2) and 0.4 W/sf (0.004 w/m2). The installed lighting power density is 0.74 W/sf (0.0074 w/m2).

SYSTEM SUMMARY

- Enclosure: R-35 average roof, R-10 average wall, TPO white roof membrane
- Lighting: EnOcean Alliance protocol wireless system, task-ambient lighting approach (fluorescent), replicated historic fixtures (LED), vacancy sensors
- HVAC: 32-well closed-loop GeoExchange system tied to six twinned water-source VRF condensing units

with variable condenser water control. Approximately 70 thermal control zones with a variety of fan coil unit styles are utilized. Dedicated outdoor air system (6,000 cfm peak (2.83 m3/s) with exhaust-side evaporative cooling and a fixed plate heat exchanger for heat recovery. All regularly occupied zones have carbon dioxide monitoring. *Figure 5*

- Service hot water: multiple electric instantaneous water heaters, to avoid recirculation losses.
- Elevator: upgraded to utilized regenerative technology. A signage program was developed to encourage occupants to use the stairs instead of the elevator for fitness.
- Controls: the building automation system is remotely hosted and augmented with several specialty systems, including an energy dashboard (QAS), a metering platform, and PV platform.
- Renewable energy: a 123 kW array consisting of SunPower E320 panels is provided. Panels are integrated in three co-planar arrays. Two arrays are on low-impact racking on the primary roof. The main array is on an elevated canopy. 12 inverters are provided to provide redundancy and better alignment with string performance.

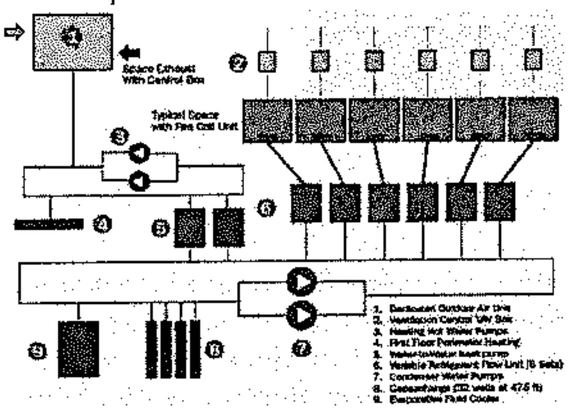


Figure 5 System diagram (reused from ASHRAE HPB June 2014)

IAQ AND THERMAL COMFORT

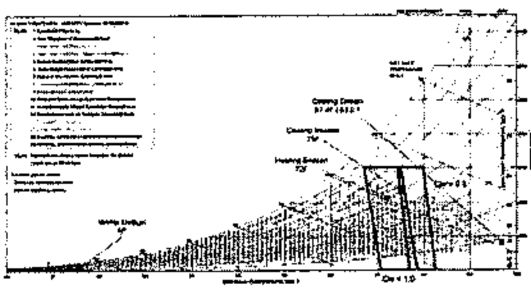
Ventilation air is supplied to each thermal zone through a dedicated outdoor air system (DOAS). Up to 30% greater breathing zone ventilation rates can be supplied than required by ASHRAE Standard 62.1-2010. Ventilation rates are regulated through multiple VAV boxes and further monitored through carbon dioxide sensors. In the first year of operation, the carbon dioxide level remained below 1,000 ppm in all zones. Ventilation is filtered through MERV 7 and MERV 13 media and cooled and heated to neutral conditions. Due to the dry climate of Grand Junction, the relative humidity is maintained below 60% at all times, without the need for aggressive dehumidification.

Acoustics and daylighting were well considered and meet ASHRAE and IESNA best practices by space type, which includes a courtroom, open and closed offices, corridors, lobbies, conference rooms, and break rooms.

Thermal comfort is achieved through compliance with ASHRAE Standard 55-2010 and control of:

- Dry bulb temperature: seasonal limits to allowable space temperature are made through the building automation system. User's can select a temperature of 75-78°F (23.9-25.5C)during the summer, 72-75°F (22.2-23.9C) during the shoulder seasons, and 69-72°F (20.5-22.2C) during the winter. *Figure 6*
- Relative humidity: no minimum relative humidity is required by ASHRAE 55. Relative humidity is limited to no more than 60%.
- Radiant temperature: the upgrade of walls with R-10 minimum insulation further aligns the mean radiant temperature with the space dry bulb temperature during occupied hours. The building has a window-to-wall ratio of 21%, which limits the impact of fenestration on mean radiant temperature.

- Air velocity: occupants can select multiple fan speeds for each zone fan coil unit. Diffusers are selected for a high ADPI with an occupied zone velocity of 40 fpm (0.2 m/s) or less. Occupants are encouraged to use potable desk fans to further increase comfort controllability.
- Clothing: a clo value of 0.5 was assumed for the summer season and 1.0 for the fall through spring seasons. Tenants are encouraged to allow a relaxed dress code to allow occupants to adapt to a wider range of conditions.
- Activity: a met value of 1.0 was assumed for occupants, correlating to typical conditions for occupants seated at work.



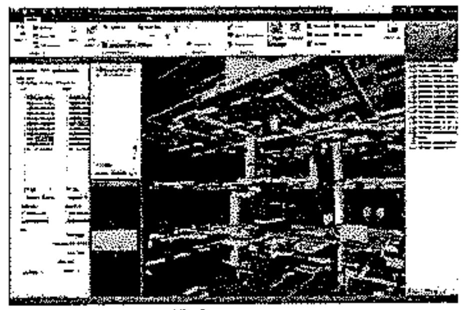


Figure 6 (LEFT) Climate analysis *Figure 7 (RIGHT) BIM*

OPERATIONS AND MAINTENANCE

A commissioning agent was engaged by the Owner during the preliminary design phase. The Cx provided a review of the design at each phase with a focus on maintainability and controllability. The design-build nature of the project ensured constructability was also reviewed very early in the design process. Appropriate service clearances are provided for all equipment. Fan coil units are installed with easy access to filters. The use of BIM during the project ensured conflicts that might impede equipment access would be avoided. *Figure 7*

All systems are integrated through a building automation system utilized the BACnet protocol for communications. This system allow for trending and visualization of all thermodynamic processes of building systems. In 2014/2015, a building analytics platform will be integrated to further allow automated trouble-shooting of systems.

The consultant and the commissioning agent were engaged for an extended 18-month post-occupancy measurement and verification process. The IPMVP Option D: Calibrated Simulation was utilized. The design energy model was re-calibrated in July 2013 and has continued to be use to review whether each building system is operating as intended. Bi-weekly meetings are held with the owner and tenants representatives to review energy performance. This is broken down by agency and building subsystem (pumps, DOAS, VRF, fans, DHW, elevator, lighting, plug load). The building manager has 24/7/365 access to the design and construction team during this period to review performance and maintenance items.

COST EFFECTIVENESS

The project was funded by the 2009 American Reinvestment and Recovery Act. This facility was identified as needing a major renovation to address Americans with Disabilities Act (ADA), historic preservation, and building usage issues. The original prospectus required the whole building project be completed for under $15 million and achieve LEED-NC Silver and a 30% reduction below ASHRAE 90.1-2007. The design-build team chose to significant exceed the requirements of the prospectus without exceeding the target budget or schedule.

Operating cost reductions were targeted through both reduction of electric demand and consumption. Natural gas use was fully eliminated from the building, reducing the complexity of maintenance associated with a boiler plant. The utility company collaborated with the design-build team during the design process by providing an independent analysis of the proposed building design, including development of a parallel DOE-2 energy model.

Energy conservation measures (which excludes the PV system) were evaluated to have under a 10-year overall payback. The owner's primary goal for the project was to utilize the lessons learned to transform practices across an 8,700 building portfolio, rather than seeing a short payback for all measures. This particularly applies to the GeoExchange and PV systems, both crucial to the net zero energy goal, but having greater than a 20-year individual payback period.

ENVIRONMENTAL IMPACT

100% of the existing structural system and building enclosure were reused and upgraded to allow for a 50-year interval prior to another major modernization. 51% of interior nonstructural elements were reused. While the building is relatively small, in the context of all buildings, the best practices developed will have a much larger impact. Lessons from this project have also helped shape the 2014 Public Buildings Service (PBS) P100, which is the GSA's design standard for projects. As the owner is the largest single property manager in the United States, its practices and adoption of technology are carefully watched by the private sector. The on-site electricity production of the building is approximately equivalent to 15 American homes, but again is relatively small compared to the larger impact of the building on design practices, particular of buildings on the National Register of Historic Places. A conscious decision was made to eliminate natural gas use and allow for an all-electric building. As the electric grid in Colorado increases its use of clean energy sources, the building's contribution to greenhouse gas emissions will further reduce.

COMMISSIONING

The owner hired a commissioning agent for fundamental and enhance commissioning. Commissioning activities for this project included:

- Multiple Design Reviews. D-B team was very open to PEER review comments made by CxA team; many suggestions were incorporated into design.
- Prepared and Managed the Commissioning Plan.
- Developed commissioning specifications.
- Provided Cx schedule Information & Integrated into the project schedule. This schedule was weekly updated to meet various phases of the construction and occupancies in an occupied building.
- Scheduled, lead, and/or attend commission meetings on monthly and/or bi-weekly basis.
- Prepared Prefunctional Checklists.
- Prepared Functional Test Procedures.
- Maintained Cx Issues Log and tracked each issue to resolution.
- Performed on-site observations during construction
- Conducted functional performance testing.
- Functional Testing: HVAC, PV, Domestic Hot Water System, Automated Lighting Systems
- Completed LEED Online Commissioning Templates.
- Compiled and submitted Commissioning Final Report
- Enhanced Commissioning
- Verified that O&M training requirements were completed
- Performed a 10 month post-occupancy warranty walk through to resolve Open issues.
- Compiled and submit LEED Systems Manual.
- Measurement, Verification, and Post-Occupancy Commissioning Services
- Participation in Weekly Energy Meetings to analyze actual energy usages and propose solutions for reduction.
- Participation in fine tuning of the systems and re-commissioning during the post-occupancy period was very

critical to achiever Net-Zero goals for this project. The D-B team, along with GSA and the Federal Agencies occupying the facility were key part of collaboration to minimize energy usage in the facility. The actual gross energy use was higher than the predicted for first year. Thru M&V and cooperation's of all the team members, current energy performances is in line or lower than predicted energy usage for the 2nd year.

SUBMETERING

Wayne Aspinall was fitted with electrical circuit submetering to drive towards net-zero energy consumption and to achieve optimal building energy performance.

Submeter Objectives

- Fine-tune Initial Building Performance: Utilize submeter data to optimize building operations in the period immediately following completion of commissioning and move in.
- Measurement and Verification of Building Performance: Building management plans to use submeter data to verify that occupants are meeting aggressive energy reduction targets and that building systems are meeting performance goals.
- Reduce Energy Consumption through Behavioral Change: Building management will use an energy model to determine a specific energy target for each occupant agency. The data provided by submetering is used to verify energy consumption by tenant. The ability to isolate energy consumption by agency allows building management to reward those agencies that meet energy performance targets with a lump-sum bonus.
- Improved Building Operations: Building management can use the submeter data to effectively and efficiently manage the building.

Achieved Benefits

- Measurement and Verification of Building Performance: The Wayne Aspinall project team has verified performance of the facilities with submeter data which is considered as a crucial component of M&V. Trending data available for the HVAC system was used by the project team to achieve substantial savings after completion of the submetering project.
- Improved Building Operations: The building operations and management team has leveraged available submeter data that is fed into the data system to effectively manage the building and reduce energy consumption. The Wayne Aspinall team achieved a 47% drop in electricity usage in January 2014 as compared to January 2013. Within the first five months of 2014, Wayne Aspinall's reduced electricity consumption was 50% less than the equivalent period within 2013, reducing total electricity cost by $5,650. Submetering played a role in helping to improve building performance, in concert with a variety of other factors, initiatives and causes. *Figure 8.*

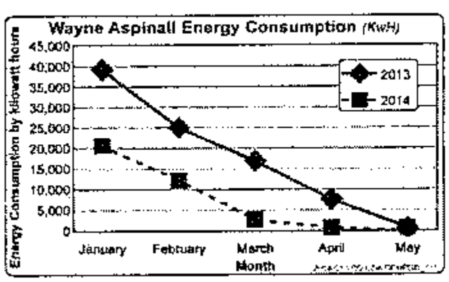


Figure 8 Trending data acquired from submetering at Wayne Aspinall