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# ENERGY EFFICIENT REHABILITATION OF A HISTORIC BUILDING IN TUCSON, ARIZONA: INVESTIGATING THE POTENTIAL FOR ENERGY CONSERVATION WHILE PRESERVING THE BUILDING'S HISTORICAL INTEGRITY

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**Abstract.** The focus of this study was to investigate the feasibility of transforming historically significant buildings with high energy requirements into high-performance constructions. The researcher suggested adaptive reuse for the case study, recommending that the building be converted from a warehouse into a café and art studio, which would be in line with the surrounding art district in Tucson, Arizona. As a result of the change in design, everything from the floor plans to the building facades and the mechanical systems were modified. During the visit to the location, the researcher was able to identify the primary factors that led to the low energy efficiency. The study was conducted using the real-life energy simulation that the DOE-2 simulation engine provides. During the process of redesigning the building, the researcher utilized both passive and active design strategies to evaluate how these techniques impacted the amount of energy consumed by the structure. The total amount of energy that was saved from all of the implemented solutions was compared to the total amount of energy that was consumed by the base case (the existing condition). The findings indicated that the chosen case study had a significant potential for reducing energy consumption, with savings amounting to more than 50 percent of the total energy usages.

**Keywords:** energy efficiency, historic buildings, rehabilitation, restoration, energy simulation, remodelling.

## Introduction

The four major end-use sectors of residential, commercial, transportation and industry have all grown their primary energy consumption in recent decades (U.S. Energy Information Administration, n.d.). The US government has released data on energy usage in residential and commercial structures, which accounted for 41.1 percent of total primary energy consumption in 2010. The 41.1 percent comprises 74% power use and 40% $CO_2$ emissions (Institute for Energy and Environmental Research, n.d.). With current and future increases in the quantity and size of buildings, this tendency may continue to rise. Energy and the environment are critical global concerns, as energy demand is expected to rise by 49% between 2013 and 2040 (Griffin et al., 2015). The use of fossil fuels as a primary energy source is likely to continue in emerging countries, resulting in increased $CO_2$ emissions in the future. $CO_2$ emissions contribute to worldwide environmental difficulties, with the greenhouse effect being one of the most severe consequences of climate change (Alam et al., 2016).

Buildings are comprised of multiple materials, construction methods, and technology. Each item uses energy throughout its life cycle, starting with material extraction and ending with deconstruction. Raw material extraction, transportation, manufacture, assembly, installation, disassembly, deconstruction, decomposition, and recycling are the stages of material energy use. "Embodied energy" refers to the energy used in the conversion and manufacture of materials, with a focus on material energy consumption and carbon emissions (Koskela, 1992). The embodied energy is the overall energy necessary in the formation of a building, including the direct energy utilized in the construction and assembly process and the indirect energy required to create the materials and components of the buildings (Crowther, 1999).

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"Embodied energy is defined as the energy required by the construction plus all essential upstream processes for materials such as mining, refining, manufacturing, shipping, erection, and the like," according to Bousted and Hancock (Dixit et al., 2010). "Embodied energy (EE) is the energy required to provide a product (both directly and indirectly) through all processes upstream (i.e., traceable backward from the finished product to consideration of raw materials)" (Treloar et al., 2001).

Low-energy buildings are concepts for lowering overall energy consumption and CO2 emissions in residential and commercial structures. After investigating 90 examples, Chastas et al. discovered that low-energy buildings consume more embodied energy than traditional structures (Figure 1) (Chastas et al., 2016). Sartori and Hestnes looked at 60 case studies of conventional and low-energy buildings, finding that embodied energy accounts for 2% to 38% of total energy usage in traditional buildings and 9% to 46% in low-energy buildings (Sartori & Hestnes, 2007). Building renovations combined with modern building technology give up a whole new world of possibilities for bettering building energy performance (Azari & Abbasabadi, 2018). The embodied energy of new construction is eliminated in the renovation of an existing structure. It is replaced by interventions embodied energy, which may be considerable or minor depending on the extent of the changes, materials, construction processes, and transportation.

This study will explore the possibility of repurposing a historical buildings structure for a new purpose and function while also making it low-energy. Despite local historic preservation regulations, the research will focus on evaluating sustainable techniques that improve building performance and are appropriate for an old historic structure. The structure's visual integrity, as well as the historical context of the building and its surroundings, will be considered. The new architectural design idea is focused on the demands of the area and reflects the building rehabilitation's flexibility and adaptability.

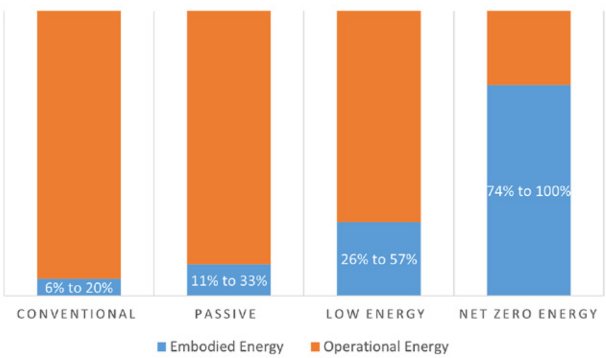


Figure 1. Illustration of the differences in embodied energy consumption corresponding to the building energy performance (Graph produced by: author; data source: Chastas et al., 2016)

## 1. Literature review

In March of 2014, the 3ENCULT project was completed. The goal of the initiative is to bridge the gap between historic building preservation and climate protection. Eight case studies in European built heritage in metropolitan regions are included in the project to explain and demonstrate a method for historical restoration. The development of passive and active energy saving measures, as well as the utilization of innovative technologies for building diagnostic and monitoring tools, are the key goals of this project. All new interventions that improve the building's energy performance have taken into account the building's condition and heritage characteristics. Wall insulation, high-performance windows, LED lighting, natural ventilation, and daylighting are among the most prominent interventions. The project team has successfully reduced energy usage by factors ranging from "Factor 4" to "Factor 10" (3encult, n.d.; Serraino & Lucchi, 2017).

G. Di Ruocco, C. Sicignano, and A. Sessa investigated and researched a historic structure in Salerno, Italy. The structure was constructed in the eighteenth century to serve as a school complex. The researchers were interested in the building exterior because of the historic preservation requirements in the area. They put three different combinations of window frames, floor and wall repair, and insulation to the test. The third combination is Corten steel fixtures, 3 cm thick insulating plaster composed of NHL lime 3.5 for walls and inter-floor slabs, and it is the most successful and balanced between energy savings and cost. The third combination saved 17 percent of the building's energy use and 27 kWh per m$^2$ year, which translates to 116,100 kWh per year overall saving for a 4300 m$^2$ space (Di Ruocco et al., 2017).

The EFFESUS project is a research initiative that looks into the energy efficiency of historic urban districts in Europe and creates techniques and systems to increase their energy efficiency. Historic urban districts are defined as structures built before 1945, both recognized and unregistered for historic preservation. These historic structures illustrate a time in construction technology and history. EFFESUS brings together cities from Spain, Sweden, Budapest, Turkey, Italy, Germany, and the United Kingdom to display and research various types of buildings, as well as materials and construction processes linked with building age. The study, which included seven case studies, was finished in August 2016. At the building level, the researchers used insulating mortars and coatings, aerogel insulation, passive heating solutions, sophisticated interior temperature management systems, and high-performance glazing/windows, among other things. The success of these solutions has been demonstrated in this project's case study, and the actual energy savings varies from one case study to another due to differences in climate and building parameters (Becherini et al., 2018; CORDIS & European Commission, n.d.; Lucchi et al., 2018).

## 2. Research methodology

This research paper looks at the possibility of repurposing historic buildings to create more sustainable and energy-efficient structures. Regardless of local historic building preservation regulations, the researcher uses a real-time energy simulation to explore alternative design implementations in order to achieve a 50% decrease in overall energy use. In this study, a concrete structure with clay brick walls in a hot desert region serves as the case study. The research approach is divided into three categories: location climatic characteristics and historical context, design analysis, and existing conditions energy efficiency observation (Figure 2). The historical context highlights the building's historical significance in relation to the surrounding neighborhood, which aids in the design analysis phase of proposing a proper use for the district's structure. The design study focuses on the present architectural arrangement and attributes of the building, which will be modified to accommodate the facility's new use and energy performance objective. Because passive design strategies like as proper orientation, natural ventilation, and daylighting have a substantial influence on building energy usage, architectural design is the first step toward a more sustainable energy-efficient built environment. The current situations energy efficiency observation focused on the causes of low energy efficiency and potential treatments. The impacts of passive and active implementation on building performance are evaluated and measured in this section of the study. The evaluation is carried out using the eQUEST energy simulation tool, which is driven by the DOE-2 simulation engine.

### 2.1. Case study location

#### 2.1.1. Climate City of Tucson

The summer season in Tucson is hot and dry, with a considerable temperature variation (avg. 26 °F) attributable to clear sky conditions. As a result, summer nights outside are delightful. Winters are moderate (avg. 58.1 °F), but the massive diurnal temperature swings might result in just a few really cold winter nights (Smith, 1945). The temperature normally ranges from 42 °F to 102 °F throughout the year, with temperatures seldom falling below 33 °F or rising over 107 °F. The duration of the day in Tucson changes dramatically throughout the year. The shortest day in 2021 will be December 21, with 10 hours and 2 minutes of daylight, while the longest day will be June 20, with 14 hours and 16 minutes of daylight. The dew point affects whether perspiration will evaporate from the skin and cool the body, thus it is used to measure the humidity comfort level. The lower the dew point, the drier it feels, and the higher the dew point, the more humid it feels. Dew point changes more slowly than temperature, therefore while the temperature may decrease at night, a humid day is usually followed by a muggy night (Weather Spark, n.d.).

#### 2.1.2. Historical background

It is a historic four-story concrete structure (Figures 3 and 4) at East Sixth Street and North Seventh Avenue in Tucson, Arizona, that is 91 years old. It used to be a storage facility with tiny administrative offices, but now it houses plumbing supplies, art galleries, and craftsmen businesses. The structure is located in the historic El Presidio area, where the majority of the structures date from 1860 to 1920. The city of Tucson was founded as a Spanish colonial colony from the El Presidio neighborhood. Sonoran style (1840s–1890), which is the oldest and most common in this neighborhood, Transformed Sonoran style (1880–1900), American Territorial (1880–1910), California Mission Revival (1895–1930), and Craftsman Bungalow Style (1905–1930) are among the architectural styles found in El Presidio (Nequette & Jeffery, 2021). This area is part of Tucson's historic warehouse arts district, which includes a variety of art forms from the street to an art gallery with paintings and sculptures. The warehouse arts area has sprung up as a result of the downtown railroad's 35-year renovation. After the Arizona Department of Transportation purchased numerous warehouse sites for destruction to develop a railroad-aligned with state highway in the late 1980s, the train attracted artists to this region.

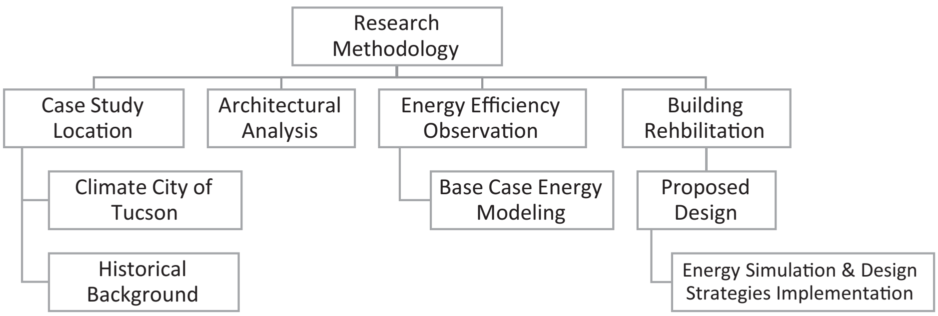


Figure 2. The research methodology diagram showing the revelation and connectivity each part of the research (source: author)


Figure 3. The north façade of the building (source: author)


Figure 4. The west façade of the building showing the art wall (source: author)

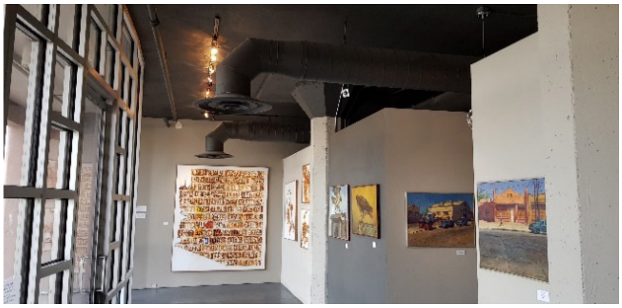

Figure 5. The current use of the first floor (source: author)

Figure 6. The Benjamin Plumbing supply store (source: author)

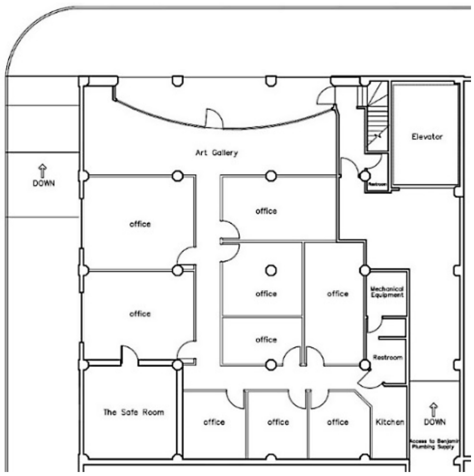


Figure 7. The first-floor plan of the art galleries and craftsman shops (source: author)

## 2.2. Architectural analysis

A four-story concrete structure with a total built-up area of 16,176 ft. sq. is the subject of the case study. Art galleries and rentable offices (Figure 5) are now placed on the first level, while plumbing supplies (Figure 6) are housed in the one-story expansion structure that is not part of this study. A passageway on the southeast corner of the building links the structure to a plumbing supplies business. Contreras Gallery and Jewelry shared the east wall of the Tucson Warehouse building. The first-floor design, shown in Figure 7, illustrates the current floor arrangement as well as the positioning of structural components. The Skelton concrete system, which comprises of columns, beams, and a flat slab, was used to build the construction. For better structural stability and to distribute the load over a broader area of the flat slab, the structure system includes a drop panel and a column head. Currently, the second, third, and fourth levels remain unoccupied. Previously, they used as storage areas. The case study's façades are Beige and Burgundy colored cement mortar with clay bricks (Figure 4).

To construct an accurate energy model, the case study characteristics and features in terms of architecture properties such as building area, window area, materials, etc., construction materials, mechanical components such as HVAC system, heating element, etc., and electrical components such as artificial lightings, smart system, office equipment, and kitchen appliances are important. The important parameters of the building are listed in Table 1, which will be used to generate the energy model for the base scenario.

Table 1. Building materials and properties (source: author)

| Building Components & Features | Details |
|---|---|
| Orientation | North |
| Building Gross Areas | 16,176 ft$^2$ |
| Roof Area | 4,612 ft$^2$ |
| Condition Floor Area | 3,084 ft$^2$ |
| Walls Area:<br>South<br>West<br>East<br>North<br>Total Walls Area | <br>2,102 ft$^2$<br>2,901 ft$^2$<br>1,841 ft$^2$<br>3,150 ft$^2$<br>9,994 ft$^2$ |
| Windows Area & Percentage of Walls Area:<br>South<br>West<br>East<br>North<br>Total Windows Area | <br><br>None – 0.00%<br>22 ft$^2$ – 0.79%<br>88 ft$^2$ – 05.17%<br>371 ft$^2$ – 12.55%<br>481 ft$^2$ – 5.51% |
| Doors Area | 33 ft$^2$ (Facing North) |
| HVAC Type | Direct cooling – Heat pump |
| HVAC Size | 3 ton unit |
| HVAC Efficiency | Cooling Efficiency is SEER 14<br>Heating Efficiency N/A |
| HVAC Economizer | N/A |
| HVAC Thermal Zones | One zone |
| Ventilation Fans | 24 hours |
| Lighting Power Density (LPD) | Building Area Type:<br>Office 1.10 w/ft$^2$, restroom. 90 w/ft$^2$, kitchen 1.2 w/ft$^2$, corridor. 5 w/ft$^2$, storage. 8 w/ft$^2$ |
| Equipment Load | 1615.725 kWh<br>Total: 1.007 kWh/ft$^2$ |
| Domestic Water Heating | Storage (gas), 100-gal |
| Building Operation | 7am to 5pm, Closed Sat & Sun |

## 2.3. Energy efficiency observation

Based on differences in construction materials qualities and component assembly, energy efficiency varies from building to building. The building envelope and mechanical system are to blame for the historic structure's poor energy performance. Due to a growing awareness of the negative environmental implications of energy consumption and CO2 emissions, these two primary components have improved in terms of performance throughout time, reflecting on building energy consumption. In this work, the researchers conducted a site visit to the structure and documented the potential causes of low energy efficiency. The case study has no insulation in the walls and just a white color coating material on the roof, which enhances energy efficiency by reflecting short-wave radiation from the sun but is mainly installed for water insulation. The case study contains single-glazed windows with unsealed frames and a mechanical pipe that was installed inappropriately, resulting in an elevated infiltration rate. The case study's daylighting was insufficient to minimize the need of artificial lighting equipment. The absence of natural light may have been ideal for the building's initial usage as a storage facility. The new usage, as well as the goal of enhancing energy efficiency, necessitates the use of daylighting. Incandescent lights are used in the case study, which use a lot of power when compared to new lighting technologies like LED.

### 2.3.1. Base case energy modeling

The researcher chose to develop an energy model for the existing condition as a baseline for the new design after pointing out the probable causes of low energy efficiency. The baseline energy model will come in handy to assess and evaluate the impact of the new design and intervention on energy efficiency. The energy simulation has taken into account the current situation, which is the utilization of just the first level (Figure 8). The yearly energy usage is calculated to be 294.88 kWh. The reuse, however, will apply to the entire structure, not just the first level. As a result, the researcher assumed that the reset floors would operate simultaneously and have the same mechanical and electrical systems as the first level. The rest of the floors were unconditioned and just had illumination because it was used for storage. The yearly energy usage of the entire structure is 352.14 kWh in the energy simulation (Figure 9).

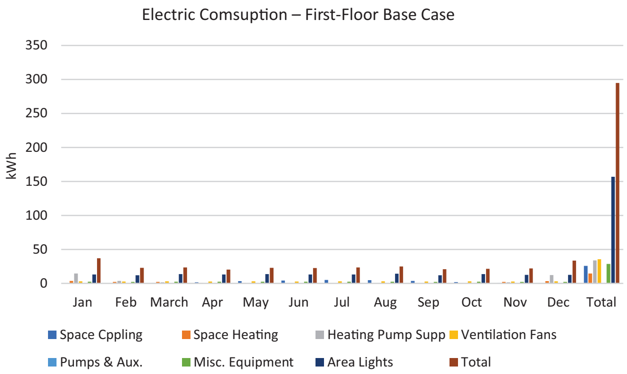


Figure 8. The result of the first-floor base case energy simulation

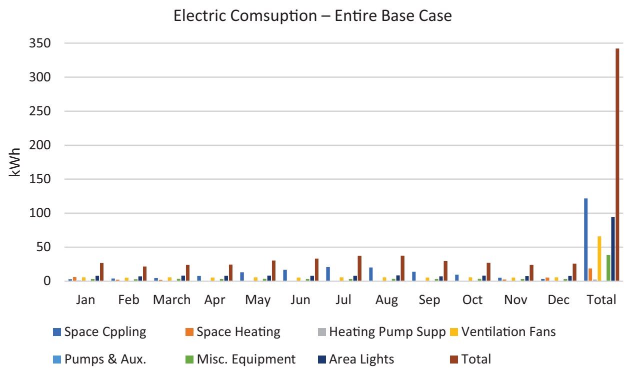


Figure 9. The result of the entire base case energy simulation

### 2.4. Building rehabilitation

In this research, a new use and purpose for the existing building was introduced by determining what is lacking in this location and what may add value to the property and the surrounding neighbourhood, which is the Tucson warehouse arts district. As it is an art district, the researcher proposed a café on the first floor as a gathering place for artists from all over the district, as well as art studios on the upper floors, to provide the artists with a space rich in art, history, and modern technology in which to unleash their creativity.

#### 2.4.1. Proposed design

Through logical interventions, the suggested design considers structural integrity. Based on the absence of energy performance in the base scenario, the new design integrates the new function with high energy performance interventions. The results direct the design process to strengthen what is lacking, introduce new design characteristics that are critical to the new usage, and increase overall energy efficiency. On the first level, there is an art display, a shop, an office, a kitchen, and an eating space (Figure 10). The eating space is in the atrium, which has clearstory windows that run the length of the building and connect to the top. The first level, as well as the corridors on the second, third, and fourth floors, received enough light from the atrium. The atrium was proposed by the researcher by removing one column from grids three and C. Three art studios with men's and women's bathrooms are located on the second level. The rest of the floors follow the identical layout as the second level, with the exception of fenestration (Figure 11).

The north elevation allowed for the harvesting of secondary daylighting, which occurs when there is no direct solar radiation except in the early morning and late afternoon throughout the summer (Figure 12). Except for one strip window for the second-floor studio, the east façade was left untouched (Figure 13). The west façade features well-known and famous wall art; therefore, it has been preserved. In a hot arid climate, it is preferable to minimize fenestration on both the west and east façades to avoid low beam solar radiation. The south elevation has been filled with glass rather than clay bricks since the south orientation window may be totally covered and shaded by suitable size overhangs (Figure 14). The atrium in the building's core takes advantage of natural light to illuminate the building's floors and enhances air circulation within the structure by allowing hot air to escape from the building's upper levels, thereby producing a suction effect that draws in fresh air from the surrounding environment through the building's exterior doors and windows (Figure 15). Figure 16 is a perspective drawing that illustrates the appearance of the new proposed north façade in relation to the current west façade, which is the side of the building that has the historic art wall.

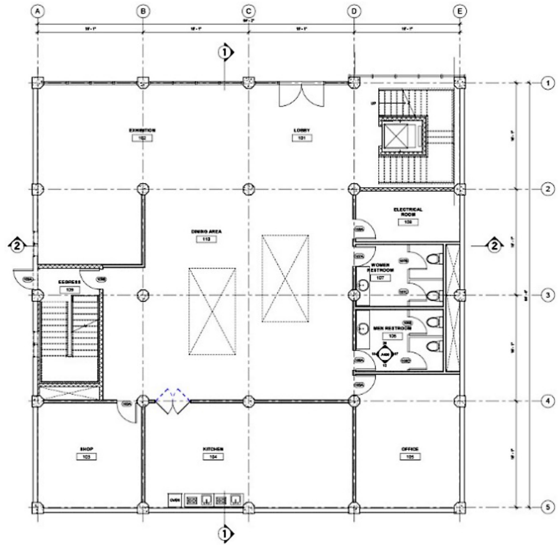

Figure 10. The first-floor plan (source: author)

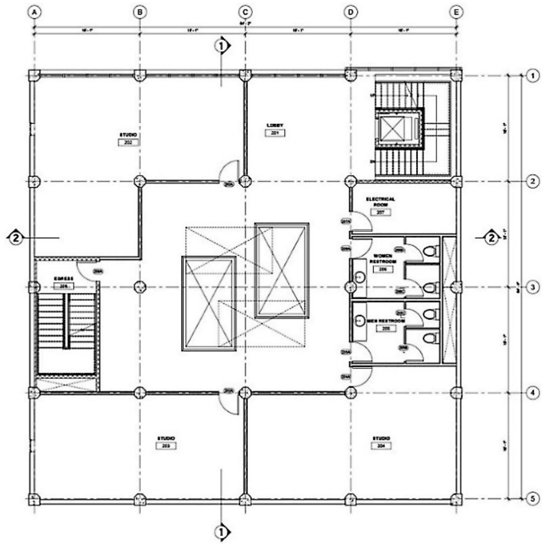

Figure 11. The second-floor plan (source: author)

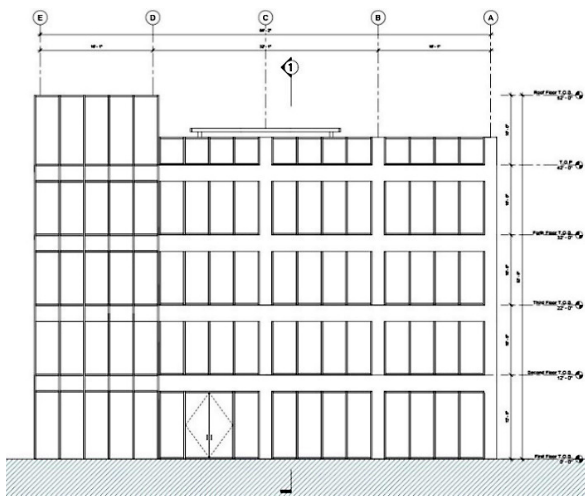

Figure 12. North façade (source: author)

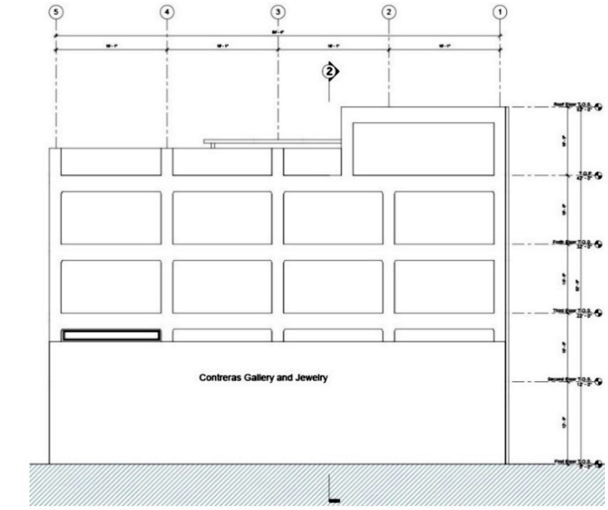


Figure 13. East façade (source: author)

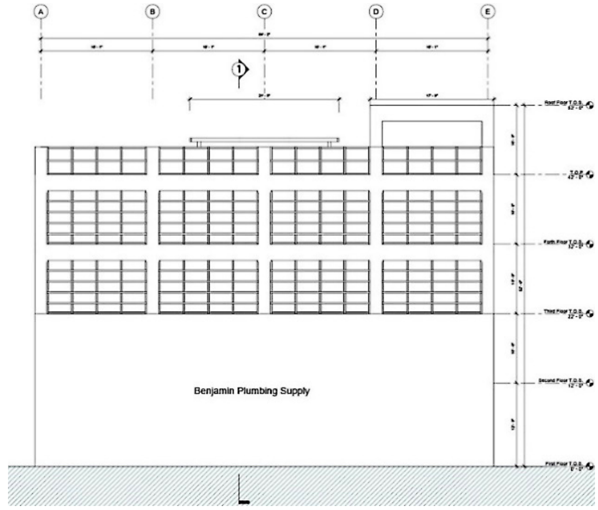


Figure 14. South façade (source: author)

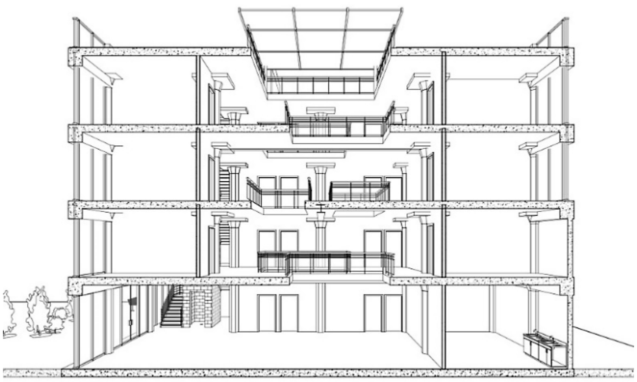

Figure 15. Section perspective (source: author)

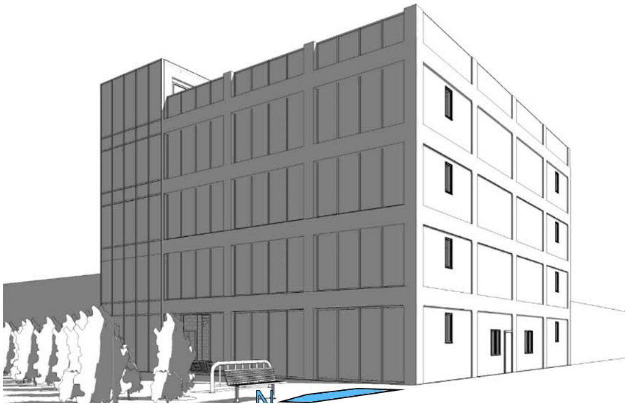

Figure 16. Perspective (source: author)

### 2.4.2. Energy simulation and design strategies implementation

The proposed design includes numerous energy-saving methods, including passive environmental strategies, enhancing the building envelope's thermal performance, and mechanical and electrical equipment. Passive design solutions strike a balance between architectural requirements, human psychological and thermal comfort, and energy efficiency. The new design incorporates natural sunlight and ventilation. The atrium and glass walls increase the amount and quality of natural ventilation and daylighting that enters the internal areas. In terms of thermal performance, the case study features an inadequate building envelope. The roof includes six inches external polyisocyanurate insulation boards with 42 R-values and a white finish on top in the proposed design. To retain the historical look of the building, including the artwork on the west façade, four inches inner polyisocyanurate insulation boards with a 28 R-value have been installed on the walls. All of the windows, old and new, are double-glazed with Argon gas and coated in a Low-E coating. An aluminum frame with a thermal breaker was coupled with the glass.

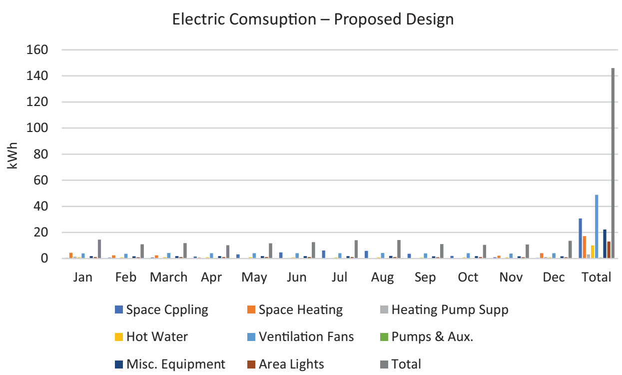


Figure 17. Energy simulation of the proposed design

The building envelope was improved, resulting in a tighter enclosure with a reduced infiltration rate. In this situation, the research assumed a 0.250 Air Change per Hour infiltration rate (ACH). With an economizer, the HVAC system replaced greater efficiency HVAC units with 21 Seasonal energy efficiency ratios (SEER). The HAVC operation schedule has a positive and negative influence on energy usage. Except on holy days, the new timetable keeps the HAVC units running 24 hours a day. After typical working hours, the thermostat setting shifts from 74–75 degrees to 78 degrees. All artificial lighting has been replaced with LED lighting that uses 6 to 8 watts. The suggested design's energy modeling is an expansion of the base case model's data and parameters. The energy simulation result shows a 55 percent reduction in energy use compared to the baseline condition. The proposed design used 146.05 kWh per year (Figure 17).

## Conclusions

As adaptive reuse reduces and limits the embodied energy for new construction and materials manufacturing, it opens up new possibilities for high-energy efficiency buildings. Adaptive reuse is more than simply a way to find a home for new functions; it's a way to honor the artifact. The suggested design featured a new internal layout that preserved the majority of the outside aspect. From the perspective of Tucsonans, the wall art on the west façade is the most important aspect to be protected, and it was successfully saved in this project. When compared to the base scenario, the proposed design has achieved a 55 percent reduction in yearly energy use. Adding shade devices and regulating natural ventilation might save even more electricity. The amount saved results in low yearly energy usage, which is equivalent to new low energy and net-zero buildings. The memories, culture, and ability for old historic structures to survive and live longer than new ones will raise the worth of the old. The researcher hopes to investigate and renovate a recognized historic structure in the future. To evaluate the capacity of the restoration and analyze the validity of local legislations, the research will be confined to local historic preservation rules and local materials.

## References

3encult. (n.d.). *Project—welcome—home*. Retrieved December 23, 2021, from http://www.3encult.eu/en/project/welcome/default.html

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators*, *70*, 466–479.

Azari, R., & Abbasabadi, N. (2018). Embodied energy of buildings: A review of data, methods, challenges, and research trends. *Energy and Buildings*, *168*, 225–235.

Becherini, F., Lucchi, E., Gandini, A., Barrasa, M. C., Troi, A., Roberti, F., Sachini, M., Di Tuccio, M. C., Arrieta, L. G., Pockelé, L., & Bernardi, A. (2018). Characterization and thermal performance evaluation of infrared reflective coatings compatible with historic buildings. *Building and Environment*, *134*, 35–46. https://doi.org/10.1016/j.buildenv.2018.02.034

Chastas, P., Theodosiou, T., & Bikas, D. (2016). Embodied energy in residential buildings-towards the nearly zero energy building: A literature review. *Building and Environment*, *105*, 267–282.

CORDIS, & European Commission. (n.d.). *Final Report Summary – EFFESUS (Energy Efficiency for EU Historic Districts Sustainability)*. Retrieved December 23, 2021, from https://cordis.europa.eu/project/id/314678/reporting

Crowther, P. (1999). Design for disassembly to recover embodied energy. In *Sustaining the future: Energy ecology architecture PLEA '99* (pp. 95–100). PLEA International.

Di Ruocco, G., Sicignano, C., & Sessa, A. (2017). Integrated methodologies energy efficiency of historic buildings. *Procedia Engineering*, *180*, 1653–1663.

Dixit, M. K., Fernández-Solís, J. L., Lavy, S., & Culp, C. H. (2010). Identification of parameters for embodied energy measurement: A literature review. *Energy and Buildings*, *42*(8), 1238–1247.

Griffin, J. M., Fantini, A.-M., Tallett, M., Aguilera, R. F., Arellano, J. L., & Ban, J. (2015). *World oil Outlook 2015*. Organization of Petroleum Exporting Countries.

Institute for Energy and Environmental Research. (n.d.). *2011 buildings energy data book (U.S. Department of Energy)*. Retrieved December 23, 2021, from https://ieer.org/resource/energy-issues/2011-buildings-energy-data-book/

Koskela, L. (1992). *Application of the new production philosophy to construction* (Vol. 72). Citeseer.

Lucchi, E., Roberti, F., & Alexandra, T. (2018). Definition of an experimental procedure with the hot box method for the thermal performance evaluation of inhomogeneous walls. *Energy and Buildings*, *179*, 99–111. https://doi.org/10.1016/j.enbuild.2018.08.049

Nequette, A. M., & Jeffery, R. B. (2021). *A guide to Tucson architecture*. University of Arizona Press.

Sartori, I., & Hestnes, A. G. (2007). Energy use in the life cycle of conventional and low-energy buildings: A review article. *Energy and Buildings*, *39*(3), 249–257.

Serraino, M., & Lucchi, E. (2017). Energy efficiency, heritage conservation, and landscape integration: The case study of the San Martino Castle in Parella (Turin, Italy). *Energy Procedia*, *133*, 424–434. https://doi.org/10.1016/j.egypro.2017.09.387

Smith, H. V. (1945). *The climate of Arizona*. College of Agriculture, University of Arizona (Tucson, AZ).

Treloar, G. J., Love, P. E., & Holt, G. D. (2001). Using national input/output data for embodied energy analysis of individual residential buildings. *Construction Management and Economics*, *19*(1), 49–61.

U.S. Energy Information Administration. (n.d.). *Annual energy Outlook 2021*. Retrieved December 23, 2021, from https://www.eia.gov/outlooks/aeo/

Weather Spark. (n.d.). *Tucson climate, weather by month, average temperature (Arizona, United States)*. Retrieved December 22, 2021, from https://weatherspark.com/y/2857/Average-Weather-in-Tucson-Arizona-United-States-Year-Round