APPLYING ENERGY EFFICIENT TECHNOLOGIES IN THE REDEVELOPMENT OF THE RAILWAY EXCHANGE BUILDING

by

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LIST OF ABBREVIATIONS

Act	Actual
DOE	Department of Energy
EIA	Energy Information Administration
GE	General Electric
HVAC	Heating, Ventilation, and Air Conditioning
kW	Kilowatt
kWh	Kilowatt hour
LED	Light Emitting Diode
MW	Megawatt
NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
PG&E	Pacific Gas and Electric
SqFt	Square Feet
W	Watt

GLOSSARY

Ballast	An electrical component to power a florescent lamp (DOE, 2009).
Deep Ring	Floors eight through sixteen of The Railway Exchange Building.
Feeder	Main Electrical Supply (NFPA, 2019).
Full Block	Floors one through seven of The Railway Exchange Building.
Microgrid	A smaller division of the power grid that contains distributed generation (Ton, 2012).
Photovoltaic	A device such as solar planes that create electrical voltage and current from the sun (NFPA, 2019).
Relay	Electronic or mechanical device used to protect power distribution and transmission equipment (Rifaat, 2016).
Shallow Ring	Floors eighteen through twenty-one of The Railway Exchange Building.
T8	A popular fluorescent lamp introduced in 1981(Rensselaer Polytechnic Institute, n.d.).
T12	Obsolete fluorescent lamp phased out since 2012 (DOE, 2009).
Tariff Book	Utility rate guide (Union Electric, 2020).

ABSTRACT

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High cost of building ownership and rent cause abandonment of large turn-of-the-century buildings, such as the Railway Exchange Building (Butt, 2014; Kukuljan, 2018). In Saint Louis, Missouri, vacancy in this category exceeds 1.2-million square feet and blights entire neighborhoods (Barker, 2019; Berg, 2010). Comparing the energy use of the building in its present state against one rebuilt for energy efficiency quantifies the cost disadvantage (Weng, 2012). Applying state-of-the-industry technology to improve the energy efficiency and thus the economics of a historic structure advances the Restoration and Improvement of Urban Infrastructure (Morgan, 2016; National Academy of Engineering, n.d.). Installing energy efficient LED fixtures proves to be a cost-effective solution for reducing the energy needs of the Railway Exchange Building. Reduced operating costs improve the viability of the Railway Exchange Building, other similar buildings, and their surrounding areas.

Keywords: Railway Exchange Building, urban infrastructure, LED, St. Louis

CHAPTER 1. INTRODUCTION

1.1 The Problem

High utility costs drive underutilization and abandonment of large turn-of-the-century buildings, such as The Railway Exchange Building (Butt, 2014; Kukuljan, 2018). As American manufacturing declines, the economy diversifies, and corporate consolidation and technology advances lead to staff reductions, urban centers must transition to uses other than office and manufacturing. The transition is difficult, and many former manufacturing cities in the rust belt find themselves awash in large empty buildings, generally old and often historic (Hartley, 2013). Even when there is demand for space, the older and vacant buildings have high operating costs. Outdated, inflexible, and inefficient systems are huge economic obstacles to use and are sometimes uncompetitive even with new construction (Butt, 2014). Lighting and HVAC represent the majority of energy costs (EIA, 2018). Reducing operating and utility costs is critical to any effort to make the buildings economically viable.

Improvements in energy efficiency can be affordable but are often very expensive. Luckily, the building owner is not the only interested party. Governments have an interest in preserving historic buildings, revitalizing neighborhoods, and stimulating economic activity, and public utilities have an interest in cutting energy costs (Berg, 2010). Making full use of tax credits and energy efficiency rebates makes the necessary improvements much more affordable and the overall reactivation more economic.

1.2 Impact of the Problem

Vacancy in large turn-of-the-century buildings in Saint Louis, Missouri exceeds one-million two-hundred-thousand square feet and blights entire neighborhoods (Barker, 2019; Berg, 2010). The Railway Exchange Building in Saint Louis, Missouri is a prime example of an underutilized large turn-of-the-century building. The building's large floor plates and overall size make redevelopment difficult in a small market. Although a developer would prefer large homogeneous tenants taking up large swaths of the building, such tenants are rare these days, particularly in a market like Saint Louis, and the cost of renovating such a large building is beyond the means of most local developers (Stritzel, 2019). One potential alternative to improving the whole building at once is to incrementally improve the building where appropriate. Incremental improvements reduce operating costs and accommodate new tenants without gutting and completely rebuilding the structure. The other advantage to this approach is that the incremental improvement plan does not require knowing the tenant mix in advance. The owner could improve core building services, lease to a few tenants at opening, and then improve and fit additional space as more tenants sign up. The building management and construction management become more difficult, but leasing to many small tenants can still generate positive cashflow.

1.3 Measuring The Problem

Comparing the energy use of the Railway Exchange Building in its present state against one rebuilt for energy efficiency quantified the cost disadvantage (Weng, 2012). The Railway Exchange Building is currently vacant. The last major tenant, Federated Department Stores, vacated the building due to excessive operating costs. Alongside other market challenges, operating expenses are a problem that must be addressed. The quantified potential energy savings of various retrofits is critical to determining whether that is possible.

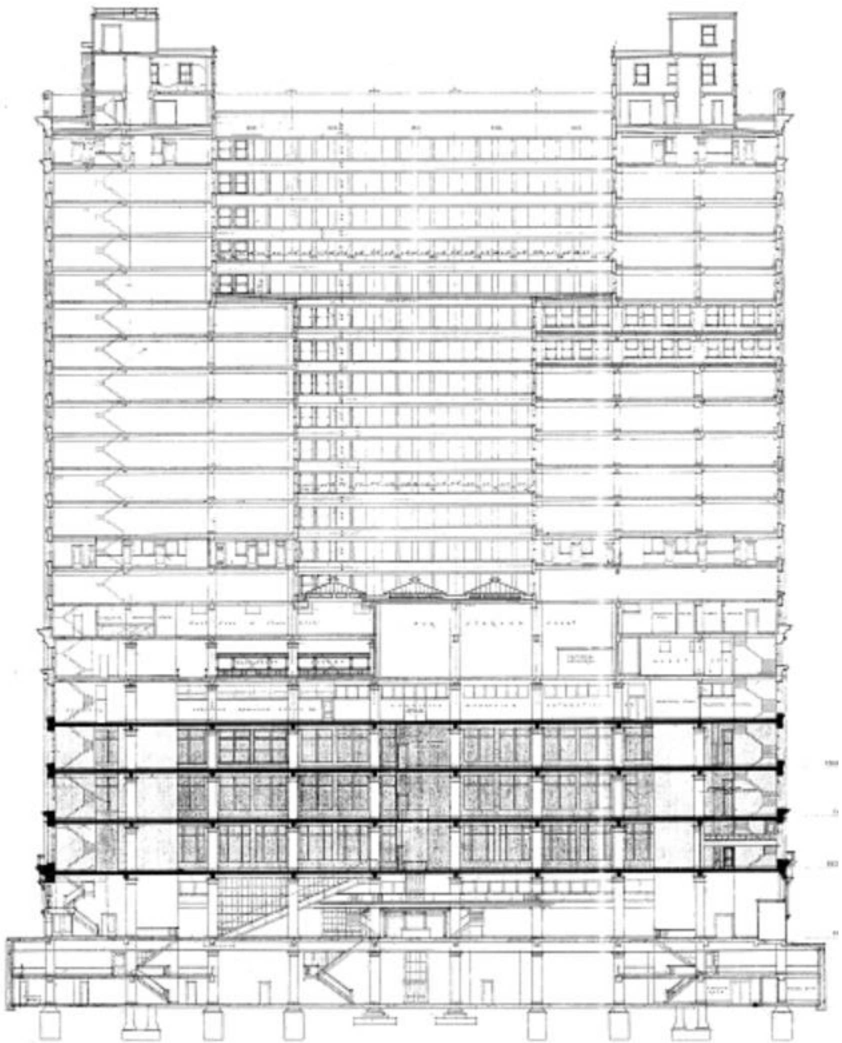

Figure 1.1 Railway Exchange Building Cross Section (Amato, 1984)

Over the main twenty-one floors (excluding basements, penthouses, and mezzanines) there are three main floor plates: full block, deep ring, and shallow ring; see Figure 1.1. Comparing the current energy costs for a given floor, estimated from as-built drawings, to energy costs with modern green technology, based on space dimensions and ideal values, quantified the cost-saving opportunities of various retrofits. The three floor plates were extrapolated to the rest of the building to compute total savings. The vacant area of the roof (including the site of the rooftop chiller plant if removed) then allowed for computing the output of a solar array installed there.

Energy-conscious renovation of the Railway Exchange Building benefits building owners with greater economic potential, tenants with cheaper occupancy, neighbors with less blight, the city with more tax revenue, and utility ratepayers with lower bills. But the benefits could be much greater if the Railway Exchange Building could serve as a template for similar renovations of similarly underutilized buildings throughout the world. The Railway Exchange Building could once again be famous as an engineering triumph as the building was back in 1913.

1.4 Grand Engineering Challenge

Ameren Missouri is the electrical service provider in Saint Louis, Missouri. Ameren strives for efficient operation and embraces new technologies, and its success in these areas allows it to offer some of the lowest electric rates in the country (Ameren Missouri, 2020c). With regulations making carbon emissions and plant construction and maintenance more expensive, reducing demand is often easier than increasing supply, and Ameren is taking advantage of new technologies to implement demand-side solutions. Ameren in 2008 projected 20% growth in demand by 2028 and considered building a new nuclear power plant (Ameren submits COL application for Callaway, 2008). Instead, thanks to energy-saving initiatives, demand has remained flat since 2012 (Ameren Missouri, 2020a). The success of the program has allowed Ameren to expand demand-side investments and to support large projects (Ameren Missouri, 2020a). Modernizing a large building provides a good return on investment due to economies of scale. The large scale allows for both lower capital costs and higher benefits on a per-square-foot basis. Just retrofitting LEDs for lighting can reduce power consumption by up to two thirds. Installing power management technologies can achieve significant further efficiencies and allow for load shedding in times of high demand (DOE, n.d.-b).

A utility reduction cost initiative for the Railway Exchange Building can provide a template for other improvements to urban infrastructure. The National Academy of Science has established fourteen grand engineering challenges. These challenges aim to overcome social, environmental, and engineering problems facing not just the United States but the entire world. One of the grand challenges is to improve urban infrastructure (National Academy of Engineering, n.d.).

Applying modern technology to improve the energy efficiency and thus the economics of an historic structure advances the Restoration and Improvement of Urban Infrastructure (Morgan, 2016; National Academy of Engineering, n.d.). The building provides data connectivity over fiber optic lines, copper data lines, and satellite dishes. The urban infrastructure that requires the most intensive improvement is the power grid. Portions of the Saint Louis electrical grid around the Railway Exchange Building, like the building itself, are over 100 years old (Leiser, 2013). The downtown district is serviced by a 480-volt ring that is robust against single point failure such as wire or a transformer (Prakash, 2016). The cable is lead jacketed which makes maintenance and repair more difficult and expensive. The loop failed for possibly the first time in sixty years in 2014 (Otto, 2014). Non-fatal failures still require significant repair and clean-up due to the environmental hazards. Further deterioration risks additional failures. Reducing system load reduces stress on components of the grid until modernization.

The modernization of the Railway Exchange Building, in addition to reducing load on the grid, offers an opportunity to implement a microgrid. Each floor of the Railway Exchange Building is the size of a few dozen houses and can be wired similarly to a small town. The floorplate size of itself is not revolutionary but does allow for tenant-level energy tracking and incentives. Combining the microgrid with digital relays under the control of the utility open up a number of possibilities for managing grid load and power factor, such as switching loads between incoming power feeds. And giving the utility access to portions of the energy management system, so as to temporarily dim certain lights or to let temperature slide in periods of high demand, can support a reduction in peaking generation capacity (Raza, 2019).

CHAPTER 2. REVIEW OF LITERATURE

2.1 The Decline of Saint Louis

To understand the current value of property in the City of Saint Louis, one must understand the history of the City from its peak to its current trough. Saint Louis was once known as the Gateway to the West and was later a hub of manufacturing from cars to clothing (Cooperman, 2013; Cooperman, 2019b). The City, unfortunately, is not at its peak (Gordon, 2008). St. Louis's population has fallen from a peak of close to one-million to fewer then four-hundred-thousand. The population loss combined with the relative poverty of the remaining population leaves many buildings vacant. These vacant, unmaintained buildings are often uneconomic even if acquired for free (Gordon, 2008, Johnson, 2020). The state of degradation is particularly true of Saint Louis' large legacy buildings such as the Railway Exchange Building.

2.1.1 History

Pierre Laclede and Auguste Chouteau founded Saint Louis in 1764, prior to American independence, due to its strategic location on the high ground at the confluence of the Missouri and Mississippi Rivers (Wayman, n.d.). The City would later become part of the state of Missouri following the Louisiana Purchase (Encyclopedia Britannica, 2020). After the Civil War, Saint Louis became a large manufacturing and rail hub. Saint Louis had the first southern rail crossing of the Mississippi River (Saint Louis City, n.d.-a). This and the city's location allowed it to become the fourth largest city in the United States by 1900 (Saint Louis City, n.d.-b).

After the Second World War, Saint Louis started to face a radical transition from well-integrated metropolis to a destination for office work and shopping (Johnson, 2020). The growth of the interstate highway system and increasingly affordable private vehicle ownership allowed middle-class families to move to suburbs. This white flight accelerated greatly with the passage of the Civil Rights Act (Naffziger, 2020). Saint Louis reached its peak census population in 1950 at 856,796. Returning soldiers bolstered the regional population, and many chose to move to the suburbs when starting families. The suburbs generally featured new single-family houses on relatively large lots. As city neighborhoods lost their longtime residents, this exodus became self-sustaining. The racial divide escalated into white flight and continued with affluent African Americans often fleeing crumbling neighborhoods soon after (Gordon, 2008).

2.1.2 The Schism

The City of Saint Louis is not part of Saint Louis County, the City having separated from the County in 1876 (Saint Louis City, n.d.-c). As a result, losing population to the County results in a complete loss of that population's tax contribution to what would normally be county-wide services, like policing and courts. By 2011, the population of the City had dropped to approximately 318,000, with the County population at approximately 999,000 (Cooperman, 2019a). This is almost a complete reversal from the 1950s, as shown in Figure 2.1.

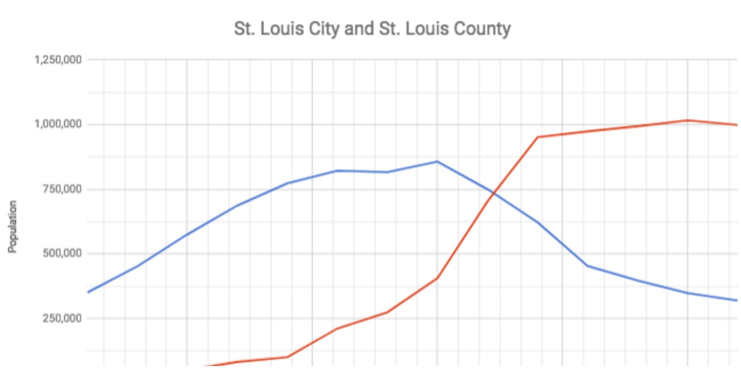

Figure 2.1 Population Saint Louis City and County (Butts, 2018)

The remaining population in the City is about half African American, with a 24% poverty rate and a per-capita income of approximately $28,000 (U.S. Census, 2019). For several decades, high numbers of office commuters, shoppers, and tourists offset the decline in the economic prosperity of City's residents, but frequent riots starting in 2014 have accelerated the departure of office tenants and the closure of retail outlets (Altman, 2017). Many County residents currently consider the City a no-go zone (Fasching-Varner, 2018). The resulting disinvestment puts further pressure on remaining businesses and residents (Trivers, 2015). The population of the city had just started to stabilize before 2020's summer of riots, but the damage has been done. Large swaths of the City once occupied by continuous rows of upper-middle-class homes now consist mostly of rubble on vacant lots (Gordon, 2008). Large office buildings that once housed thousands of workers sit empty (Kukuljan, 2020). The city owns over 11,000 vacant and abandoned buildings, and private owners own countless others (Butts, 2018). The Railway Exchange Building is one of the many vacant buildings.

2.2 The Railway Exchange Building

The history of the Railway Exchange Building is as grand as the building itself and the city in which it resides. The building exists as a window back to classical architecture but, on the other hand, highlights a century of progress in electrical systems. The Railway Exchange Building still casts a long shadow over downtown Saint Louis and remains the second largest commercial building in Missouri, occupying the whole block at 601 Olive Street.

The building, designed by architects Mauran, Russell, and Crowell, opened in 1913 with the Famous and Barr Company, later Famous-Barr, operating a large department store on the lower floors and office tenants occupying the upper floors. The building, due to its unprecedented scale, was built nearly fireproof to appease city regulators and prospective tenants concerned about such a large structure catching fire (Trampe, 2020). Under its ornate, classically inspired white terracotta exterior, the building consisted of twenty-one floors of steel encased in concrete, with ubiquitous fire glass, countless fire sprinklers on every floor, dual fire pumps, and valves to allow fallback to a fire engine. Although some of the equipment is dated, including one fire pump that is likely original to the building, the general fire protection scheme falls very much in line with modern standards (LaMouria, 2008).

The Railway Exchange Building originally had a very distinct utility scheme. Also rather uniquely, the building had no loading docks or trash bins of its own. The Kingston Building, located to the north of the Railway Exchange Building on Saint Charles Street, served as warehouse, loading dock, and cogeneration plant for the Railway Exchange Building, supplying steam, chilled water, alternating current, and direct current. Running alongside these services in the connecting tunnel were goods entering the store from manufacturers and goods leaving the store to be delivered to customers. Figure 2.2, on page 11, provides an overview of the two-building arrangement. A dedicated building-specific power plant in an urban area was as rare in 1913 as it would be today. The concept is getting renewed attention these days due to the importance of energy efficiency and the increasing availability of combined-cycle gas turbines, which efficiently generate electricity but can also make steam from waste heat (DOE, 2016). As the city's electrical grid and district steam service improved, the power plant was no longer needed. The power plant closed to make way for a chiller plant and, by 1940, Famous-Barr and most of the office floors had air conditioning (LaMouria, 2008).

The Union Electric downtown grid made extensive use of underground lead-insulated cable, much of which is still in service today (Leiser, 2013). After the closure of its power plant, the Railway Exchange Building received power from Union Electric via two dedicated 4160-volt feeds and four 208-volt feeds from the downtown loop (Associated Consulting Engineers, 1994). May Department Stores, the building's owner and main tenant, installed two redundant 13.8-kilovolt feeds and substations on the 9th and 12th floors in 1987 to support its growing electrical needs, including the increasingly important computer room on the 9th floor (Fiedler, 2002). The building, with its many high-capacity utility connections, could easily support a microgrid as part of a smart green energy solution. The reconfiguration of the building into a smart microgrid would align with the Grand Engineering Challenge of improving urban infrastructure (National Academy of Engineering, n.d.).

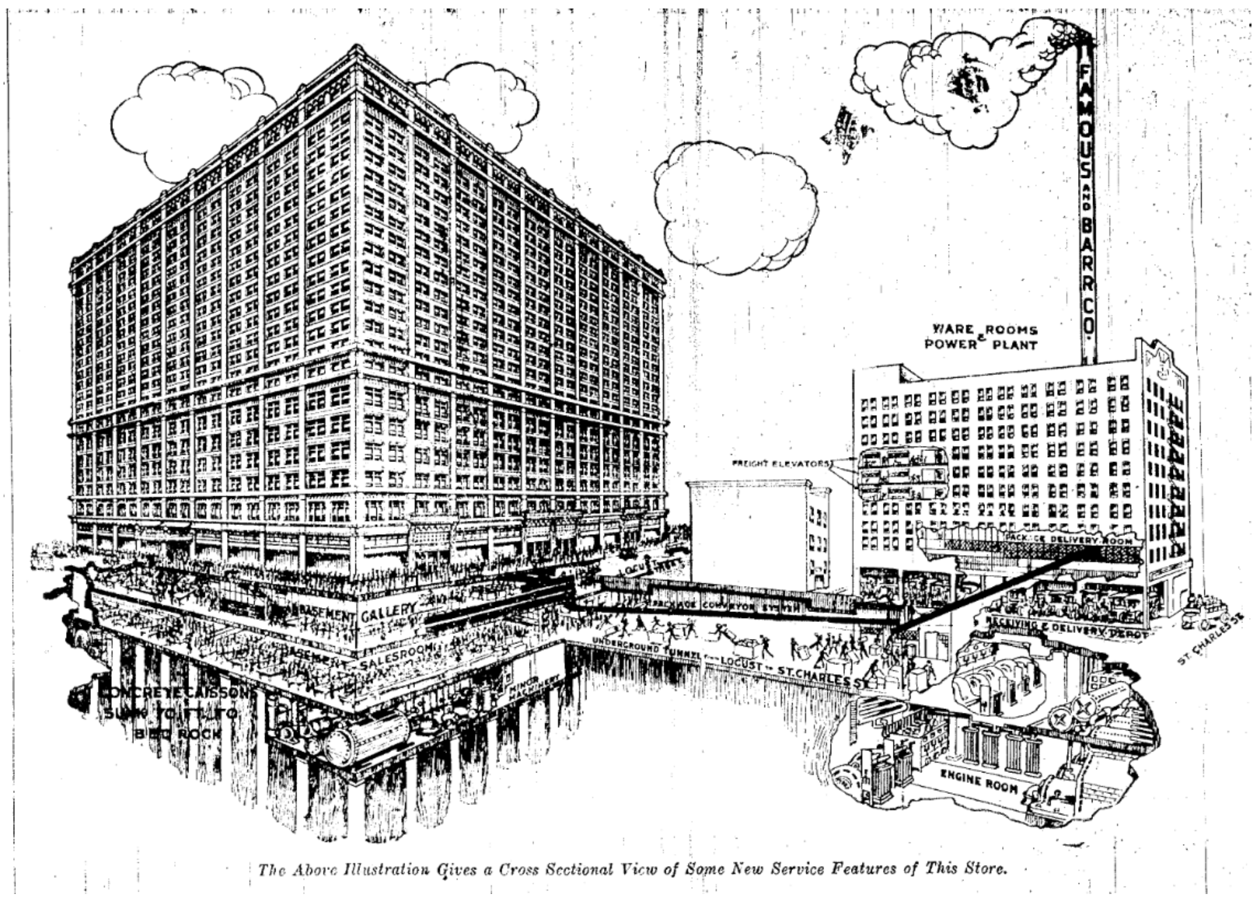

Figure 2.2 Layout of Building and Utilities (Famous and Barr Company, 1913)

Downtown Saint Louis, early in 1980, was declining. Crime and neglect were making it less attractive for shoppers, and many stores and office tenants were moving out of the city (Hohmann, 2010). May Department Stores, which owned the Railway Exchange Building and Famous-Barr, partnered with Melvin Simon and Associates, a mall developer, to convert the two blocks to the north of the building into an urban mall called Saint Louis Centre. The new mall connected the Famous-Barr store on the south end to the Stix, Baer, and Fuller store to the north on Washington Ave, with three-story bridges and stores over the streets to create a seamless shopping experience. St. Louis Centre opened in 1985 and was a huge success in its early years (Huber, 2012).

Like preceding urban renewal projects in St. Louis, St. Louis Centre eventually failed. A combination of better suburban shopping options and declining downtown office occupancy cut traffic, and the mall entered a death spiral, closing in 2006. In 2010, a developer demolished the large bridges and converted what remained into a parking garage, with limited street-level retail. The Famous-Barr store suffered from the same issues and closed in 2013 (Vanishing STL, 2010).

The Railway Exchange Building is currently unoccupied and is a block-sized black hole in the central business district, but it has already once played a large part in urban renewal, and it may be able to do so again.

2.3 Energy Efficient Technology

Since the Railway Exchange Building opened 108 years ago, the building has seen several substantive technological advancements. The Railway Exchange Building was the largest commercial building in the world when it opened in 1913. The building was connected to a dedicated cogeneration plant providing steam and electrical power. The building’s direct current traction elevators, brine coolers, and high-wattage incandescent lights were state-of-the-art at the time (LaMouria, 2008). By the time the building closed, it had several alternating current elevators, ubiquitous variable frequency drives, centrifugal chillers, several automatic transfer switches, fiber optic Internet service, and several energy management systems. Most of the technologies that will bring the Railway Exchange Building into the 21st century have appeared in small form already somewhere in the building but still have significant untapped potential.

The U.S. Energy Information Administration (2018) classifies lighting as the largest building energy load followed by HVAC in the United States. When the Railway Exchange Building opened, it did not have air conditioning, so its initial load was significantly less than the building's current configuration. The second floor of the Famous-Barr store in the building, for example, had a lighting load of 56kW (Humphrey, 1912a). The building used traditional incandescent lamps that released most of their energy in heat and were 10% efficient (Dikeou, 2014). Later renovations of the store introduced standardized fluorescent fixtures throughout the sales areas using T12 tubes, generally mounted where the incandescent fixtures had been. Rebuilt office floors also incorporated fluorescent fixtures, including T8 tubes in some places in later years.

Due to the large square footage of the building and the low cost of lighting retrofits, upgrading to more efficient lighting will generate large net savings. LED technology, compared to fluorescent technology, wastes less energy generating heat for the same amount of light and can reduce energy usage by more than 33%. Many LED fixtures, unlike most fluorescent fixtures, are well-suited to dimming and can even change color (Waste Reduction Partners, 2015).

Scheduling and occupancy detection, combined with an energy management system, can further reduce energy usage by cutting lighting and cooling to unoccupied areas. The store and the office portion of the building both have energy management systems with scheduling features, and many of the office areas have occupancy sensors, but the systems are outdated and do not support modern features and inputs like weather and the position of the sun. The lighting zones tend to be rather large, which requires lighting whole zones even when, for example, only one person is working late in that area. Some modern light fixtures allow for individual control over ethernet, which, combined with per-desk occupancy detection, could decrease energy costs considerably (Pacific Northwest National Laboratory, 2019).

Replacing most of the light fixtures in the office portion of the building is straightforward. The majority of the substantive (rather than decorative) light fixtures are two-foot-by-four-foot four-bulb T12 fixtures, which are still likely the most common commercial fixtures in North America. There are two easy retrofits for T12 fixtures. The least expensive is simply replacing the fluorescent tubes with LED tubes and bypassing the ballast. The ballast bypass is about as labor-intensive as replacing the tubes and the ballast, which is routine maintenance. Adding network control generally requires replacing the entire fixture and running new data cabling. Running network cable is relatively easy with a drop ceiling, as is present on most of the office floors.

Heating, ventilation, and air conditioning (HVAC) represents the second largest portion of building energy use in the United States (EIA, 2018). The Railway Exchange building has gone through many iterations of climate control technology. When the building opened, there was no air cooling, central brine-based refrigeration, forced air ventilation on only a few lower floors, and steam heat from the buildings own coal cogeneration facility. The Railway Exchange building later stopped producing its own electricity and steam but started producing its own chilled water. The building then briefly resumed producing steam with new boilers and returned to district steam after a few years. The building has never been gutted, and much of its physical plant is obsolete. Successive reconfigurations of spaces and systems have also left behind tremendous amounts of unused and overlapping equipment, wiring, and piping.

The building has many possible energy sources for heating. The building has district steam service, boilers, and heavy electrical service (LaMouria, 2008). Large areas of the building have window radiators and forced air ductwork. As for cooling, the building could continue to rely mostly on centrifugal chillers and cooling towers to supply chilled water. The building could also use district steam to drive absorption chillers. The city steam plant now uses combined cycle natural gas turbines that produce steam as a byproduct, one that has very little use during the summer. If the building had a residential component, placing per-unit air conditioning units on the 11th floor and 22nd floor roof decks might allow for better cost allocation and user flexibility than a central chiller. Many spaces in the building, including computer rooms and the former chief executive suite, already have such arrangements.

Even if centrifugal chillers continue to make sense for the building's needs, there are many opportunities to cut costs. The rooftop chiller plant, which currently serves the middle floors and the conference facility on the 21st floor, dates to 1986, uses small chillers, and is likely in poor condition. Even the chillers in the main chiller plant, which are ten years newer, may not be as efficient as new chillers with advanced refrigerants. Damage from a flood several years ago may necessitate their replacement anyway. There is the possibility that rebuilding the main chiller plant in its existing space with new technology could serve the entire building, significantly reducing electrical costs and the operational costs of maintaining a second plant and associated piping. Whether this is possible and offsets the significant capital cost requires further study.

Producing electricity from steam may no longer make sense for a commercial building, but there are other generation options that may make sense. The building's large footprint, flat membrane roof, and height present an opportunity to install rooftop solar panels. The 22nd floor roof is about 41,000 square feet and is seldom shadowed by other buildings (Humphrey, 1912c). With a solar density in Saint Louis of 4.95 kWh/m^2/day, a retail electric rate of between 4.75 and 9.41 cents/kWh, low interest rates, and current tax incentives, a system of this size at the Railway Exchange Building may be viable, particularly if other initiatives allow the removal of the cooling equipment on the northwest quadrant of the roof (National Renewable Energy Laboratory, n.d.-a; Union Electric, 2020).

Efficiency divides cost over area. Energy efficiency initiatives reduce costs, but finding ways to increase the usable space in the building can have the same effect. A complete overhaul of the building could probably reduce the horizontal footprint of the vertical wiring and piping by up to 50%, and installing a single smart elevator control system and matching capacity to new uses could also allow reclaiming at least a full bank of elevators, which could serve as small offices or telephone rooms on each floor.

2.4 Potential Funding Opportunities

The largest obstacle to the redevelopment and reactivation of the Railway Exchange Building is funding. At twenty-one stories plus basements and mezzanines and 1.2-million square feet, the Railway Exchange Building is massive (LaMouria, 2008). A project of such scale may be outside the ability of any private developer in the Saint Louis market to finance.

The likelihood is high that, in the current local economic climate, operating the reactivated building would not cover the reactivation costs at any reasonable interest rate. Keeping costs down and finding the right combination of incentives is critical to the success of the project.

Finding ways to decrease capital investment and thus development costs is important. Reusing the physical plant if in good condition, like elevators, standpipes, and electrical distribution, decreases capital costs. Decreasing design costs is also important. A developer recently spent $3-million on concept drawings for the building (Kukuljan, 2019). One way to reduce cost is to take advantage of the uniformity of the building, which has only three major floor profiles, to cut the number of unique floor plans. The uniformity also allows for a much faster study of systems upgrades and changes.

Cost reduction goes only so far when trying to rehabilitate a vacant and obsolete building for the future, so finding cost offsets is critical.

There are a multitude of funding options at the city, state, and federal levels. The most accessible incentives for this project are from the local electric utility, Ameren Missouri. Partially to reduce carbon emissions and partially to support higher rates without higher bills for customers, Ameren Missouri works aggressively to reduce demand in its service territory (Ameren Missouri, 2020a). The demand reduction also allows for more flexibility in upgrading and replacing cabling and transformers. Work on this front in the Downtown Underground District in Saint Louis, which still relies heavily on century-old lead cabling, incidentally, advances the Grand Engineering Challenge pertaining to urban infrastructure (National Academy of Engineering, n.d.).

Ameren offers multiple incentive programs to offset the cost of energy-saving upgrades. One program for installing network-controlled lights provides a rebate of $4 per lamp or $0.45

per watt of reduced operating power. Rebates over $15,000 require pre-approval but are still possible. Ameren also offers rebates for replacing motors, chillers, and appliances and for installing occupancy sensors, smart controls, and variable frequency drives. The incentives normally scale with the project size, which can translate into a lot of money for a large building (Ameren Missouri, 2020b).

Another Ameren program encourages demand response to power availability. Ameren pays customers to give control of some of their loads to the balancing authority for the transmission control area. Ideally, the end user does not notice the changes. The large volume of the Railway Exchange Building and its thermal capacitance make it perfect for such a scheme. A temporary decrease in cooling might have a very small impact on the internal temperature, but the slowdown of the fan motors, chilled water pumps, and chillers could dramatically decrease instantaneous power consumption. Likewise, temporarily activating a more aggressive dimming profile for internal lighting and cutting exterior cosmetic lighting in periods of power scarcity could cut power consumption significantly without a significant impact on occupant comfort. As thickening regulations knock progressively more electrical generation capacity offline, real-time demand control is likely to become critical to the stability of the power grid (Ameren Missouri, n.d.).

Another financing option is historic tax credits (LaMouria, 2008). The Railway Exchange Building was added to the national historic registry on June 11th, 2009. The historic registry addition allows the building to access state and federal tax credits. The federal program covers up to 20% of the project cost, and the Missouri program covers up to 25% if the project secures approval. The actual amount that accrues to the project can be considerably smaller. Tax credits have value only when used to offset income tax liability, so they are often sold to a third party such as a bank at a discounted price (Novogradac, 2020). Because the tax credits depend upon the successful completion of the project, the buyers of the tax credits carefully evaluate the project risks and thus save government agencies the expense and political difficulty of doing so. Ideally, the project makes an uneconomical but significant building that cannot be torn down economically viable again and eventually generates additional tax revenue to offset the cost of the tax credits (Missouri Department of Economic Development, n.d.).

The prospects of the Railway Exchange Building have suffered significantly from the rising crime and vacancy rates in the surrounding area. Another federal program exists to offset this difficulty. New Market Tax Credits exist to fund capital expenses, including real estate improvements, for qualified Community Development Entities in low-income areas. The area surrounding the Railway Exchange Building is likely to meet the program requirements in the near future, and the size of the project would certainly justify the legal expense of creating a Community Development Entity (U.S. Department of the Treasury, n.d.).

Redeveloping the Railway Exchange Building is unquestionably financially problematic, but many of the challenges also come with offsets. Taking advantage of all available incentives, credits, and subsidies decreases the net cost of the project, perhaps enough to make reactivation feasible.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research Methodology

The research methodology for the project was to extract data from building plans and documents, to compute energy usage, and to compare against modern green technology scaled to the same spaces. The energy comparison allowed computation of the potential cost savings of green energy improvements. Lower operating costs support higher capital investment, lower rent, and higher profit for the building owner, all of which increase the odds of the building being renovated and occupied.

The original construction plans for the Railway Exchange Building from 1913 and additional plans covering 100 years of subsequent modifications allowed for constructing a list of lighting equipment present on a representative floor when the building opened and when it closed. Applying standard use patterns and present-day utility prices provided an estimate of pre-upgrade operating costs.

Proposed retrofits for lighting are sized for the area according to modern standards, with energy use and installation cost calculated from that size. Applying the same patterns and prices as used for the pre-upgrade operating costs provided an estimate of post-upgrade operating costs. Comparing the difference in energy cost to the installation cost, net of available incentives, showed the return on investment. These numbers helped to determine whether reactivating the building is economically viable.

3.2 Research Instruments

The research documentation included construction drawings of the Railway Exchange Building from 1913 and from subsequent years. The building has three main floor layouts, full block, deep ring, and shallow ring. The fifth, thirteenth, and twenty-first floors are representative of these layouts. Extrapolating from the numbers from these floors based upon the number of similar floors in the building gave approximate full-building figures. The original heating and wiring plans were drawn by H. H. Humphrey of Mauran, Russell & Crowell, a noted St. Louis architecture firm, between 1912 and 1913 for the building's developer, the Monadnock Realty Company. Later drawings come from the architects of the most recent renovations of the selected floors. Frank Trampe, who served as an adviser to recent owners of the building, located and digitized the drawings in 2014. Drawings used are included in the appendix. The drawings provided the requisite data, including counts and wattages of light fixtures and proposed solar array zones on the roof.

3.3 Analysis Sample

The sample consisted of three representative floors of the Railway Exchange building. The important analytical outputs from those floors are lighting energy consumption and total utility cost for each technology and the total upgrade cost. The inputs included the number of lights and their per-unit wattages. For the solar array analysis, inputs included available area, power per square foot based upon technology and solar factor, and installation cost.

3.4 Assumptions

Several assumptions served to work around unknowns and to remove unnecessary variables. The only available source of historic utility costs for the Railway Exchange Building is the recollection of a former building manager, which is not exact or granular. Even if such costs were known precisely, they were not be readily comparable to plan-based estimates of post-retrofit energy costs. As such, the analysis relied entirely on plan-based estimates of pre-upgrade and post-upgrade energy costs according to present-day utility prices.

The analysis also assumed that certain upgrades would constitute full replacement. With lighting, the analysis also left out the labor costs of upgrades on the assumption that building maintenance staff would carry them out during already scheduled shifts. This may be unrealistic for a closed, vacant building, but it makes the analysis more applicable to a struggling building that has not yet closed.

Due to missing plan sheets, the analysis used the lighting layout from the eighth floor to represent the lighting layout of the thirteenth and twenty-first floors in 1913.

3.5 Procedures for Data Gathering

The number of light fixtures per floor comes from the 1913 heating and wiring plan. On the store floors, lighting upgrades have generally retained the location and wiring of the original fixtures. Proposed new upgrades assumed the same fixture arrangement.

The electric prices came directly from tariff books for Ameren Missouri. For simplicity, calculations used the prices associated with the 13.8-kilovolt feeders that currently serve the corporate floors (9-13), subject to the small primary service rider.

3.6 Statistical Measures

The statistical measure of the project was a comparison of past and present energy usage and energy cost. The energy cost was compared in current (2021) dollars and energy prices in order to support a present-day reader. The large installed base of legacy equipment made such a comparison possible. Figure 3.1 sets forth the cost comparison equation at the heart of this analysis. A return on investment calculation that includes equipment cost and installation was used to determine if the reduction in energy costs justifies the capital costs of the project.

$$Reduction\ in\ Cost = (Historical\ Load * Energy\ Cost) - (Retrofit\ Load * Energy\ Cost)$$

Figure 3.1 Cost Savings of Energy Efficiency Retrofit

3.7 Limitations and De-limitations

This analysis was limited by the availability of data and the unrepeatability of real world situations. Real world energy costs are influenced by losses in wiring systems and aging of hardware. The Railway Exchange Building was examined as an ideal installation. If a fixture's nominal power draw is one hundred watts, it was counted at one hundred watts. In addition, the return on investment varied based on the efficiency of labor.

3.8 Presentation of Data

Tables show energy efficiency, load, and cost for lighting in various configurations on the three floors. Table 3.1 on page 24 shows the configurations of the analyzed floors. The table shows the quantity of fixtures, the type, and the wattage. These configurations formed the basis of the lighting load calculations.

Table 3.1 Lighting Configuration

Historic Wattage	Qty	Current Approximation	Qty	Act Watt	Proposed	Qty	Act Watt
Full Block							
Deep Ring							
Shallow Ring							

The energy usage figures for the selected floor plans in each of the three configurations were calculated from the data in Table 3.1. The three floor plans are full block, deep ring, and shallow ring. The three fixture configurations are from 1913, from 2013, and from after the retrofit. The table also shows the annual energy cost based upon a standard work year of two thousand hours plus two extra hours per work day to account for building hours extending beyond working hours on both ends.

Table 3.2 Lighting Load

		Load Per Hour (kW)	Energy Cost 2021 2500hr ($)
1913	Full Block		
	Deep Ring		
	Shallow Ring		
2013	Full Block		
	Deep Ring		
	Shallow Ring		
Retrofit	Full Block		
	Deep Ring		
	Shallow Ring		

Table 3.3 on page twenty-six shows the calculated reduction in annual lighting energy costs relative to the 1913 and 2013 baselines. The table also shows the cost of the new fixtures and the computed simple payback period.

Table 3.3 Energy Cost Reduction

		Cost Of Retrofit ($)	Change in Cost 1913 ($)	Change in Cost 2013 ($)	Payback Period 2013 (Years)
Retrofit	Full Block				
	Deep Ring				
	Shallow Ring				

Finally, Table 3.4 shows the important parameters of the proposed solar array, in particular its size and nominal output. The estimated annual energy output and the cost of the equivalent energy from the utility are also shown.

Table 3.4 Solar Load

	Name Plate Size (kW)	Array Size (SqFt)	Roof Area (SqFt)	Effective Average Generation (kWh)	Energy Cost ($)
Roof					

3.9 Return on Investment

The return on investment calculation used the simple payback model for each individual energy project, with the assumption that the building reopens and operates at capacity. Using the simple payback model simplifies the overall analysis by eliminating interest rate considerations and thus makes it more accessible to those considering the retrofits studied.

CHAPTER 4. RESULTS

4.1 Introduction

The energy use study of the Railway Exchange Building offered insights not just into the economics of present-day retrofits but also into century-old light and power schemes. The building's space use patterns and available technologies changed significantly over the course of a hundred years and so did its building systems and energy consumption. The energy analysis showed the LED lighting retrofit to have a payback period of under three years. The payback period proved that a modern technology, LED lamps, would reduce operating costs enough to offset capital improvement costs.

A 1.2-million-square-foot building naturally has many light fixtures and use patterns, so an efficient analysis required significant simplification. Labor costs, power costs, and subsidies also introduce significant variability. Examining three representative floors, assuming subsidies to balance labor costs, and assuming one ideal electric service with a static rate significantly reduced complexity without significant loss of accuracy. Gaps in input documentation were filled in accordance with standard practices.

Likewise, the energy output of a solar panel array depends on a wide range of highly variable factors like altitude, atmospheric opacity, obstructing structures, and day length, so the analysis relied on an outside tool that uses averages for the general area and assumed no obstructions. To save the trouble of devising an installation plan, which is unnecessary for energy calculations, the analysis also set the panel area as a fixed portion of the main roof area.

The goal was to establish the unit cost and benefit of the improvement and its scale and then to compute the net benefit and the payback period. For light fixtures, determining how many fixtures of a particular size are present on a floor, how much energy they draw for each technology, and how much that energy costs was the core part of the calculation. For solar panels, the main calculation reflects how much power each panel generates, how many panels fit on the roof, and how much the generated power would cost if purchased from the local electric utility.

4.2 Lighting

As noted in section three, the lighting analysis required several simplifying assumptions. The first assumption was that three floor layouts, full block, deep ring, and shallow ring, adequately represented the entire building. The model ignored mezzanines, penthouses, and the extra ceiling height and lighting requirements of the lower floors. The analysis also assumed that fixture positions remained static from 1913 and that later fixtures all used T-12 fixtures with newer electronic ballasts, which are more efficient than legacy magnetic ballasts. A tour of the building in 2013 showed both assumptions to be largely true on the store floors. The light fixture positions on the upper floors have changed considerably, but the overall density remained roughly the same, and most fixtures were T-12s (Amato / Reed Associates Architects, 1984). Due to missing sheets in the heating and wiring plan deck, the study inferred the fixture positions from the regular bays on the eighth floor. The study assumed 100-watt fixtures in stairwells instead of the 25-watt fixtures in the plans to ensure compliance with modern building codes (NFPA, 2021). The proposed retrofit placed new fixtures on the existing layout. An expansion in 1928 and a reconfiguration in 1994 converted three floors from deep well layout to full block layout (Associated Consulting Engineers, 1994). The analysis assumed that all floors received electrical service under Ameren Missouri's small primary service tariff schedule, with no internal distribution loss. The analysis excluded installation labor cost and rebates and incentives.

The fifth floor represented the full block floor. The thirteenth floor and the twenty-first floor, with fixture power and spacing implied from the eighth floor heating and wiring plan, represented the deep ring floor and the shallow ring floor respectively (Humphrey, 1912a,b). Table 4.1 shows the fixture count for the building in 1913, the building today, and the building after the proposed retrofit, all per the inferences and adjustments previously described.

The economic analysis used current prices for parts and power. The actual wattages (electrical consumption) correspond to currently available hardware. The existing single-lamp fixtures are assumed to use GE GE-132-MV-PS-H ballasts, and two-lamp and four-lamp fixtures are assumed to use Advance RELB-2S40-N ballasts (Grainer, n.d.-a, n.d.-b). The retrofit uses the GE EQ 32-watt lamp, which goes into an existing fixture with the ballast bypassed. The lamp costs seven dollars. All three of these parts are available from industrial catalog supplier Grainger and retail store Lowes (Lowes, n.d.).

The smaller floors, which incidentally are also vertically shallower than the store floors, have a higher lighting density, to the point that the deep ring has a higher lighting load than the full block floor (Humphrey, 1912a). The increased lighting load resulted in part from the higher light requirements of an office environment and in part from the extra non-ceiling lighting in a retail space. The lighting load increased from 1913 to 2013 as a result of increases in illumination exceeding increases in efficiency.

Table 4.1 Lighting Configuration

Historic Wattage	Qty	Current Approximation	Qty	Act Watt	Proposed	Qty	Act Watt
Full Block							
100	318	4 Lamp 40w Fluorescent	450	144	4 Lamp 32W LED	450	56
80	4	4 Lamp 40w Fluorescent	4	144	4 Lamp 32W LED	4	56
60	111	2 Lamp 40w Fluorescent	111	72	2 Lamp 32W LED	111	28
50	33	1 Lamp 40w Fluorescent	33	17	1 Lamp 32W LED	33	14
40	28	1 Lamp 40w Fluorescent	28	17	1 Lamp 32W LED	28	14
25	11						
Deep Ring							
100	430	4 Lamp 40w Fluorescent	439	144	4 Lamp 32W LED	439	56
25	9						
Shallow Ring							
100	346	4 Lamp 40w Fluorescent	355	144	4 Lamp 32W LED	355	56
25	9						

Table 4.2 on page thirty-one shows the lighting load for each of the three fixture configurations for each of the three floor plates and the electricity cost for two-thousand-five-hundred hours, which corresponds to the traditional two-thousand-hour work year plus two hours per workday of margin. The energy cost of 4.59 cents per kilowatt-hour comes from averaging the three winter rates from Ameren Missouri's dba Union Electric (2020) small primary service tariff guide. Note that power is significantly cheaper during the winter than during the summer.

Table 4.2 Lighting Load

		Load Per Hour (kW)	Energy Cost 2021 2500hr ($)
1913	Full Block	41.825	5,175.84
	Deep Ring	43.225	5,349.09
	Shallow Ring	34.825	4,309.59
2013	Full Block	74.405	9,207.62
	Deep Ring	63.216	7,822.98
	Shallow Ring	51.120	6,326.10
Retrofit	Full Block	29.386	3,636.52
	Deep Ring	24.584	3,042.27
	Shallow Ring	19.880	2,460.15

Table 4.3 on page thirty-two shows the parts cost for retrofitting each floor, the difference in energy costs relative to the 1913 and 2013 baselines, and the simple payback period relative to the 2013 baseline. The payback period is under three years in all cases, which indicates a very good return on investment. As noted previously, the analysis excluded installation labor cost and rebates and incentives. If salaried building maintenance staff carry out the retrofit and the building owner maximizes use of financial incentives, the net savings may be significantly greater than those in the table.

Table 4.3 Energy Cost Reduction

		Cost Of Retrofit ($)	Change in Cost 1913 ($)	Change in Cost 2013 ($)	Payback Period 2013 (Years)
Retrofit	Full Block	14,693	1,539.32	5,571.1	2.64
	Deep Ring	12,292	2,306.82	4,780.71	2.57
	Shallow Ring	9,940	1,849.44	3,865.95	2.57

4.3 Solar

The Railway Exchange Building has unusually large floor plates, greater than 42,000 square feet. The scale extends to the building's roof, which has the same square footage as the shallow ring floors (Humphrey, 1912b). The roof accommodates a large solar panel installation, which, combined with the lack of taller buildings to the south, supports large-scale generation of solar power. Economic challenges facing the project include low commercial power prices and high installation costs. Table 4.4 on page thirty-three shows the proposed size of the of The Railway Exchange Building solar array. The array was allocated sixty percent of the total area of the main (22nd floor) roof, which leaves room for cooling towers, vents, and walkways. The array was assumed to have an ideal generation capacity of ten watts per square foot.

The National Renewable Energy Laboratory System Advisor Model is a piece of software that applies a location-specific weather model to predict actual solar generation over a year. The resulting value and the energy cost according to the previously computed energy price of $0.0459 per kilowatt-hour appears in Table 4.4. The National Renewable Energy Laboratory provides an estimated installation cost, inclusive of design, parts, and labor, of $1.85 per watt

(Fu, 2017). The solar installation has a 28.75-year simple payback. A payback so close to the expected thirty-year life of the project (NREL, n.d.-b), without interest or maintenance included, would normally suggest that the project is not viable. But the analysis does not account for subsidies and other incentives. Given how close the project is to economic viability, even a moderately sized subsidy or tax credit would make the solar installation economically attractive.

Table 4.4 Solar Load

	Name Plate Size (kW)	Array Size (SqFt)	Roof Area (SqFt)	Effective Average Generation (kWh)	Energy Cost ($)
Roof	252.81	25,281	42,125	354,456	16,269.53

The proposed solar installation for the Railway Exchange building like the lighting retrofit was conservatively modeled. The conservative designs were to highlight that the retrofit stand on their merits. That their installation would provide greater benefits then the models.

4.4 Summery and Impact

The extremely short payback period of the lighting retrofit makes its economic benefit clear, even for a building without assured long-term occupancy. The per-fixture nature of the retrofit offers a number of additional advantages. The building owner can upgrade just fixtures whose ballasts fail, which reduces the effective cost of the retrofit to the cost difference between an old ballast and a new set of lamps. The owner can focus on fixtures subject to heavy use to maximize the energy savings. The building owner can also carry out improvements with existing maintenance staff as time allows to keep marginal labor costs at zero. Incremental upgrades combined with a short payback period become self-financing, which is a major advantage for a building in a marginal financial position.

Given the low power prices, the solar panel installation is not a certain financial winner without incentives, at least under the limited model set out. The model, however, left out a number of considerations that might contribute significantly to the value proposition. In particular, some prospective tenants seeking to project an environmentally friendly image might seek a location that uses renewable energy (Oberle,2010). Producing power on-site during very hot days reduces strain on the power grid when it is most susceptible to demand-induced failures (Milligan, 2010). Lastly, although the impact is less significant than for a sprawling single-story building, solar panels help to deflect heat from the building, decreasing energy costs for cooling during the summer (Dominguez, 2011).

The price of electricity has a very large impact on the economics of energy-saving initiatives and the rate used here is unusually low, 80% less than some small-service rates in California, for example. The large scale and unusual history of the Railway Exchange Building give it access to primary voltage service, and its location in Missouri makes that service very cheap. As such, an energy-saving project that is of marginal benefit at the Railway Exchange Building could be a major winner at a building subject to significantly higher power prices (PG&E, 2021).

The lighting retrofit is economically viable even when power prices are 4.95 cents per kilowatt-hour power suggests that it is suited to almost any large building with legacy light fixtures. Although the solar retrofit is not economically positive in a 4.95 cents per kilowatt-hour power environment, it is to be worthwhile in any similar building with higher energy prices.

The Railway Exchange Building is not the only vacant building in an urban area. Finding ways to decrease the operating costs of such underutilized buildings improves their economic viability and their occupancy. Increased occupancy and thus density in an urban environment advances the Grand Engineering Challenge of improving urban infrastructure, and any decrease in load on the power grid further advances the Challenge.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary

The Railway Exchange Building has seen many changes in the century since its opening. Tenants and entire industries have come and gone, the surrounding area has changed from the top retail and office location in the region to a blighted backwater and technology has advanced considerably (Gordon, 2008). The building must adopt present-day technologies to survive in present-day market conditions.

For the Railway Exchange Building to move into the next century, it needs to contend with a changing city, one in which tenants are scarce, buildings plentiful, and rent low (Hoebbel, 2021). The economic viability of a building in a low-rent environment depends upon low operating costs.

The Railway Exchange Building provided an opportunity to examine hypothetical operating cost reduction projects applicable to other buildings: an LED lighting retrofit and the installation of a rooftop solar array. The Railway Exchange Building is particularly well-suited to both projects due to its large number of standard light fixtures and its large flat roof area.

The LED lighting retrofit analysis compared the original 1913 configuration, the present-day configuration, and the post-retrofit configuration, extrapolating from three floor plates that represent the vast majority of the usable space in the building. Fixture positions come from the original 1913 plans, with the present-day and retrofit configurations using present-day fixture sizes. The 1913 configuration, limited by available technology, used only incandescent lamps with basic reflectors and thus generated excessive heat and insufficient illumination by present-day standards. Today, the Railway Exchange Building, like many buildings, uses four-tube fluorescent fixtures for almost all of its primary interior illumination. Fluorescent illumination is more efficient than incandescent illumination but less efficient than LED illumination (Dikeou, 2014). Even with the improvement in efficiency, the present-day lighting configuration uses more electricity than the 1913 configuration due to a significant increase in fixture wattage.

The LED retrofit, which provides equivalent illumination to the present configuration, dramatically reduces operating costs. The retrofit reduces operating costs by greater than fifty percent and uses the existing fixtures. Installation is as simple as bypassing the ballast and replacing fluorescent tubes with LED tubes. Replacing tubes and ballasts is routine maintenance for fluorescent fixtures, so the LED retrofit involves negligible marginal labor costs, particularly if carried out by building staff as ballasts fail or as scheduling slack allows. The negligible labor requirements and the low cost of the LED tubes combine to make the LED retrofit very inexpensive.

The Railway Exchange Building is large, over 1.2-million square feet, and is a significant consumer of power. The Railway Exchange Building's 10,921 light fixtures draw 1,420,973 watts per hour, the equivalent of 1,157 houses (EIA, n.d.). The LED retrofit reduces power consumption by about 60.83%, the equivalent of 704 houses. 704 houses represents a significant reduction in electrical use and reduces the load on the local electrical grid, allowing for cable and equipment replacement, reducing the chance of failure, or freeing power for other uses. Each of these outcomes advances the Grand Engineering Challenge of improving urban infrastructure.

The Railway Exchange Building is also well-positioned for solar generation with its sunny location and its large, high roof. Assuming 60% coverage to allow for existing penthouses and equipment, the Railway Exchange Building's main roof allows for a 25,281-square-foot solar installation. The solar panel would generate an average of 354,456 kilowatts over the course of a year, enough to power 33 houses (EIA, n.d.). Unfortunately, the Railway Exchange Building's access to low-cost power devalues the solar energy to the point of making the project economics marginal. The payback period using the optimistic simple model is 28.75 years, which is approximately the life of the system (DOE, n.d.-a). A similar building without access to inexpensive electricity, though, would likely benefit from a similar installation. The economic benefits of a rooftop solar installation extend beyond power generation. Such benefits include green marketing and improved roof heat rejection.

5.2 Conclusions

5.2.1 Interpretation of Findings

LED lighting retrofit for the Railway Exchange Building clearly pays for itself quickly, even with low power costs and without subsidies. The model excludes labor costs, but installation may realistically come without labor costs in several likely scenarios, such as upgrading fixtures only as ballasts fail.

To facilitate comparisons and to simplify computations, the lighting study simplifies and standardizes floor layouts, fixture selection, and fixture performance. The lighting study also makes use of industry-standard performance figures. No reason arose to doubt the reasonableness of these simplifications or the accuracy of the results. The simplifications likely improve the general applicability of the results.

The solar installation does not provide a clearly positive payback, at least with the low power prices applicable to the Railway Exchange Building. The economic viability of a solar installation is highly dependent upon solar factor, local power prices, and site characteristics. Even with a favorable solar factor and a generally unobstructed location, the low power prices make an installation at the Railway Exchange Building a less than attractive proposition.

The solar study was based entirely upon standard unit performance figures from the National Renewable Energy Laboratory System Advisor Model scaled to a fixed portion of the main roof area. Actual performance will vary somewhat from that, but not enough to change the result.

5.2.2 Implications of Findings

Legacy buildings similar to the Railway Exchange Building sit underutilized or abandoned in urban areas, in part due to high operating costs. Finding ways to reduce energy use and thus operating costs of such buildings would lead to increased occupancy and revitalization of surrounding areas.

Beyond the immediate effects on occupancy, reducing energy use also helps to improve electrical transmission and distribution infrastructure. Reduced load allows the utility to perform heavy maintenance that requires temporary deactivation of cabling and equipment. Even without upgrades, reduced per-building loads allow existing infrastructure to serve more buildings. Enhancing the reliability and capacity of urban electrical service advances the Grand Engineering Challenge of revitalizing urban infrastructure.

One other function of reducing energy usage is to improve the operating margins for electric utilities. When a unit of power provides more value to the customer, the utility can charge more for it. Ameren, the local electric utility in Saint Louis, offers generous subsidies for LED lighting retrofits to reduce system demand (Ameren Missouri, 2020b). Ameren recently proposed a rate hike, but the estimated impact on a residential customer is less than the savings from installing LED light fixtures in a house (Hoffman, 2021).

The Railway Exchange Building has a long history and an extensive paper trail documenting that history. The Railway Exchange Building provides historical and modern perspectives on building electrification, lighting, and energy use. The lessons learned from studying the Railway Exchange Building are likely applicable to similar buildings.

Power prices play a major factor in the economics of any energy-saving project. The reduction of power cost must pay for the project cost over the lifetime of the project. The Railway Exchange Building is located in a cheap power market and has its own transformers, which allow it access to cheaper primary voltage service. 4.59 cents per kilowatt-hour is the average variable rate for the Railway Exchange Building. The United State commercial average is 10.68 cents per kilowatt-hour, more than twice that of the Railway Exchange Building (EIA, 2020). The low power prices applicable to the Railway Exchange Building mean that any savings would be even greater for a similar building elsewhere. Energy-saving projects that work at the Railway Exchange Building likely work elsewhere too.

5.3 Recommendations

Of the two potential projects for the Railway Exchange Building, only one is an economic winner: the LED lighting retrofit. The Railway Exchange Building's existing configuration is well suited to the installation of LEDs. The building's existing four-foot light fixtures allow for a conversion that is similar to routine maintenance. The electrician installs the LED lamps just like regular fluorescent tubes after bypassing the ballast. The building's scale makes the project economics favorable. Incentives from the local electric utility also contribute. The payback time is exceptionally fast at 2.64 years. The payback period is considerably shorter than the twenty year life span at two thousand five hundred hours a year (Lowes, n.d.). Retrofitting fixtures only when existing ballasts or lamps fail would further decrease the marginal cost of the retrofit and shorten the payback period.

The solar panel installation offers some benefits, but its economics are marginal at best and do not justify the project. The first goal of an energy efficiency project is to reduce operating costs by more than the installation cost. The solar installation fails to reduce operating costs sufficiently to justify its installation costs. Even excluding maintenance costs, the optimistic simple payback period of the solar installation is 28.75 years. That payback period falls close to the lifespan of the system. Unusually low energy prices contribute significantly to the long payback period. A building located in a more expensive energy market would likely see significant economic upside from a solar panel installation. The solar array would help to attract environmentally conscious tenants and would also reduce the load on the local grid.

5.3.1 Looking Beyond The Railway Exchange

The Railway Exchange Building study leads to additional lines of inquiry. The first is the application of LED lighting to residential units. Installation labor is free at a large commercial building when the maintenance staff have schedule slack. Installation can also be free in a residential setting. The free installation requires electrical competency of the resident. Residential lighting may have lower average utilization but is also subject to higher power prices and generally starts with less efficient illumination. One major challenge is choosing and packaging products that fit each target residence and that the resident can install unaided.

The other matter meriting study is the accrual of economic benefits of improved demand-side electrical efficiency. This study focused on economic benefits for energy consumers (landlords and tenants). The economic impacts on the producer merit more study as the impact could be larger. Electric utilities presumably subsidize efficiency projects so that they can increase prices and margins over the long run without increasing customer bills. The utilities would idle or close their least efficient plants and charge higher rates on the remaining power generated.

The economic benefits of improving the energy efficiency of the Railway Exchange Building are likely to extend far beyond the building and its owners and tenants. Ultimately, benefits would extend to tenant employees, other buildings and businesses in the surrounding area, the city, the state, taxpayers, and the electric utility. Although the payback for the building owner is critical to making a decision on capital improvements, the overall payback may be much greater.

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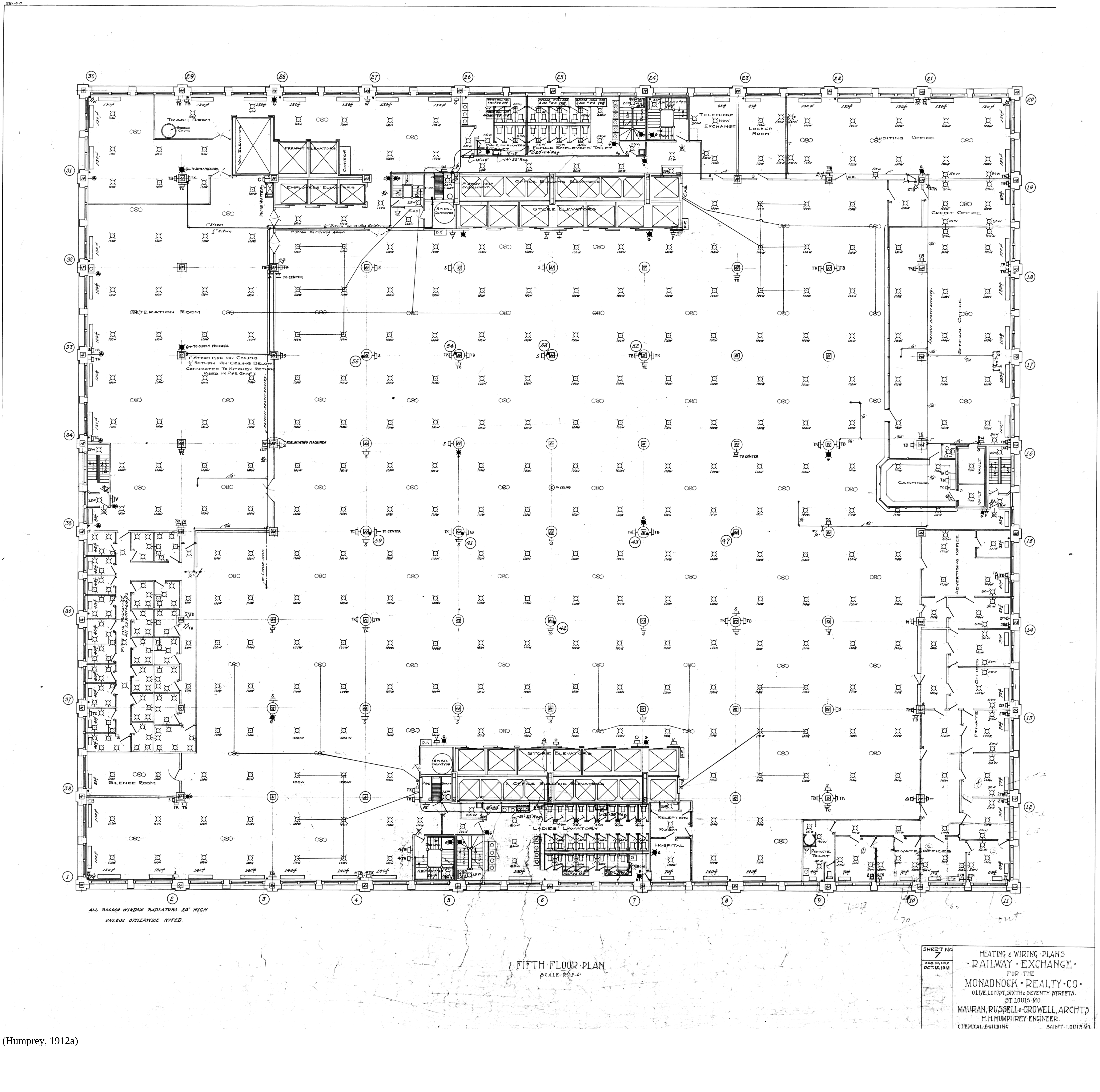
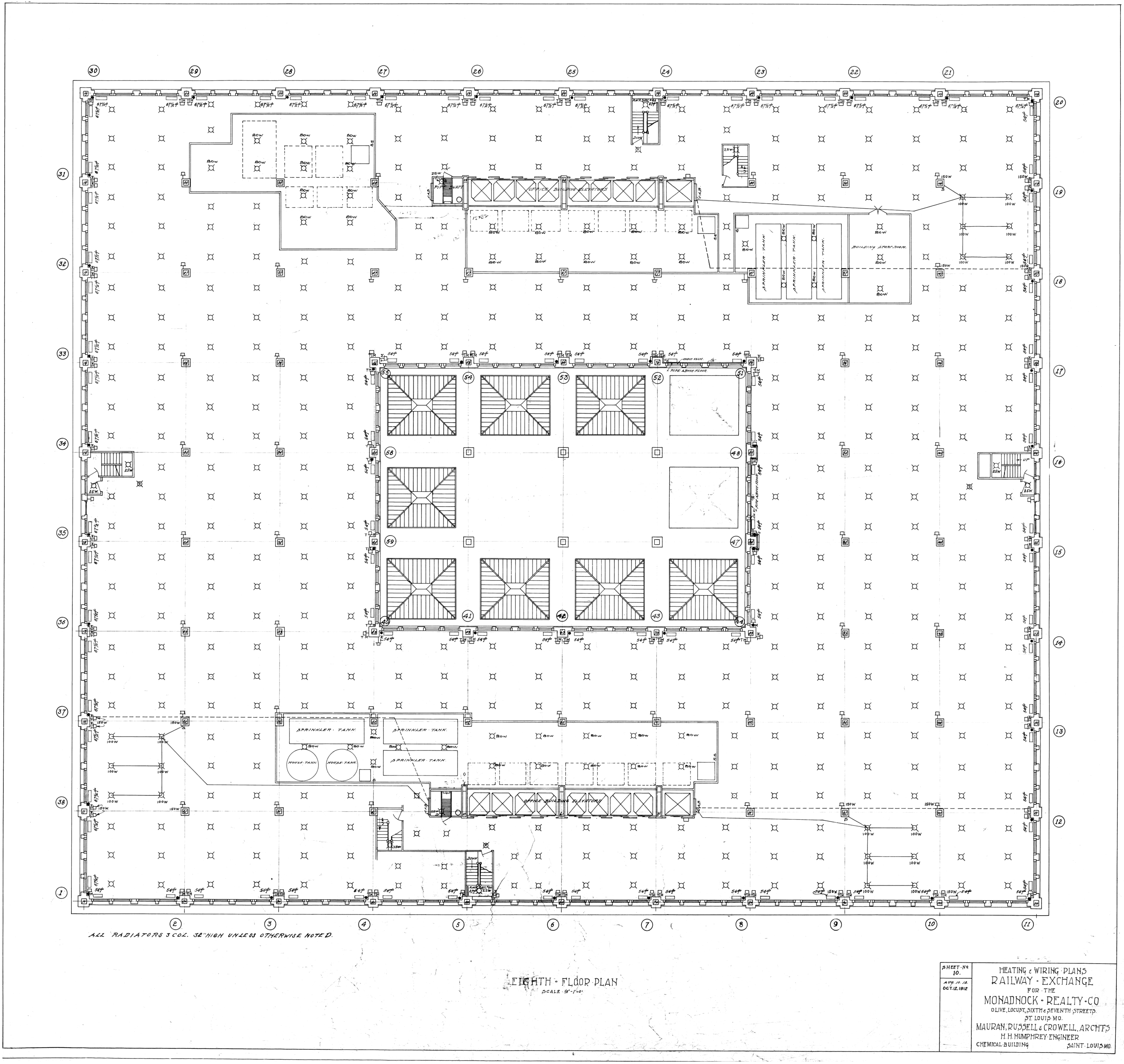
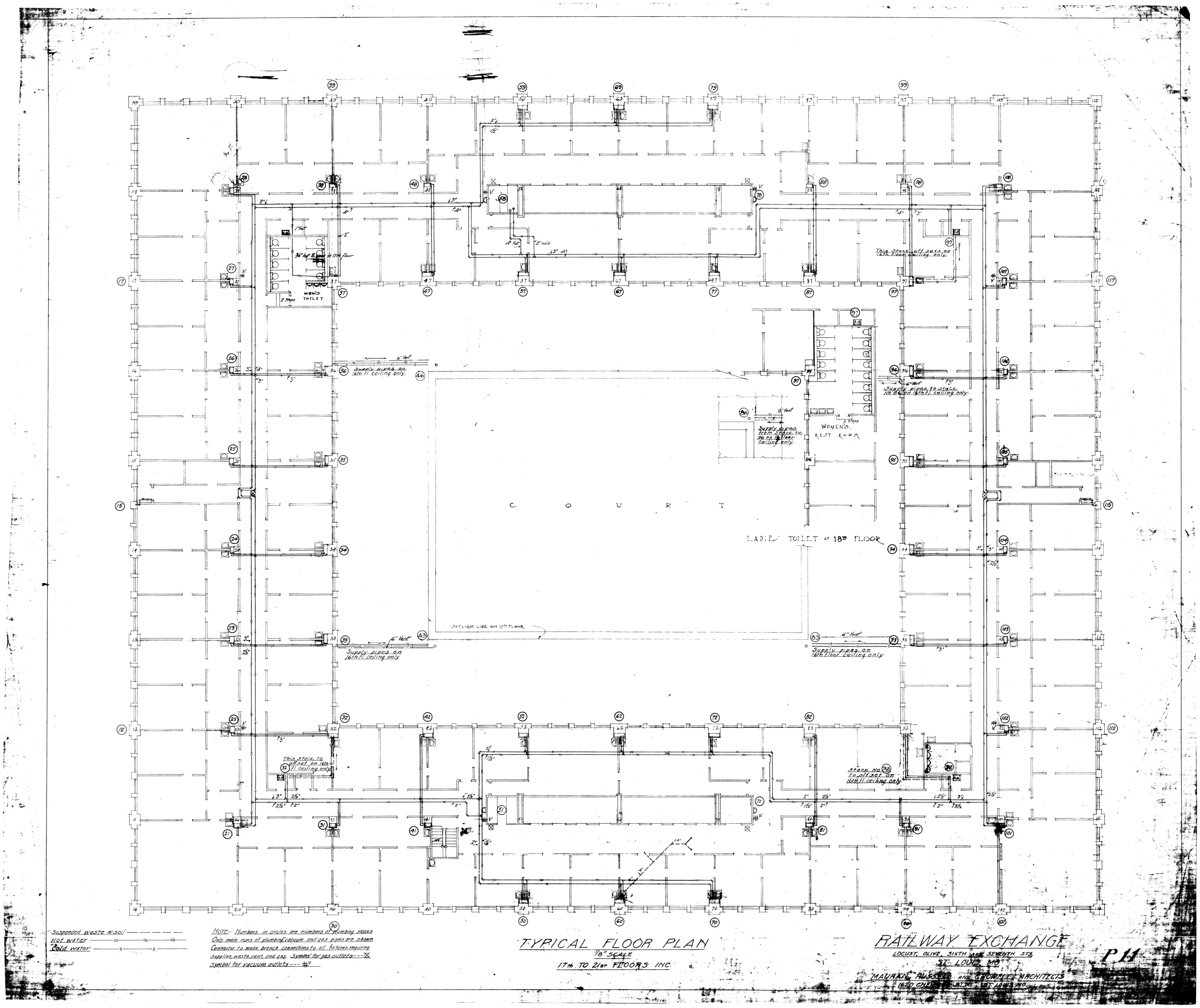
APPENDIX A. SELECT BLUEPRINTS OF THE RAILWAY EXCHANGE BUILDING



(Humprey, 1912a)



(Humprey, 1912a)



(Humprey, 1912c)