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REVIEW PAPER

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# WHY DO CHICAGO BUILDINGS NOT RETROFIT?

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## ABSTRACT

Retrofitting buildings undeniably offers opportunities to lower energy consumption and greenhouse gas emissions. However, choosing particular retrofit techniques is complex and needs planning. Several techniques exist for modifying buildings to use nearly zero energy. Chicago is world-famous for its downtown skyscrapers, neighbourhood bungalows and leafy suburbs. Still, behind their façades, Chicago-area buildings conceal an embarrassing and expensive reality: they use too much energy. By strategically combining available resources and existing knowledge, the Chicago area can make its physical structure more energy efficient, bringing environmental and economic benefits to the eight million people in this region. Therefore, the main focus of this study is to explore pertinent solutions, analyse the impact of such solutions on building energy efficiency and suggest renewable energy technologies. Extensive research involving numerical simulations or experiments is necessary to assess the feasibility of implementing these techniques in the specific climatic conditions of Chicago.

**Keywords:** decarbonisation, carbon dioxide emission, climatic strategies, retrofitting, Chicago

## INTRODUCTION

In the 21st century, finding ways to minimise the carbon footprint in the construction industry has emerged as a key focus within the realm of modern sustainable interdisciplinary design. Rapidly developing countries are placing ever-higher legal requirements on the designers of new buildings in terms of the materials and construction technologies used. The question of existing buildings and how to make them less carbon-intensive and more comfortable for their occupants is increasingly beginning to be raised. In the United States, buildings are typically responsible for 40% of all carbon emissions – that figure rises to 70% in the city of Chicago. The transportation footprint is relatively modest, which contributes to this imbalance. However, like many older cities, Chicago's buildings frequently have out-of-date, inefficient systems that result in high energy loads. So, why do building owners not undertake any retrofitting measures to improve the quality of the building?

There is an enormous environmental problem in today's world. Designers, lawmakers and users must start undoing the harm done to the earth since the Second Industrial Revolution. The undeniable development brought to the world by the changes brought about by mass production on assembly lines and access to electricity has also led to greater exploitation of natural resources and littering of the urbanised environment with waste and greenhouse gases (Filho et al., 2023). There is now an increased awareness among producers of goods and designers and users of the carbon footprint of products and buildings (PCF – product carbon footprint). The sectors still generating the most significant carbon footprint are the construction sector and transport. In 2002, The 2030 Challenge's scientists

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estimated that 10 years of global reductions in greenhouse gas emissions are needed to avoid catastrophic climate change (Intergovernmental Panel on Climate Change [IPCC], 2021). Chicago created the Chicago Climate Action Plan in 2008 to address these problems. Today, designers know that progressing sustainably calls for more than just creating new, energy-efficient structures or increasing the number of hybrid vehicles on our road. There is an urgent need to drastically modify the current metropolis' landscape, changing how it looks and functions. Proper integration between a city's components is necessary for an urban ecosystem (City of Chicago Department of Environment, Parzen, Urban Sustainability Associates & The Center for Neighborhood Technology The City of Chicago Department of Environment, 2009). Smart energy systems depend on smart infrastructure development, just as smart buildings depend on smart transportation networks. Decarbonisation aims to make cities healthier, more sustainable and more habitable by enhancing the performance of all significant metropolitan systems.

Several buildings in the Chicagoland area have already undergone retrofitting. The energy efficiency of the buildings, landmarks and residences that make up Chicago is essential to creating a thriving, climate-resilient and sustainable city. Although climate efforts and new building rules are critical first steps toward achieving net zero emissions in Chicago, retrofits are the most crucial component in addressing one of the city's largest greenhouse gas emitters. For property owners throughout the city, building retrofits are vital for three reasons: the weather in Chicago; subterranean climate change and cost savings to improve user comfort and building efficiency. The paper focuses on the analysis of selected buildings in Chicago, and results in the identification of key factors (KF) contributing to the lack of retrofitting.

## LITERATURE REVIEW

### Law regulations

In the United States, buildings produce an average of 40% or more of the nation's carbon emissions – that percentage increases to 70% in Chicago. Commercial space in downtown Chicago takes up 90% of land use, which is responsible for 97% of carbon dioxide emissions. The Chicago Loop, in contrast, is mainly devoid of residential space and the services and infrastructure that many homeowners appreciate in their communities (e.g. grocery stores, daycare centres, parks and schools). This pushes people who work there to look for adequate housing and living spaces elsewhere in the city. As new technology has become commonplace in our daily lives, energy consumption in the United States (and, consequently, in Chicago) has substantially increased over the previous few decades, significantly surpassing population growth. While emerging technologies have put more stress on the ageing infrastructure, they also provide new opportunities to boost energy, information intelligence and distribution efficiency by creating new infrastructure intelligence (IPPC, 2021).

Building owners are encouraged by the voluntary Retrofit Chicago initiative to commit to cutting energy use by 20% over five years. Retrofit Chicago, established in 2012, has expanded from 12 to over 75 buildings, totalling more than 50 million square feet. The programme produces custom energy road maps for building owners to explore routes in order to cut energy use and increase annual savings. In 2018, Chicago officials estimated the programme had reduced emissions by 70,000 mt and saved 90 million kWh annually based on energy reporting by building owners. The city is looking for strategies to broaden engagement outside of the downtown area so that additional buildings can join in and take advantage of the pooled knowledge and resources.

Passed in 2013, the Chicago Energy Benchmarking Ordinance requires residential, commercial and institutional buildings over 50,000 square feet to report energy consumption annually. The programme aims to empower building owners and renters to make knowledgeable decisions about energy usage and promote energy efficiency. It also gives the city information it can use to focus programme resources more effectively. The 2019 Chicago Energy Benchmarking Report highlighted nearly $74 million in savings from energy reductions and its highest compliance rate (at 91%) of buildings covered under the ordinance. Furthermore, the new Chicago Energy Rating System requires building owners to display their energy performance to the public through a placard. Chicago was the first American city to require this level of public transparency for energy use. The Illinois Climate and Equitable Jobs Act (CEJA) was passed in September 2021 by the Illinois State Legislature. The CEJA sets Illinois on a path to 100% clean energy by 2050 and 100% carbon-free power by 2045. Beyond renewable energy build-out, the CEJA also commits to holding utilities accountable, creating an equitable clean energy future for all, ensuring affordability of energy bills, assisting the transition of fossil fuel communities and creating good-paying carbon-free jobs. Stand-out actions include an annual $80 million commitment to workforce and contractor development in equity-focused communities, minimum diversity and equity requirements for renewable energy projects, ending formula rates, a $40 million grant programme for fossil fuel communities in transition and an annual $80 million for electric transportation projects (Chicago, 2020).

The International Code Council (ICC) has approved the 2021 International Energy Conservation Code (IECC), which achieved the biggest energy efficiency gains in the past decade by updating requirements for insulation, lighting and water the 2021 IECC as part of the Chicago Energy Transformation Code in 2022. Under state law, Chicago can also consider a "Stretch Energy Code" starting in 2024. Regularly scheduled updates to the Chicago construction codes, based on model codes from the ICC and others, also provide opportunities to facilitate and promote building decarbonisation (City of Chicago, 2022).

The City of Chicago is dedicated to a building decarbonisation strategy that develops an equity-focused building emission reduction strategy that lessens financial burdens on residents and businesses through energy efficiency, renewable energy, electrification and innovation in new construction. This strategy is a component of the Green Recovery Agenda. To direct the creation of a collection of implementable building decarbonisation policies and programme recommendations, the City of Chicago established a Building Decarbonization Project' team in 2020. The Working Group is made up of participants from the private, public, and non-profit sectors, including experts in sustainability, architects and designers, workforce development organisations, builders and developers, building managers and operators, small businesses, community organisations, utilities, environmental justice and advocacy groups, youth groups focusing on climate change, labour unions, and universities. The policy development process included four phases: best practices research, extensive stakeholder engagement, policy development working group, and ongoing policy development and implementation. The working group identified numerous pressing issues that must be resolved in the upcoming years to decarbonise Chicago's building stock. Financial incentives to reduce carbon emissions in buildings are generally lacking. Most financial aid is funded through grants and cannot be scaled to meet changing needs; therefore, it is necessary to identify funding sources for decarbonisation initiatives in all buildings (City of Chicago, 2023).

## Decarbonisation strategies

There are substantial information gaps regarding how to decarbonise buildings. A crucial option, building electrification, is poorly understood by the general public, and information is not easily available (Das & Ghosh, 2023). Additionally, there is a dearth of knowledge regarding utility programmes, rebates, retrofits and energy efficiency advantages (Sareen et al., 2023). Even though most people know about energy efficiency and renewable energy sources, there is still a need to address this because of the lack of adoption. Creating a communicative network of players that can develop, pilot and scale decarbonisation initiatives throughout the city is tough. There is a limited workforce to achieve the retrofits needed at scale. Among their other priorities, city authorities' capacity to quickly adopt decarbonisation programmes and offer citywide support is likewise constrained. To assist community participation and household energy transitions, building capacity will be necessary for non-profits, community-based groups and other non--profit organisations. This will be crucial for reducing energy use and costs in older and smaller residential homes that require retrofitting. The city, commercial enterprises, housing providers and industrial operations are examples of large institutions facing new problems in managing innovation ambiguities, shifting power dynamics and developing new drivers for inclusive economic growth. The benefits of building decarbonisation must be concentrated in frontline areas where residents and business owners who stand to gain the most from improvements must have access to the resources they need to engage in and finish projects effectively.

One of the country's most well-known and diverse skylines is that of Chicago. According to legend, this is where the skyscraper was erected in the years following the Great Fire of 1871. Architectural periods have been used to group buildings in Chicago based on their materials, scale, plan and aesthetic expression; however, to properly establish energy reduction plans, buildings must finally be classed according to their energy era and general performance readiness.

The Chicago Central Area Decarbonization Plan attempts to make a dynamic urban environment while lowering downtown Chicago's carbon emissions (Table 1). This is not a checklist, in contrast to other plans. It takes a comprehensive approach to improving the social, economic and environmental facets of city life in Chicago. The plan sets itself apart from other city plans by emphasising an integrated strategy for problem-solving. The analysis does not only arrive at a reduction number derived from a given set of applicable assumptions; instead, it analyses all the carbon sources typical of the urban condition. The plan establishes a framework for preserving the metropolitan core's economic and cultural vitality regarding energy and carbon. The assumption that growth may continue without having a detrimental environmental impact

**Table 1.** Retrofitting solutions in public buildings decarbonisation

| Retrofitting solution | Description |
|---|---|
| Building envelopes | Building design has evolved significantly as a result of energy codes. Architects and engineers must constantly consider the behaviour of modern buildings concerning the environmental effect and energy needs. Demand for high-performance buildings is growing among owners and occupants. With the help of technology that maximises human comfort, buildings are gradually rediscovering their connection to the outside world. |
| Vertical transportation systems | Between 2% and 10% of the energy in a typical downtown building can be accounted for by the energy used by lifts and escalators. This is dependent on the size, number and function of the building, mainly the frequency and volume of lift activity. Although standard vertical transportation equipment has improved efficiency by around 50%, many outdated systems are still in use. Additionally, new technologies have been created to enhance lift systems by utilising digital controls to reduce the number of trips. |
| Lighting systems | Lighting systems have significantly improved compared to the original gas lamps in Chicago's early buildings. The ideal amount of daylight for the human eye can be used to build and automatically operate daylight lighting systems. However, a lot of modern structures have excessive lighting. The required lighting density at the time was estimated to be up to five times higher than what is typical today. The building was heated in part with the aid of lights. |
| Equipment or plug load | The electricity required for anything that must be plugged into an electrical outlet can be most easily understood as the equipment load in a building. While other building loads (such as lighting and envelope) have declined over time, plug loads have increased – particularly since the 1980s when computers were used extensively. The use of Energy Star-rated (or superior) equipment and automatic shutdown are two actions that can be implemented right away to lessen equipment loads. As electronic equipment develops and uses less energy, future technologies can further lower these burdens. |
| Green roofs and roof insulation | While roof insulation and low albedo or green roofs remain essential for mitigating the urban heat island effect in Chicago's downtown area, the impact is noteworthy despite buildings usually having a relatively small proportion of roof area. This effect is especially pronounced with older, dark-coloured roofs, which can reach temperatures of around 200 F in the summer. Additionally, green roofs play a crucial role in capturing stormwater runoff, contributing to reduced carbon emissions by eliminating the need for water treatment. |
| Energy sources | Assessing carbon emissions in buildings is impossible without considering the source of a building's energy. The energy that leaves power plants is lost in large amounts as it passes over the electricity grid. Peak energy demand has an impact on costs as well as the amount of energy coming from coal-fired power plants. Buildings can reduce their contribution to carbon emissions by managing and storing energy to lessen these peaks. While renewable on-site generating enables buildings to operate carbon-free, on-site energy generation can also cut transmission losses. |

is essential to the viability of cities and urban living. Cities may become hubs for healthy, diverse lifestyles with little impact on the environment thanks to decarbonisation (Chicago, & Building Decarbonization Policy Working Group, 2022).

## PUBLIC BUILDINGS TYPOLOGY IN CHICAGO CITY CENTRE

Numerous helpful comparisons can be made based on a building's energy era due to the historical evolution of technology in buildings and how structures have been used over time (Table 2).

Heritage buildings are the first category, comprising all buildings between roughly 1880 and 1945. Although these structures span a considerable amount of time, they all share a few fundamental characteristics like their construction type (usually masonry, stone or terra cotta with punched windows) and their utilisation of natural light and ventilation as intended when they were first built. Mid-century modern architecture is the second category.

Mid-century modern buildings comprise structures built between 1945 and 1975. A revolution in architecture took place after World War II, giving rise to a new breed of high-rise skyscrapers made of glass and steel and intensively illuminated. To make mainly glass elevations, curtain walls were created. The building loads caused by these significant amounts of glass and complex lighting systems might be mitigated thanks to more sophisticated HVAC systems. However, the drawback of these architectural advancements was a dramatic rise in building energy consumption. The 1973 OPEC oil embargo not only led to tighter fuel-efficiency regulations for cars, but it also raised people's awareness of how much energy is consumed in buildings. It encouraged increased investment in the initial cost of building energy-saving technologies. Large buildings constructed after 1975 frequently incorporated energy-saving technology, including insulated glass, variable volume air systems and solar films or coatings to lower energy loads and operating costs. These post-energy-crisis buildings fall into structures constructed between roughly 1975 and 2000. The last group of buildings are the energy-conscious buildings that were built between 2000 and the present during the current global drive toward energy efficiency. The Chicago Energy Code was adopted in 2001, coinciding with the rising popularity of LEED and other green standards.

### Heritage: 1880–1945

Due to their short lease spans and substantial thermal mass for heat absorption, heritage buildings offer excellent options for natural ventilation, daylighting and heat absorption. However, many of these structures have not benefited fully from advancements in building technology over time. Sometimes a building's designation as a landmark will prevent it from getting full sustainable improvements.

### Mid-century modern: 1945–1975

Due to the invention of curtain walls, modern structures frequently have a lot of glass. Technology during this time altered how structures were constructed. Artificial interior control has essentially replaced using the natural environment for heating, cooling and lighting. Due to changes in how offices are used, substantial HVAC systems and dense lighting became standard. Building construction was accelerated by mass manufacture, which also decreased costs and enhanced adaptability.

### Post energy crisis: 1975–2000

The 1970s energy crisis had an impact on building construction methods. Insulating glass, heat-gain-reduction solar coatings, more effective HVAC systems and less lighting were all developed for high-rise structures. However, internal plug loads in buildings rose as computers advanced.

### Energy consciousness: 2000–present

Building design has undergone a significant change as a result of energy codes. Architects and engineers nowadays must maintain a constant understanding of how building behaviour relates to environmental effects and energy needs. High-performance buildings are starting to be in demand from owners and renters. Slowly but surely, buildings are rediscovering their connection to the outside world – now balanced with technology that maximises human comfort.

**Table 2.** Public buildings in Chicago City Architectural description based on the chosen timeline

| Specification | Timeline | | | |
|---|---|---|---|---|
| | Heritage (1880–1945) | Mid-century modern (1945–1975) | Post energy crisis (1975–2000) | Energy consciousness (2000–present) |
| Typical exterior wall materials | brick, stone, terra cotta (uninsulated) | stone, aluminium, steel, and other curtain wall systems, concrete | Systems for curtain walls: aluminium, stone and concrete. Mirrored or dark-tinted insulating glass was used until the 1990s. Clearer glass with low-E coatings from 1990 to 2000, 60–80% is glass. The implementation of thermal breaks. | Curtain wall systems: aluminium, stone, concrete. Insulated glass with low-E coatings is the industry standard in the United States. As energy codes become stricter, glass percentages become lower. Triple-glazing and double-skinned walls are introduced. |
| Typical exterior wall technology | structural steel and reinforced concrete | Most curtain walls were constructed before thermal breaks were developed, and most glass is single pane because insulating units were still in the early stages of development. Between 50 and 80% of it is glass. | steel, concrete, composite | concrete-steel composite |
| Windows | Double-hung windows with single-pane, clear glass.<br>Glass percentage: 25–50% | Windows typically have transparent glass with manual shading systems and are slightly tinted (green, grey or bronze). | – | – |
| Ventilation systems | The HVAC system has generally been retrofitted or completely replaced over the years, especially for buildings older than 1930. Therefore, many mechanical systems exist in these buildings, from radiators to fan coil units to variable-volume overhead systems. Often, systems do not operate optimally because of changes over the years. Cooling systems have likely been added to the original building as air conditioning was not widely used before 1950. Many heritage buildings have opportunities for natural ventilation from short lease spans or light wells, but sometimes these have been covered over. Some buildings use district heating and cooling due to a lack of plant capacity. Others have large rooftop units added. | Mechanical systems often have perimeter induction or fan coil units that supply ducted systems with interior air. The conventional internal system is a constant electric reheat. Nowadays, it has mostly been replaced in many buildings by a variable volume system, which is more efficient. Although many mechanical plants have been converted for variable volume and economiser cycles, they were also originally constant volumes. | Tan coil or induction units along the periphery with ducted variable volume systems for the interior air. As less heating was required along the outer glass walls, loads fell. Variable equipment started to be used in mechanical facilities. | The VAV or tan coil systems with less perimeter heat are needed for better envelope performance.<br>Use economiser cycles, variable frequency pumps, drives, and digital controls. |

| | | | | |
|---|---|---|---|---|
| Electricity and lightning | Opportunities exist for natural light through short lease spans and light wells – especially in the oldest buildings. Buildings that did not initially have electric lighting have been retrofitted. However, early lighting retrofits typically have fewer lights than the over-lit buildings from the 1950s through the 1970s. Therefore, lighting and electrical loads in older buildings often consume less energy than in later buildings. | Buildings were planned with heat by light in mind, and lighting density in the middle of the 20th century was frequently as high as 5 W per square feet. It was discovered over time, with the advancement of computers, that these high levels were not required and that using the HVAC system for heating was more effective. Therefore, lighting density was frequently decreased during later tenant fit-outs. Introducing new technologies led to increased equipment loads (also known as plug loads). | Lighting steadily reduced from 1970s levels as heat-by-light incentives were phased out. Partial or complete retrofits/de-lamping may have decreased lighting loads.<br>With the development of computers, office space became much more energy-intensive in terms of plug loads. This often caused overall electrical energy use, especially in office buildings and trading floors, to increase sharply. | Lighting levels were reduced to meet energy codes and LEED. Natural daylight and light sensors are the industry standard to meet energy guidelines. New technologies such as compact fluorescent lighting and LEDs are becoming more common. Plug loads remain high, but more efficient equipment is being developed to save energy. |
| Typical layout | Shallow lease spans and narrow floor plates or large floor plates with one or more light wells. | Typical layout – 30,000–50,000 square feet floor plans with a central core are very large. | Large floor plates of 30,000–50,000 square feet with a central core. | Large floorplates remain typical for office space, but more attention is paid to orientation, and shallower lease spans for natural light. |
| Site and surroundings | The early planners of Chicago protected the lakefront. However, architects of the first high-rise buildings and early zoning regulations did not yet have a strong awareness of site improvements with positive environmental impact, such as setbacks and green or porous areas. | Large public areas were widespread in the mid-century era, bringing more sunshine into the city. Still, they were frequently composed of hard surfaces such as granite paving, which badly affected stormwater management and the urban heat island effect. | With increased zoning requirements for landscape, buildings after 1975 tend to be surrounded by more trees and have a site design sensitive to pedestrians. New city ordinances raised awareness of stormwater management. | New environmental awareness has encouraged the use of permeable surfaces, urban parks, and stormwater retention. When selecting a site, the rehabilitation of brownfield areas and pollution cleanup are encouraged. High development density and mixed-use buildings in urban areas allow better access to cleaner public and bike transportation than cars. The importance of public parks remains high, enhanced by the development of Millennium Park in recent years. |
| Building representation | Carson, Pirie, Scott & Company Building<br>Marshall Field and Company Building<br>The Pittsfield Building<br>The Fisher Building<br>Monadnock Building<br>The Marquette Building | 860-880 N. Lake Shore Drive<br>875 N. Michigan Avenue<br>Lake Point Tower Condominium<br>330 N. Wabash Avenue<br>Marina City<br>Richard J. Daley Center<br>Inland Steel Building<br>Willis Tower<br>Federal Center<br>McCormick Place Lakeside Center<br>S. R. Crown Hall<br>Keck-Gottschalk-Keck apartments | Franklin Center<br>Two Prudential Plaza<br>311 South Wacker Drive<br>900 North Michigan<br>Water Tower Place<br>Chase Tower<br>Three First National Plaza | St. Regis Chicago, formerly Wanda Vista Tower<br>One Chicago East Tower<br>NEMA Chicago<br>Aqua<br>One Bennett Park<br>Salesforce Tower Chicago<br>110 North Wacker |
| Renewable energy | – | – | After the energy crisis, ideas about integrating solar energy into buildings were being developed. However, due to long payback periods, building-integrated renewable energy was not generally used in the Central Loop. | Buildings are beginning to integrate energy generation elements such as solar panels and wind turbines. Tax incentives are making these elements more financially viable. |

## SUCCESSFUL RETROFITTING EXAMPLES IN CHICAGO

Retrofitting efforts in Chicago City have demonstrated a satisfactory success rate. Choosen examples from different periods showcase the implementation of retrofitting strategies. Notable instances include the Field Building, Chase Tower and Willis Tower.

### Field Building

The Field Building (Fig. 1) was constructed in 1934 as a 535-feet (163.1 m) 45-story skyscraper on the site bounded by South Clark Street, South LaSalle Street and West Adams Street. The architect was the firm of Graham, Anderson, Probst & White. It is considered the last major office building erected in Chicago before the Great Depression and the World War II construction hiatus, which ended with the building of One Prudential Plaza in 1955.

**Fig. 1.** Field Building

Source: © Peter Niemczak.

Many of the latest innovations, such as high-speed lifts and air conditioning, were incorporated into the building's design. The lobby features a multi-level arcade between LaSalle and Clark Streets, allowing pedestrians to walk between the two streets and access the retail space without exiting the building. The lift indicator panel and mailbox in the lobby are in an integrated design that resembles the building's exterior shape. The building rises from a four-story base that covers the entire site. The exterior of the first story is faced with polished black granite. Windows are framed with polished aluminium or Monel metal and have black and polished aluminium spandrel panels. The entrances on the east and west façades rise the entire height of the base and are also framed in black granite. Five pilasters, clad in white Yule marble, divide the bays featuring revolving doors that serve as entrances to the lobby. The upper levels are covered in limestone, with vertically grouped windows set back to accentuate the building's height. The 45-story rectangular tower is positioned at the centre of the base and is reinforced by shorter 22-story towers at each of its four corners.

Environmental Systems Design, Inc. (ESD) worked on a retrofit of the 1.2 million square feet, 44-story Bank of America building (1934) in Chicago. Improvements included updates to standby and emergency life-safety generation systems. The installation included the required generator and related life safety systems to comply with the 2000 Chicago Electric Code.

The ESD also provided lower tower electrical distribution engineering upgrades, emergency generator design, and other HVAC, plumbing, energy and lift studies and improvements.

The ESD provided LEED commissioning services and detailed retro-commissioning and re-engineering.

The commissioning process produced over $300,000 in annual savings in low-cost, immediate energy conservation measures.

The process also identified long-term energy conservation measures to be implemented as space renovations occur, anticipated to result in additional energy savings of $900,000 per year.

### Chase Tower

Chase Tower (Fig. 2), located in the Chicago Loop area of Chicago, in the US. state of Illinois at 10 South Dearborn Street, is a 60-story skyscraper completed in 1969. At 850 feet (259 m) tall, it is the 14th-tallest building in Chicago, the tallest building inside the Chicago 'L' Loop elevated tracks and, as of May 2022, the 66th-tallest in the United States. JPMorgan Chase has its US and Canada commercial and retail banking headquarters here. The building is also the headquarters of Exelon. The building and its plaza (Exelon Plaza) occupy the block bounded by Clark, Dearborn, Madison and Monroe streets.

**Fig. 2.** Chase Tower

Source: © Peter Niemczak.

The ESD was tasked with creating a plan to revamp and enhance the mechanical, electrical, plumbing, life safety, security and control systems in the 2.4 million square feet Chase Tower. The main aim was to make the renovated building top-notch for the next 50 years by adding new and improved amenities for both the public and tenants, all while cutting down on energy use.

**Willis Tower**

The Willis Tower (originally the Sears Tower) is a 110-story (Fig. 3), 1,451-feet (442.3 m) skyscraper in the Loop community of Chicago in Illinois, United States. Designed by architect Bruce Graham and engineer Fazlur Rahman Khan of Skidmore, Owings & Merrill (SOM), it opened in 1973 as the world's tallest building – a title it held for nearly 25 years. It is the third-tallest building in the Western Hemisphere and the 23rd-tallest worldwide. Each year, more than 1.7 million people visit the Skydeck observation deck (the highest in the United States), making it one of Chicago's most popular tourist destinations. The building occupies a site bounded by Franklin Street, Jackson Boulevard, Wacker Drive, and Adams Street. Graham and Khan designed the building as nine square "tubes" clustered in a 3 × 3 matrix; seven tubes were set back on the upper floors. The tower has 108 stories as counted by standard methods, though the building's owners count the main roof as 109 and the mechanical penthouse roof as 110. The façade is made of anodised aluminium and black glass. The base of the building contains a retail complex known as the Catalog. The tower's lower half was initially occupied by retail company Sears, which had its headquarters until 1994, while the upper stories were rented out.

**Fig. 3.** Willis Tower (Formerly the Sears Tower)

Source: © Peter Niemczak.

The structure was called the Sears Tower from its construction until the naming rights were included in a 2009 lease with the Willis Group. Local area residents still refer to the building by its old name. As of April 2018, the building's largest tenant is

United Airlines, occupying around 20 floors. Other major tenants include the building's namesake, Willis Towers Watson, and law firms Schiff Hardin and Seyfarth Shaw. Morgan Stanley became the building's fourth-largest tenant in 2017.

## WHY EXISTING BUILDING DO NOT RETROFIT?

### Lack of a reliable system for benchmarking and comparing

Buildings use voluntary systems like Energy Star to compare themselves to other structures. Even though Energy Star is still evolving as a tool for unusual occupancy applications, it works best for commercial buildings. It does not discuss how existing structures stack up against current regulations or other structures. As a result, there is minimal rivalry or attention to energy improvement or savings.

### Lenient requirements for existing buildings' energy codes

There is currently no minimum performance criterion for existing buildings, despite energy codes and ASHRAE standards becoming more demanding for new construction. Only significant renovations, and only to a limited extent, are necessary to comply. Requiring older buildings to comply with the new code could pose a significant financial challenge. However, a more practical approach could involve gradually adopting less stringent energy requirements and offering incentives during renovations to enhance the performance of existing structures. Furthermore, there is an emerging trend for publicly funded projects to incorporate mandated energy criteria.

### Payback periods

Energy service companies (ESCOs) and ComEd/ /DCEO incentives can be used to finance projects with short payback periods (usually fewer than 10 years). In comparison, some of these incentives have even faster payback requirements of three to seven years. Longer payback initiatives are frequently avoided due to financial constraints.

### Inability to sub-meter

Individual tenant lighting in business buildings is frequently not metered, and implementing such metering has a significant upfront cost. Additionally, switching from 277 to 480-volt power is frequently necessary.

### Cost transfer to tenants results in a lack of motivation

Large commercial and residential structures frequently use leases or assessments to transfer base building costs onto tenants. Consequently, there is currently minimal motivation to enhance energy efficiency. However, with building occupants becoming increasingly aware of these costs, a more competitive market may eventually favour structures with lower pass-through utility rates.

### Lack of personal and professional commitment and coordination

Some structures lack the benefit of proactive or knowledgeable management and operational employees. Other times, active personnel suggest energy-saving measures but fail to coordinate them with financial attempts to secure funding.

### Lack of corporate support and business community engagement

A lack of corporate support can stall energy-saving projects and investments.

### Financial challenges

Some building owners do not have the resources or credit scores to qualify for the loans required to fund significant energy renovations.

Considerable energy savings projects are frequently too intrusive or large-scale to be paid for as a scheduled capital investment; they are better carried out as part of a more extensive rehabilitation project. However, financing these kinds of projects may prove challenging if credit is not readily available or owners cannot raise the funds necessary to repay sizable debts annually.

### System of comparison and benchmarking that is consistent

Establish a rule requiring existing structures to benchmark their energy consumption intensity.

This approach will aid in pinpointing structures with the greatest potential for energy savings. It will also encourage owners and occupants of underperforming buildings to acknowledge and disclose their energy usage.

## CONCLUSIONS

It is crucial to encourage all buildings to save using existing incentives. However, the energy savings required to meet the targets outlined by the Chicago Climate Action Plan and the 2030 Challenge are too drastic to rely solely on current incentives and building owners' efforts to upgrade. To accomplish these aims, more motivational and leadership strategies will be needed. As a result, the following crucial step is to start a pattern of upgrading buildings downtown based on the 30% savings target by creating groups of buildings to cooperate as pilot projects. Based on the most significant square footage, owners and operators, a critical group of 83 buildings has been determined to construct a pilot project to have the best possible impact in the target area. If this collection of buildings (which account for over 70% of the downtown square footage) can achieve a 30–40% reduction, this will surpass the CCAP's goals. The reduction objective of 8 million mt of $CO_2$ for the target area stated in this chapter is consequently more aggressive than the average level of the citywide CCAP goal, which assumes a 30% energy savings in half of all buildings. The Loop should be a leader in achieving the CCAP targets. Buildings can be grouped into energy districts based on their shared uses, locations or eras as potential options for experimental initiatives. Divining buildings into target districts might make sense to enable smaller, more targeted initiatives. Dividing buildings into target districts could be a sensible strategy to facilitate smaller, more focused initiatives. The savings potential of these pilot buildings is currently being assessed and categorised based on their current performance and the reduction techniques discussed earlier in this chapter. The pilot groups can be improved upon and linked with finance strategies particular to that group of buildings when each building is further investigated, as is covered in the Funding chapter.

It should come as no surprise that Chicago's built environment accounts for about 70% of the city's greenhouse gas emissions, given the estimated 23,000 commercial, institutional and industrial buildings dispersed throughout the city. Decarbonising this industry is, therefore, necessary to help Chicago achieve its aim of lowering GHG emissions.

The nomenclature and categorisation schemes of the International Building Code, along with green building regulations, were integrated into the city's building codes in this update. While updating building codes and initiating community projects can contribute to a reduction in greenhouse gas (GHG) emissions from buildings, achieving a complete elimination may not be feasible. The increasing prevalence of climate change combined with Chicago's growing population means that increasing building energy efficiency is becoming an increasingly important concern, especially in terms of existing commercial buildings. Not only is retrofitting buildings – essential for reducing the city's overall carbon emissions, but it also updates and renovates the existing building stock, allowing many older structures to continue to be profitable for many years. Older buildings will be able to draw new tenants and residents seeking more healthy, comfortable and efficient space once they are upgraded to modern green standards. Auditing, retrofitting and commissioning are the three processes that must be taken to boost the energy efficiency of existing buildings.

### Authors' contributions

Conceptualisation: P.N.; methodology: P.N. and A.S..; validation: P.N.; investigation: P.N.; resources: P.N.; data curation: P.N.; writing – original draft preparation: P.N..; writing – review and editing: P.N. and A.S.; figures: P.N.; supervision: A.S.; project administration: A.S.

All authors have read and agreed to the published version of the manuscript.

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## DLACZEGO BUDYNKI W CHICAGO NIE SĄ MODERNIZOWANE?

### STRESZCZENIE

Budynki i biura na obszarze Chicago należy dostosować do standardów efektywności energetycznej odpowiednich dla XXI wieku, zarówno ze względu na oszczędzanie środków finansowych, jak i redukcję emisji gazów cieplarnianych, która negatywnie wpływa na klimat. W niniejszym badaniu dokonano analizy koncepcji modernizacji o charakterze energooszczędnym, uwzględniając jej główne etapy oraz działania interwencyjne. Zmniejszenie zużycia energii w budynkach przekłada się na wydłużenie ich trwałości oraz redukcję długofalowego wpływu na środowisko naturalne. Stanowi to kluczowy cel modernizacji pod kątem oszczędności energetycznej. Co więcej analiza potencjalnych kierunków przyszłych badań wykazała, że istnieje konieczność przeprowadzenia dokładnej oceny i zbadania potencjału oszczędności energetycznych, związanych z różnymi wariantami i kombinacjami modernizacji. Równie istotnym aspektem będzie przeprowadzenie dokładnej oceny ekonomicznej i środowiskowej integracji tych technologii z obszarami budowlanymi. Obszar Chicago może podjąć się znaczącego zadania polegającego na uczynieniu swojej infrastruktury bardziej efektywną energetycznie dzięki wdrożeniu strategicznej integracji dostępnych zasobów i zastosowaniu istniejącej wiedzy, co przyczyni się do korzyści zarówno ekonomicznych, jak i ekologicznych dla ośmiu milionów mieszkańców tego regionu.

**Słowa kluczowe:** dekarbonizacja, emisja dwutlenku węgla, strategie klimatyczne, modernizacja, Chicago