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WOOD X BUILDINGS

NEW YORK CITY DEPARTMENT OF SANITATION

NYC DDC TOWN +GOWN: NYC

NYC DDC

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Figure 1. Streets of New York (City Neighborhoods, 2026)

GLOSSARY

Term	Definition
ArcGIS	Geographic information system (GIS) software for creating, managing, analyzing, and visualizing spatial data
Archetype; Building class	Classification code assigned by New York City Department of Finance to categorize buildings based on their primary use, occupancy, and structural characteristics for taxation, property assessment, and other administrative purposes
Borough-Block-Lot; BBL	Designated code for each building/property in New York City to identify their locations, used for paying property taxes or completing certain tax or Department of Finance applications; also known as parcel numbers
Brownstone	Row houses constructed during the nineteenth century and characterized by brown-red facade and have unique architectural features, such as ornate facades with elaborate details, tall and narrow structures, and front stoops leading up to the main entrance
Building code	Regulations established by New York City Department of Buildings that govern the design, construction, alteration, and maintenance of buildings to ensure public safety and compliance
Building typology	Building classification based on their form, function, and design characteristics defined by New York City Department of Building
Carbon footprint	The total amount of greenhouse gases that are emitted into the atmosphere annually by a person, building, organization, or company
Circular construction	Sustainable approach to building that prioritizes resource efficiency, waste reduction, and material reuse throughout a structure’s lifecycle by designing buildings for adaptability, using sustainable materials, and implementing closed-loop systems

Term	Definition
Circular design	Ideas that consider a product's end-of-life to ensure its materials are easily recoverable, components are fixable, and the entire structure is built with disassembly in mind, in order to eliminate waste by keeping products, materials, and resources in use for as long as possible
Circular economy	Specific approach within sustainability that minimizes waste and keeps materials and products in circulation for as long as possible to maintain their highest value
Construction and Demolition; C&D	Activities associated with building, renovating, repairing, and destructing structures, including residential homes and commercial buildings, whether conducted partially or in full
Cost-benefit analysis	Data-driven decision-making that compares estimated cost and benefit associated with a project
Eligibility funnel	A methodological framework for identifying buildings most likely to contain recoverable old-growth timber
Embodied carbon	The greenhouse gas emission generated by the manufacturing, transportation, installation, maintenance, and disposal of a product
Geographic information system; GIS	Integrated collection of computer software and data used to view and manage geographic information about places, analyze spatial relationships, and model spatial processes; allows information to be displayed and analyzed
Greenhouse gases; GHG	Gases in the atmosphere that traps heat near the Earth's surface, thus causing average global temperature to rise significantly
Life-cycle Assessment; LCA	Systematic method for quantifying and evaluating the environmental impact associated with a product across all stages of its life cycle
Mid-rise residential building	Residential building typology characterized by medium-height structures, approximately 5 to 12 stories
New York City Department of Building; DOB	New York City government agency that regulates construction, enforces building codes and zoning laws, and ensures the safety of all buildings in the city
New York City Department of City Planning; NYC Planning	City agency that is responsible for the strategic development, land use, and zoning of New York City

Term	Definition
New York City Department of Design and Construction; DDC	New York City government agency responsible for managing capital construction projects of both new and renovated public facilities, e.g., firehouses, libraries, police precincts, courthouses, senior centers
New York City Department of Sanitation; DSNY	Municipal agency responsible for maintaining public cleanliness, safety, and health through waste collection, recycling, disposal services, and street cleaning operations
New York State Department of Environmental Conservation; NYSDEC	State-level agency that protects and enhances New York's natural resources and environment through the regulation and management of water, land, and air quality
Old-growth wood	Timber harvested from mature trees that developed over several centuries under natural forest conditions
Primary Land Use Tax Lot Output; PLUTO	Extensive land use and geographic data files at the tax lot level, provided by New York City Department of City Planning (NYC Planning); contains more than seventy fields derived from data maintained by New York City agencies
Python	Open-source programming language used for data processing, quantitative analysis, computational modelling, and visualization
Quota Acts	Collective term for the Emergency Quota Act of 1921 and the Immigration Act of 1924 which set specific limits on the number of immigrants admitted to the United States each year
Reclaimed wood	Wood salvaged from existing structures and reuse in new construction, architectural, or design purposes
Rowhouse	Residential buildings that formed as a continuous row of attached houses that share common side walls
Structural wood	Refers to wood used as a load-bearing component in a building, including elements such as beams, joists, columns and framing
Tenement	Row houses that had been converted from single-family dwellings that were later converted into narrow, low-rise multifamily apartment buildings
Tenement act	Regulation for multi-family housing in New York City that introduces minimum standard regarding sanitation, ventilation, and fire safety

Term	Definition
Virgin forest	Forest ecosystem that has developed under natural conditions without significant human disturbance and is characterized by mature, original tree growth
Wood intensity factor; WIF	Percentage of estimated structural wood in a building compared to its floor area using a defined system boundary of key components consists of beams, joists, and columns that make up the frame
Zoning and Land Use Application; ZoLa	Web-based GIS application maintained by New York City Department of Planning and New York City Department of Information Technology and Telecommunications, that provides zoning and related information for New York City, including address, borough, block, and lot (BBL), intersection, and place of interest
.csv	comma-separated values; plain text file format for structuring text that uses a comma to mark where one value ends and another begins
.fgdb	Spatial database format used to store, manage, and organize large collections of geospatial datasets within a single database structure
.shp	Geospatial vector data format to store the location, shape, and attributes of spatial features

EXECUTIVE SUMMARY

New York City (NYC) is made up of five boroughs: Manhattan, Brooklyn, Queens, The Bronx, and Staten Island. It contains a dense and aging building stock that represents a largely untapped source of recoverable materials. While construction and demolition (C&D) activity generates approximately 5.3 million tons of material flows each year, current practices prioritize rapid demolition and disposal, resulting in the loss of potentially high-value materials and contributing to landfill and greenhouse gas (GHG) emissions. This project focuses on repositioning buildings as "material banks," with a specific focus on old-growth wood as a case study for advancing circular economy implementation at a citywide scale.

In collaboration with Town+Gown: NYC, the Urban Resource Recovery Working Group, the New York City Department of Sanitation (DSNY), and the New York City Department of Design and Construction (DDC), this research develops a proof-of-concept methodology to estimate the quantity and distribution of old-growth wood within New York City's building stock. The goal is to create a replicable and scalable framework that can inform policy, planning, and investment decisions while simultaneously serving as a foundation for expanding similar methodologies to other material streams.

The analysis began with publicly available datasets, primarily NYC PLUTO and ZoLa, which provide parcel-level information on building characteristics such as age, size, use, and typology. These datasets were supplemented by a literature review, historical construction analysis, and stakeholder interviews to identify the relationship between specific building attributes and the likelihood of containing old-growth wood.

This study focuses on buildings six stories and below, constructed primarily before 1938, aligning with historical construction practices that relied heavily on timber framing prior to the widespread adoption of steel and reinforced concrete systems, which began at the end of the 19th century. While this approach provides a strong proxy for identifying material presence, it does not confirm structural composition at the individual building level. As such, results should be interpreted as indicative rather than definitive, forming a screening tool and estimation.

The methodology applies an “Eligibility Funnel” to progressively narrow the full building dataset into a subset of high-probability candidates. Using PLUTO and ZoLa, buildings are filtered based on construction era, number of floors, and building class or archetype to isolate typologies most likely to contain structural timber. This process is implemented using spreadsheet modeling and GIS-based analysis (ArcGIS), enabling both quantitative estimation and spatial visualization.

The quantification process utilized a “Wood Intensity Factor” (WIF) tailored to the specific building typologies. The WIF represents the ratio of estimated wood volume to total floor area for a representative building within each typology. By applying these specific intensity factors to the cumulative floor area of identified building classes, the study provides a scalable estimate of available timber across the urban landscape.

The analysis indicates that all five boroughs in New York City contain a substantial and geographically distributed stock of embedded old-growth wood, concentrated in primarily low-rise residential buildings, walk-up apartments, and certain industrial typologies such as warehouses. Our estimate suggests that 147 million cubic feet of structural wood may exist within eligible buildings, representing a significant opportunity for material recovery.

This volume of material contains approximately 3.7 million metric tons of carbon dioxide, a carbon stock comparable to a forest three times the size of Manhattan. Retaining this wood prevents decomposition emissions and reduces the overall demand for virgin timber. Deconstruction introduces a complementary economic dimension. Unlike demolition, current practices depend on labor intensive material recovery, creating skilled jobs while supporting local processing and reuse markets. At scale, this could generate thousands of new local green jobs and tens of millions of dollars in direct economic activity. Together, these outcomes position wood recovery, as both a practical emissions reduction strategy and a foundation for a localized circular economy.

Based on the model's results and supporting literature, it is recommended that the city look to three primary strategies. First, the city should validate the model against empirical data to ensure long-term accuracy. Second, the city must expand the systematic infrastructure required to support deconstruction, with a focus on strengthening secondary markets. Finally, the city should streamline the development of a specialized workforce to ensure the recovery process remains cost-effective and yields the highest material returns.

01.INTRODUCTION

1.1 BACKGROUND

New York City is home to 8.5 million people and over 1 million buildings. (NYCEDC, 2024). While often defined by its skyline, much of the city consists of low- to mid-rise residential buildings, such as rowhouses, brownstones, and tenements; over half of these (55%) were built before 1938. Each year, approximately 2,000 buildings are demolished across the five boroughs (NYCDOB, 2025).

Figure 2. Collage (Urban Omnibus, 2016)

This cycle of construction and demolition generates over 5 million tons of material annually, a significant share of the city's waste stream. At the same time, New York City’s building stock is responsible for almost 70% of its total greenhouse gas emissions (NYCEDC, 2024). Globally, these carbon emissions account for 40%, with materials and construction contributing 13%.

To date, the primary focus has been on reducing operational emissions from heating, cooling, and lighting. Increasingly, attention is shifting towards embodied carbon. Supported by groups such as NYCEDC’s Mass Timber Studio, this encompasses emissions from material extraction, processing, and assembly of key materials, such as concrete, steel, and wood.

Many older buildings in New York City contain structural timber harvested during periods of rapid urban expansion in the mid-to-late 19th and early 20th centuries. Although this wood remains embedded within the city's existing building stock, it is often lost when buildings are demolished and is treated as waste rather than a retained usable resource. In 2024, New York City Department of Buildings (DOB) issued over 100,000 permits for construction projects, the highest total in five years, while initial permits for new building projects increased by more than 24% over the previous year (NYCDOB, 2024). Recovering wood from existing buildings presents an opportunity to reduce waste, lower demand for new resources, and avoid emissions associated with both disposal and production.

1.2 PROBLEM IDENTIFICATION

While some municipalities across the country have adopted or tested deconstruction policies, New York City and State do not yet have a comprehensive ordinance or mandate. As a result, most demolition activity continues to prioritize speed and cost over material recovery. Existing construction and demolition systems remain largely linear, with limited infrastructure dedicated to salvage, processing, storage, and redistribution of reusable building materials.
Without reliable estimates of material availability, it becomes difficult to evaluate the feasibility of large-scale reclamation systems, develop supporting infrastructure, or inform future policy and investment decisions.

1.3 CARBON MITIGATION FRAMEWORKS IN NEW YORK CITY

The Clean Construction Executive Order (EO23) was signed into law by the Mayor Adams Administration in 2022. This legislation builds on the city's embodied carbon reduction target by mandating that city projects adopt practices that reduce emissions, such as requiring whole project life-cycle assessments (LCA), promoting low-emissions construction vehicles, and encouraging material reuse. Although the order does not directly address salvaged wood, the city is clearly working toward greater material reuse, and these practices will result in increased adoption of salvaged materials and greater demand for low-carbon options. Additionally, the city joined the C40 Clean Construction Accelerator in 2023, a coalition of eight global cities committed to decarbonizing the building and construction industry (NYCMOCEJ, 2022).

To address this growing waste problem, DSNY recently developed a Draft Solid Waste Management Plan (2026–2036). This ten-year framework aims to reduce the agency's carbon footprint (McDonnell & Kitchner, 2016). In the document, DSNY assesses its current management practices, identifies more sustainable alternatives, and outlines an implementation plan. It also establishes eight main targets, one of which is C&D waste. This focus area describes how DSNY aims to implement EO23, expand the inclusion of construction and demolition waste in the circular economy, and divert materials from landfills, including the recovery of wood.

Statewide, the New York State Department of Environmental Conservation (NYSDEC) promotes adaptive reuse and the utilization of salvageable materials, with the agency including a reuse locator tool on its website. The agency emphasizes the importance of repurposing salvaged materials in new construction and renovations, and has published guidance on proper deconstruction. Before deconstruction occurs, NYSDEC recommends that a detailed assessment of the building be performed to determine what materials can be salvaged, and after these materials are removed, they can be transported to a storage facility to be sold and used for new developments (NYSDEC, 2024). In terms of state legislation, the Beneficial Use Rule (6 NYCRR 360.12) states that if waste materials can be used productively, they may no longer be legally considered garbage. In order to comply, the recovered material, such as wood, cannot be contaminated, meaning it must contain no lead, asbestos, or chemical waste (N.Y. Comp. Codes R. & Regs. tit. 6, § 360.12, 2023).

1.4 POLICY LANDSCAPE: ENABLING A CIRCULAR ECONOMY IN THE BUILT ENVIRONMENT

The transition toward a circular economy in New York's built environment is beginning to take shape through a set of complementary policy developments that address material recovery, reuse, and design. As stated above, while current systems largely treat C&D debris as waste, emerging legislation and guidance signal a shift toward recognizing buildings as material banks of recoverable value.

Assembly Bill A3029

This bill, sponsored by Assemblywoman Anna Kelles, aims to enable the structural reuse of deconstructed materials by directing the State's Uniform Code to establish standards for reclaimed lumber, including grading and assumed structural properties. The policy directly targets the code and liability constraints that currently limit reclaimed materials to non-structural or niche uses. By standardizing grading assumptions, the legislation would effectively transform reclaimed wood into a code-compliant input rather than a waste byproduct.

Senate Bill S8168

Sponsored by Senator Brian Kavanaugh, this bill shifts how C&D materials are managed by emphasizing diversion, recovery, and reuse rather than disposal. While not exclusively a deconstruction mandate, it establishes the policy basis for increasing recovery rates and reducing landfill dependency. It is supported in parallel by legislation such as A8637, which seeks to expand reclaimed material use by addressing market barriers to reuse and pushing a system centered around material recovery.

At the City level, the New York City Economic Development Corporation (NYCEDC) Circular Construction Guidelines embed circular economy principles into capital projects, including material reuse, life-cycle carbon assessment, and design for disassembly. These guidelines help shift circularity upstream, which positions material recovery not as an end-of-life consideration, but as a design constraint and opportunity at the early stages of project development.

For example, the SPARC Kips Bay Master Plan, led by NYCEDC, will redevelop the Hunter College Brookdale campus into a life sciences and health care hub with more than two million square feet of new academic, clinical, and research space. The project alone is expected to generate approximately 12,000 construction jobs and $42B in long-term economic output (NYCEDC, 2023), making it one of the largest public developments in New York City. This scale creates significant material demand and embodied carbon, while also providing a clear opportunity to integrate circular construction practices.

Figure 3. SPARC Kips Bay Construction Plan (NYCEDC, 2023)

The phased redevelopment of an existing campus allows for selective deconstruction and material recovery, while new construction can incorporate reclaimed materials and prioritize assemblies designed for future disassembly. As a publicly led project, SPARC provides a direct and immediate opportunity to apply circular design at scale, reducing waste and emissions while establishing a precedent for future development.

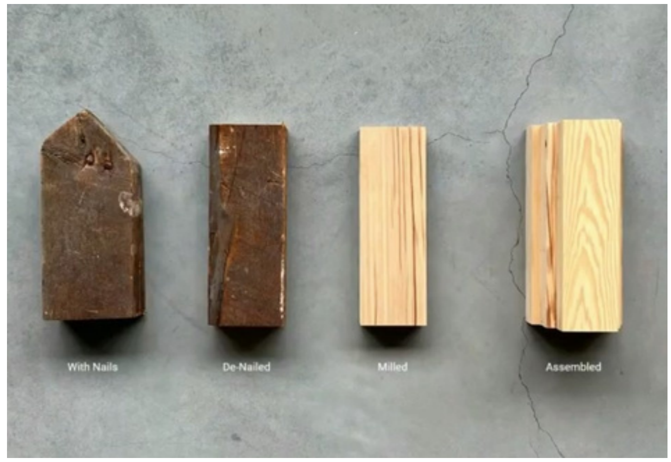
1.5 HOUSING DEVELOPMENT PRIORITIES UNDER THE NEW ADMINISTRATION

With a new administration focused on increasing housing stock while incorporating sustainable design principles, there are new opportunities to repurpose salvaged old-growth wood in real estate and renovation projects. The recently announced social housing expansion program will result in the building of 200,000 new affordable units, with four projects already approved as of April 2026. The administration also plans to reinstate the "Just Home" supportive housing project, providing formerly incarcerated individuals with housing, while also investing heavily in New York City Housing Authority (NYCHA) repairs (NYC Mayor’s Office, 2026). All of these projects will require substantial amounts of building materials, and integrating salvaged materials may offer a lower-carbon approach to construction.

1.6 RESEARCH OBJECTIVES

This study develops a proof of concept methodology to estimate the quantity and geographic distribution of reclaimable old-growth wood contained within New York City's existing building stock. Using publicly available datasets, the research identifies building typologies and construction eras most likely to contain structural timber and estimates the potential volume of recoverable material at the parcel, neighborhood, and citywide scale. The methodology is intended to serve as a replicable framework that can later be adapted to quantify other construction and demolition materials.

Figure 4. Life Cycle of Reclaimed Wood
(CO Adaptive, 2026)



Beyond quantification, the study evaluates the broader systems required to support material recovery and circular construction in New York City. Identifying reclaimable wood is only one component of a functioning reclamation ecosystem. This also depends on coordinated processes for deconstruction, sorting, transportation, storage, reprocessing, inventory management, and resale.

Additionally, this research investigates the downstream applications and market potential of reclaimed wood, including opportunities for adaptive reuse, interior finish applications, furniture, and emerging structural reuse practices. Particular attention is given to how reclaimed wood may reduce embodied carbon, divert waste from landfills, and offset demand for virgin construction materials.

This study is intended to contribute preliminary research that may support future municipal policy, regulatory development, and circular construction guidance within New York City. Findings aim to provide policymakers, agencies, and industry stakeholders with an initial framework for understanding the scale of recoverable material embedded within the city and the infrastructure necessary to support a more circular construction economy.

02.LITERATURE REVIEW

Identifying old-growth wood for reclamation in New York City raises fundamental questions: What is old-growth wood exactly? Does the industry use specific standards or constraints to define it? How fungible are the constraints that define the material? Are these definitions functional, characteristic-based, or qualitative? Next, there was a series of questions around how the wood could possibly be identified, what methodologies would be useful, and whether similar projects had been undertaken. Has a different city tried an approach targeting old-growth wood specifically (as opposed to all wood) as a material? Were there existing successes or failures that could be leveraged to build our methodology or approach?

To narrow the broad field of city policy, industry requirements, and technical definitions down into a workable landscape, a significant literature review was undertaken. This review spanned peer-reviewed articles, historical documentation, industrial white papers, and a series of informational interviews with current industry professionals. It establishes the technical and credible framework for the report’s methodology and feasibility strategies. The appendix contains all materials reviewed in their totality for easy reference.

2.1 DEFINING OLD-GROWTH WOOD

Old-growth wood refers to timber harvested from trees that have matured over several centuries under natural forest conditions. In the forests that supplied early urban development in the northeastern United States, trees commonly reached ages of 500 to 1,000 years before harvest (RE Store, 2021), in contrast to modern construction lumber, typically sourced from trees grown and harvested within 25 to 35 years (Domel, 2015). This extended growth period is the primary determinant of the material properties that distinguish old-growth wood from contemporary lumber.

Figure 5. Old-growth Wood (left) and Modern Wood (right)

Standardized lumber dimensions changed over time as milling, kiln drying, and transportation economics and national sizing standards pushed framing members toward smaller finished dimensions. As a result, the nominal 2x4 no longer reflects its actual size, which was standardized at 1.5x3.5 by the mid 20th century (Curtis, 2018).

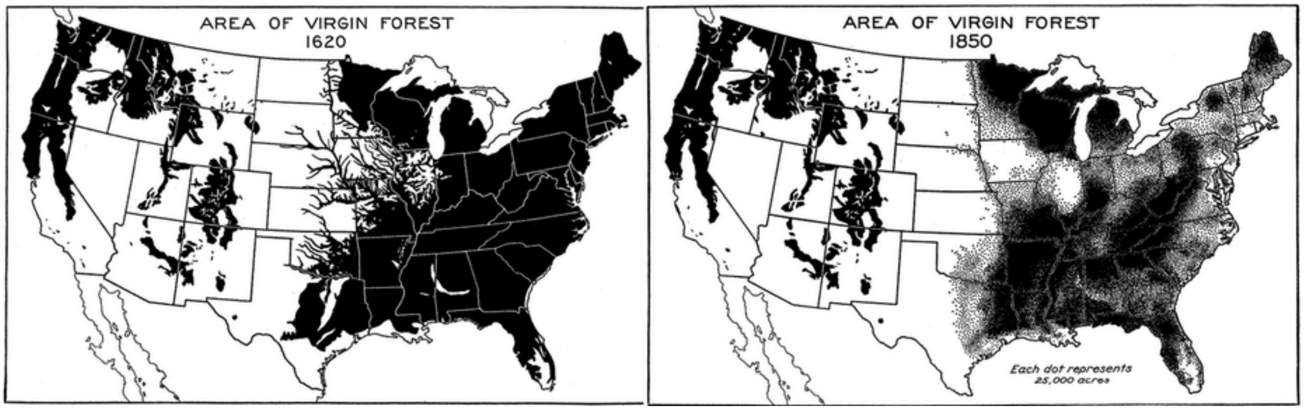
The prolonged growth cycle produces wood with tightly spaced annual rings and a high proportion of dense latewood (see Figure 5), resulting in greater strength, dimensional stability, and resistance to environmental degradation. Unlike modern fast grown lumber, which is more susceptible to warping, shrinkage, and reduced structural performance, old-growth timber maintains integrity over long periods of time. These characteristics made it particularly well-suited for structural applications, including beams, joists, and floor systems that were expected to perform reliably under sustained load and variable environmental conditions.

2.2 SCALE AND ORIGIN OF THE WOOD IN NEW YORK CITY BUILDINGS

The largest repository of old-growth wood in the Northeastern United States is embedded in New York City's buildings, according to Mukund Palat Rao, scientist at Lamont-Doherty Earth Observatory's Tree Ring Lab at Columbia University (Duncombe, 2023).

At the time of early European settlements in the 1600s, the United States had approximately 820 million acres of forest, representing nearly 50% of the country's total land area (Greeley, 1925). Historical and contemporary analyses indicate that, although forest clearing began in the 1700s and early 1800s, large-scale deforestation significantly accelerated with industrial expansion in the mid-1800s (see Figure 6).

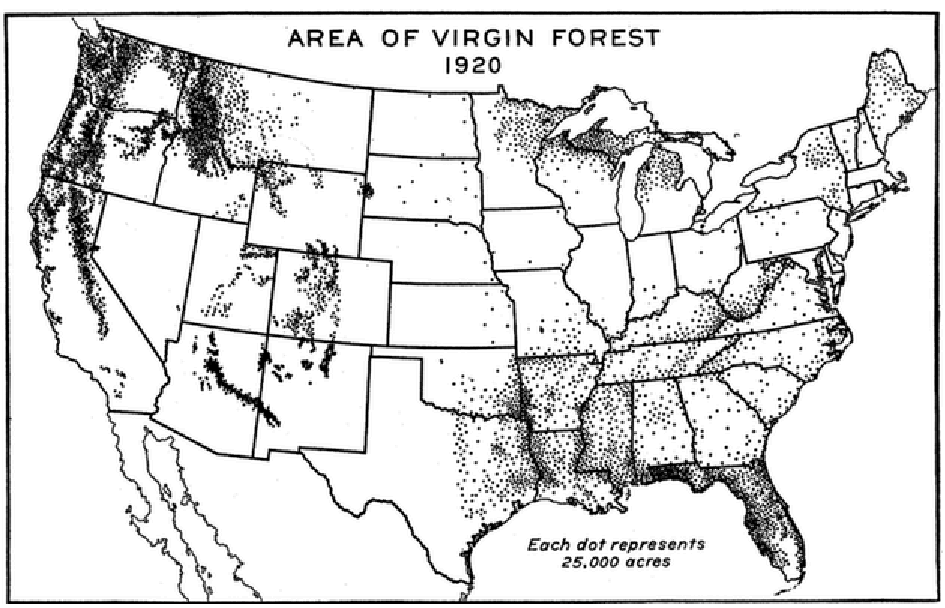
Figure 6. Virgin Forest Cover in the United States: 1620 (left) to 1850 (right)



Note: By 1850, approximately 200 million acres, nearly 25%, had been cleared, marking a shift in land use and timber availability (Greeley, 1925).

By 1920, the area of remaining virgin forest in the United States had declined to 138 million acres (See Figure 7), representing roughly 17% from pre-colonial levels (Greeley, 1925). Taken together, these maps of the virgin forest cover highlight not only the scale and speed of forest depletion but also the transition from abundant, locally sourced timber to increasingly scarce and geographically distant supplies. This shift is evident in the long-distance timber supply networks reflected in New York City’s building stock (Krajik, 2021; Leland et al, 2021).

Figure 7. Virgin Forest Cover - 1920



Note: In 1920, the amount of virgin timber in the United States was estimated at 1.6 trillion board feet (Greeley, 1925).

Figure 8. Lumber Prices Relative to Production and Consumption

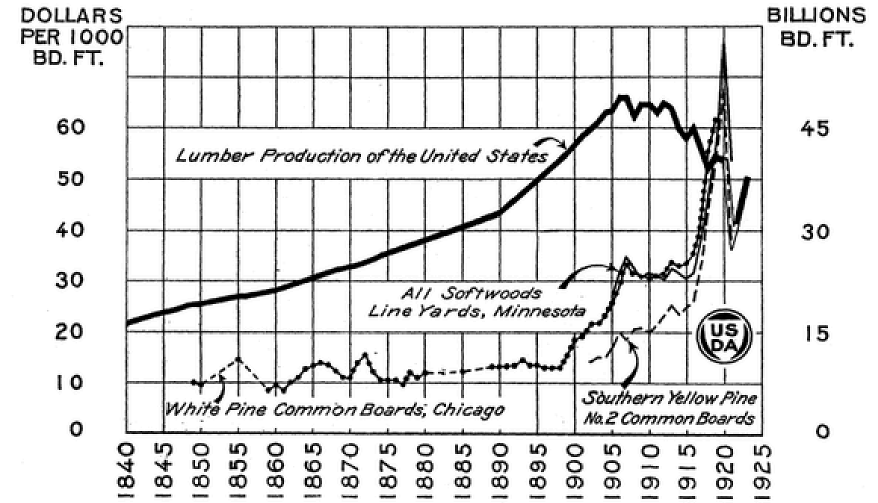


FIGURE 13.—The United States still has mills and timber capable of producing a cut equal to that of 1907; but prices of lumber are now so high and transportation so costly that the consumer cannot afford to buy as much lumber as he once did. (Chart adapted from 1922 Yearbook, U. S. Dept. of Agriculture.)

Note: As the more accessible virgin forests were rapidly depleted, the transportation of timber became increasingly dominated by railways. This resulted in longer hauls and a steady increase in average retail prices (Greeley, 1925).

Taken together, historical and economic analyses demonstrate a clear linkage between large-scale deforestation, rising timber prices, and the gradual substitution of alternative construction materials (Greeley, 1925; Krajik, 2023).

2.3 DRIVERS OF CONSTRUCTION AND MATERIAL USE IN NEW YORK CITY, 1800S-MID-20TH CENTURY

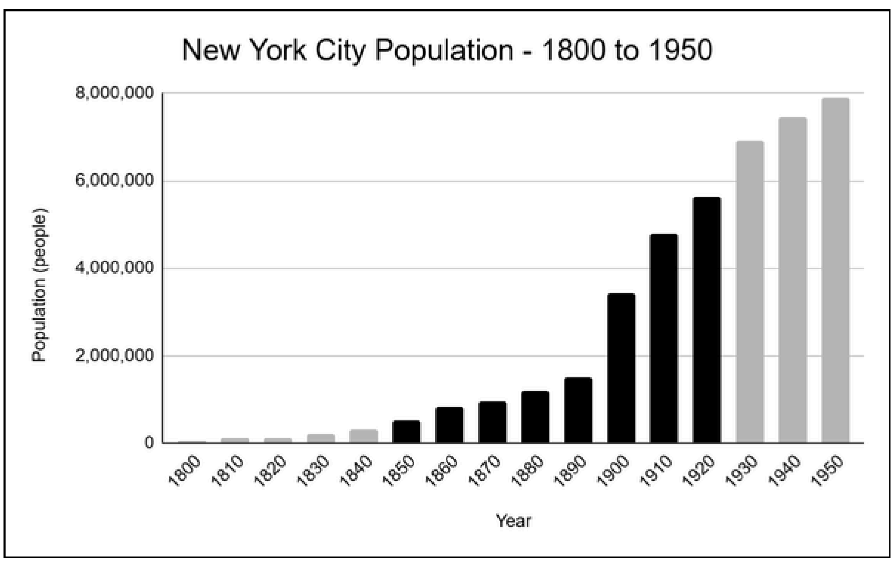
Despite the common perception of New York City as a landscape dominated by skyscrapers made of steel, glass, and concrete, the majority of its building stock is made up of low- and mid-rise structures that contain wood as a major structural component. Fewer than 1.5% of New York City's approximately one million buildings exceed seven stories, while over 95% are constructed with wood-frame or masonry-and-wood systems (Bergsagel & Lynch, 2019). The use of wood in the New York City building stock is not incidental but the result of a set of interacting historical forces that both enabled and constrained its application.

Rapid population growth and the need for dense, affordable housing favored wood as an abundant and inexpensive structural material. At the same time, repeated urban fires and evolving building regulations discouraged wood exterior construction and led to a transition toward masonry and brick exteriors with timber-framed interiors. The gradual introduction of alternative materials and technologies, such as steel, concrete, and the invention of the elevator, reshaped construction practices in the city over time. Together, these forces shaped both the use of structural wood and its evolving role in building construction. The following sections examine these drivers in turn.

Population Growth and Housing Demand

The building and architectural history of New York City is closely linked to the growth of its population. The first European settlers were the Dutch, and they arrived in the 1620s. During this period of early colonization, population growth was slow but steady (Krajick, 2021). In the 19th century, successive waves of European immigrants drove a period of rapid expansion. Between 1850 and 1920, New York City's population grew more than tenfold, from 500,000 to over 5 million (see Figure 9). This period of sustained growth was ultimately curtailed by the Quota Acts of 1924, which sharply restricted immigration from southern and eastern Europe.

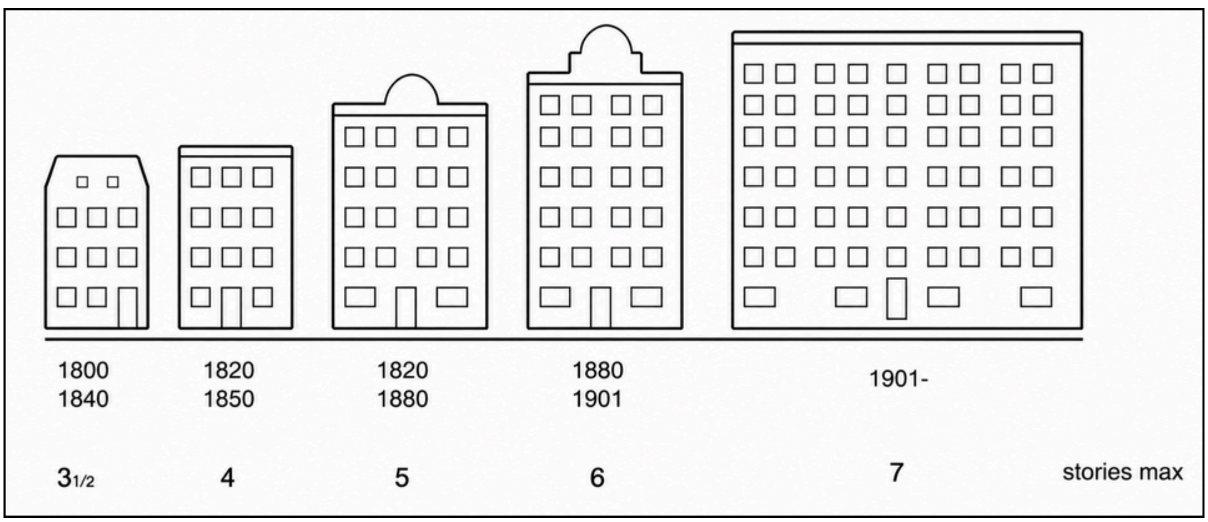
Figure 9. Rapid Population Growth - 1850 to 1950



Note: The graph above summarizes the results of the decennial censuses conducted between 1840 and 1950 (over a 100-year period), showing an upward trend in population growth, with the most significant increase beginning in the early 20th century (Gibson, 1998).

To accommodate its rapid growth in population, New York City was forced to expand quickly. Meeting the housing needs of millions of new residents required the construction or expansion of vast numbers of residential buildings. During this period, buildings that had once been single-family dwellings were increasingly divided into multiple living spaces to accommodate the growing population. Tenement buildings became the dominant housing typology for the working class. Many of these buildings were concentrated in and around the Lower East Side area and provided housing, albeit with minimal consideration for light, ventilation, or safety. By 1900, some 2.3 million people (a full two-thirds of New York City's population) were living in tenement housing (History Channel, 2010). As illustrated in Figure 10, the massing and form of tenement buildings evolved over time in direct response to successive building code reforms. These regulatory changes, which will be discussed later in this chapter, reshaped building layouts to address concerns around density, light, air circulation, and fire risk, producing distinct typological phases over time.

Figure 10. Typical Massing For Tenement Buildings Over Time



Note: By the 1830s, In addition to residential buildings, many other buildings were erected – including warehouses, office buildings, houses of worship, and schools, to name a few – to support the burgeoning economy and population (Marcum, 2022).

While the time of cramped tenement buildings is in the distant past, the current building stock suggests that they are still relevant today. Rather than being systematically replaced, many of these structures have persisted, often modified but structurally intact, particularly in neighborhoods such as the Lower East Side and East Village, where historic district designations have allowed them to withstand the test of time. (NYCLPC, 2012; Marcum, 2022). As a result, the fire risks, material constraints, and structural characteristics associated with these systems continue to shape both the performance and the management of New York City's buildings today (Howe, 2014; Krajick, 2021).

Fire Risk and Material Constraints

Fire posed a constant threat in densely built environments such as New York in the 18th and 19th centuries. The three great fires of 1776, 1835, and 1845 collectively transformed the city's approach to construction by exposing the vulnerabilities of wood-based urban development, catalyzing investments in infrastructure and fire-resistant materials, and validating early regulatory efforts such as fire limits.

Figure 11. Great Fire of 1776 Illustration

Note: On September 21, 1776, a tavern on Whitehall Street caught fire. The patrons were unable to stop the fire, and soon it raged, spreading to the west side of Manhattan (Bowery Boys, 2021)

These three great fires illustrate a critical transition in New York City's building practices. While the shift from all-wood to brick-and-wood construction reduced the likelihood of large-scale urban fires, it did not eliminate underlying vulnerabilities, as timber remained widely used in interior structural systems. As a result, fire risk was mitigated but not resolved, setting the stage for more systematic regulatory interventions through building codes in the late 19th and early 20th century (Howe, 2014; Krajick, 2021).

Building Codes and Regulatory Evolution

The evolution of building codes in New York City reflects the gradual efforts to manage risks associated with the use of wood in construction without fully displacing it as a primary material (See Figure 12). Building codes evolved over time and addressed safety and health in stages.

Tenement House Law of 1867. The Tenement House Act of 1867 represents the first formal attempt to regulate multi-family housing conditions in New York City. The law established a legal definition for tenements and introduced minimum standards for sanitation, ventilation, and fire safety (Plunz, 2016; Tenement House Committee, 1895).

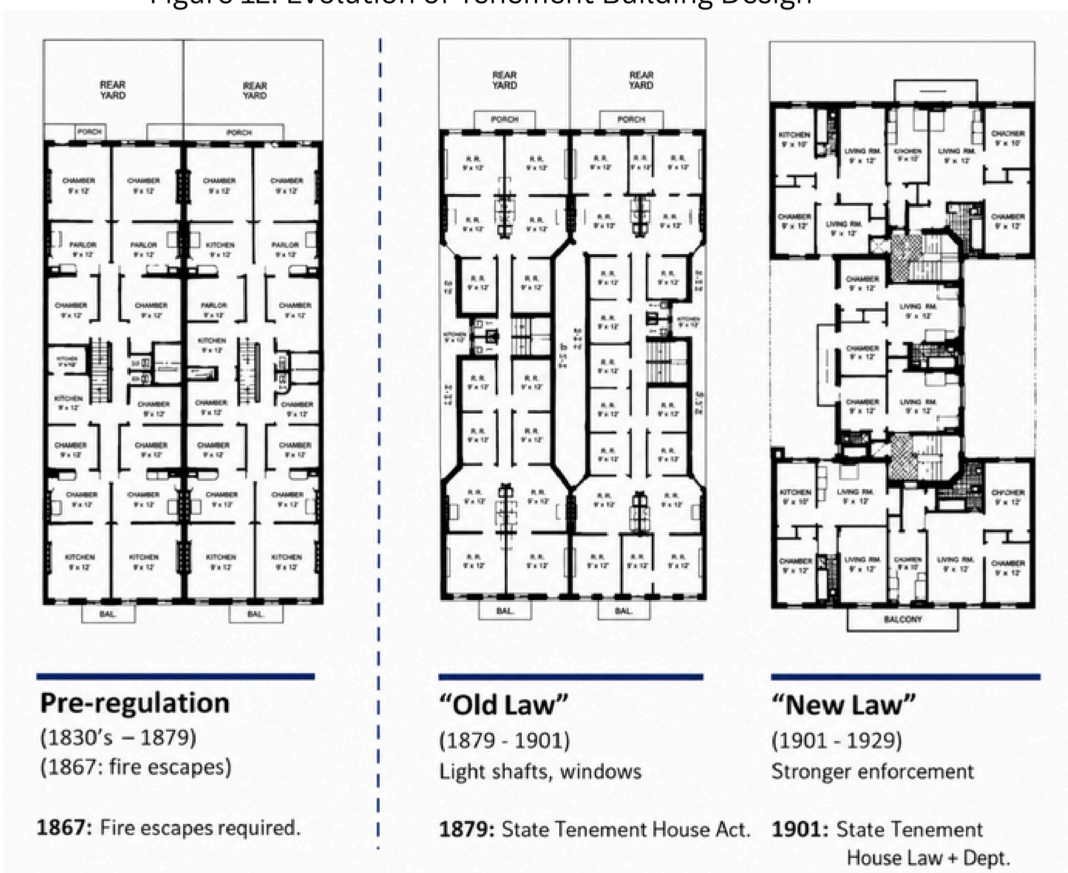
With the passage of this law, fire escapes were installed on exterior facades to provide an alternative means of exit in the event of fire, reflecting growing concern over the risks associated with densely occupied buildings constructed with combustible interior materials (Plunz, 2016; Tenement House Committee, 1895). However, these measures were limited in effectiveness, as they did not address the underlying fire risk associated with wood interior systems or the role of stairways and interior layouts in facilitating fire spread (Fryer, 1901; Plunz, 2016). As a result, while the 1867 law marked an important step in recognizing fire safety as a regulatory issue, it did not fundamentally alter construction practices or materially reduce fire risk (Howe, 2014; NYCLPC, 2012).

Tenement House Law of 1879 - The Old Law (1879 to 1901). The Tenement House Law of 1879, commonly referred to as the “Old Law,” expanded earlier regulatory efforts by introducing requirements for improved light and ventilation, most notably through the use of air shafts. These provisions led to the widespread adoption of the “dumbbell” tenement form, which attempted to bring light and air into interior rooms (NYCLPC, 2012; Plunz, 2016). While the Tenement House Act marked a shift in public health governance, it had a limited impact on construction materials.

Tenement House Law of 1901 - The New Law (1901 to 1929). A more substantive regulation came into effect in the early 1900s called the Tenement House Law of 1901, commonly referred to as the “New Law.” While the law is often associated with improvements in light and ventilation, it also introduced targeted fire safety requirements that began to reshape material used in critical building components.

In fact, the first chapter in the laws is titled, "Protection from Fire", perhaps signaling its importance over the other chapters: Light & Ventilation as well as Sanitation Provisions. As part of the fire protection measure, the law imposed fireproof construction requirements in areas most vulnerable to fire ignition and vertical fire spread. For example, openings between stairways and adjoining spaces were to be protected with self-closing fireproof doors, reflecting an understanding that stair shafts acted as primary conduits for vertical fire spread (Fryer, 1901).

Figure 12. Evolution of Tenement Building Design



Note: The evolution of New York City Tenement House Laws reflects the incremental changes to regulate multi-family housing in New York City with minimum standards for sanitation, ventilation, and fire safety (Marcum, 2022).

1916 Zoning Resolution. The 1916 Zoning Resolution in New York City was the nation's first comprehensive zoning law and represented a major shift in urban regulation. It was the first comprehensive framework to control building height, bulk, and land use in the city. It introduced required setbacks and limited lot coverage to address growing concerns over overcrowding and the loss of light and air in dense urban areas. The law fundamentally reshaped building forms and massing (Barr, 2016).

Although the resolution was not directly concerned with construction materials, it had important indirect effects on residential development. By regulating building size and configuration, it influenced interior layouts and reduced some of the extreme density associated with earlier tenement forms.

New York City building codes progressively redefined where and how wood, a highly combustible material, could be used. Wood remained the dominant material in much of the residential building stock due to its cost and availability, but was increasingly restricted or supplemented with fire-resistant materials in high-risk areas, such as stairwells and points of egress. Over time, this hybrid regulatory framework facilitated a gradual transition toward more fire-resistant construction in certain building types, particularly larger and taller structures.

Broader Material Innovation

Steel framing and the elevator were part of a broader wave of material innovation during the turn of the 20th century and into the 1950s. Advances in metallurgy and structural engineering expanded the range of building materials to include stainless steel, monel metal, and aluminum. At the same time, traditional materials, such as brick, terracotta, tile, and stone, benefited from industrialized production methods and became more consistent, more affordable, and available in a wider variety of forms. Concrete, in particular, experienced the most rapid growth during this period, emerging as a versatile and increasingly dominant construction material (Jester, 2014).

Declining material costs, technological innovation, and industrialized production fundamentally reshaped construction practices in urban centers. These changes not only enabled taller buildings, but they also shifted the relative importance of traditional materials, reducing the reliance on structural wood in favor of steel. The changes coincided with rising lumber prices due to scarcity, further reinforcing the move toward substitution.

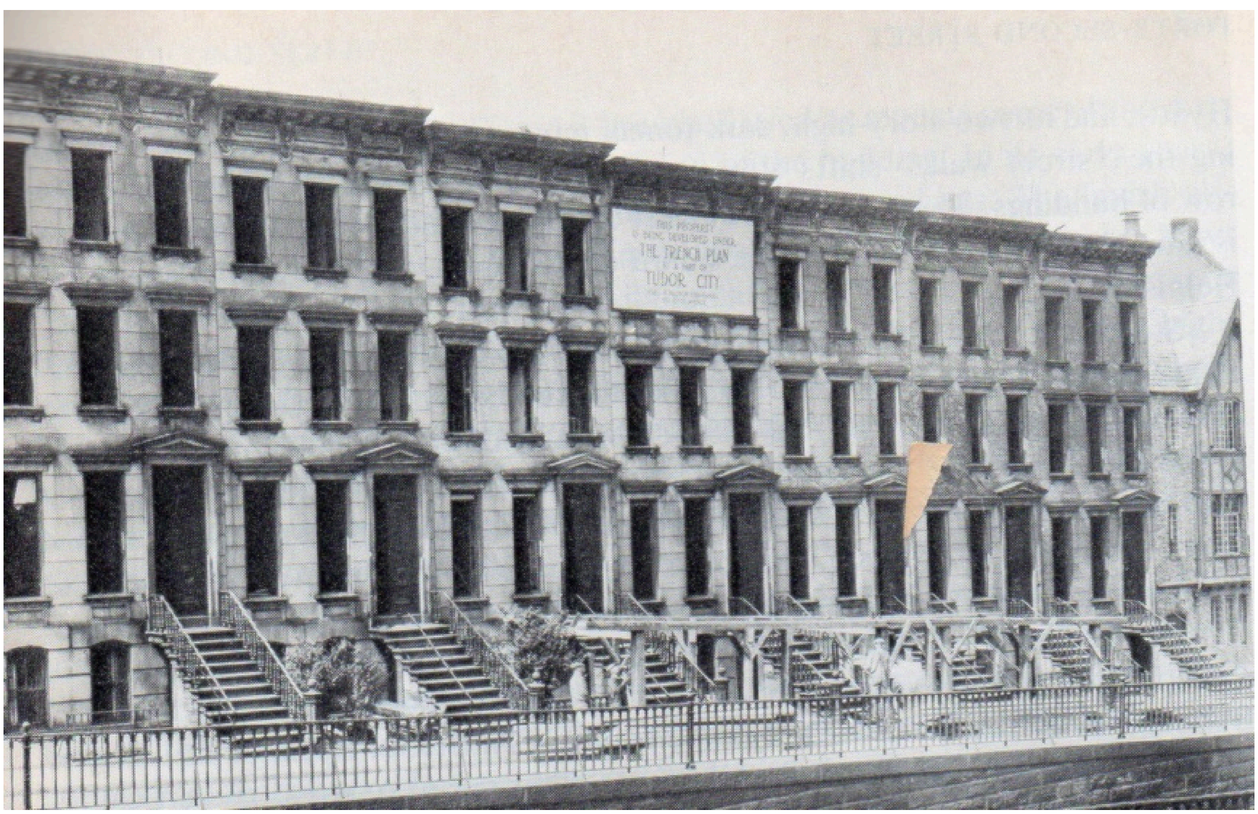
It is important to note, however, that these material and technological shifts were not uniform across all building types. Different typologies, such as tenements, brownstones, warehouses, and commercial buildings, adopted new materials and construction methods at varying speeds and in different ways. Understanding how these transitions manifested across building types is critical to assessing patterns of wood use in the New York City building stock, as will be discussed in the next section.

2.4 EVOLUTION OF BUILDING TYPOLOGY AND WOOD USE

Brownstones and Row Houses

While commonly referred to as “brownstones,” these buildings are part of the broader row house typology, an important form of 19th-century residential construction in New York City. These three-to-five floor structures were tall and narrow, and therefore, well-suited to dense urban centers. They combined masonry exterior walls and wood interior structural systems, including joists, beams, and floor framing (NYCLPC, 1969). The term “brownstone” refers specifically to the name of the sandstone used on the facade, which came from Connecticut and New Jersey and had a reddish-brown color from the presence of iron oxide in the rock (Hassan, 2023).

Figure 13. Historic Brownstone Row Houses (Ephemeral New York, 2025)



Initially developed as single-family homes for New York City's upper class, brownstones were associated with wealth and status. Although more affordable than some alternatives, they remained relatively expensive compared to other housing options of the period and were highly desirable to the city's growing upper class (Hassan, 2023). The precise origins of the first brownstone residences remain uncertain. However, a 1926 New York Times article, written at a time when brownstones were already perceived to be in decline, attributed their early development to a group of row houses constructed in the late 1830s on an unnamed block in Chelsea (Young, 1926). As the city's population grew in the 1840s and 1850s, brownstones became increasingly common in upper- and middle-class neighborhoods such as Greenwich Village, Madison Square, and Murray Hill (Ephemeral New York, 2025).

Row houses, including brownstones, were typically developed as speculative housing and constructed in continuous rows of identical or slightly varied units, often built simultaneously by a single developer (NYCLPC, 2012; Tasse-Winter, 2024). This repetitive, block-scale approach to construction enabled efficient use of land, labor, and materials, while also driving consistent demand for timber used in interior structural systems.

Architecturally, row houses were characterized by a consistent set of elements, including elevated stoops, raised parlor floors, sunken areaways, and projecting cornices, which together created a recognizable and cohesive streetscape (NYCLPC, 2004). This vertical organization which typically consisted of a raised basement, formal parlor level and upper residential floors, reflected social hierarchies and shaped internal spatial arrangements (NYCLPC, 2004).

From a material perspective, earlier row houses were constructed using larger and heavier wood members, reflecting both the availability of dense, old-growth timber and less standardized construction practices. Over time, these systems evolved toward more standardized lumber dimensions and more efficient use of materials, in line with broader industrialization trends (Krajick, 2021). For the purposes of this analysis, brownstone-era row houses are grouped into three periods—pre-1875, 1875–1895, and 1896–1916 – which serve as proxies for underlying shifts in timber sourcing, material standardization, and construction practices.

Office Buildings

Wood-Intensive, Low-Rise Office Era (Pre-1879). Before the widespread adoption of passenger elevators in the 1870s, office buildings in New York City were height-constrained and typically constructed using load-bearing exterior masonry walls combined with interior structural wood for the beams, joists, planking, and roof. The upper floors were less desirable and often under-utilized due to the need to climb stairs (Nichols, 2018).

By the mid-1800s, metal elements started to emerge and supplement the traditional systems. First, Friedman (1995) explained that it was cast iron columns and beams, followed by the introduction of wrought iron beams in the mid-1850s. However, he further noted that these buildings still relied on masonry walls for primary load-bearing support, and wood remained widely used in floor construction. As a result, while structural experimentation was underway, wood continued to play a significant, though not exclusive, role in the structural systems of low-rise office buildings during this period.

Transitional High-Rise Office Era (1879–1900). Beginning in the 1870s, office building construction in New York City entered a period of rapid transformation driven by technological and economic change. The elevator fundamentally altered the value of upper floors, making taller buildings economically viable (Nichols, 2018). At the same time, advances in iron and steel production, particularly the declining cost of steel after the 1870s, as aforementioned in the previous section, enabled the development of more efficient structural systems. During this transitional period, Friedman (1995) noted that the construction evolved from masonry and wood-based systems to hybrid configurations incorporating iron columns and beams, and eventually to full steel skeleton frames by the late 1880s and 1890s. Although wood continued to be used in floor assemblies and interior components, the author further mentioned that its role in primary load-bearing systems declined significantly. By the end of the 1800s, steel had largely supplanted wood as the dominant structural material in office buildings, facilitating the rapid growth of taller commercial structures in lower Manhattan.

Tenement Buildings

Figure 14. Axonometric of a New York Dumbbell Tenement (Disasterous History, 2021)

Tenement buildings represent a distinct and important residential typology within New York City's building stock, shaped by rapid population growth driven by mass immigration in the 19th and early 20th centuries. Early forms emerged through the subdivision of single-family row houses into multi-family dwellings and, over time, through purpose-built structures designed to maximize occupancy (Plunz, 2016). By the early 1900s, tenements had become the dominant form of working-class housing, with contemporary accounts indicating that nearly two-thirds of New York's population lived in tenements (Plunz, 2016). At the same time, the city contained approximately 80,000 to 100,000 tenement buildings, housing more than two million residents (Plunz, 2016; Tenement House Committee, 1895).

Similar to row houses, tenements were constructed with masonry exterior walls and wood interior structural systems, including floor framing, partitions, and staircases. However, tenement buildings were designed to accommodate significantly higher densities, often housing multiple families per floor and, in some cases, dozens of households within a single building (Plunz, 2016). This intensity of occupancy was especially high in neighborhoods such as the Lower East Side, which was described at the time as one of the most densely populated areas in the world (Tenement House Committee, 1895).

Similar to other building types, tenements evolved over time. However, unlike office buildings, where changes were driven primarily by technological advancement, the evolution of tenements was shaped largely by key building code regulations that addressed public health and fire risk incrementally. The periods below reflect shifts in construction practices and material use, which were driven primarily by regulatory intervention rather than technological innovation.

Pre-1879: Unregulated Growth & Maximum Wood Exposure. Prior to the Tenement House Act of 1867, tenement construction was unregulated. Early forms of multi-family housing emerged through the subdivision of existing row houses into boarding houses and apartments as immigration increased and wealthier residents moved uptown.

Alongside these conversions, early purpose-built examples began to appear; for instance, in 1833, industrialist James Allaire constructed what is often considered Manhattan's first tenement, a four-story, sixty-foot-deep, barracks-style building for his workforce on Water Street (Burrows & Wallace, 1999). Over time, purpose-built tenements replaced subdivided row houses and were designed to maximize occupancy on standard 25-by-100-foot lots (Plunz, 2016; Tenement House Committee, 1896). Known as "pre-law" tenements, these buildings were characterized by dense layouts, limited ventilation, and inadequate access to light and air.

Structurally, these buildings combined masonry exterior and party walls with wood interior systems, including floor framing, partitions, and staircases (Howe, 2014; NYCLPC, 2012). Under conditions of extreme density and subdivision, these wood systems created continuous combustible pathways. In the absence of protected egress routes, stairways and air shafts acted as conduits for vertical fire spread, with risks further exacerbated by high occupancy levels (Fryer, 1901; Plunz, 2016; Tenement House Committee, 1895).

1879–1901: Standardization & Expansion ("Old Law" Tenements). This period marked a phase of rapid expansion and standardization in tenement construction, driven by continued population growth and increasing formalization of building regulations. The Tenement House Act of 1879, referred to as the "Old Law", introduced requirements for improved light and ventilation, most notably through the use of air shafts. These provisions led to the adoption of the "dumbbell" tenement form, which sought to bring light and air into interior rooms while maximizing buildable area on standard lot sizes (Plunz, 2016; Tenement House Committee, 1896; NYCLPC, 2012).

Despite these regulatory changes, the primary objective of tenement development during this period remained the maximization of occupancy. Buildings were constructed in repetitive rows with highly standardized layouts, allowing for efficient construction and rapid scaling across neighborhoods. These buildings often housed dozens of families under highly congested conditions, with multiple households per floor and limited separation between units (Plunz, 2016; Tenement House Committee, 1895). Architecturally, they were typically executed in simplified versions of the Italianate style, with later examples in the early 1870s and 1880s reflecting the influence of the neo-Grec style (NYCLPC, 2012).

From a material perspective, however, construction practices remained largely unchanged. Tenements continued to rely on load-bearing masonry exterior and party walls combined with wood interior structural systems, including floor framing, partitions, and staircases (Howe, 2014; NYCLPC, 2012). As a result, this period reflects a divergence between regulatory intent and material outcomes. Although the 1879 law improved access to light and air, it did not materially reduce fire risk, and in some cases, features such as narrow air shafts may have further facilitated vertical fire spread (Fryer, 1901; Plunz, 2016). Wood remained the dominant interior material, and the underlying risks associated with dense, wood-framed interiors persisted.

1901–1916: New Law Tenements & Early Steel Integration. More substantive changes emerged with the Tenement House Law of 1901, commonly referred to as the "New Law." Rather than replacing wood as the dominant interior material, the law targeted specific high-risk elements, prompting incremental substitution and the use of fire-resistant materials in key areas (Fryer, 1901; NYCLPC, 2012). In practice, this produced hybrid assemblies: masonry shells with predominantly wood interiors, but with selectively upgraded components (e.g., protected stair enclosures and fire-doors). The changes helped better manage fire risk without fully transforming the underlying material system (Plunz, 2016).

Across the same period, advances in industrial construction began to appear at the margins of residential buildings. While steel and reinforced concrete were increasingly used in commercial, industrial, and high-end residential buildings, their adoption was limited, uneven, and localized in tenements (NYCLPC, 2012; Barr, 2016). As a result, most New Law tenements were materially consistent with earlier buildings, even as they incorporated selective upgrades driven by regulation.

The 1916 Zoning Resolution further influenced the evolution of tenement buildings by regulating building form, height, and lot coverage. Although not a materials code, it changed building form and economics, encouraging different massing and light-court configurations and contributing to a gradual shift away from earlier tenement models (Barr, 2016).

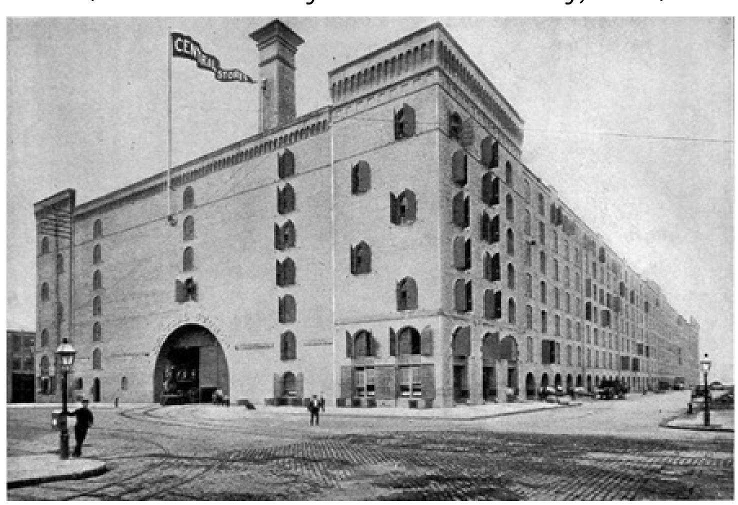
Taken together, this period reflects a code-driven incremental transition. This distinguishes tenements from warehouses and office buildings, where material changes were more directly driven by structural innovation and the broader adoption of steel and concrete systems (Plunz, 2016; NYCLPC, 2012).

Warehouses

The development of warehouse and industrial buildings in New York City was closely tied to the city's emergence as a major center of trade and manufacturing in the 19th century. As industrial production and port activity expanded, particularly along the Hudson River and Brooklyn waterfronts, demand grew for large-scale storage and distribution facilities located near shipping and rail infrastructure (NYCLPC, 2007, 2008). By the early 20th century, Brooklyn had become one of the largest manufacturing centers in the United States, with a large concentration of industrial activity located in the DUMBO District (NYCLPC, 2007). The buildings in this area provide a concentrated record of evolving construction practices and material systems.

Early warehouse construction relied heavily on slow-burning, or mill construction, which is a system that emerged in the 1820s and 1830s in response to repeated fires in textile mills (Langenbach, 2013; Leichenko & Loewenberg, 1917). These fires exposed the vulnerabilities of traditional timber framing, prompting the development of a heavier structural system designed to reduce fire spread. As described by Randall Langenbach (2013), slow-burning construction replaced conventional timber framing with large wood columns and beams, combined with thick plank floors spanning directly between beams. The structural wood pieces used were substantial in dimension, with beams exceeding 12 inches in thickness and floors constructed of 2.5 to 3 inch planks (Leichenko & Loewenberg, 1917). The importance of the system is that it reduced the pace of consumption, as large wood elements would char slowly rather than ignite quickly. It also had the added advantage of being more efficient and reducing labor costs (Langenbach, 2013). A 1917 publication titled, The Development and Design of Mill Constructed Buildings, by Leichenko & Loewenberg, demonstrates the extent to which mill construction had become a formalized building system by the early 1900s, documenting the standardized design approaches, structural configurations, and performance characteristics of heavy timber buildings.

Figure 15. Warehouse, Heavy Timber Framing (Lamont-Doherty Earth Observatory, 2021)



The abundance of old-growth timber made this construction method feasible. In particular, Longleaf pine, valued for its strength and ability to be milled into large beams, was commonly used in this type of construction. Wood mills could produce beams that were 12 to 18 inches in width and up to 30 feet in length (Delta Millworks, 2024). Many of the earliest warehouses (pre-1896), including those in DUMBO, were constructed using this system (NYCLPC, 2007). These buildings had masonry exterior walls with large, ground-floor openings for loading and unloading, while their internal structures consisted of massive wooden columns, beams, and connections. As a result, they represent some of the most wood-intensive building types in the city's historic building stock.

By the late 19th century, industrial buildings were increasingly designed for efficiency, durability, and fire resistance, with growing use of iron structural elements and fire-resistant materials such as terracotta (NYCLPC, 2008). This shift resulted in hybrid systems that combined traditional timber framing with emerging industrial materials, often while retaining the external appearance of earlier masonry warehouse structures.

The transition became particularly evident in the late 1890s. Buildings constructed prior to 1896 are generally characterized by heavy timber structural systems, while those built from 1897 onward increasingly incorporate steel framing and fire-resistant floor systems, including terracotta tiles and, later, reinforced concrete (NYCLPC, 2007, 2008). The evolution of the Grand Union Company complex in DUMBO illustrates this shift: its initial building (1896–1897) employed a slow-burning timber structure, while subsequent expansions maintained similar exterior forms but incorporated steel frames, terracotta floors, and, by 1915, reinforced concrete construction (NYCLPC, 2007).

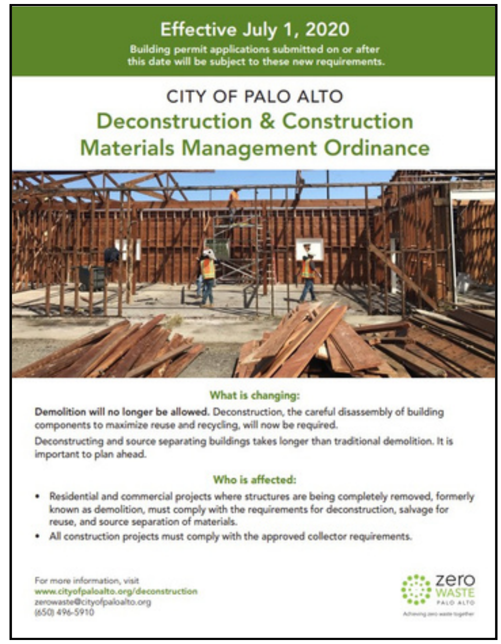
2.5 CASE STUDIES OF WOOD RECLAMATION PROJECTS

Reclaiming old-growth wood from deconstructed buildings is, in practice, a logistically demanding, regulatory-constrained, and market-dependent endeavor. This report also discusses case studies encompassing the topics of wood reclamation as it has been attempted by other cities across the United States including, Palo Alto and San Antonio.

Palo Alto

The City of Palo Alto implemented Ordinance No. 5472, a salvage-based deconstruction ordinance, on June 10, 2019. This ordinance is designed to maximize salvage for reuse, reduce landfill disposal, and increase both the quality and the quantity of source-separated materials from whole-structure removals. It applies to covered projects, that is, involving whole structure removal, covering both residential and commercial whole-structure removals, regardless of building age. As such, the program extends beyond historically designated buildings and encompasses all eligible structures within the city.

Figure 16. City of Palo Alto Deconstruciton Ordinance



Deconstruction, salvage for reuse, and source separation requirements became effective as of July 1, 2020. Building permit applications that were submitted on or after this date were subject to these new requirements. That is, demolition was no longer allowed after that date, and instead, deconstruction, which the city defines as the careful disassembly of building components to maximize reuse and recycling, was and will be required of all residential and commercial projects.

San Antonio

The Vacant Buildings and Deconstruction ordinance, identified under Chapter 12 of the San Antonio City Code, was adopted in September 2022 and later expanded in 2025. Under the ordinance, mechanical razing of any residential single-family home, multi-unit, and accessory structure built before 1945 is not allowed, even if the structure is not in a historic zoning overlay. Only careful deconstruction, or reverse engineering, and salvaging the building materials is permitted for properties approved for removal.

Although deconstruction costs on average incur approximately $3,000 more than demolition, the City introduced financial support to offset these additional expenses through the Alamo Area Council of Governments Solid Waste Pass-Through grant and the Office of Historic Preservation’s budget.

Figure 17. San Antonio Deconstruction Ordinance

The case studies document this gap honestly, where cities have the policy infrastructure before the salvage market exists. Some have the research institutions with the engineering workflows and coding bodies that are yet to be formally adopted. Taken together, these case studies reveal that material itself is rarely the limiting factor; rather, the constraints are institutional, economic and infrastructural.

03.METHODOLOGY

3.1 METHODOLOGICAL DESIGN

This project addresses two primary research questions: first, the extent to which old-growth wood exists within New York City's building stock; and second, whether a scalable methodology can be developed to identify buildings suitable for material recovery within a circular economy framework.

To address these questions, the methodology combines typological analysis, volumetric modeling, and spatial visualization through a three-stage process: identification, quantification, and visualization (see Figure 18). Additionally, a sensitivity analysis was conducted to evaluate the reliability of key assumptions and variables used throughout the model.

1. Identification

The first stage identifies building typologies across New York City that are most likely to contain old-growth wood. This process combines historical research, structural analysis, and PLUTO building data to evaluate how wood was used across different building classes and construction eras. Buildings were categorized by typology, height, age, and structural characteristics to establish a framework for identifying likely recovery candidates. Particular focus was placed on low- and mid-rise residential and industrial buildings constructed prior to the widespread adoption of steel and reinforced concrete structural systems.

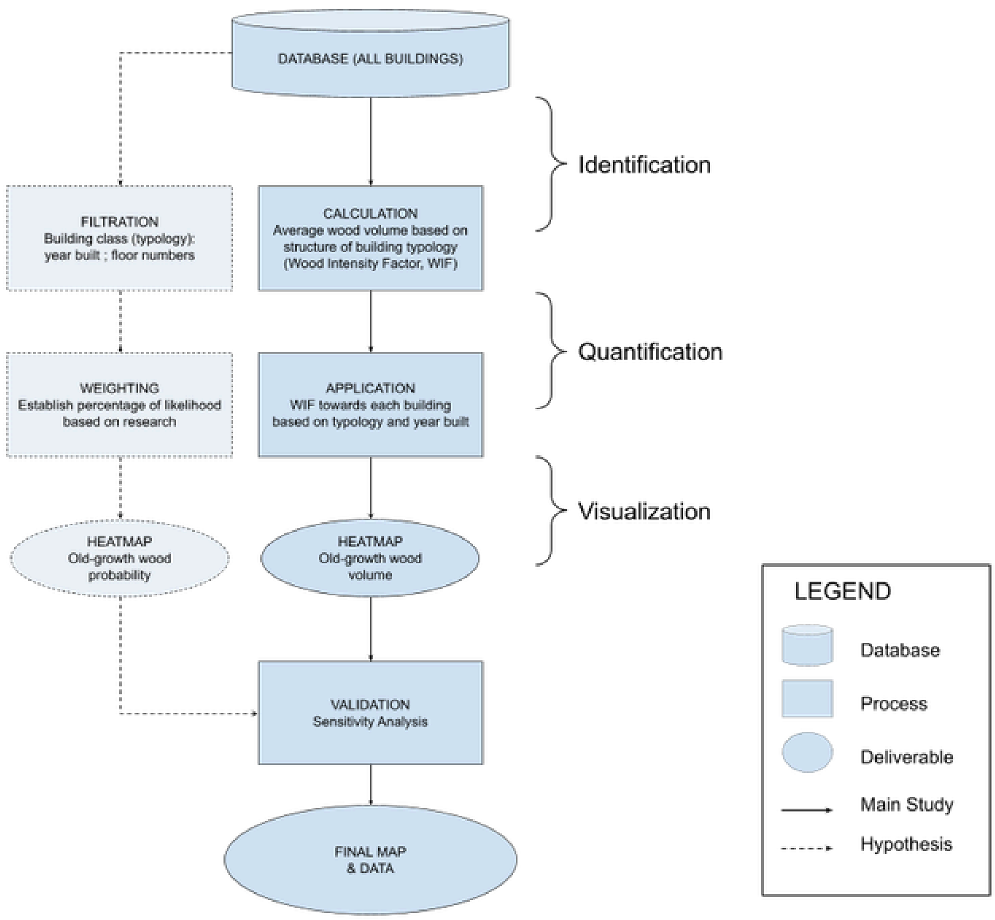
2. Quantification

The second stage develops a volumetric model to estimate the quantity of old-growth wood embedded within representative building typologies. Structural components, including floor joists, girders, flooring, roof framing and decking, were analyzed to calculate total wood volume by building type and era (Table 1). These values were then normalized by floor area to generate a wood intensity factor (WIF), expressed as cubic feet of wood per square foot of building area. The resulting WIF values enable scalable estimation of wood volume across the broader PLUTO dataset.

3. Visualization

The final stage translates the quantitative analysis into spatial visualization using GIS mapping tools. WIF values and eligibility criteria were applied to individual parcels within the PLUTO dataset to estimate building-level old-growth wood volume across the five boroughs. The resulting maps visualize the geographic distribution, concentration, and recovery potential of embedded wood resources throughout New York City. This approach also establishes a replicable methodology that can support future analysis of additional C&D material streams.

Figure 18. Workflow of the Project Methodology



3.2 DATA COLLECTION

Research for this project started with an analysis of the PLUTO dataset published by NYC Planning, which is an aggregate of information pertaining to buildings located on tax lots across the five New York City boroughs. Another main resource provided by NYC Planning is ZoLa, an interactive map showing zoning and land use, which also uses an assortment of data.

The dataset is provided in two formats and can be downloaded from NYC Planning's website: a plain text file (.csv) for calculation use in Microsoft Excel, and shapefiles (.shp and .fgdb) for geographic information systems (GIS) use, which refers to data analysis at a spatial level. .fgdb is a geodatabase, which can be regarded as a folder containing many files, mainly .shp, a shape file that can be evaluated using GIS programs. These shapefiles pinpoint each building or area in the city with metadata such as type of area or building, borough inclusion, safety codes, etc. (Appendix A).

Python was used periodically throughout the project to sort and reformat the PLUTO dataset. Due to the size of the file, Python was utilized to split it up by borough, allowing more reactive data analysis without the need of dedicated computer labs. Then, to visualize the quantitative outputs, the ArcGIS program in its online version is used.

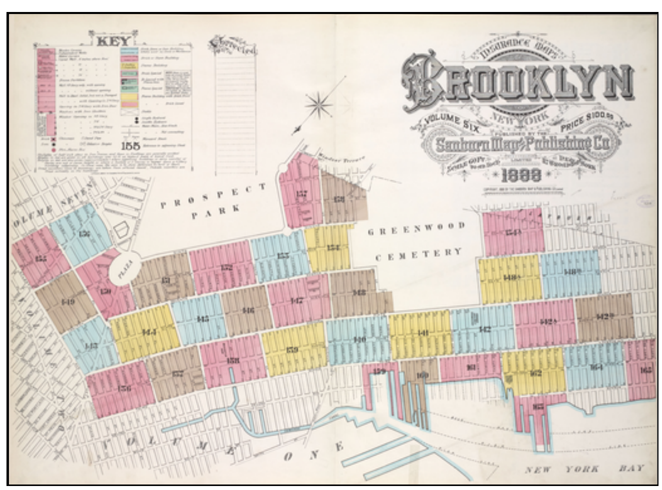
To support the literature review, 12 Interviews were conducted to incorporate insights from experts and academia (Appendix B). These interviews also offered practitioners' perspective regarding PLUTO data reliability as the main source for building a volumetric model in this project. Moreover, these interviews provided contextual understanding of current practices and concerns regarding the deconstruction process for old-growth wood in the city.

3.3 DATA ANALYSIS

Building Typology

New York City buildings are classified according to their primary use and building type, both of which strongly influence wood use and overall material volume. Since many buildings constructed during the late 19th and early 20th centuries followed standardized and repetitive construction methods (Figure 19), representative assumptions could be developed for each major building class.

Figure 19. Sanborn Map, Brooklyn



As construction practices evolved, buildings increased in scale and gradually transitioned toward steel, masonry, and reinforced concrete systems. Changes in building codes, fire safety regulations, and structural design standards further influenced how wood was incorporated across different building types and periods of construction. To account for these shifts, the analysis separates buildings into distinct construction eras based on typology and historical code transitions, allowing for more accurate wood volume estimations (Table 1).

Table 1. Era Separation of Building Types

Type of Building	Building Class	Archetype	Era
Low-Rise Residential	A	Detached	<1900
			1901-1938
	B	Brownstone	<1875
			1875-1895
			1895-1916
Walk-up apartments / tenements	C + S	Tenement	<1879
			1879-1900
			1901-1916
Slow-burn Mill Warehouse	E	Warehouse	<1896
Transitional Warehouse			1897-1916
Office with commercial (1–6 stories)	O	Office Building	<1879
			1880-1901

Eligibility Funnel

Summarizing the initial study, a set of appropriate characteristics is developed. By setting them up as an eligibility funnel (Figure 20), buildings in PLUTO data are filtered down, and as a result, buildings that have a higher probability of old-growth wood can be roughly estimated. Based on how many characteristics they have, shown by how many steps of the eligibility funnel they can go through, a 'low', 'moderate', 'high', or 'very high' value is set to each datapoint of the PLUTO data. A 'no data' is given to buildings that do not have enough information for these characteristics.

Visualizing these values (Figure 21) helped to illustrate the range of data that could be developed and, more importantly, establish an initial proof-of-concept through a GIS application that produced the intended spatial deliverable.

Figure 20. Eligibility Funnel of Old-growth Wood Candidate Buildings

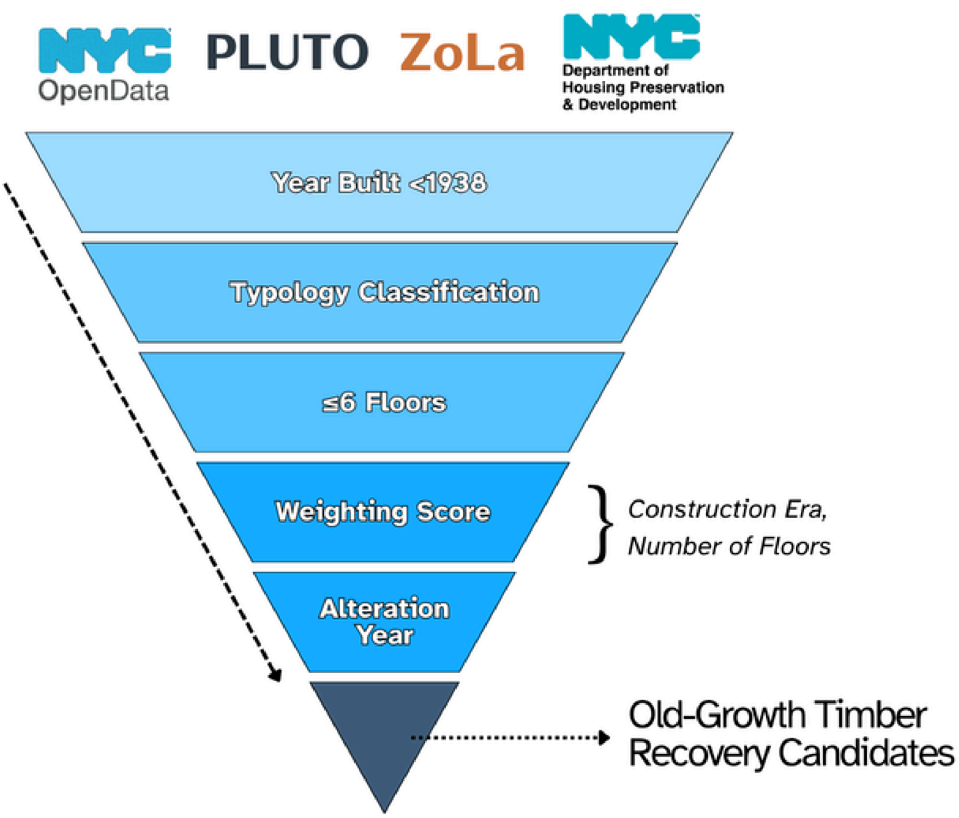
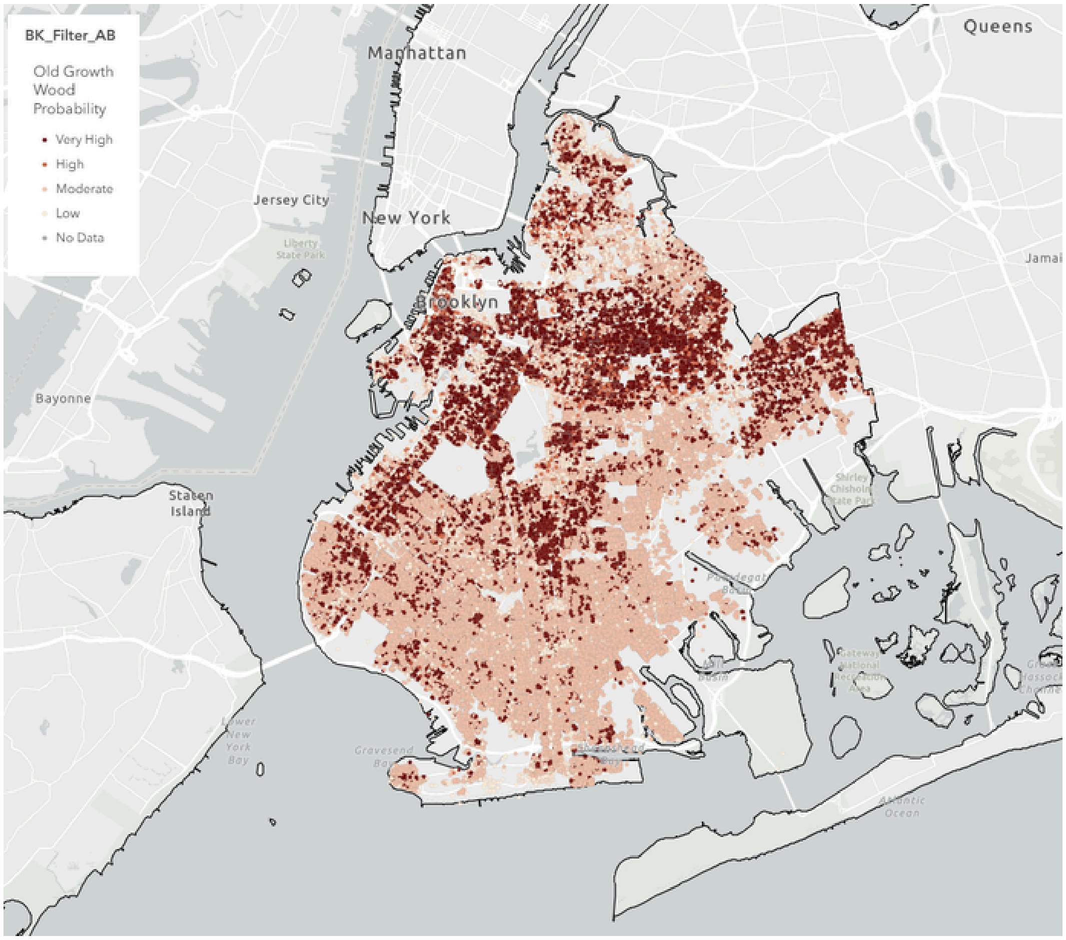


Figure 21. Old-growth Wood Probability Heatmap of Brooklyn



Wood Intensity Factor (WIF)

The quantitative aspect of the assumptions needed to be improved for a heightened accuracy of the model. This translates to the calculation of the volume of old-growth wood within a building, which first needs the identification of appropriate parts. These include joists, main beams/girders, flooring planks (Figure 22), and roof framing. Other building components, such as stairs, window frames, door frames, interior walls, subfloors, and cabinetry, are excluded in this estimation, due to their low recovery value and and the high likelihood that they have been altered to comply with city ordinances in effect at the time. The system boundary used to determine the WIF is illustrated in detail in Figure 23.

Figure 22. Example of Old-growth Wood Joist

Figure 23. System Boundary of Calculated Old-growth Wood in Building to Generate Wood Intensity Factor

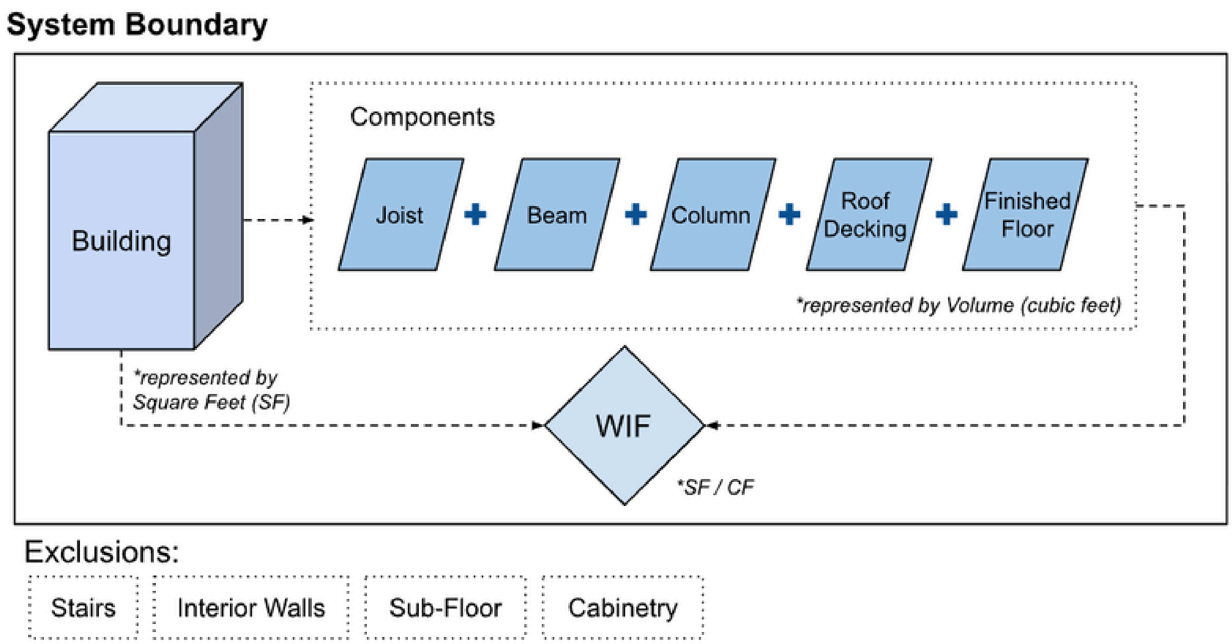


Table 2 shows an example of building components identification for a brownstone, together with underlying assumptions, calculation formulas, and estimated volume results for each component.

Table 2. Component Level Wood Volume Estimate (Representative Brownstone of 1875-1895)

Component	Key assumptions	Calculation	Estimated volume (cf)
Floor joists	3 in x 10 in joists, 9.5 ft span, 16 in spacing, 3 floors	Joist count × member volume	413
Main beam or girder	1 central girder per floor, 8 in x 12 in, 45 ft length, 3 floors	Girder volume × floors	90
Flooring planks	0.75 in hardwood flooring, 855 sf per floor, 3 floors	Floor area × plank thickness × floors	160
Roof joists	3 in x 8 in joists, 35 joists	Joist count × member volume	110
Roof decking	0.75 in plank decking, 855 sf roof area	Roof area × deck thickness	53
Total estimated wood volume	*19 ft x 45 ft footprint, 3 floors, 2,565 sf total floor area*	*Sum of component volumes*	*826*

These numbers were derived from literature-based research and calculated from average width, depth, and number of floors obtained from PLUTO data. These calculations were then cross-referenced with the median values of the building area, which were also provided from existing PLUTO data. Summing the wood volume of these components, then dividing it over the total building area, results in the percentage of the building that can be categorized as old-growth wood. Referred to as the wood intensity factor (WIF), applying it to any building estimates the wood volume depending on how big the building is. The calculation is then replicated for all by building type and years, depending on how the parts are used for the building structure, per the aforementioned era separation. The WIF calculation results for each building class are shown in Table 3.

Table 3. Wood Intensity Factor For Each Building Class And Construction Era

Building Class	**Archetype**	**Era**	**Wood intensity factor (WIF)**
A	Detached	<1900	0.312
		1901-1938	0.199
B	Brownstone	<1875	0.362
		1875-1895	0.303
		1895-1916	0.260
C + S	Tenement	<1879	0.381
		1879-1900	0.280
		1901-1916	0.211
E	Warehouse	<1896	0.570
		1897-1916	0.220
O	Office Building	<1879	0.220
		1880-1901	0.123

ArcGIS Visualization

To create the final visualization of the data analysis, the calculated WIF needs to be added to the existing PLUTO dataset. The first step is to add it as a new column called [Intensity_Factor]. This is done by using 'Data Mode' in the online ArcGIS platform, which will show the data in a table format instead of the map visualization.

Using SQL language (Figure 24), the WIF values are added to the new column for each datapoint - representing a building - based on their type and the year they were built. These values are provided in the dataset in columns [bldgclass] and [yearbuilt], respectively. It should be noted that some buildings have null values for either column, and are given an automatic WIF value of '0'.

[bldgclass] data is represented by two characters, a letter and a number. The letter represents the building class (Table 1), and the number is the land use value. Since the research only identifies separation of general building types (the letter), the code searches the dataset using the argument 'LIKE' and value 'X_' where 'X' represents the type and '_' represents any numerical value.

Figure 24. SQL Code for Wood Intensity Factor Addition to PLUTO Data

```
CASE
WHEN yearbuilt = 0 THEN 0
WHEN bldgclass LIKE 'A_' and yearbuilt <=1900 THEN 0.312
WHEN bldgclass LIKE 'A_'
   and yearbuilt > 1900 and yearbuilt <=1938 THEN 0.199
WHEN bldgclass LIKE 'B_' and yearbuilt <=1875 THEN 0.362
WHEN bldgclass LIKE 'B_'
   and yearbuilt > 1875 and yearbuilt <=1895 THEN 0.303
WHEN bldgclass LIKE 'B_'
   and yearbuilt > 1895 and yearbuilt <=1916 THEN 0.260
WHEN (bldgclass LIKE 'C_' or bldgclass LIKE 'S_')
   and yearbuilt <=1879 THEN 0.381
WHEN (bldgclass LIKE 'C_' or bldgclass LIKE 'S_')
   and yearbuilt > 1879 and yearbuilt <=1900 THEN 0.280
WHEN (bldgclass LIKE 'C_' or bldgclass LIKE 'S_')
   and yearbuilt > 1900 and yearbuilt <=1916 THEN 0.211
WHEN bldgclass LIKE 'E_' and yearbuilt <=1896 THEN 0.570
WHEN bldgclass LIKE 'E_'
   and yearbuilt > 1896 and yearbuilt <=1916 THEN 0.220
WHEN bldgclass LIKE 'O_' and yearbuilt <=1879 THEN 0.220
WHEN bldgclass LIKE 'O_'
   and yearbuilt > 1879 and yearbuilt <=1901 THEN 0.123
ELSE 0
END
```

Volume Calculation

The final calculation was performed in Python by filtering the PLUTO dataset and aggregating the cumulative square footage. While the total area was primarily derived from the existing sqrft column, two specific corrections were applied to address data gaps.

First, for rows listed with zero square footage, the model distinguished between vacant lots and buildings with missing area data. Records lacking bldg_depth and width were disregarded as vacant. However, for records containing depth and width dimensions, square footage was calculated by multiplying those dimensions by the number of floors.

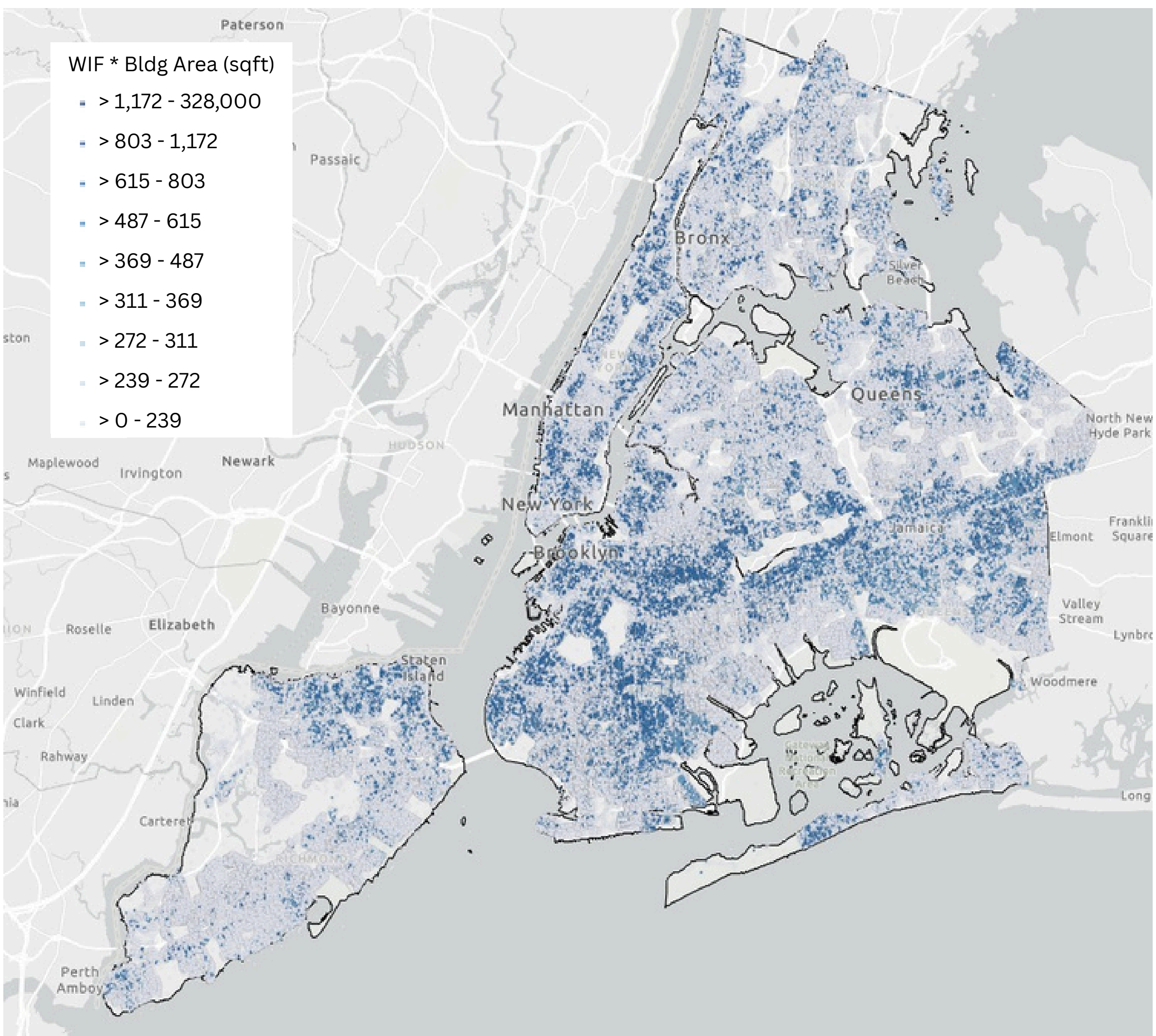
Second, the dataset was filtered to exclude anomalies and structures outside the research scope. Buildings listed with a construction year of "0" were removed to ensure data integrity. Additionally, buildings exceeding seven stories were excluded, as structures of this height are unlikely to utilize old-growth wood in their primary framing. The complete code for these calculations is provided in Appendix C.

04. IMPLEMENTATION

4.1 GIS RESULTS

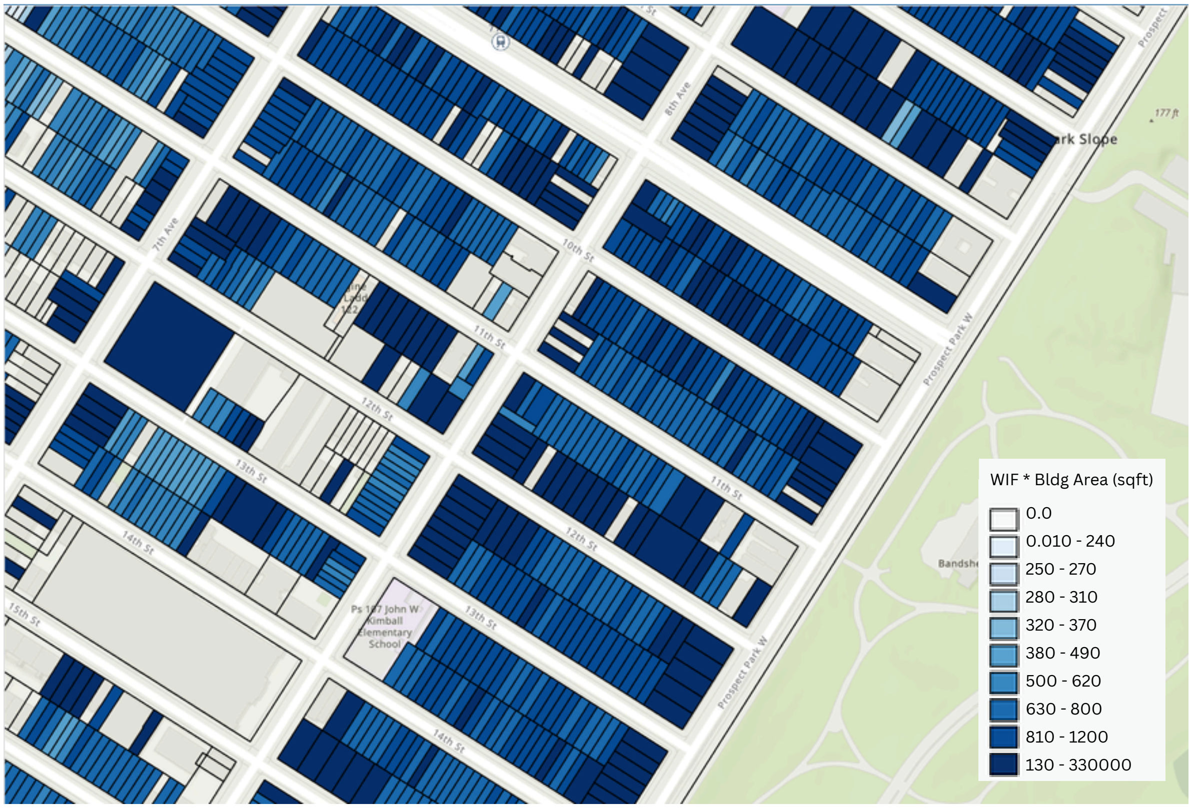
With the WIF value readily available in the dataset, multiplying it by each building's area estimates the wood volume per structure. A final map is then developed with these values. Shown by a gradient for wood volume, building points that have more old-growth wood are signified by a darker shade (Figure 25). Having an overview of the city helps establish focus locations, prioritizing areas with high-density clusters of old-growth wood.

Figure 25. Map of New York City With Wood Intensity Factor Applied to Each Building



Reflecting the population spread of the city from the early 1800s, most of the old-growth wood is located in Brooklyn, more specifically, its Western and Center parts. Meanwhile, Manhattan's southern tip has displaced the material as skyscrapers and more modern architecture populate the area.

Figure 26. Zoomed-in Map of Buildings with Wood Intensity Factor Gradient (Park Slope, Brooklyn)



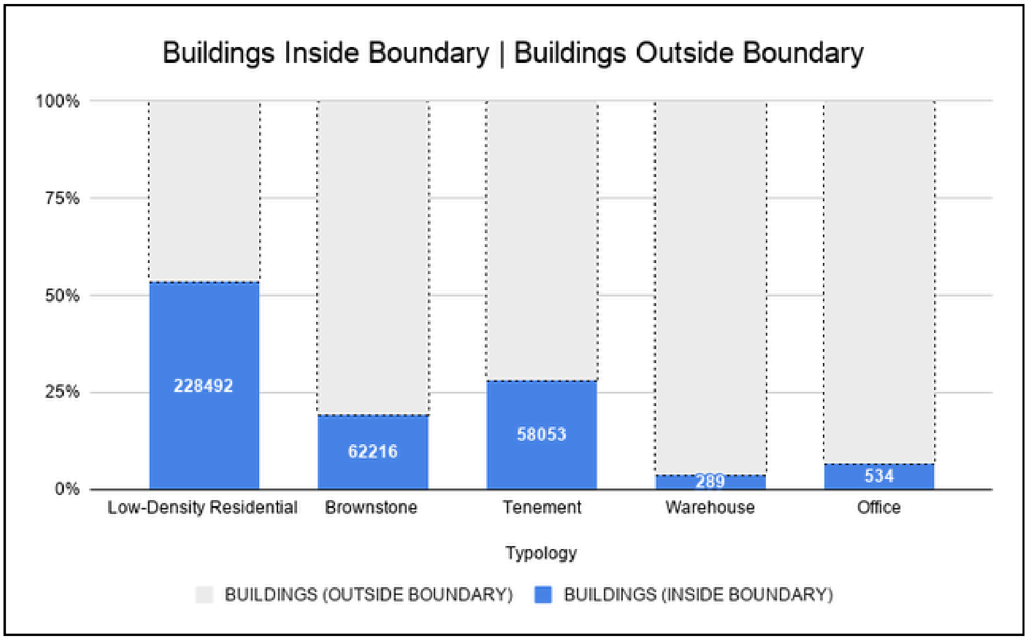
The method also helps ingrain the data granularly, with old-growth wood estimates available at the individual building/parcel level (Figure 26). Tagged to the Borough-Block-Lot (BBL) code, a unique identifier for buildings, this data can also be officially incorporated as an additional aggregate in PLUTO. Furthermore, if used in the process of granting demolition permits, it can trigger engagement from other system actors like C&D recycling facilities or for reuse by lumber companies such as SawKill (Appendix B).

4.2 PYTHON RESULTS

Across the entire city, 349,584 buildings (Figure 27) met the criteria for the final filter, representing a cumulative area of 633,466,856 ft^2 and a total wood content of 147 Mcf (Million Cubic Feet). This distribution can be further broken down by typology, as illustrated in Figure 28.

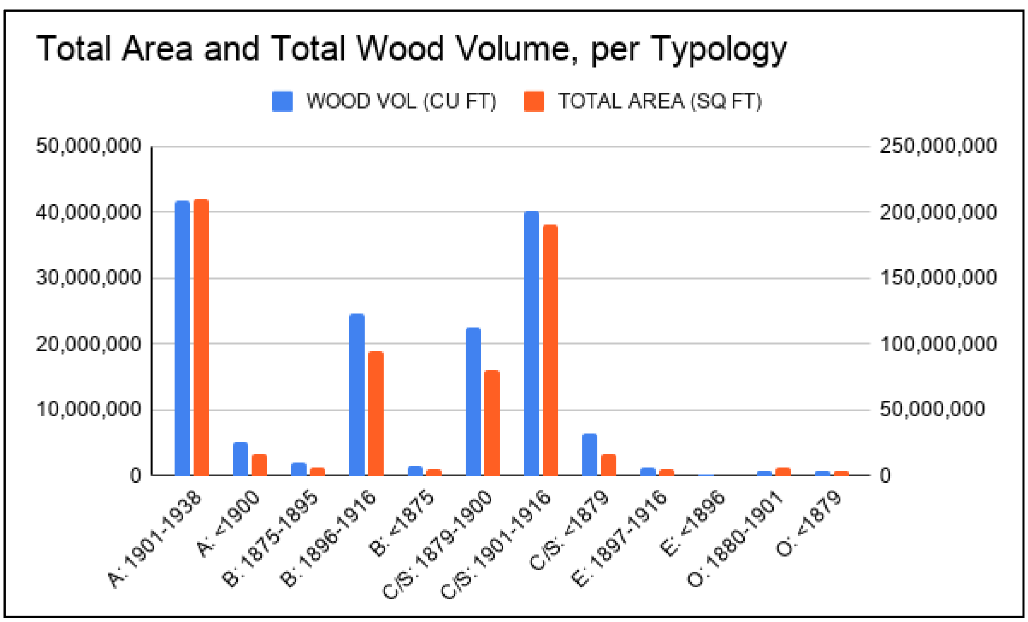
Brooklyn (BK) holds the city's largest wood reservoir, containing 59.9 Mcf across 133,531 buildings (251.3 million ft^2). Manhattan (MN) follows with 36.2 Mcf across 19,527 buildings (145.4 million ft^2), while Queens (QN) ranks third with 29.9 Mcf across 143,549 buildings (142.9 million ft^2). The Bronx (BX) and Staten Island (SI) contain the lowest volumes, with 14.0 Mcf (26,573 buildings) and 6.59 Mcf (26,404 buildings), respectively. This breakdown is illustrated in figure 29.

Figure 27. Buildings Within the Model's Scope



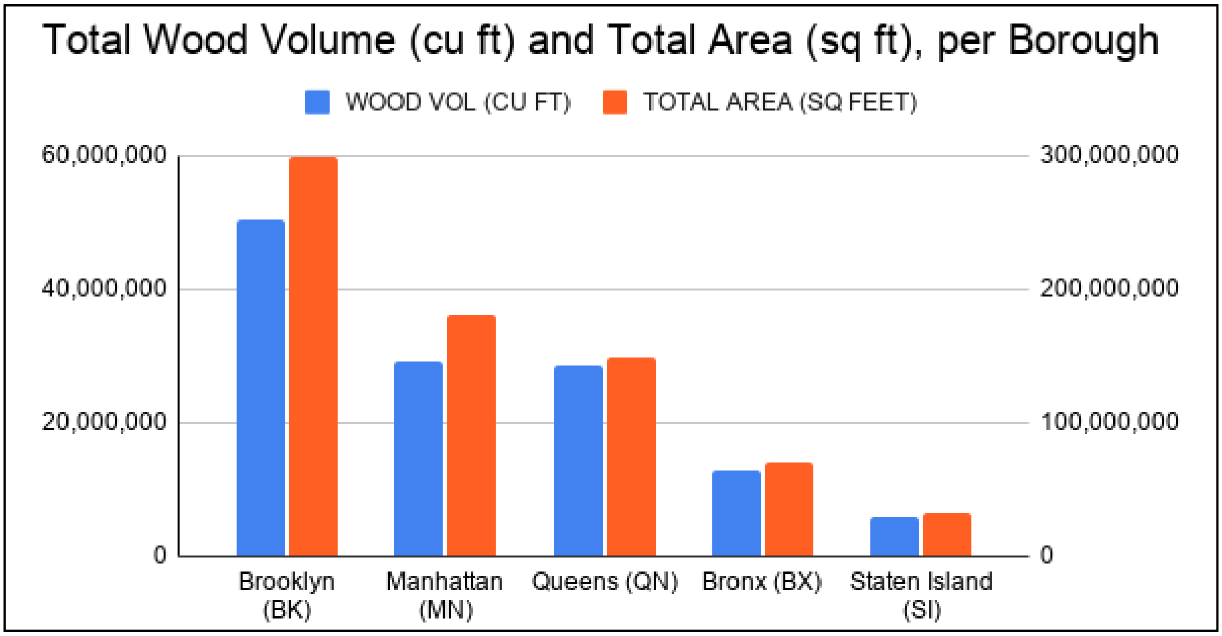
Note: This graph shows the ratio between total number of buildings per typology (no era restrictions), and the amount that fell within the model's scope.

Figure 28. Wood Volume And Total Area Across the Typologies



Note: By typology (era specific), a breakdown of total wood and square footage. Few typologies and eras are responsible for a majority of old-growth wood.

Figure 29. Total Wood Volume and Total Area, per Borough



Note: Wood volume (left) and total area (right) are on seperate axis, with the relationship being determined by WIFs. Total area is only inclusive of buildings that fall within the model's output.

4.3 MODEL PERFORMANCE

Though the methodology has tried to reflect the research and is designed to be as accurate as possible, reviewing the two components used for the GIS analysis shows some constraints possessed by the model. First, the area of the building is based purely on the availability of PLUTO data. Input inaccuracy might produce false negatives for buildings with values of 0.

Application of WIF is also based on the classification of PLUTO data, specifically, building class and year. Mislabeling of building class might occur, also inaccurate calculation of built year as records become unreliable the farther back in history. Most importantly, the calculation of WIF itself uses a generalization of building design based on the class. The numbers of elements in the system boundary and their corresponding sizes could be less uniform than initially thought of. Consequently, the range of the elements can be bigger than expected, and skew the median value.

Finally, these figures estimate total volume and do not account for material recoverability or physical condition. The real-life conditions might differ greatly from this calculation.

CARBON STORAGE QUANTIFICATION

Figure 30. Reconstructed map of predevelopment Manhattan, Eric Sanderson, 2009

The estimated stock of old growth wood, approximately 147 million cubic feet, was translated into stored carbon dioxide by assuming a dry wood density of 30 lb/ft^3, consistent with representative wood density ranges reported by the U.S. Forest Service Forest Products Laboratory; by assuming that dry wood is composed of approximately 50% carbon by mass; and by converting carbon to carbon dioxide using the U.S. Environmental Protection Agency's standard 44/12 molecular weight ratio. This yield is approximately 3.7 million metric tons of CO2 stored.

4.4 Sensitivity Analysis

A five-scenario sensitivity analysis was developed to evaluate how changes in core assumptions affect the estimated volume of old-growth wood in New York City's building stock. Because each building typology has distinct structural characteristics, the analysis does not treat uncertainty as a single uniform variable. Instead, it tests the combined effect of two critical parameters: the eligibility year boundary and the WIF.

The WIF is the primary driver of model uncertainty. It is derived from typology based assumptions about structural systems, member dimensions, spacing, and included wood components as noted on Table 2. To test this uncertainty, the model applies WIF multipliers of +15%, +5%, Baseline, and -10%. These adjustments reflect potential variation in structural wood intensity, alterations over time, and the inclusion or exclusion of components outside the baseline system boundary (see Table 4).

The eligibility boundary was also tested using two cutoff years. The 1938 boundary reflects the broader period of likely old-growth wood use across much of the eligible building stock, while the 1916 boundary represents a more conservative assumption tied to earlier construction practices and high likelihood of old-growth wood. When the cutoff year was reduced from 1938 to 1916, the greatest reduction occurred in low-density residential, indicating that small residential structures are particularly sensitive to the eligibility year assumption.

Table 4. Sensitivity Analysis, Estimated Wood Volume

Scenario	Eligibility Boundary	WIF (Multiplier)	Estimated Wood Volume (million cf)
High	≤1938	15%	~169
Med	≤1938	5%	~154
Base-Case	≤1938	Baseline	~147
Plausible	≤1916	Baseline	~111
Low	≤1916	-10%	~100

The results range from approximately 100 million cubic feet (Mcf) under the low scenario to 169 Mcf under the high scenario. This spread confirms that total wood volume is highly dependent on WIF assumptions and the selected eligibility boundary. Even under the most conservative scenario, the model identifies a substantial stock of wood across New York City’s low- and mid-rise buildings.

Future refinement should focus on calibration and validation. This could include comparing assumed floor area and typology classifications against PLUTO data, benchmarking WIF values against prior comparable studies, and conducting sample checks in selected areas across each borough. Additional testing should also evaluate system boundary decisions, including whether to exclude roof components due to weather exposure, include subflooring, or account for secondary elements such as staircases and partition walls.

05.FEASIBILITY ANALYSIS

5.1 OVERVIEW

The methodology and results indicate that New York City may contain as much as 147 million cubic feet of wood within eligible buildings, revealing a material stock of considerable scale. This volume is roughly equivalent to the amount of virgin timber that would be sourced from a forest approximately the size of three Manhattans and contains approximately 3.7 million metric tons of carbon dioxide stored in the wood itself. The feasibility question then, is not whether the resource exists, but whether the current systems of building removal, material handling, and market exchange are capable of capturing its value.

This analysis evaluates the financial and environmental feasibility of deconstruction relative to conventional demolition within New York City's built environment. Using a representative pre-1875 brownstone, the assessment compares removal costs, material recovery potential, and estimated downstream value associated with reclaimed wood.

Annually, approximately 2,000 buildings are demolished citywide, contributing to the estimated 5.3 million tons of material handled through the C&D waste stream, based on private transfer reports to DSNY. Of this total, approximately 2.1 million tons were classified as C&D debris, with the remainder consisting largely of fill material.

At the broader state level, the NYS Department of Environmental Conservation (NYS DEC) estimates that C&D is composed primarily of concrete, asphalt, brick, soil, and wood, with wood representing approximately 15% of the waste stream by weight. While an estimated 64% of this material is recycled, 26% is landfilled, 9% is exported for disposal, and a small fraction is combusted.

These material flows remain largely linear. Most construction materials are imported into the city, while much of the resulting waste is transported outside the five boroughs for processing or disposal. Deconstruction offers an alternative by shifting building removal away from disposal and toward material recovery and reuse. Its feasibility however, depends not only on the direct cost of removal, but also on how value is distributed across the recovery chain. Property owners typically bear the upfront cost of building removal, while the economic value of salvaged wood is often realized later by processors, fabricators, and resale markets.

Interviews with practitioners, including CO Adaptive, suggest that *this imbalance is also fundamentally a design problem*. Buildings are not typically designed for disassembly, which increases labor costs and reduces material recovery potential. Emerging approaches, including work developed by the Cornell Circular Construction Lab, demonstrate how mechanically fastened mass timber systems, such as groove-laminated timber, can enable structural reuse through reversible connections. Designing for disassembly preserves material value and reduces end-of-life labor, improving feasibility across a building's lifecycle rather than at the point of demolition alone.

Figure 31. CNC - GrooveLam (Cornell Circular Construction Lab, 2022)

Figure 32. Modular Assembly (CO Adaptive, 2026)

As a result, deconstruction operates within a distributed economic structure, where costs are incurred at the point of removal, but value can be captured later in the material lifecycle. This structural misalignment remains a key barrier to adoption, even in cases where total system value may exceed the cost of demolition.

5.2 GENERAL ASSUMPTIONS

This analysis is based on a set of standardized assumptions derived from the project's material estimation model and industry-informed benchmarks:

- **Building typology:** <1875, low-rise (≤6 stories), Brownstone
- **Wood intensity factor:** applied at the building level to estimate total structural wood volume
- **Recovery rates:**
  - **Demolition:** minimal recovery (~0-5%)
  - **Deconstruction:** high recovery potential (~80%)
- **Material composition:** focus on structural wood: joists, beams, finished flooring
- **Cost structure:** includes labor, transportation, disposal, and basic processing
- **Market conditions:** conservative assumptions for bulk reclaimed wood pricing

**These assumptions are intended to provide a directional but scalable framework, recognizing that actual outcomes will vary based on building condition, location, and market dynamics.*

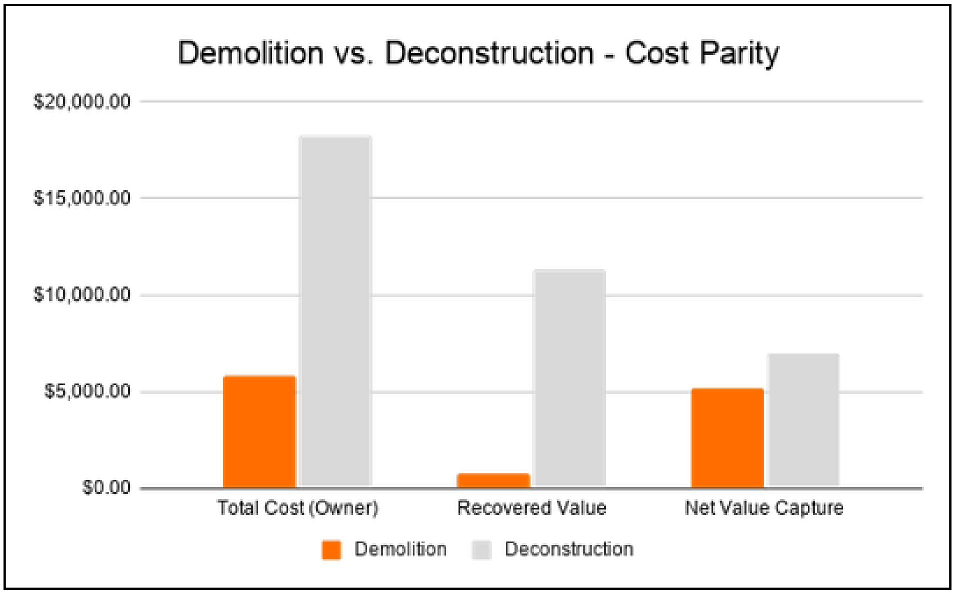
5.3 COST-BENEFIT ANALYSIS

A comparative cost-benefit analysis was conducted to evaluate demolition versus deconstruction across the typical lifecycle segments. What is the cost to the owner, and what is the potential recovered material value within the reuse market? Assumptions include prevailing labor rates from the NYC Comptroller for house wreckers and job intensity factors informed by US EPA workforce estimates.

At the building level, conventional demolition presents a lower upfront cost, approximately $5,841, driven by speed and reduced labor requirements. Deconstruction is estimated at $18,292, reflecting the added labor for selective dismantling, sorting, and material handling.

Material recovery provides an opportunity to offset a portion of this value gap. Demolition yields minimal salvage (~0-5%), or roughly $709 in value, while deconstruction, which assumes an 80% recovery rate, generates approximately $11,343. On a net basis, costs converge to $5,132 for demolition and $6,949 for deconstruction, reducing the difference to roughly $1,800 and indicating near cost parity.

Figure 33. Demolition vs. Deconstruction Cost Comparison



However, this building-level comparison understates the potential economics of deconstruction, which operates as a multi-stage value chain rather than a single transaction. Costs are front-loaded at the point of removal, while value is realized downstream. Unlike demolition, which incurs disposal costs; deconstruction enables material recovery that can generate revenue through resale or donation. Reclaimed wood can command significantly higher market value than its disposal cost, and when donated, materials exceeding the $5,000 threshold may qualify for federal tax deductions if supported by a qualified appraisal (Build Reuse). Taken together, these value streams can offset a meaningful share of upfront costs and strengthen the financial case for recovery.

5.4 LEARNING FROM PRIOR STUDIES ON DECONSTRUCTION AND REUSE

The methodological logic of this study also aligns closely with Felix Heisel, Joe McGranahan, and the ScanR framework, which emphasizes the importance of evaluating material content and reuse potential prior to demolition or deconstruction. Their approach combines building surveys with digital scanning in order to document not only quantities of material, but also information necessary for salvage planning, such as quality, hazards, and likely reuse pathways. This reinforces the importance of treating building stock as a pre-demolition resource base that can be screened and analyzed before materials enter the waste stream.

In the context of this research, that logic supports the use of typology, age, and construction characteristics as a way to estimate where recoverable wood is likely to exist at scale, even where direct access to each building is not possible (Heisel et al., 2022). Earlier work has shown that pre-demolition surveys, material inventories, and documentation tools are essential in identifying salvageable materials before they enter the waste stream.

Building on these findings, there is an opportunity that New York City could use demolition and major alteration permit filings to trigger Building Block Lot (BBL) screening for buildings likely to contain recoverable structural wood. This would create an earlier point of intervention, allowing public agencies, reuse organizations, and private market actors to assess salvage potential and prepare for recovery before building removal begins.

Figure 34. DOB NOW: BUILD: Demolition Permit Filing

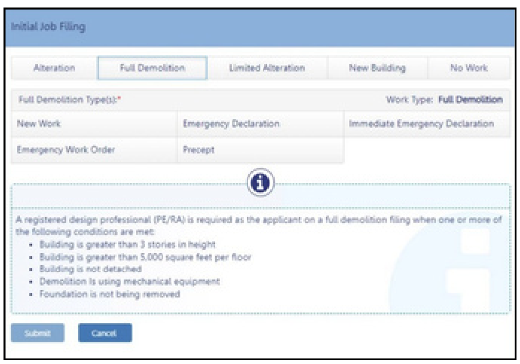


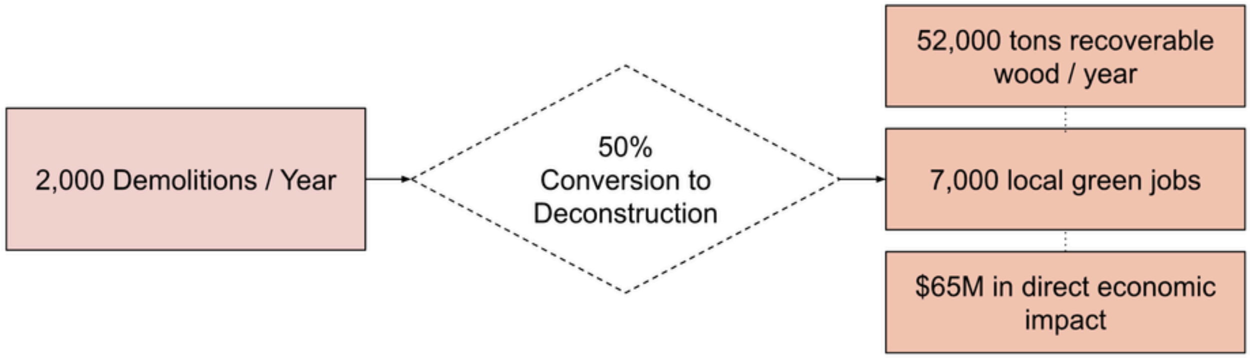
Figure 35. Illustrative, Permit Level Screening: Linking BBLs to Recovery Opportunities

BBL	OG Candidate	Total Estimated Wood Volume (cubic feet)
3089320592	Opportunity!	481.91
3089000084	Opportunity!	631.07
3089001000	Opportunity!	552.19
3089550114	Opportunity!	143.43
3017890028	Opportunity!	372.91
3060170021	Opportunity!	817.53
3060170069	Opportunity!	817.53
3060070012	Opportunity!	567.97
3060170046	Opportunity!	1097.21
3060340026	Opportunity!	756.11

5.5 MARKET POTENTIAL

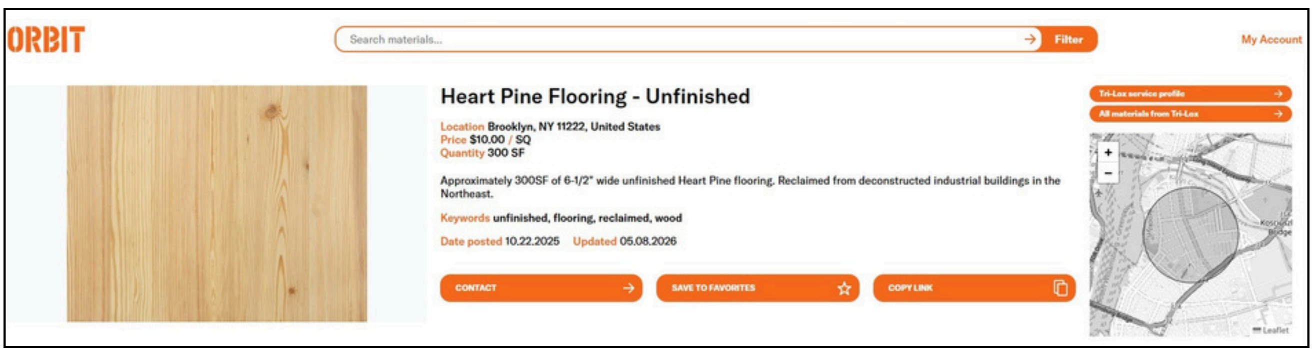
To understand the broader impact of this ecosystem, we modeled a scaled workforce development scenario to illustrate the direct economic impact in addition to creating a pipeline of new local jobs. Assuming 2,000 demolitions based on New York City permit data, and a 50% conversion rate to deconstruction, approximately 1,000 buildings per year could enter the deconstruction pipeline. Based on average building characteristics and recovery assumptions, this would result in an estimated 52,500 tons of recoverable wood annually. At a conservative market value of $1,000 per ton, this equates to an estimated $52.5 million in annual recoverable material value downstream, in addition to $6.3 million in avoided disposal costs. Due to its labor-intensive nature, deconstruction also represents a significant source of job creation, generating an estimated 7 direct jobs per project, or approximately 7,000 jobs annually under this scenario.

Figure 36. Projected Benefits of Converting 50% of Demolitions to Deconstruction, NYC



New York City already has an emerging private sector ecosystem that supports material recovery, exchange, remanufacturing, and specification across different stages of the reuse value chain. Orbit Exchange functions as a digital marketplace for the circular construction economy, designed to facilitate demand for used and surplus construction materials by streamlining procurement, donation, and partner identification. This ecosystem includes processors such as SawKill Lumber, showing the commercial viability of reclaimed wood as a high-value building product.

Figure 37. Orbit Exchange Listing for Reclaimed Heart Pine Flooring



Taken together, these organizations illustrate that key elements of a circular wood economy already exist in New York City. What remains underdeveloped is the connective infrastructure needed to scale them, including reliable material aggregation, grading, storage, and procurement pathways. The presence of companies like SawKill Lumber and Tri-Lox suggests that the principal challenge is not whether a market for reclaimed wood can exist, but whether policy, infrastructure, and project delivery systems can expand and connect existing capacities into a more coordinated urban framework.

5.6 RISK AND REUSE PATHWAYS

A key constraint on the profitability of deconstruction in New York City lies in the interval between material recovery and end use. Once wood is removed from a building, it enters a cost chain that includes on-site sorting, transportation, denailing, grading, storage, and ultimately resale. Cooper Recycling, a major intermediary in the city's C&D material flow, is designed to receive mixed debris and process roughly 2,000 tons per day, with wood comprising about 15% of the stream by weight. The facility separates material rapidly and moves it to downstream markets with minimal delay (see Appendix B). In that system, throughput is essential: material that arrives today is expected to leave by the next day. In a place like NYC, where land and industrial space command a premium, prolonged storage can quickly undermine profitability. As a result, even when recoverable wood is present in meaningful quantities, time and space can determine whether it retains value or becomes a cost burden.

Supporting collateral, such as the Part 360 tracking form, creates a record of debris movement; however, its paper-based and often handwritten format limits data quality. Entries may be incomplete, inconsistent, or difficult to interpret, especially with a form that is structured primarily to support regulatory compliance rather than material recovery analysis. Cooper Recycling also noted that reporting tends to focus on inbound and outbound quantities rather than detailed material pathways, making it difficult to trace wood by type, quality, or final destination once it enters the broader recovery stream. In conversations with the NYSDEC, it was noted that salvaged architectural elements, such as wood beams, flooring, and light fixtures, may fall outside the definition of solid waste when they are intended for direct reuse in their original function without processing.

By contrast, materials managed through a Beneficial Use Determination (BUD) framework are subject to a different regulatory logic. NYSDEC guidance indicates that, in general, the recipient of a BUD material should not be paid, since payment may weaken the material's status as a product with market value rather than waste. These distinctions reveal a fragmented system in which direct reuse, waste handling, and beneficial use are governed by different rules and documented through uneven forms of recordkeeping. The current system can show where debris moves, but offers limited insight into what reusable material is being lost, recovered, or redirected to higher-value uses.

At the same time, this bottleneck should not affect the intrinsic value of reclaimed wood or the range of applications it can serve. Tri-Lox and SawKill Lumber provide a strong example of how wood recovered from historic buildings can be remanufactured into finished flooring, paneling, and custom millwork. Dimensional lumber, beams, furniture, and other architectural products for contemporary use. This is especially true for finished flooring, which represents one of the more scalable end markets for recovered wood because it can absorb substantial material volumes while preserving much of the wood's character and embodied value. Insights from SawKill Lumber notes that a meaningful share of recovered wood with architectural value ultimately leaves the city, and in cases, the state, for fit-outs and design applications elsewhere. That observation points to a broader structural issue: the challenge is not only recovering old-growth wood but also building the local capacity to retain more of its second life, localized within the city.

The principal risk, therefore, is not whether recoverable wood exists, but whether NYC has the storage capacity, market visibility, grading systems, and procurement pathways needed to preserve that value and direct different grades of material toward appropriate reuse applications before handling costs reduce them to lower value outcomes. A more standardized and transparent tracking framework is therefore needed, one capable of capturing not only quantities and destinations, but material conditions, reuse potential, and final end use. Framed this way, profitability depends not on a single premium market, but on a coordinated system capable of moving recovered wood efficiently across a spectrum of local end uses.

06. CONCLUSIONS

This study developed a proof-of-concept methodology to identify and estimate the quantity of old-growth wood embedded within New York City's building stock. Starting from a broad research question, the project combined historical analysis, building typology, parcel level data, and spatial modeling to create a citywide screening framework for likely recovery candidates. In doing so, it reframed old-growth wood not simply as material encountered through salvage efforts, but as a distributed urban resource that can be systematically identified, mapped, and evaluated.

The analysis identified approximately 349,584 buildings that met the final eligibility criteria, representing about 633.5 million square feet of floor area and an estimated 147 million cubic feet of old-growth wood. This stock is concentrated in older low-rise residential buildings, walk up apartment buildings, and selected industrial typologies, with the largest volumes located in Brooklyn, Manhattan, and Queens. These results indicated that recoverable old-growth wood in New York City is substantial in both scale and geographic distribution.

This suggests that buildings can be understood as material banks whose embedded value is routinely lost through demolition and disposal. Recovering structural wood could reduce waste, preserve biogenic carbon, offset some demand for virgin materials, and support local economic activity. At the same time, the study makes clear that identifying material is only the first step. Recovery depends on a broader system of deconstruction, sorting, transportation, storage, and reuse that does not yet operate at a sufficient scale in New York City.

Together, the findings suggest that wood recovery in the city is technically plausible and increasingly relevant to the city's climate and waste reduction goals. Its expansion, however, will depend on strong data systems, more reliable material tracking, enabling policies, and investment in the infrastructure and markets needed to keep recovered wood in circulation.

6.1 KEY FINDINGS AND OBSERVED LIMITATIONS

A central finding of this study is that old-growth wood can be identified indirectly through building characteristics. The strongest proxy was the relationship between construction period, typology, and historical material practice. Buildings constructed during certain eras, specifically prior to 1938, and within certain classes, were more likely to contain substantial quantities of structural timber. Filtering by age, type, and height provided a workable basis for estimating likely wood volume at the building, neighborhood, borough, and citywide scales.

Even where wood is present in significant quantities, reuse outcomes remain sensitive to building condition, extraction method, contamination, and the capacity of downstream markets to process and reuse materials of varying type, dimension, and grade. Interviews and feasibility analysis suggest that the current C&D systems remain optimized for speed and throughput rather than selective dismantling and reuse. The challenge, therefore, is not only locating wood but preserving its value long enough to reach an appropriate second use.

There are several limitations that should also be acknowledged. The methodology relies heavily on secondary datasets, particularly PLUTO, which practitioners have identified as inconsistent in certain fields. Specifically, there is concern around the accuracy of the year built variable, which is central to a method that uses construction era as a proxy for likely old-growth wood presence. Additionally, the model provides an estimate rather than a direct physical measurement of wood in buildings. Actual reclaimable wood will vary according to undocumented alterations, deterioration, renovation history, and condition at the time of extraction.

The sensitivity analysis further shows that the results are highly dependent on assumptions related to the wood intensity factor and the eligibility boundary. Across the five tested scenarios, estimated wood volume ranged from 100 to 169 million cubic feet. This range does not diminish the model’s usefulness, but it does indicate that uncertainty remains significant for downstream planning. More broadly, this study was intentionally designed around specific material and geography. The assumptions, typological eras, and wood intensity calculations were tailored to NYC’s historic building stock and to old-growth wood in particular. As a result, the precise calculations are not directly transferable to materials such as glass or steel, even though the broader method remains relevant for future material recovery models.

6.2 RECOMMENDATIONS

While questions of sorting, transport, storage, and resale fall beyond the immediate scope of this report, the literature, interview findings, and empirical analysis make clear that any effort to recover old-growth wood at scale will depend on economic feasibility and strong systems for reclamation. Experts consistently pointed to the large volume of wood currently lost within New York City's construction and demolition stream, while also emphasizing the variation in species, dimensions, condition, and quantity that complicates recovery after deconstruction.

Although these challenges require further study, the research presented here identifies three high-level recommendations to support future implementation:

Validate the model through empirical data and pilot programs

To validate the methodology, the model's estimates must be compared against the actual material yields found within a given building. This requires comparing modeled estimates with quantities recovered through demolition audits and selective dismantling, and can be achieved through two primary methods: onsite demolition audits and targeted pilot programs. Due to existing material separation practices during demolition, empirical, high-value data could be gathered at a low cost. Additionally, a recovery pilot supported by T+G and the DDC would allow ongoing testing regarding the true yields of deconstruction, as well as the costs of transportation, storage, and reuse. Over time, this testing should expand beyond wood to include additional recoverable materials so the methodology can support a broader framework for urban material recovery.

Optimize the economic and logistical infrastructure for secondary wood markets

To ensure the economic viability of deconstruction, three pathways should be explored: Logistical Optimization, Economic Incentivization, and Market Integration. First, physical constraints in collection and storage can be mitigated by the utilization of industrial business zones and other centralized hubs. This ensures demolition companies can optimize truck usage and streamline deliveries while providing secondary markets with additional pick-up and storage capacity. Second, establishing a quantifiable market value per cubic foot for old-growth wood provides both an investment baseline and could be used to inform public incentives. Finally, the city should prioritize developing local end-use markets for old-growth wood. In doing so, additional barriers to market development should be identified and removed.

Formalize the development of a deconstruction workforce

Beyond data and economic impact, the city must prioritize the development of a capable deconstruction workforce, the ultimate linchpin of an emerging circular economy. Proper education and training are necessary to ensure recovery workflows are optimized for maximum yield. Furthermore, current regulatory barriers that inhibit deconstruction and the reuse of reclaimed materials must be dismantled. Additional research into this developing labor market will be essential, alongside public-facing communication regarding the benefits of deconstruction.

6.3 FINAL NOTES: TO A SUSTAINABLE FUTURE NEW YORK CITY

This project establishes a starting point for a material recovery framework tailored to New York City. Its contributions lie not only in estimating a substantial stock of wood but in showing that circular recovery depends on the coordination of data, design, infrastructure, labor, and markets. While old-growth wood was the focus of this analysis, the broader significance extends beyond a single material stream.

There is an invisible forest the size of three Manhattans within our buildings.

If New York City is to move toward a more circular built environment, it must begin to see demolition not as the end of a building's life, but as the beginning of a new material cycle. This report offers an initial framework for that transition by pairing historical analysis with spatial modeling to identify where recoverable old-growth wood is likely contained across the city's building stock. The path to a more regenerative city will depend not only on new materials and new construction, but on our ability to recognize, map, and recover the resources already embedded in the city we have built.

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APPENDIX A

PLUTO DATA DETAILS

- BOROUGH (Borough)
- TAX BLOCK (Block)
- TAX LOT (Lot)
- COMMUNITY DISTRICT (CD)
- CENSUS TRACT 2020 (BCT2020)
- CENSUS BLOCK 2020 (BCTCB2020)
- CENSUS TRACT 2010 (CT2010)
- CENSUS BLOCK 2010 (CB2010)
- SCHOOL DISTRICT (SchoolDist)
- CITY COUNCIL DISTRICT (Council)
- ZIP CODE (ZipCode)
- FIRE COMPANY (FireComp)
- POLICE PRECINCT (PolicePrct)
- HEALTH CENTER DISTRICT (HealthCenterDist)
- HEALTH AREA (HealthArea)
- SANITATION DISTRICT BORO (SanitBoro)
- SANITATION DISTRICT NUMBER (SanitDist)
- SANITATION SUBSECTION (SanitSub)
- ADDRESS (Address)
- ZONING DISTRICT 1 (ZoneDist1)
- ZONING DISTRICT 2 (ZoneDist2)
- ZONING DISTRICT 3 (ZoneDist3)
- ZONING DISTRICT 4 (ZoneDist4)
- COMMERCIAL OVERLAY 1 (Overlay1)
- COMMERCIAL OVERLAY 2 (Overlay2)
- SPECIAL PURPOSE DISTRICT 1 (SPDist1)
- SPECIAL PURPOSE DISTRICT 2 (SPDist2)
- SPECIAL PURPOSE DISTRICT 3 (SPDist3)
- LIMITED HEIGHT DISTRICT (LtdHeight)
- SPLIT BOUNDARY INDICATOR (SplitZone)
- BUILDING CLASS (BldgClass)

- LAND USE CATEGORY (LandUse)
- NUMBER OF EASEMENTS (Easements)
- TYPE OF OWNERSHIP CODE (OwnerType)
- OWNER NAME (OwnerName)
- LOT AREA (LotArea)
- TOTAL BUILDING FLOOR AREA (BldgArea)
- COMMERCIAL FLOOR AREA (ComArea)
- RESIDENTIAL FLOOR AREA (ResArea)
- OFFICE FLOOR AREA (OfficeArea)
- RETAIL FLOOR AREA (RetailArea)
- GARAGE FLOOR AREA (GarageArea)
- STORAGE FLOOR AREA (StrgeArea)
- FACTORY FLOOR AREA (FactryArea)
- OTHER FLOOR AREA (OtherArea)
- TOTAL BUILDING FLOOR AREA SOURCE CODE (AreaSource)
- NUMBER OF BUILDINGS (NumBldgs)
- NUMBER OF FLOORS (NumFloors)
- RESIDENTIAL UNITS (UnitsRes)
- TOTAL UNITS (UnitsTotal)
- LOT FRONTAGE (LotFront)
- LOT DEPTH (LotDepth)
- BUILDING FRONTAGE (BldgFront)
- BUILDING DEPTH (BldgDepth)
- EXTENSION CODE (Ext)
- PROXIMITY CODE (ProxCode)
- IRREGULAR LOT CODE (IrrLotCode)
- LOT TYPE (LotType)
- BASEMENT TYPE/GRADE (BsmtCode)
- ASSESSED LAND VALUE (AssessLand)
- ASSESSED TOTAL VALUE (AssessTot)
- EXEMPT TOTAL VALUE (ExemptTot)
- YEAR BUILT (YearBuilt)
- YEAR ALTERED 1 (YearAlter1)
- YEAR ALTERED 2 (YearAlter2)
- HISTORIC DISTRICT NAME (HistDist)
- LANDMARK STATUS (Landmark)
- BUILT FLOOR AREA RATIO (BuiltFAR)
- MAXIMUM ALLOWABLE RESIDENTIAL FAR (ResidFAR)
- MAXIMUM ALLOWABLE COMMERCIAL FAR (CommFAR)

- MAXIMUM ALLOWABLE COMMUNITY FACILITY FAR (FacilFAR)
- BORO CODE (BoroCode)
- BOROUGH, TAX BLOCK & LOT (BBL)
- CONDOMINIUM NUMBER (CondoNo)
- CENSUS TRACT 2 (Tract2010)
- X COORDINATE (XCoord)
- Y COORDINATE (YCoord)
- ZONING MAP # (ZoneMap)
- ZONING MAP CODE (ZMCode)
- SANBORN MAP # (Sanborn)
- TAX MAP # (TaxMap)
- E-DESIGNATION NUMBER (EDesigNum)
- APPORTIONMENT BBL (APPBBL)
- APPORTIONMENT DATE (APPDate)
- PLUTO – DTM BASE MAP INDICATOR (PLUTOMapID)
- 2007 FLOOD INSURANCE RATE MAP INDICATOR (FIRM07_Flag))
- 2015 PRELIMINARY FLOOD INSURANCE RATE MAP INDICATOR (PFIRM15_Flag)
- VERSION NUMBER (Version)
- CHANGED BY DCP (DCPEdited)
- LATITUDE (Latitude)
- LONGITUDE (Longitude)
- NOTES (Notes)

APPENDIX B

INTERVIEWS

Interviewee: Tobie Cornejo - L+M
Category: Architect, Preservation, Housing

Summary: Conversation with Tobie Cornejo brought the discussion down to project level realities in housing. The interview highlighted that structural wood is often the most plausible salvage stream, while finish materials are frequently damaged by contamination, paint layers, adhesives, plaster, or asbestos related flooring conditions. The notes also suggest that many useful structural elements may already have been replaced with metal during gut renovations, narrowing what remains available. There was also a strong focus on labor, prevailing wage, and whether a convincing market case for reuse can be made in practice. Compared with more theoretical circularity discussions, this conversation was more grounded in renovation realities and the tension between what may exist in a building and what is actually practical to recover.

Interviewee: Dave Bennik - RE-USE, NYC Circular Construction Network
Category: Reuse, Circular Strategy

Summary: Our conversation with Dave was framed around infrastructure, labor, and value capture. Dave's insight pointed to the gap between demolition, which is optimized for speed with machines, and deconstruction, which requires more labor but can reduce disposal costs and preserve material value. He discussed the broader reuse ecosystem, including transport, storage, resale, remanufacturing, nonprofit reuse stores, and even smaller scale secondary products and structures. Particularly useful was his framing of material value as something that changes depending on the sales environment, from a low value fire sale to a high value showroom sale. He also raised policy levers such as public procurement, waste requirements, and models like Portland's restrictions on demolition.

Interviewee: Andrew Dolkart - Columbia University, Preservation Architect
Category: Preservation Architecture, Historian

Summary: Andrew Dolkart brought an architectural history lens that helped ground the project in how New York actually developed. His notes suggest that the most promising old wood stock is tied to specific neighborhoods, typologies, and moments in urban growth, including masonry rowhouses, apartment buildings under six stories, older commercial buildings, and some factories. He expressed skepticism about relying too heavily on PLUTO for early building history and instead suggested using historic atlases, land books, and representative study areas such as Park Slope, Brooklyn Heights, the Navy Yard, and parts of Manhattan. He also clarified that landmark status often applies primarily to the exterior unless otherwise designated, which is important when thinking about both preservation and recoverability.

Interviewee: Tim Lynch - Thornton Tomasetti, Forensic Engineer
Category: Forensic Engineer

Summary: Tim Lynch offered the most direct technical guidance for structuring the methodology. He framed New York's building stock through code eras, distinguishing pre 1916 integrated systems, transitional buildings between 1916 and 1938, and post 1938 disparate systems where materials became more standardized and engineered. He reinforced that 1938 is a logical major cutoff, while also noting that the strongest old growth period likely peaks earlier, around 1870 to 1915. He identified prelaw and old law tenements, rowhouses, small mass housing, some lofts, and houses of worship as strong candidates, while recommending immediate exclusion of garages, NYCHA concrete buildings, and most later steel and concrete buildings. He also highlighted the importance of using HPD as a parent dataset for early housing and treating alteration years as a risk factor rather than an automatic exclusion.

Interviewee: Felix Heisel - Cornell, Circular Construction Lab

Category: Director Circular Construction Lab, Academic

Summary: Felix Heisel contributed a foundational research perspective that directly informed this study. His published work on pre-demolition material surveying, LiDAR enabled material assessment, deconstruction economics, and urban mining in the United States helped shape both the methodological structure and the broader feasibility framing of the capstone. In the interview, he emphasized that while citywide material estimates can be generated through archetype based modeling, the more difficult task is validating what is actually accessible, recoverable, and reusable in practice.

Interviewee: Joe McGranahan - Arup / Cornell Circular Construction Lab

Category: Architect, Material Modeling, Circular Construction

Summary: Joe McGranahan discussed the project from the perspective of prior research conducted alongside Felix Heisel through the Cornell Circular Construction Lab. As a co-author on research related to LiDAR based material surveying, and deconstruction case study analysis, his perspective was especially useful in reinforcing the value of archetype based estimation methods and the importance of linking large scale modeling to field validation. He also emphasized the distinction between estimating total material stock and understanding what portion is actually recoverable and reusable under real project conditions.

Interviewee: Alan Solomon - SawKill Lumber
Category: Reclaimed Wood Supplier / Market Actor

Summary: Alan Solomon provided the richest material specific insight into how reclaimed wood actually moves through the system. He described New York as a major repository of older lumber and gave concrete examples of how species and wood quality vary by era and location, from eastern white pine in very early buildings to southern longleaf pine and later softwoods arriving through changing regional supply chains. He emphasized that his role typically begins after wood is removed from the structure, not at the demolition stage, and that recoverability depends heavily on hand dismantling, permitting, liability, trucking, and the ability to aggregate enough volume to justify hauling. He also stressed that larger beams are the most realistic salvage target, while smaller material is often crushed, layered into what he described as “frankenstein” assemblies, or too labor intensive to recover. Importantly, he showed how material value changes by species, patina, hardness, and end use, and suggested that even when lumber is viable, margins remain tight.

Interviewee: Bobby Johnston - CO Adaptive
Category: Architect, Circular Design

Summary: Insights from CO Adaptive highlighted both the design potential and the broader constraints of material reuse. While recoverable material exists within the building stock, the current system is not yet equipped to capture and reuse it at scale, in part because relatively few designers and project teams are trained to work with reclaimed materials or design around site available supply. CO Adaptive’s work points to emerging reuse pathways, including modular assemblies and mechanically fastened systems such as groove laminated timber, which can support easier disassembly and future reuse. Their perspective suggests that greater standardization of these systems could reduce future deconstruction labor while preserving material value and improving life cycle outcomes.

COOPER RECYCLING

Interviewee: Morgan Cassidy - Cooper Recycling
Category: C&D Processor, Recycling Infrastructure

Summary: Cooper Recycling is the largest C&D debris recycling facility in New York City; handling approximately 2,000 tons of C&D per day, with wood representing about 15% of inbound material by weight. Their perspective highlighted that current tracking systems focus primarily on tonnage, origin, and destination rather than the detailed identification of reusable wood or other high value materials. This means that once materials enter the mixed debris stream, much of their reuse potential is effectively lost. The interview reinforced that structural and architectural salvage must typically be separated upstream, before materials reach a conventional recycling facility, and that the current system is optimized for throughput rather than selective recovery. More broadly, Cooper's highlighted the importance of source separation, better material tracking, and intermediary infrastructure if reuse is to occur at scale rather than remaining incidental to the waste stream.

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Interviewee: Kathleen Prather - NYSDEC
Category: Environmental Engineer, Regulatory

Summary: Our conversation with NYSDEC was especially useful for understanding the legal and administrative side of material recovery. The discussion focused on the distinction between material identified for reuse before it becomes waste and material that enters the waste system and is then governed primarily through Part 360 regulations and Beneficial Use Determinations. The notes also highlight that current state systems track movement by tonnage, origin, and destination, but are not set up to capture the more granular information needed to understand reuse potential for specific materials such as structural wood. The interview therefore reinforced that once material leaves the city as waste, opportunities for higher value reuse become much harder to preserve.

Interviewee: Amanda Kiminsky - BUILDING PRODUCT ECOSYSTEMS
Category: Scaling reclamation, Material Reuse

Summary: Our conversation focused on the operational logistics and shifting economics of source-separating high-volume materials like glass and drywall. The discussion revealed that labor costs for manual separation are often overstated by crews, suggesting that with strategic planning, such as utilizing the "pre-permit" window for deconstruction; deconstruction can match or exceed the speed of traditional demolition. Amanda also emphasized the role of data in market development; for instance, the emergence of new gypsum recycling in NYC was directly enabled by better data availability. Furthermore, the interview highlighted a turning point in financial feasibility: as landfill tipping fees rise and the potential for carbon pricing looms, the traditional demolition model becomes increasingly expensive compared to the long-term infrastructure advantages of deconstruction.

Interviewee: Elizabeth Zink, Tri-Lox, Research & Business Development
Category: Reclaimed Wood Processing, Manufacturing

Summary: Tri-Lox provided a practical perspective on reclaimed wood supply chains, showing that reuse depends as much on sourcing, storage, and processing as on manufacturing itself. The interview highlighted that while demand for reclaimed wood has grown alongside interest in low carbon construction, scaling remains constrained by high costs, limited local infrastructure, and weak policy support. Tri-Lox's experience also showed that product development often has to respond to the material that is actually available, rather than a fixed specification, particularly in a city where softwood appears more common than hardwood in the salvage stream. More broadly, the discussion pointed to the need for stronger local systems to connect material recovery, processing, and end use.

APPENDIX C

PYTHON CODE INPUT

```
import pandas as pd
import numpy as np
df = pd.read_csv('PLUTO_DATA.csv')#Ensure your local copy of PLUTO is named appropriately

def print_borough_salvage_summary(df):
   # --- 0. Borough Column Check ---
   # Standardize column name to lowercase 'borough' if it exists as 'Borough'
   if 'Borough' in df.columns:
       df = df.rename(columns={'Borough': 'borough'})
   elif 'borough' not in df.columns:
       raise KeyError("Error: A 'borough' column is required for this analysis. Please
ensure your dataframe contains this column.")

   # --- 1. Clean and Prepare Columns ---
   cols_to_fix = ['bldgarea', 'yearbuilt', 'numfloors', 'numbldgs', 'bldgfront',
'bldgdepth']
   for col in cols_to_fix:
       df[col] = pd.to_numeric(df[col], errors='coerce')

   # --- 2. THE IMPUTATION FIX ---
   missing_area_mask = (df['bldgarea'] == 0) | (df['bldgarea'].isna())
   proxy_area = df['bldgfront'] * df['bldgdepth'] * df['numfloors']
   df.loc[missing_area_mask, 'bldgarea'] = proxy_area[missing_area_mask]

   fixed_count = missing_area_mask.sum()
   print(f"[*] Imputed missing area for {fixed_count:,} building records using footprint
data.\n")

   # --- 3. Filter Valid Rows ---
   df_clean = df[
       (df['bldgclass'].notna()) &
       (df['yearbuilt'] > 0) &
       (df['numfloors'] < 7) &
       (df['bldgarea'] > 0) &
       (df['borough'].notna()) # Ensure borough is valid
   ].copy()

   df_clean['Typology'] = df_clean['bldgclass'].str[0].str.upper()
```

```
# --- 4. Map Buildings to their Specific Table Category ---
def assign_category(row):
    t = row['Typology']
    y = row['yearbuilt']

    if t == 'A':
        if y <= 1900: return 'A (Detached): <1900'
        elif 1901 <= y <= 1938: return 'A (Detached): 1901-1938'
    elif t == 'B':
        if y < 1875: return 'B (Brownstone): <1875'
        elif 1875 <= y <= 1895: return 'B (Brownstone): 1875-1895'
        elif 1896 <= y <= 1916: return 'B (Brownstone): 1896-1916'
    elif t in ['C', 'S']:
        if y < 1879: return 'C/S (Tenement): <1879'
        elif 1879 <= y <= 1900: return 'C/S (Tenement): 1879-1900'
        elif 1901 <= y <= 1916: return 'C/S (Tenement): 1901-1916'
    elif t == 'E':
        if y < 1896: return 'E (Warehouse): <1896'
        elif 1897 <= y <= 1916: return 'E (Warehouse): 1897-1916'
    elif t == 'O':
        if y < 1879: return 'O (Office): <1879'
        elif 1880 <= y <= 1901: return 'O (Office): 1880-1901'

    return np.nan

df_clean['Detailed_Category'] = df_clean.apply(assign_category, axis=1)

# --- NEW ADDITION: Count Unmapped Buildings <= 1938 grouped by Borough ---
unmapped_mask = (df_clean['yearbuilt'] <= 1938) & (df_clean['Detailed_Category'].isna())
unmapped_by_boro = df_clean[unmapped_mask].groupby('borough')['numbldgs'].sum()

# Drop the unmapped buildings to calculate final totals
df_final = df_clean.dropna(subset=['Detailed_Category']).copy()

# --- 5. Apply WIF and Calculate Wood Volume ---
wif_dict = {
    'A (Detached): <1900': 0.312,
    'A (Detached): 1901-1938': 0.199,
    'B (Brownstone): <1875': 0.362,
    'B (Brownstone): 1875-1895': 0.303,
    'B (Brownstone): 1896-1916': 0.260,
```

```
    'C/S (Tenement): <1879': 0.381,
    'C/S (Tenement): 1879-1900': 0.280,
    'C/S (Tenement): 1901-1916': 0.211,
    'E (Warehouse): <1896': 0.570,
    'E (Warehouse): 1897-1916': 0.220,
    'O (Office): <1879': 0.220,
    'O (Office): 1880-1901': 0.123
}

df_final['WIF'] = df_final['Detailed_Category'].map(wif_dict)
df_final['Total_Wood_cuft'] = df_final['bldgarea'] * df_final['WIF']

# --- 6. Calculate the Sums BY BOROUGH ---
# We group by both 'borough' and 'Detailed_Category' and reset_index so we can iterate
summary = df_final.groupby(['borough', 'Detailed_Category']).agg(
    Total_Buildings=('numbldgs', 'sum'),
    Total_Area_sqft=('bldgarea', 'sum'),
    WIF=('WIF', 'first'),
    Total_Wood_cuft=('Total_Wood_cuft', 'sum')
).reset_index()

# Sort for clean output layout
summary = summary.sort_values(by=['borough', 'Detailed_Category'])

# --- 7. Print the Console Tables ---
boroughs = summary['borough'].unique()

# Track citywide totals
grand_total_bldgs = 0
grand_total_area = 0
grand_total_wood = 0

for boro in sorted(boroughs):
    print("\n" + "=" * 105)
    print(f"BOROUGH: {str(boro).upper()}")
    print("=" * 105)
    print(f"{'CATEGORY (TYPOLOGY & ERA)':<28} | {'BUILDINGS':<10} | {'TOTAL AREA (SQ
FT)':<18} | {'WIF':<5} | {'WOOD VOL (CU FT)':<18}")
    print("-" * 105)

    # Filter data for just this borough
    boro_data = summary[summary['borough'] == boro]
```

```
        for index, row in boro_data.iterrows():
            bldgs = int(row['Total_Buildings'])
            area = int(row['Total_Area_sqft'])
            wif = row['WIF']
            wood = int(row['Total_Wood_cuft'])
            cat = row['Detailed_Category']

            print(f"{cat:<28} | {bldgs:<10,} | {area:<18,} | {wif:<5.3f} | {wood:<18,}")

        print("-" * 105)

        # Calculate Subtotals for the Borough
        boro_bldgs = int(boro_data['Total_Buildings'].sum())
        boro_area = int(boro_data['Total_Area_sqft'].sum())
        boro_wood = int(boro_data['Total_Wood_cuft'].sum())

        print(f"{'BOROUGH TOTAL':<28} | {boro_bldgs:<10,} | {boro_area:<18,} | {'N/A':<5} |
{boro_wood:<18,}")

        # Print the unmapped buildings count for this specific borough
        boro_unmapped = int(unmapped_by_boro.get(boro, 0))
        if boro_unmapped > 0:
            print(f"[*] Note: {boro_unmapped:,} unmapped/out-of-era buildings (<= 1938)
excluded in {str(boro).upper()}.")

        # Accumulate Grand Totals
        grand_total_bldgs += boro_bldgs
        grand_total_area += boro_area
        grand_total_wood += boro_wood

    # Print the Citywide Grand Total
    print("\n" + "=" * 105)
    print(f"{'CITYWIDE GRAND TOTAL':<28} | {grand_total_bldgs:<10,} | {grand_total_area:<18,}
| {'N/A':<5} | {grand_total_wood:<18,}")
    print("=" * 105)

    total_unmapped = int(unmapped_by_boro.sum())
    print(f"[*] Total Citywide Unmapped Buildings (<=1938): {total_unmapped:,}\n")

    return summary

# --- Execution ---
final_summary_df = print_borough_salvage_summary(df)
```

PYTHON CODE OUTPUT

Output (Adjusted to fit document layout)

```
[*] Imputed missing area for 237,357 building records using footprint data.

==========================================================================================
CATEGORY (TYPOLOGY & ERA)     | BUILDINGS   | TOTAL AREA (SQ FT) | WIF   | WOOD VOL (CU FT)
==========================================================================================
A (Detached): 1901-1938       | 221,125     | 210,356,079        | 0.199 | 41,860,859
A (Detached): <1900           | 7,367       | 16,073,851         | 0.312 | 5,015,041
B (Brownstone): 1875-1895     | 2,685       | 6,614,576          | 0.303 | 2,004,216
B (Brownstone): 1896-1916     | 57,926      | 94,565,375         | 0.260 | 24,586,997
B (Brownstone): <1875         | 1,605       | 4,256,608          | 0.362 | 1,540,892
C/S (Tenement): 1879-1900     | 17,938      | 80,488,696         | 0.280 | 22,536,835
C/S (Tenement): 1901-1916     | 36,320      | 189,993,123        | 0.211 | 40,088,549
C/S (Tenement): <1879         | 3,795       | 16,573,527         | 0.381 | 6,314,513
E (Warehouse): 1897-1916      | 270         | 5,286,010          | 0.220 | 1,162,922
E (Warehouse): <1896          | 19          | 172,716            | 0.570 | 98,448
O (Office): 1880-1901         | 364         | 6,132,592          | 0.123 | 754,308
O (Office): <1879             | 170         | 2,953,700          | 0.220 | 649,814
-----------------------------------------------------------------------------------------
GRAND TOTAL                   | 349,584     | 633,466,858        | N/A   | 146,613,399
==========================================================================================
[*] Note: There are 269,359 other buildings built in or before 1938
    that were excluded from this calculation (unmatched typology or out-of-era limits).


==========================================================================================
BOROUGH: BK
==========================================================================================
CATEGORY (TYPOLOGY & ERA)     | BUILDINGS   | TOTAL AREA (SQ FT) | WIF   | WOOD VOL (CU FT)
------------------------------------------------------------------------------------------
A (Detached): 1901-1938       | 62,478      | 65,225,465         | 0.199 | 12,979,867
A (Detached): <1900           | 3,377       | 6,318,315          | 0.312 | 1,971,314
B (Brownstone): 1875-1895     | 2,030       | 4,681,446          | 0.303 | 1,418,478
B (Brownstone): 1896-1916     | 33,593      | 57,550,402         | 0.260 | 14,963,104
B (Brownstone): <1875         | 1,201       | 3,074,415          | 0.362 | 1,112,938
C/S (Tenement): 1879-1900     | 10,199      | 31,340,752         | 0.280 | 8,775,410
C/S (Tenement): 1901-1916     | 18,354      | 72,647,783         | 0.211 | 15,328,682
C/S (Tenement): <1879         | 2,080       | 7,077,087          | 0.381 | 2,696,370
E (Warehouse): 1897-1916      | 132         | 2,230,487          | 0.220 | 490,707
E (Warehouse): <1896          | 12          | 70,946             | 0.570 | 40,439
O (Office): 1880-1901         | 68          | 1,036,596          | 0.123 | 127,501
O (Office): <1879             | 7           | 73,030             | 0.220 | 16,066
------------------------------------------------------------------------------------------
BOROUGH TOTAL                 | 133,531     | 251,326,730        | N/A   | 59,920,881
[*] Note: 112,931 unmapped/out-of-era buildings (<= 1938) excluded in BK.
```

BOROUGH: BX

CATEGORY (TYPOLOGY & ERA)	BUILDINGS	TOTAL AREA (SQ FT)	WIF	WOOD VOL (CU FT)
A (Detached): 1901-1938	14,902	14,733,120	0.199	2,931,891
A (Detached): <1900	470	678,544	0.312	211,705
B (Brownstone): 1875-1895	34	69,092	0.303	20,934
B (Brownstone): 1896-1916	5,655	9,624,164	0.260	2,502,282
B (Brownstone): <1875	4	9,120	0.362	3,301
C/S (Tenement): 1879-1900	603	1,642,014	0.280	459,764
C/S (Tenement): 1901-1916	4,856	35,988,021	0.211	7,593,472
C/S (Tenement): <1879	9	19,524	0.381	7,438
E (Warehouse): 1897-1916	28	1,184,207	0.220	260,525
O (Office): 1880-1901	12	21,380	0.123	2,629
BOROUGH TOTAL	26,573	63,969,189	N/A	13,993,946

[*] Note: 30,011 unmapped/out-of-era buildings (<= 1938) excluded in BX.

BOROUGH: MN

CATEGORY (TYPOLOGY & ERA)	BUILDINGS	TOTAL AREA (SQ FT)	WIF	WOOD VOL (CU FT)
A (Detached): 1901-1938	681	3,078,981	0.199	612,717
A (Detached): <1900	1,659	6,872,536	0.312	2,144,231
B (Brownstone): 1875-1895	439	1,559,625	0.303	472,566
B (Brownstone): 1896-1916	941	2,749,047	0.260	714,752
B (Brownstone): <1875	338	1,047,654	0.362	379,250
C/S (Tenement): 1879-1900	6,624	46,360,839	0.280	12,981,035
C/S (Tenement): 1901-1916	6,726	65,904,108	0.211	13,905,766
C/S (Tenement): <1879	1,655	9,343,400	0.381	3,559,835
E (Warehouse): 1897-1916	43	582,891	0.220	128,236
E (Warehouse): <1896	5	75,346	0.570	42,947
O (Office): 1880-1901	255	4,964,043	0.123	610,577
O (Office): <1879	161	2,874,406	0.220	632,369
BOROUGH TOTAL	19,527	145,412,881	N/A	36,184,286

[*] Note: 12,089 unmapped/out-of-era buildings (<= 1938) excluded in MN.

BOROUGH: QN

CATEGORY (TYPOLOGY & ERA)	BUILDINGS	TOTAL AREA (SQ FT)	WIF	WOOD VOL (CU FT)
A (Detached): 1901-1938	123,114	106,853,384	0.199	21,263,823
A (Detached): <1900	215	270,328	0.312	84,342
B (Brownstone): 1875-1895	159	243,310	0.303	73,723
B (Brownstone): 1896-1916	13,686	18,765,451	0.260	4,879,017
B (Brownstone): <1875	46	82,720	0.362	29,944
C/S (Tenement): 1879-1900	264	638,129	0.280	178,676
C/S (Tenement): 1901-1916	5,971	14,689,437	0.211	3,099,471
C/S (Tenement): <1879	29	62,034	0.381	23,634
E (Warehouse): 1897-1916	52	1,264,715	0.220	278,237
O (Office): 1880-1901	13	84,552	0.123	10,399
BOROUGH TOTAL	143,549	142,954,064	N/A	29,921,271

[*] Note: 104,768 unmapped/out-of-era buildings (<= 1938) excluded in QN.

BOROUGH: SI

CATEGORY (TYPOLOGY & ERA)	BUILDINGS	TOTAL AREA (SQ FT)	WIF	WOOD VOL (CU FT)
A (Detached): 1901-1938	19,950	20,465,126	0.199	4,072,560
A (Detached): <1900	1,646	1,934,127	0.312	603,447
B (Brownstone): 1875-1895	23	61,101	0.303	18,513
B (Brownstone): 1896-1916	4,051	5,876,310	0.260	1,527,840
B (Brownstone): <1875	16	42,698	0.362	15,456
C/S (Tenement): 1879-1900	248	506,959	0.280	141,948
C/S (Tenement): 1901-1916	413	763,772	0.211	161,155
C/S (Tenement): <1879	22	71,481	0.381	27,234
E (Warehouse): 1897-1916	15	23,708	0.220	5,215
E (Warehouse): <1896	2	26,424	0.570	15,061
O (Office): 1880-1901	16	26,019	0.123	3,200
O (Office): <1879	2	6,264	0.220	1,378
BOROUGH TOTAL	26,404	29,803,992	N/A	6,593,014

[*] Note: 9,560 unmapped/out-of-era buildings (<= 1938) excluded in SI.

CITYWIDE GRAND TOTAL	349,584	633,466,856	N/A	146,613,398

[*] Total Citywide Unmapped Buildings (<=1938): 269,359