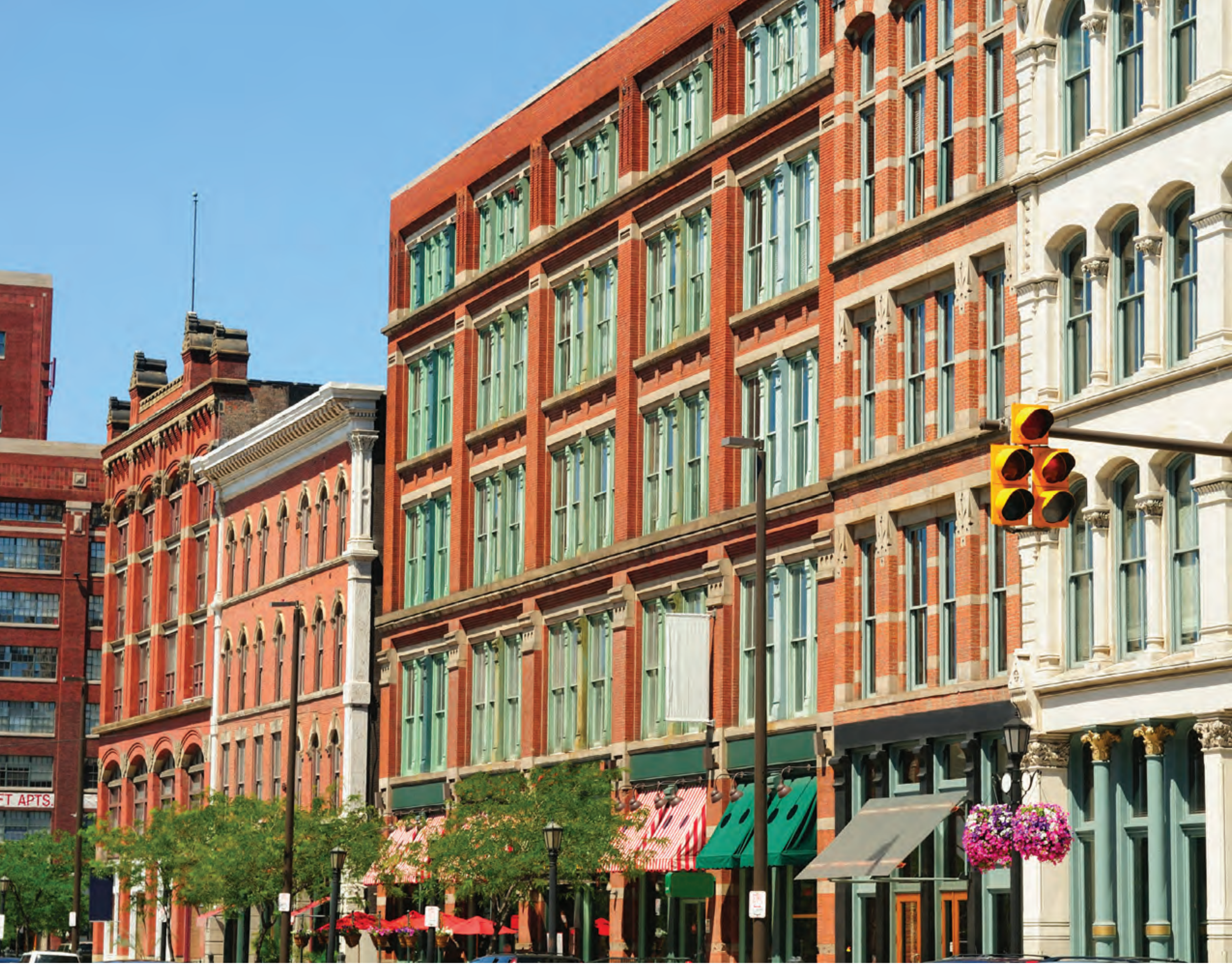

The Greenest Building: Quantifying the Environmental Value of Building Reuse

A REPORT BY:

Preservation Green Lab
NATIONAL TRUST FOR HISTORIC PRESERVATION®

WITH SUPPORT FROM:

THE SUMMIT FOUNDATION

IN PARTNERSHIP WITH:

CASCADIA GREEN BUILDING COUNCIL

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EXECUTIVE SUMMARY

Until now, little has been known about the climate change reductions that might be offered by reusing and retrofitting existing buildings rather than demolishing and replacing them with new construction. This groundbreaking study concludes that building reuse almost always offers environmental savings over demolition and new construction. Moreover, it can take between 10 and 80 years for a new, energy-efficient building to overcome, through more efficient operations, the negative climate change impacts that were created during the construction process. However, care must be taken in the selection of construction materials in order to minimize environmental impacts; the benefits of reuse can be reduced or negated based on the type and quantity of materials selected for a reuse project.

This research provides the most comprehensive analysis to date of the potential environmental impact reductions associated with building reuse. Utilizing a Life Cycle Analysis (LCA) methodology, the study compares the relative environmental impacts of building reuse and renovation versus new construction over the course of a 75-year life span. LCA is an internationally recognized approach to evaluating the potential environmental and human health impacts associated with products and services throughout their respective life cycles.[1] This study examines indicators within four environmental impact categories, including climate change, human health, ecosystem quality, and resource depletion. It tests six different building typologies, including a single-family home, multifamily building, commercial office, urban village mixed-use building, elementary school, and warehouse conversion. The study evaluates these building types across four U.S. cities, each representing a different climate zone, i.e., Portland, Phoenix, Chicago, and Atlanta. A summary of life cycle environmental impacts of building reuse, expressed as a percentage of new construction impacts, is shown in the following figure (Summary of Results).

This research provides the most comprehensive analysis to date of the potential environmental impact reductions associated with building reuse.

KEY FINDINGS AND ANALYSIS

BUILDING REUSE ALMOST ALWAYS YIELDS FEWER ENVIRONMENTAL IMPACTS THAN NEW CONSTRUCTION WHEN COMPARING BUILDINGS OF SIMILAR SIZE AND FUNCTIONALITY.[2]

The range of environmental savings from building reuse varies widely, based on building type, location, and assumed level of energy efficiency. Savings from reuse are between 4 and 46 percent over new construction when comparing buildings with the same energy performance level. The warehouse-to-multifamily conversion – one of the six typologies selected for study – is an exception: it generates a 1 to 6 percent greater environmental impact relative to new construction in the ecosystem quality and human health impact categories, respectively.[3] This is due to a combination of factors, including the amount and types of materials used in this project.

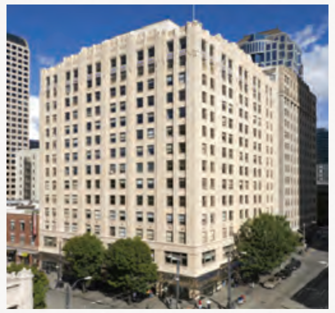
ENVIRONMENTAL IMPACTS OF RENOVATION AS A PERCENTAGE OF NEW CONSTRUCTION

Legend

- New Construction (represents 100%)

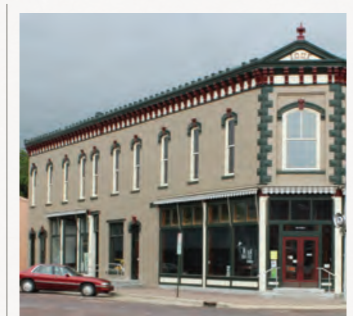
Rehabilitation + Retrofit in:

- Chicago
- Atlanta
- Phoenix
- Portland

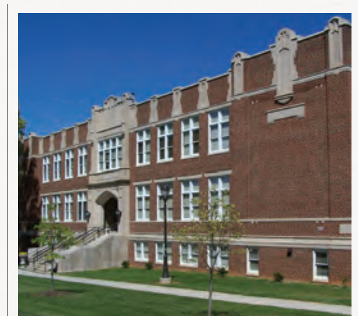


Commercial Office

Warehouse to Office

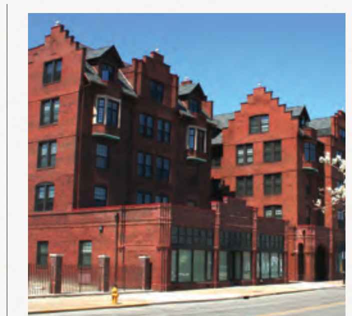


Mixed-Use

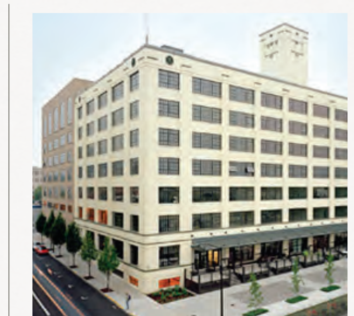


Elementary School

Single-Family



Multifamily



Warehouse to Multifamily

Impact	Case	City	Commercial Office	Warehouse to Office	Mixed-Use	Elementary School	Single-Family	Multifamily	Warehouse to Multifamily
Climate Change	Base Case	Chicago	-9%	-5%	-16%	-7%	-10%	-9%	-7%
		Atlanta	-10%	-5%	-17%	-7%	-11%	-10%	-7%
		Phoenix	-12%	-6%	-19%	-8%	-11%	-11%	-8%
		Portland	-13%	-7%	-21%	-10%	-12%	-11%	-8%
	Advanced Case	Chicago	-12%	-7%	-20%	-9%	-15%	-12%	-11%
		Atlanta	-13%	-7%	-20%	-9%	-16%	-13%	-12%
		Phoenix	-14%	-8%	-23%	-10%	-16%	-14%	-13%
		Portland	-16%	-9%	-25%	-12%	-17%	-14%	-13%
Resource Depletion	Base Case	Chicago	-8%	-4%	-15%	-7%	-10%	-9%	-6%
		Atlanta	-9%	-4%	-15%	-7%	-10%	-9%	-6%
		Phoenix	-10%	-5%	-18%	-8%	-11%	-11%	-7%
		Portland	-12%	-6%	-20%	-9%	-11%	-10%	-7%
	Advanced Case	Chicago	-11%	-5%	-18%	-9%	-15%	-12%	-9%
		Atlanta	-11%	-6%	-19%	-9%	-16%	-12%	-9%
		Phoenix	-13%	-7%	-22%	-10%	-17%	-14%	-10%
		Portland	-15%	-8%	-24%	-12%	-17%	-13%	-10%
Human Health	Base Case	Chicago	-15%	-7%	-33%	-9%	-21%	-17%	+6%
		Atlanta	-14%	-6%	-29%	-7%	-18%	-14%	+5%
		Phoenix	-12%	-5%	-26%	-6%	-14%	-12%	+4%
		Portland	-15%	-7%	-30%	-8%	-19%	-15%	+5%
	Advanced Case	Chicago	-15%	-9%	-38%	-11%	-26%	-20%	+5%
		Atlanta	-14%	-8%	-34%	-9%	-23%	-18%	+5%
		Phoenix	-12%	-7%	-31%	-7%	-19%	-15%	+4%
		Portland	-14%	-8%	-35%	-10%	-24%	-18%	+5%
Ecosystem Qualty	Base Case	Chicago	-20%	-7%	-34%	-11%	-29%	-24%	+1%
		Atlanta	-20%	-7%	-34%	-10%	-28%	-23%	+1%
		Phoenix	-24%	-8%	-41%	-11%	-30%	-27%	+1%
		Portland	-27%	-9%	-44%	-13%	-33%	-30%	+1%
	Advanced Case	Chicago	-14%	-8%	-39%	-12%	-32%	-28%	-1%
		Atlanta	-14%	-8%	-38%	-11%	-31%	-27%	-1%
		Phoenix	-16%	-9%	-44%	-13%	-33%	-31%	-1%
		Portland	-17%	-10%	-46%	-14%	-35%	-33%	-1%

A full description of each impact category and the methods used to evaluate them is located in the *Technical Appendices*. Base Case = average energy performance; see Section 4 on methodology for determining energy use. Advanced Case = 30% more efficient than Base Case.

Reuse-based impact reductions may seem small when considering a single building. However, the absolute carbon-related impact reductions can be substantial when these results are scaled across the building stock of a city. For example, if the city of Portland were to retrofit and reuse the single-family homes and commercial office buildings that it is otherwise likely to demolish over the next 10 years, the potential impact reduction would total approximately 231,000 metric tons of CO_2 – approximately 15% of their county's total CO_2 reduction targets over the next decade.[4] When scaled up even further to capture the potential for carbon reductions in other parts of the country, particularly those with a higher rate of demolition, the potential for savings could be substantial. Given these potential savings, additional research and analysis are needed to help communities design and employ public-policy tools that will remove obstacles to building reuse.

REUSE OF BUILDINGS WITH AN AVERAGE LEVEL OF ENERGY PERFORMANCE CONSISTENTLY OFFERS IMMEDIATE CLIMATE-CHANGE IMPACT REDUCTIONS COMPARED TO MORE ENERGY-EFFICIENT NEW CONSTRUCTION.

It is often assumed that the CO_2-reduction benefits gained by a new, energy efficient building outweigh any negative climate change impacts associated with the construction of that building. This study finds that it takes 10 to 80 years for a new building that is 30 percent more efficient than an average-performing existing building to overcome, through efficient operations, the negative climate change impacts related to the construction process.[5] As indicated in the following table, an exception also exists here for the warehouse-to-multifamily building conversion. Upon analysis, this adaptive use scenario does not offer the carbon savings provided by other reuse scenarios.

> This study finds that it takes 10 to 80 years for a new building that is 30 percent more efficient than an average-performing existing building to overcome, through efficient operations, the negative climate change impacts related to the construction process.

Building reuse alone cannot fulfill the urgent task of reducing climate change emissions. The summary of results of this study, shown on the previous page, documents how reuse and retrofitting for energy efficiency, together, offer the most significant emissions reductions in the categories of climate change, human health, and resource impact. Certainly, the barriers to retrofits are numerous. However, a variety of organizations are presently working to address the obstacles to greening existing buildings. This study finds that reuse and retrofit are particularly impactful in areas in which coal is the dominant energy source and more extreme climate variations drive higher energy use.

MATERIALS MATTER: THE QUANTITY AND TYPE OF MATERIALS USED IN A BUILDING RENOVATION CAN REDUCE, *OR EVEN NEGATE,* THE BENEFITS OF REUSE.

In general, renovation projects that require many new materials – for example, an addition to an elementary school or the conversion of a warehouse to a residential or office use – offer less significant environmental benefits than scenarios in which the footprints or uses of the buildings remain unchanged. In the case of the warehouse-to-multifamily conversion scenario, the newly constructed building actually demonstrated fewer environmental impacts in the categories of ecosystem quality and human health.

Year Of Carbon Equivalency For Existing Building Reuse Versus New Construction

This study finds that it takes between 10 to 80 years for a new building that is 30 percent more efficient than an average-performing existing building to overcome, through efficient operations, the negative climate change impacts related to the construction process. This table illustrates the numbers of years required for new, energy efficient new buildings to overcome impacts.

Building Type	Chicago	Portland
Urban Village Mixed Use	42 years	80 years
Single Family Residential	38 years	50 years
Commercial Office	25 years	42 years
Warehouse to Office Conversion*	12 years	19 years
Multifamily Residential	16 years	20 years
Elementary School	10 years	16 years
Warehouse to Residential Conversion	Never	Never

*The warehouse-to-multifamily conversion (which operates at an average level of efficiency) does not offer a climate change impact savings compared to new construction that is 30 percent more efficient. These results are driven by the amount and kind of materials used in this particular building conversion. As evidenced by the study's summary of results, as shown on page VII, the warehouse-to-residential conversion does offer a climate change advantage when energy performance for the new and existing building scenarios are assumed to be the same. This suggests that it may be especially important to retrofit warehouse buildings for improved energy performance, and that care should be taken to select materials that will maximize environmental savings.

Although warehouse conversions and school additions require more material inputs than other types of renovation projects, reusing these buildings is still more environmentally responsible – in terms of climate change and resource impacts – than building anew, particularly when these buildings are retrofitted to perform at advanced efficiency levels. Better tools are needed to aid designers in selecting materials with the least environmental impacts. Such resources would benefit new construction and renovation projects alike.

Warehouse conversions and school additions require large materials inputs, however reusing these buildings still has lower climate change and resource impacts.

STUDY OBJECTIVES AND APPROACH

Every year, approximately 1 billion square feet of buildings are demolished and replaced with new construction in the United States.[6] The Brookings Institution projects that some 82 billion square feet of existing space will be demolished and replaced between 2005 and 2030 – *roughly one-quarter of today's existing building stock.*[7] Yet, few studies to date have sought to examine the environmental impacts of razing old buildings and erecting new structures in their place. In particular, the climate change implications of demolition and new construction, as compared to building renovation and reuse, remain under-examined.

Although awareness about the need to reduce near-term climate change impacts is growing, a greater understanding of the potential environmental savings that can be offered by reusing existing buildings rather than developing new buildings is still needed. This study compares the environmental impacts of building demolition and new construction relative to building renovation and reuse. The study has three key objectives:

- To compute and compare the life-cycle environmental impacts of buildings undergoing rehabilitation to those generated by the demolition of existing buildings and their replacement with new construction;
- To determine which stage of a building's life (i.e. materials production, construction, occupancy) contributes most significantly to its environmental impacts, *when* those impacts occur, and what drives those impacts; and
- To assess the influence of building typology, geography, energy performance, electricity-grid mix, and life span on environmental impacts throughout a building's life cycle.

In examining these themes, the authors consider potential opportunities to reduce carbon emissions and other negative environmental impacts through building reuse and explore how differences in building type, climate, and energy-efficiency levels affect these opportunities.

This research is intended to serve as a resource for those who influence and shape the built environment, including policy makers, building owners, developers, architects, engineers, contractors, real estate professionals, and non-profit environmental, green building and preservation advocacy groups. To that end, the study identifies key environmental considerations and challenges related to new construction, retrofits and reuse. Findings from this study should be considered in light of the myriad realities that affect development decisions, such as building codes, zoning, financing, demographics, and design trends.

Each year, approximately 1 billion square feet of buildings are demolished and replaced with new construction.

CONCLUSIONS

For those concerned with climate change and other environmental impacts, reusing an existing building and upgrading it to maximum efficiency is almost always the best option regardless of building type and climate. Most climate scientists agree that action in the immediate timeframe is crucial to stave off the worst impacts of climate change. Reusing existing buildings can offer an important means of avoiding unnecessary carbon outlays and help communities achieve their carbon reduction goals in the near term.

Most climate scientists agree that action in the immediate timeframe is crucial to stave off the worst impacts of climate change. Reusing existing buildings can offer an important means of avoiding unnecessary carbon outlays and help communities achieve their carbon reduction goals in the near term.

This report sets the stage for further research that could augment and refine the findings presented here. Study results are functions of the specific buildings chosen for each scenario and the particular type and quantity of materials used in construction and rehabilitation. Great care was taken to select scenarios that would be representative of typical building reuse or conversion projects. However, environmental impacts will differ for building conversions that use different types and amounts of materials. Others are encouraged to repeat this research using additional building case studies; replicating this analysis will enhance our collective understanding of the range of impact differences that can be expected between new construction and building reuse projects.

This study introduces important questions about how different assumptions related to energy efficiency affect key findings. In particular, further research is needed to clarify how impacts are altered if a new or existing building can be brought to a net-zero level using various technologies, including renewable energy.

ABOUT THE PROJECT TEAM

This research was made possible by a generous grant from the Summit Foundation to the National Trust for Historic Preservation. The project was coordinated by the Preservation Green Lab, a programmatic office of the National Trust, which is dedicated to advancing research that explores the sustainability value of older and historic buildings and identifying policy solutions that help communities leverage their built assets. The project team includes Cascadia Green Building Council, Quantis LLC, Skanska, and Green Building Services.

ENDNOTES

1. Section 1 of this report explains Life Cycle Assessment (LCA) in greater detail.

2. Where energy performance for renovated and new buildings is assumed to be the same.

3. The warehouse-to-multifamily conversion required significantly more new materials than other reuse scenarios tested in this study. The table on page IX provides additional details.

4. Based on demolition rates between 2003-2011 provided by City of Portland Bureau of Planning and CO_2 emission targets as outlined by the City of Portland and Multnomah County 2009 Climate Action Plan. Reduction in CO_2 emissions assumes both the new and the existing buildings are considered to be of the same size and functionality.

5. In this study, energy-use figures for average-performing existing buildings, also known as the 'Base Case,' were established using national survey data and other recent research. More details are provided in Section 4 of the for the report. For purposes of this study, the term 'new, efficient buildings,' or the 'Advanced Case,' refers to new buildings that achieve 30 percent greater energy efficiency over Base Case energy performance.

6. National figures tracking demolition are out-of-date. However, a 1998 study by the U.S. Environmental Protection Agency (EPA) provides a sense of the annual scale of demolition nationwide; it estimates that approximately 925 million square feet of residential and nonresidential space were demolished in 1996. U.S. Environmental Protection Agency: Office of Solid Waste, "Characterization of Building-Related Construction and Demolition Debris in the United States," EPA530-R-98-010. (Washington: U.S.Environmental Protection Agency, June 1998).

7. Arthur C. Nelson, "Toward a New Metropolis: The Opportunity to Rebuild America" (Washington: Brookings Institution, 2004).