The Alarming Repricing of Office Buildings:

Obsolescence, ESG, and Healthy Buildings

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Preface | Thesis

Obsolescence is insidious and unpredictable. Many factors, among them technology, new business practices, pandemics, and evolving standards of environmental stewardship and user health and wellness can suddenly render an office property obsolete. The market will react to these changes and reprice properties based on their degree of obsolescence. **This is the in-process, long-term dynamic the office market faces, creating winners and losers.**

The office market is increasingly bifurcated:

(1) Energy efficient, healthy office properties with supply-demand imbalances; and

(2) Obsolete office properties, which suffer from aging systems and poor energy efficiency as well as a failure to recognize changing tenant demands and governmental standards.

Regardless of the number returning to the office, many people will demand updated, sustainable, healthy space, as demonstrated by large tech firms signing mega leases during the pandemic.

Our thesis: Four big ideas.

1. Real estate always obsolesces, but COVID increased the pace. It put a spotlight on environmental sustainability as well as the health and wellness in buildings. Consequently, tenants and their workers (herein inclusive of employees and contractors) responded by placing a premium on sustainability, healthy working conditions, and amenities. These changes are accelerating obsolescence and penalizing energy inefficient and unhealthy buildings.

2. New energy efficiency and indoor environmental standards, as well as governmental regulations, are pressuring tenants to favor carbon-friendly, healthy buildings globally. London, for example, has instituted new regulations that will bar owners from leasing buildings that do not achieve certain carbon neutrality goals. The market has begun to ascribe a "green premium" and "brown discount" to rents and value. We expect this spread to widen as governments at all levels strive to address climate change. This is an acute issue that like a tsunami is heading west from Europe.

3. A critical supply-demand imbalance exists. Energy efficient, healthy buildings are a small subset of the entire office inventory, and this finding applies to all MSAs. Accelerated obsolescence reduces the supply of buildings that tenants will seek. Growing demand for energy efficient, healthy buildings will result in rent and price increases for those assets due to the supply-demand imbalance.

4. We estimate that 70% of the existing office stock will suffer from accelerating obsolescence. Repricing of space and assets will require institutional investors to audit their office investments and decide which to hold, renovate, or sell. Redevelopment of energy inefficient and unhealthy buildings and development of new, state-of-the-art energy efficient, healthy buildings will become an attractive option.

Energy Efficient. This paper uses the terms energy efficient and sustainable interchangeably. In the near-term the target is carbon neutrality. The attainment of this goal will create an even stronger green premium.

A warning signal to investors. This paper is an early strategy alert for institutional investors, many of whom have not anticipated the repricing of office properties due to obsolescence in the face of evolving tenant demands and government standards. **We expect that the repricing will accelerate and peak over the next three to five years. The time to act is now.**

Outsourced Research deeply appreciates the inspiration, trust and collaboration of Coretrust Capital Partners, LLC.

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The Alarming Repricing of Office Buildings

I. Executive Summary

- **Introduction:** Office building obsolescence is the most important office building performance threat; COVID is an accelerant of in-process changes. Obsolescence is creating a supply-demand imbalance increasing the rents and values of energy efficient, healthy buildings.[1]

- **Sustainability and Path to Carbon Neutrality.** LEED is now a requirement for leading tenants, whose workers increasingly value minimizing environmental impact. Carbon neutrality is a requirement that is just around the corner.

- **What are the characteristics of a healthy building?** The dimensions of a healthy building include ventilation, air quality, thermal health, water quality, noise, lighting (natural and ambient), and several others.

- **Benefits of healthy buildings: A financial analysis.** A healthy building has better ventilation and reduced pathogens. Better air quality improves worker health and productivity and can increase tenants' pro forma net income by 10%.[2]

- **Energy Efficiency and Healthy Buildings.** Healthy buildings, without energy efficiency and the push towards carbon neutrality, do not capture the full green premium and vice versa. Fortune 500 tenants, workers, and prominent investors alike now demand offices with healthful environments, energy efficiency, and amenities. While energy efficiency and healthy buildings may work counter to each other, experience suggests that this apparent conflict can be minimized.

- **The office inventory: Vintage and size differentiation**. The correlation between worker performance and building size and vintage is not only positive but statistically significant. As a rough proxy for energy efficient and healthy buildings, we adopt buildings whose vintage is 21 years or less and size is greater than 250,000 square feet. This subset constitutes less than 6.1% of the national inventory. Buildings of recent vintage generally have less incurable obsolescence and larger buildings provide economies of scale. Some, but not all, older buildings can be made healthy.

  The two ways of addressing the limited supply of sustainable, healthy buildings are (1) new development, and (2) retrofitting existing buildings. Retrofitting existing buildings has the benefit of producing a smaller carbon footprint than new development (e.g., new development generates new emissions by creating new steel

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[1] Obsolescence can be functional, economic, and physical. Locations can become obsolete as urban areas grow and change. Sub-optimal floorplate sizes or shapes and too little floor-to-ceiling separation are examples of physical obsolescence. Economic obsolescence is the loss of value resulting from external economic factors, such as technological change, to an asset or group of assets.

At the end of a building's useful life, it does not collapse in a heap of rubble. In this study, obsolescence refers to buildings that exhibit some degree of impairment, which would require significant reinvestment to cure, if curing is even possible. We do not estimate the cost to cure obsolescence.

Curing some obsolescence is not always economically feasible. That does not mean that buildings with significant obsolescence are not valuable; the presence of tenants would argue the opposite; however, it suggests that the value is impaired.

One additional concern is what happens to building value when new standards become enforceable government regulations. The government, as will be the case in London, may not permit the leasing of buildings whose obsolescence is so severe that the building cannot meet minimal standards.

We focus on the portion of the inventory that has some degree of obsolescence — slight or critical —and we ascribe a value to that portion or the inventory, not to the cost to cure.

[2] See Allen and Macomber, 2020

and concrete) and is likely to involve properties in better locations.

- **Stylized office model: COVID and changing standards are accelerating change**. Tenants and workers will shift their preference to energy efficient, healthy buildings and they will use new portable technologies to monitor building energy efficiency and health real-time. Energy efficient, healthy buildings will benefit and the larger portion of the inventory comprising obsolescing buildings will suffer value losses.

- **Office labor markets: WFH, migration, and agglomeration**. Working from Home ("WFH") is an important reaction to the pandemic, but it will not have a large effect on the rate of obsolescence. For the purpose of this paper, we accept prominent surveys that project a hybrid solution of one or two days working from home per week.[3]

- **A mixed blessing:** WFH is a mixed blessing for both employers and employees, who likely overestimate the benefits of WFH and underestimate the value of working at the office. Employers may implement a WFH strategy but not to the detriment of their culture, growth, profitability, and long-term enterprise value.

- **Who are the winners and losers?** We sort the office properties into three categories: The Endangered Third (approximately 30% of the inventory, by our estimate), the Mediocre Middle (in the 40% range), and the Winners (roughly 30%).

- **How serious is the obsolescence problem?** Total obsolescence in the older MSAs could be substantial. For example, assuming that the value of the New York Metropolitan Area's ("MSA") office inventory is about $500 billion, which we believe is a conservative estimate, we estimate total obsolescence to be between $123 and $190 billion of inventory value,[4,5] which is not an estimate of the cost to cure. This estimated range is equivalent to the value of between 60 - 100 Empire State Buildings.[6] We further estimate that approximately one-third of the office inventory expressed in square footage is obsolete.[7]

- **The prices of older and smaller office buildings could decline on average by at least 20% over the next three year to five years** based, in part on, CoStar's historical cap rates and building CoStar building quality ratings. (See Appendix B.)

- **Strategies for investors**. Institutional investors should audit their portfolios to assess which properties to sell, rehabilitate, and keep. The new energy efficient, healthy building supply will increase slowly implying that investing in sustainable, healthy buildings is a long-term durable strategy. Therefore, investors that sell obsolete properties should acquire sustainable, healthy buildings. Just as investors see the wisdom of selling obsolete properties, the

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[3] See Nicholas Bloom, June 2021

[4] The $500 billion estimate uses the average per square foot sales price ($537/SF) according to RCA from 2012-2021 in the MSA and then multiplies that by the total inventory of 922 million SF.

[5] Our analysis consists of a high-low estimate of inventory value associated with obsolescence in the NY MSA for new buildings (<21 years old) and older buildings (>21 years old). On the low-end, we estimate that 10% of new buildings and 25% of older buildings are obsolete. On the high-end we estimate that 20% of new buildings and 40% of older buildings are obsolete. These percentages are multiplied by the total inventory of 922 million, producing 228 million SF to 354 million SF, which is then multiplied by RCA's $537/SF.

[6] The 2.2 million square foot Empire State Building in 2020 officially was transferred over to the Empire State Realty Trust for $1.89 billion.

[7] The older MSAs have proportionally more obsolescence in relation to their inventories. For example, New York MSA's total obsolescence is 14.1% of total US obsolescence even though the New York MSA's inventory is 7.8% of the U.S. inventory.

market is already adjusting the price of these buildings, so time is of the essence.

- **Conclusions**. **Office building obsolescence, not COVID, is the big story**. COVID simply accelerated in-process changes. Evolving building sustainability and health standards, as well as heightened employee and tenant concerns regarding environmental impacts and in-office health and safety, will force a significant repricing of office assets.

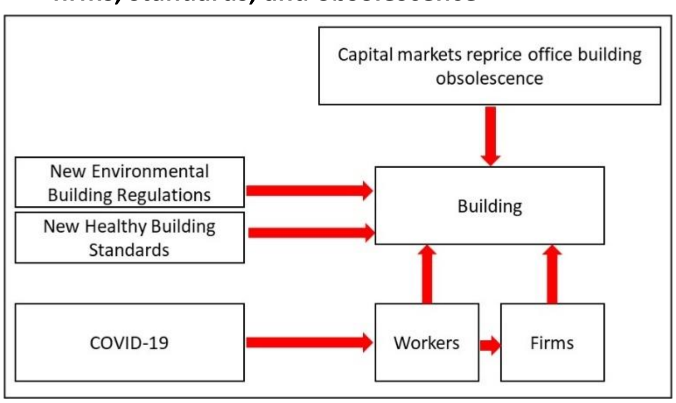
II. Introduction

This report concludes that office building obsolescence is the most important threat to the performance and pricing of the office inventory, not COVID. The pandemic has ripped off the band-aid to expose festering obsolescence throughout most of the office inventory. **Most of the changes, such as the promulgation of new building energy efficiency and health standards, and working from home were proceeding before COVID, albeit more slowly.**

Buildings and their owners will feel the impact of capital markets repricing, the creation of new building standards (especially for sustainable, healthy buildings) and changing worker preferences.

Exhibit 1 shows the components of change. COVID-19 affects worker preferences and perceptions of safety. Firms react by accommodating workers, mostly skilled employees, who seek the safety and convenience of working from home. However, how will workers respond when COVID has become endemic – a point we are fast approaching? We expect that culture, collaboration, career advancement, and overall social health will bring the focus back on the office.

Exhibit 1. Network of change: COVID, workers, firms, standards, and obsolescence



Source: Outsourced Research

New environmental standards combined with health and wellness criteria will define what constitutes a desirable building. Without COVID, the increasing emphasis on sustainability and the development pace of new healthy building standards would have been slower. We discuss many factors contributing to building sustainability and health. The age and obsolescence of the inventory is an important consideration. Obsolescence, however, is not just a function of age; it reflects changes in preferences and technology. Hence, obsolescence develops in a non-linear manner.

Critically important is that sustainable, healthy buildings, especially in the larger, denser MSAs, constitute a very small share of the total inventory. **Consequently, a relatively small percentage decrease in the demand for space in older buildings will likely result in a significant proportionate increase in the demand for sustainable, healthy space.** As demand shifts, the price and rental rates of sustainable, healthy buildings will increase, possibly substantially.

WFH has provided workers with a pause to reconsider their work-leisure decision, which is the tradeoff workers make, given time and income budget constraints, between work and non-work (Appendix C). The wage rate of skilled office workers is a good indicator of the opportunity cost of commuting. The COVID risk penalty affects this opportunity cost. If COVID is less virulent or less lethal, then expected commuting cost decreases.

Whatever the risk penalty, workers and firms will likely adopt a hybrid model and, when they do, they will migrate to better buildings. Workers, on average, will likely work from home no more than two days a week. **Consequently, the impact on total office space demanded will be slight. Moreover, space per worker will not necessarily decline; it may even increase. We observe that new space plans today show little, if any, change in space per worker.**

The repricing of the office inventory will reflect the confluence of many factors, including evolving expectations of sustainability, building health standards, and worker preferences.

III. Sustainability and Path to Carbon Neutrality

Pre-pandemic, an office building's Energy Star rating and LEED certification were merely check-the-box for multinational tenants considering new office space. Post-pandemic, such certifications are critical for several reasons:

1. Many employers have made public commitments to achieve carbon neutrality by 2025, 2030, etc. Tenants are increasingly seeking not only aesthetically appealing, healthy buildings with many amenities, but also buildings whose features align with their stated environmental objectives. Carbon neutrality is such a target.
2. Workers are now more environmentally conscious and want their employer to make work site choices that limit carbon emissions, and thus reduce their environmental footprint.
3. Carbon taxes are coming. A June 2020 Pew survey found that 73% of Americans supported taxing corporations based on the amount of carbon emissions they produce.

This paper acknowledges that the technology does not yet exist to enable buildings to achieve carbon neutrality for Scope 1 and Scope 2[8] emissions without purchasing renewable energy certificate ("RECs") options or carbon offsets.

This paper also acknowledges that there will be, at least in the short-term, a divide between national and multinational firms that publicly commit to carbon neutrality and smaller, localized firms without such public proclamations. Given the importance Millennials and Gen Z consumers place on the environment, it is a matter of time when enough stakeholders demand it of local firms.

It is critical to highlight that achieving Energy Star or LEED requires a sophistication that many smaller building owners do not have and an expense that many small buildings cannot bear. Moreover, for energy inefficient buildings that cannot achieve such energy certifications, if they do attempt to purchase carbon offsets, that expense will be materially greater than it would be for a building of comparable size and MSA that has already completed investments for energy efficiency.

If there is excess supply in the office market, rental growth rates are weak or negative, tenants will have enhanced bargaining power and owners will bear most of the burden of the cost of carbon offsets. Of course, in a tight market the reverse would be true; tenants would bear most of the incremental cost.

We show in Appendix B that a shift in tenant preferences would weaken the demand for energy inefficient, unhealthy buildings and greatly increase the price of energy efficient, healthy buildings, which represent a small sector of the total office inventory.

Hence, we would expect that tenants would bear much of the burden of the carbon offsets in the smaller energy efficient, healthy sector but that owners of the more unhealthy, inefficient, and obsolete buildings would shoulder the burden of these offsets. The unequal sharing of the costs of the offsets would widen the profitability gap between the haves and the have nots in a world of increasing obsolescence.

[8] Scope 1 emissions are greenhouse gas ("GHG") emissions released on site (gas only). Scope 2 emissions are upstream GHG emissions at the source of gas and electricity.

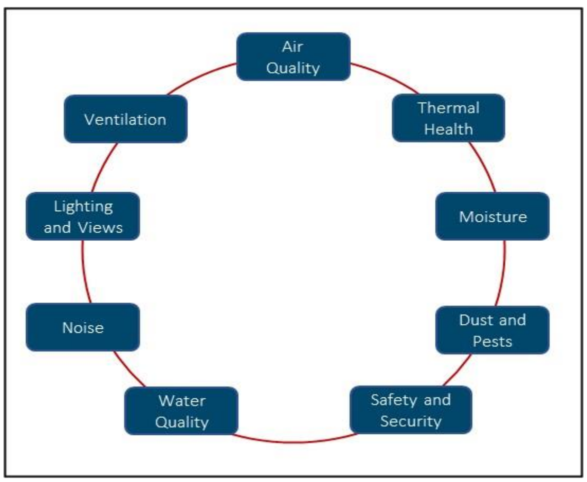
IV. What are the characteristics of a healthy building?

Healthy buildings present an emerging investment opportunity. A Harvard research team[9] (Allen and Macomber[10], or "AM") has written an important book that summarizes years of research regarding worker productivity and air quality; they have applied their research to office buildings.

They show that healthy buildings have a major impact on health and productivity, and that, in turn, healthier buildings significantly increase tenant profitability, rents, and building value.

A healthy building has nine foundational components, as shown in Exhibit 2. The older the building, the less likely that the building is healthy, because of aging infrastructure and systems.

Exhibit 2. Nine Foundations of Healthy Buildings.



Source: Allen and Macomber. **Healthy Buildings**

The nine elements of a healthy building are:

- **Ventilation**. Standard building ventilation is 20 cfm/person. See section V.
- **Air quality**. Controlling the level of volatile organic compounds (VOCs), pathogens, carbon dioxide, and particulates promotes air quality.
- **Thermal health**. Temperature is an individual issue and more than comfort. Individual performance reflects many factors, temperature and humidity being just two.
- **Water quality**. The water company ensures water quality up to where the pipe meets the building. Inside the building, there is often significant variation in water quality due to bacteria (e.g., Legionella), stagnation, acidity, contaminants (e.g., lead), and other factors.
- **Moisture**. Aside from major water problems, such as broken pipes, mold is a major allergen.
- **Dusts and pests**. Dust caries dangerous chemicals and other pollutants like dust mites.
- **Acoustics and noise**. Different working zones require different noise standards. Minimizing transmission across zones can improve worker productivity and comfort.
- **Lighting and views**. Not all light is equal. Spectrum, intensity and timing are important. Workers, staring at a brick wall, are more likely to be impacted negatively than workers enjoying better views.
- **Safety and security**. This consideration pertains to the inside of the building as well as its surrounding area. Poor security elevates the stress levels of a building's users.

In addition to AM's list, we add the following comments:

- **Sanitation of space and air.** Tenants, post-pandemic, will increasingly focus on air and space sanitation technologies, which eliminate up to 99.9% of pathogens in the air.
- **Touchless.** Many healthy buildings have implemented touchless technologies to complement healthy building elements.

[9] See Allen and Macomber.

[9] AM, with whom we have communicated, endorses our size and vintage approach

V. Assessing the benefits of a healthy building: A financial analysis

The office building industry has focused primarily on energy and physical capital, while neglecting human capital. Healthy buildings do both.

AM has reported a strong relationship between ventilation (including levels of VOCs and CO_2) and cognitive function performance. They have tested the impact of building health on nine cognitive dimensions; the impacts are significant. They show that the "either-or" choice between health and energy conservation is a false choice.

The bottom line. The revenue gains from higher productivity and cost savings from better health, even after adjusting for slightly higher energy costs, can increase the tenant's bottom line by more than 10%.

AM introduces the pro forma income statement of a consulting firm in which high levels of cognitive performance are critical. The analysis shows that, even if energy costs are increased by 30%, the change hardly affects the tenant's bottom line. Payroll constitutes two-thirds of total expenses; rent is 9% and energy is 0.9% of total expenses. Note that properties with upgraded building systems can achieve healthy building status with energy consumption increases in the range of 10% to 15% or less.

Reducing absenteeism by 1.6 fewer days per week alone increases net income by 1.8%. Increased cognitive performance increases tenant revenues by 2% to 10%. When AM assumed 2%; the incremental increase in net income was 9%.

Using the AM example, improved tenant profitability could allow the landlord to increase the rent. An MIT study published in February 2021 suggests that this impact is already 4.4% to 7.7% more rent per square foot. We expect this impact to increase as more tenants negotiate new leases in healthy buildings.

Hidden information. Not all new buildings are healthy buildings and not all old buildings are unhealthy. Larger buildings offer economies of scale and greater social networking opportunities, but large buildings can be unhealthy, especially if they are designed according to minimum, outdated standards and have not been upgraded. (Of course, design standards are distinct from operating standards.)

Certification matters. The office building sector is analogous to a used car market. Try selling your 4-year-old luxury car in the used car market. Without a warranty, the market will ascribe lower pricing. Signaling superior building health is critical. Certification by independent organizations, the publication of performance statistics, worker and tenant monitoring, and real-time internet-reporting of building health can reduce the information gap. They also promote enhanced pricing of healthy buildings. We believe that the quantification of a building's health will become a standard feature in leasing and sales due diligence.

The approaching global wave. Offering memoranda, especially in Europe, have already begun to include building energy efficiency and health metrics.

The UK and certain European countries have adopted regulations that, if the owner cannot meet minimum acceptable quality levels, especially with regard to energy and health, bar the owner from leasing the property. A failure to make buildings healthier and more sustainable will hurt valuations. The Europeans are leading the way, for now, but the pursuit of healthier, more efficient buildings will affect most developed countries. Healthier buildings are not just a European or US concern, it is a global aspiration.

VI. Energy Efficiency *and* Healthy Buildings

This paper is supportive of AM's assertion of healthy building value, but we propose that a building must be healthy *and* energy efficient to capture the full benefit of the green premium.

This paper does not devalue amenities, location, or the aesthetic appeal of the building and its common areas. To the contrary, these are table stakes. They were required pre-COVID and are required just as much today. We focus on energy efficiency and health premiums because COVID has increased the priority that tenants and investors place on these factors.

The Energy Efficiency versus Healthy Space Paradox.

Building operators quickly identify that many healthy building operating procedures can work counter to sustainability efforts and efforts to achieve carbon neutrality. For example, a healthy building may increase HVAC operating hours and fresh air purges, which obviously use more energy.

The following provides a more detailed look at the energy efficiency, healthy space paradox.

Bractlet, a technology firm that helps operators optimize building performance, prepared an analysis that evaluated energy consumption before and after health and operational upgrades at a large office building in a gateway market. Bractlet evaluated the impact of these upgrades by utilizing the building's "digital energy twin" (a simulation of the building taking into account architectural nuances, weather, occupancy, and operations) that performed at 97.6% accuracy from January 2017 through February 2020. The analysis below indicates the energy impact on the building from March 2020 through December 2021.

Factors increasing consumption increased energy costs by about 13%:

- Increased HVAC run hours & flushing
- Utilization of in-duct UV-C lights
- Utilization of bipolar ionization in elevator cabs
- Increase to MERV-14 air filters

Factors decreasing consumption reduced energy expenses by 27.5%:

- Reduced occupancy and heat load
- Reduced occupancy decreased plug load
- Implementation of LED lighting retrofits
- Implementation of building automation system ("BAS") optimizations

LED implementation and BAS optimization reduced energy consumption by approximately 7.5% in this analysis. The analysis shows that modernizing building systems can materially reduce the adverse impact of healthy building technology on energy efficiency.

It is critical to acknowledge that certain healthy building technologies require energy efficient upgrades, such as modern air handlers or chillers. Upgrades such as implementing MERV-14 filters or increased HVAC operating hours would either be impossible to implement with older building systems or would significantly reduce the useful life of those systems.

While energy efficient and healthy are not the same, it is extremely difficult to operate a healthy building without having introduced modern, energy efficient systems.

VII. The office inventory: Vintage, size, quality and cap rates

We lack a national inventory of buildings for which there are assigned health metrics. We assume that healthy buildings are larger buildings of recent vintage. (AM confirm that size and vintage are reasonable assumptions, given the lack of available data.) We suspect that while the correlation is not perfect, size and vintage are a good starting point in estimating the inventory of healthy office buildings.

Office buildings of more recent vintage probably have more modern heating and cooling equipment, other energy efficient systems, and health-related technologies.

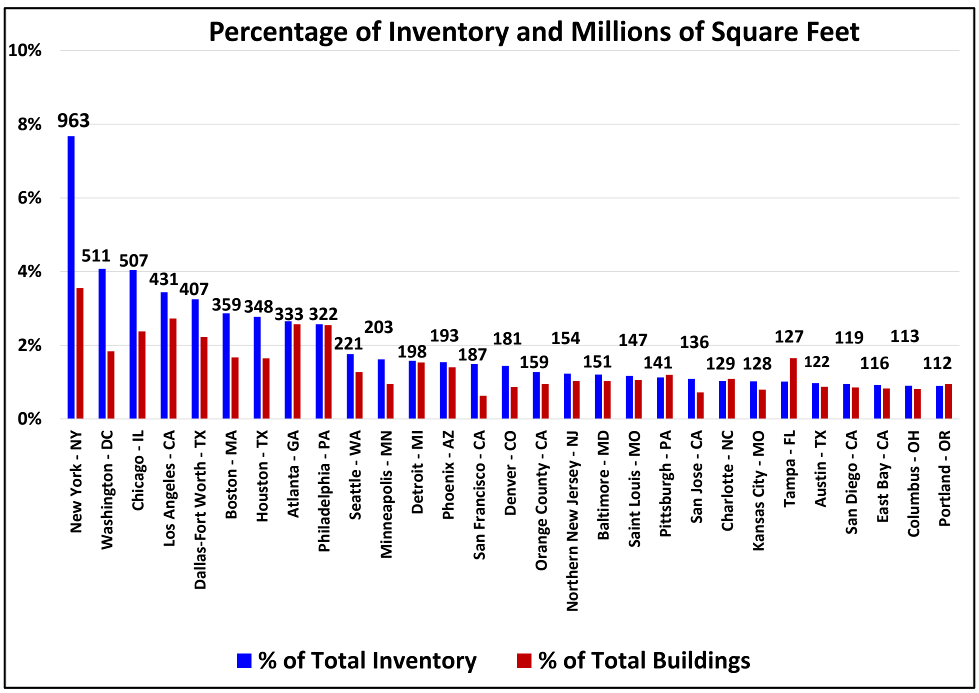
Larger buildings offer scale economies in retrofitting and implementing amenities attractive to tenants.

Larger floor plates and greater floor-to-ceiling separations facilitate more modern and healthier working environments.

Size and vintage, if they are as important as we think, provide a useful first-cut analysis of the office building inventory.

Healthy buildings across all MSAs comprise a very small subsector of the office inventory. We expect that this subset shrinks when we limit the data to LEED certified properties, and even more when estimating the percent of owners willing to pursue carbon neutrality. We estimated for selected MSAs the percentage of buildings that are large and that were built in 2000 or later. We began our analysis using office inventory data by MSA, as shown in Exhibit 3.

Exhibit 3. The size distribution of office area by the largest MSAs



Source: COSTAR

Appendix A presents an analysis of the size and vintage distributions of the entire US and selected MSA office inventories. If healthy buildings are highly correlated with larger buildings of more recent vintage, then this group represents a small share of the office inventory.

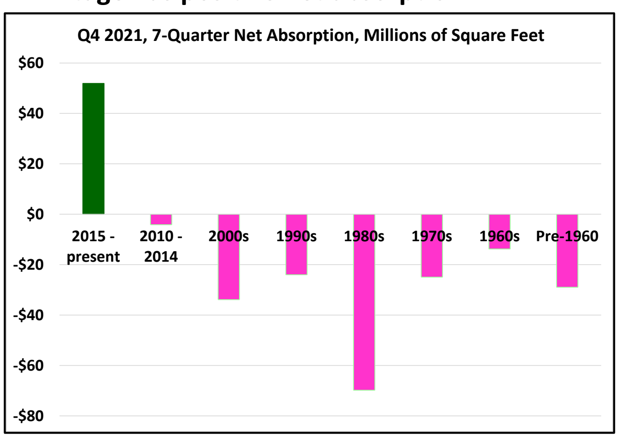
Here are selected findings that suggest that healthy buildings are a small subset of the office inventory:

- Buildings that are no more than 11 years old and no less than 250,000 square feet comprise 3.0% of the national inventory.

- Similarly sized buildings 21 years or less represent 6.1% of the inventory.
- Ignoring vintage, buildings over 250,000 square feet are 25.7% of national inventory.
- A selection of MSA shares for buildings more than 250,000 square feet and less than 21 years old are: New York (7.7%), San Francisco (11.2%), Los Angeles (3.3%), Philadelphia (5.2%), and Dallas (9.1%).

We predict that tenants will sharply discriminate between energy inefficient, unhealthy properties and energy efficient, healthy buildings. Before COVID, net absorption for all property vintages was strongly positive. Such was not the case for the seven quarters ending Q3-2021. On a macro basis, only properties built after 2014 had a positive net absorption during the pandemic. Tenants clearly prefer newer buildings when the market is uncertain and under stress, as shown below:

Exhibit 4. Only the most recent office building vintage has positive net absorption.



Source: JLL

The capital markets are no less discriminating today and will be even more so in the future. Now is the time to take obsolescence seriously. The capital markets already make cap rate distinctions by quality. For example, COSTAR grades buildings by quality scale and cap rates that are inversely correlated with COSTAR assessments (The best buildings have 4- and 5- star ratings; the worst 1-2 stars). For each vintage, the cap rates of larger properties are lower than the cap rates of properties smaller than 250,000 square feet. (Appendix A)

Investors should take note: A small shift of tenants from the more numerous, smaller, and older buildings to our much smaller subset of energy efficient, healthy buildings will dramatically increase the price and rents of efficient, healthy buildings. This increase will be proportionally greater than the percentage decrease in the price and rents of energy inefficient, non-healthy buildings.

In the near future, we expect price distinctions to become dramatic. Ignoring obsolescence, energy efficiency and healthy building attributes will prove painful.

There are two ways to address the limited supply of energy efficient, healthy buildings:

- New development, and
- Retrofitting buildings to achieve greater energy efficiency and healthy conditions.

Retrofitting existing buildings has the benefit of producing a smaller carbon footprint than new development (e.g., new development generates new emissions by construction involving new steel and concrete) **and is likely to involve properties in better locations.**

Investment implications: The new energy efficient, healthy supply will increase, but slowly, implying that **investing in energy efficient, healthy buildings is a long-term, durable, and highly profitable strategy.** Investors should sell obsolete buildings with declining rents and buy energy efficient, healthy buildings – or those that lend themselves to a value-add retrofit strategy. Not only will the value of these assets grow faster, but the investor will be protected against the declining value of obsolete properties.

VIII. Stylized office model: COVID and changing standards will accelerate change

In Appendix B, we present a detailed office model that demonstrates the effects of a shift from energy inefficient, unhealthy to energy efficient, healthy buildings. The assumptions and stylized facts are as follows:

- Earlier we showed that healthy buildings across selected large MSAs comprise a small subset of the total office inventory.
- We assume, based on the MIT study, that the rental rate for healthy buildings exceeds that of unhealthy buildings by an amount we call the rental gap.
- Most of the office building inventory is old. Hence it is likely that there is significant embedded obsolescence, some of which is economically incurable.
- Obsolescence has been a chronic and growing problem. Heretofore, it has largely been a hidden problem.
- COVID, however, is a recent shock that is forcing innumerable social and economic adjustments, the place of work being just one such change.
- COVID has accelerated in-process changes and new standards that predate COVID. These forced changes are also causing firms and workers to reconsider their preferences.
- An important consideration is that the upgrading of the existing inventory, especially the older inventory, will occur with a considerable lag. In many cases, upgrading older office properties under the new standards may be uneconomic, thus forcing demolition or change of use.

The model demonstrates the impact of a decrease in demand at current prices. (Note that a demand curve shows the relationship between price and quantity. Other factors, such as income, can shift the demand curve, while holding prices constant.) Hence, given changing tenant preferences favoring efficient, healthy buildings, we expect a leftward shift in the demand for inefficient, unhealthy buildings: At any rent, the demand for energy inefficient, unhealthy space declines. As a result, the equilibrium rent in the energy inefficient, unhealthy sector falls.

As Appendix B demonstrates, the largest rental change—an increase—occurs in the energy efficient, healthy office sector.[11] Since the energy efficient, healthy inventory is so small, the demand curve shifts to the right intersecting the supply curve at a much higher rental rate.

The gap between the equilibrium rental rates in energy inefficient, unhealthy and energy efficient, healthy buildings increases significantly. The market responds accordingly. **The price of inefficient, unhealthy buildings falls sufficiently to justify capital improvements that bring the property up to current standards. Owners of the inefficient, unhealthy buildings who are unable or unwilling to make necessary capital improvements will suffer losses.**

The important underlying assumption is that the pool of energy efficient, healthy buildings is small, which amplifies the impact of changes in the larger inventory of inefficient, unhealthy buildings through the substitution effect.

The rents and capital values of healthy buildings increase in relation to the number of unhealthy buildings. Therein lies an historic investment opportunity.

[11] We assume similar demand elasticities and an inelastic supply curve since the inventory adjusts slowly with a substantial lag.

IX. Office labor markets: WFH, migration and agglomeration

Worker migration. The popular press reports worker migration from the CBDs to the suburbs, but not much inter-MSA migration. These stories may be exaggerated. The flows may not be substantial in relation to the total number of skilled or unskilled workers within an MSA. (Appendix C)

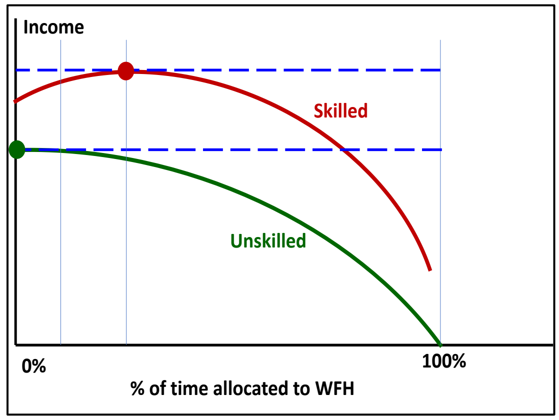
Suburbanization and work from home seems to be greater in larger, denser MSAs, such as New York and San Francisco, where the opportunity cost of commuting, especially with a COVID penalty, is high. Workers rightly focus on safety and clearly enjoy the flexibility and freedom of working from home. Some of these workers will discover that working from home sacrifices the benefits of proximity and social interaction. Hence, we are not surprised to see that the rate of suburbanization of workers is slowing and maybe even reversing. Many of the moves, even the inter-MSA migration, may be transient.

Working from home. Surveys indicate that workers prefer an average of two days working from home. Employers prefer that workers spend few days working from home as shown by Google, Apple, and Facebook signing mega leases during the pandemic. We expect that employee and employer preferences will continue to converge.

People do not always reveal their preferences to a pollster. Budgets force people to make financial tradeoffs, which surveys do not. The choices may be at variance with survey responses reported during a pandemic. Nevertheless, for purposes of analysis, we assume two days of WFH, a typical average response.

Exhibit 5 shows the hypothetical tradeoff between days worked at home and income. It indicates that skilled workers are more likely to elect WFH, whereas lower paid, unskilled workers are less likely.

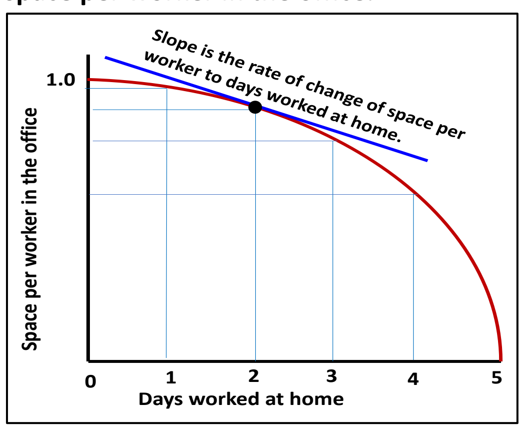
Exhibit 5. Skilled workers are more likely to elect working from home, especially during a pandemic.



Source: Outsourced Research

If two days WFH becomes the norm, the impact on space per worker (or total leased office space) should be slight since companies will need to allocate adequate space for each worker on day(s) when workers in the office overlap, as shown in the hypothetical graph, Exhibit 6.

Exhibit 6. Two days at home do not materially affect space per worker in the office.



Source: Outsourced Research

X. The winners and the losers: Building size, vintage, MSA size and density

A heterogenous office market. A property's value reflects the value of a bundle of attributes, none of which trade individually in a market. However, with lots of data and the appropriate analytics, we can unravel the implicit value of these attributes.

When we ask the question, "Who will be the winners?", we are asking not just what the value of each attribute will be, but what will be the relative weighting of each attribute during and following COVID. For example, workers may prize certain characteristics that would not have mattered pre-COVID.

The quality of air is one of the most important and sought-after attributes today. Energy efficiency is another. The demand for some attributes varies by price and income elasticity. Higher income workers may value attributes differently and this valuation at the margin may change over the business cycle. Most of these attributes are costly to change and inelastic. A repricing of these attributes can result in significant changes in the overall price of a property. The attributes of the largest and newest, most energy efficient, and healthier properties may have higher elasticities and, hence, may be easier to adjust.

How do we define obsolete? Even "obsolete" buildings trade in the market, unless the government forces extreme retrofit or removal of "obsolete" buildings. London indicates that it plans to withhold from owners the right to lease their space if they fail to achieve certain carbon neutrality goals by 2030. The cities of New York and Boston have imposed commercial building carbon taxes that are being phased in over the next decade. Will the US or any of its other MSAs adopt similar legislation? Which buildings are least likely to meet new energy efficiency, health standards and what penalties will governments (or tenants) assign?

New environmental standards, the catalyst for new building codes, certifications, and regulations, will define what constitutes an energy efficient or healthy building. Without COVID, the pace of development of new healthy building standards would be slower. Market and regulatory pressures are amplifying the desires for tenants seeking energy efficient healthy buildings.

Obsolescence is not the same as removal of buildings from the inventory. Obsolescence can lead to price and rental reduction, and even change of use. Our model shows the impact of a shift in the demand from unhealthy to healthy buildings. Our findings are as follows:

- A hybrid solution—partial working from home—is profit maximizing for many firms.
- There is no significant reduction of total office space occupancy, assuming approximately one-to-two days per week of working from home. Space per worker is unlikely to shrink; in fact, in a post-COVID world, space per worker could increase.
- Excessive WFH may stifle long-term innovation and growth through the loss of agglomeration economies relating to face-to-face contact and knowledge spillovers.
- Videoconferencing, while beneficial, is an imperfect substitute for in-person interaction.
- Newer buildings with amenities and employer-funded financial incentives will help attract workers back to the office.
- The impact of a shift in workers' and firms' preferences from energy inefficient, unhealthy to energy efficient, healthy buildings can result in significant changes in rents, cap rates, and prices. This effect will be strongest in larger, denser, and older cities.

XI. Strategies for investors

Cream rises to the top. The best buildings will be newer or deeply retrofitted; they will generally be larger and sustainable. They will offer healthy attributes, flexibility, and ample amenities, especially in the larger, denser cities.

Size matters because larger buildings can internalize beneficial economic spillovers, promote social networking, and achieve economies of scale (and scope) in the provision of tenant services.

The owners of larger buildings can spread the costs to upgrade building systems and meet new standards over more building area.

This dynamic constitutes an acquisition and consolidation opportunity as the market will increasingly penalize the majority of the inventory that does not conform to these characteristics.

Investors should do the following:

- **Launch obsolescence audits**. As institutional investors understand the implications of obsolescence, they should launch detailed audits of their own portfolio. This will be a huge, time consuming but necessary effort that may not yield immediately actionable results.
- **Determine which properties to sell or retain**. The results of these audits will better inform decisions to sell or retrofit. Similarly, this will inform investors' ability to replace obsolete office properties with energy efficient, healthy buildings.
- **Risk-analytics and office property asset allocation**. Institutional investors need more data and the correct analytic tools. Risk metrics and Monte Carlo are good tools for dealing with the inherent uncertainty in the data. These stochastic tools account for uncertainty and help investors estimate risk-adjusted returns as well as the probability of returns within specified ranges. The standard deterministic tools fail to address uncertainty properly.

Investors can achieve alpha returns in the office market by pursuing value-add and opportunistic strategies, such as the retrofitting of older, well-located, energy inefficient, unhealthy buildings.

The haves and have nots. The burden (and rewards) of change will vary by building age, size, location, amenities, and technology.

XII. Conclusion

Obsolescence, not COVID, is the biggest threat that office building owners face. COVID, which will either disappear or become endemic, is but an accelerant of in-process changes.

Obsolescence is ubiquitous, insidious, long-lasting, and an increasing burden as workers, tenants, and investors assess office buildings' value with finer precision. The promulgation of building energy efficiency and health standards, and the public scoring of building obsolescence will drive change. Tenants and their workers now have the means and incentives to measure building energy efficiency and health real-time and to vote with their feet when owners are unresponsive to market signals.

We expect that these changes will benefit the smaller subset of healthy buildings, the size of which we approximate using building size and vintage. **Energy efficient, healthy buildings are a small share of the entire inventory, so they should experience a disproportionate uplift in market rents and valuation.**

How should we sort the winners and the losers? Here is a suggested typology:

- **The "Endangered Third"**. We estimate that approximately 30% of the office building inventory is obsolete in that it no longer addresses the full needs of tenants. The market will significantly discount these assets' prices. Many owners forget that buildings are organisms that require constant attention, including CAPEX. Instead, many of these buildings suffer from deferred maintenance and, in many cases, the buildings and their locations are functionally obsolete and incurable.

- **The "Mediocre Middle"**. Another segment is in the range of 40%: The marginal mediocre middle. These properties will realize little, if any, appreciation and will require conservative underwriting given the long-term changes afoot and inherent uncertainty regarding the impact of these changes. Obsolescence is insidious because its full extent is hidden from view. As a result, a pricing gap between buyer and seller will emerge and transactions volume in the older sector will weaken until pricing changes. In fact, fluctuations in trading volume can indicate the presence of hidden information and market inefficiency.

- **The "Winners"**. The remaining roughly 30% are already the winners or will be soon. This subset is attracting new tenants and renewing existing tenants, who are expanding their space, paying higher rents, and obtaining amenity-rich, technologically up-to-date, and strategically located accommodations. The supply of winners – energy efficient, healthy buildings – is less than the total supply of space. Hence, we expect a shift in tenant demand from the endangered third, the unhealthy buildings, to the winners. The value of the former will decline, and the latter will appreciate.

How serious is the obsolescence problem? Total obsolescence in the older MSAs could be substantial. For example, if the value of the New York MSA office inventory is approximately $500 billion, we estimate that the obsolete inventory is valued between $123 and $190 billion, which is not an estimate of the cost to cure obsolescence. This is equivalent to the value of 60 to 100 Empire State Buildings. We further estimate that one-third of the office inventory expressed in square footage is obsolete.

Hence, workers and firms will consider obsolescence when accepting job offers or signing leases. More firms will require the return of WFH employees to realize the benefits of team dynamics, and related elements of human capital. We believe that this adjustment may take time. Crucially, we expect that firms will <u>not</u> likely decrease their total space demand or space per worker even if employees spend one or two working days out of the office.

The Alarming Repricing of Office Buildings

The ESG tsunami is heading west, starting in Europe, sweeping across the US and eventually heading toward Asia. Conformance with ESG standards, including energy efficiency and health and wellness will differentiate the winners from the rest.

The separation between the winners and the losers will be most apparent in the larger, denser cities.

XIII. Appendix A: Office inventory analysis by quality, age, and size

The office inventory is heterogeneous within and across MSAs. This heterogeneity reflects differences in vintage, quality rating, building size, amenities, location, and, of increasing importance, obsolescence.

The size and vintage of the entire US inventory reveals some important characteristics. We include in Appendix A similar charts for eight MSAs. These MSAs show significant variation.

Exhibit 7[12] includes vintages shown by column and sizes exhibited by row. The total US office inventory is 11.890 billion square feet. We focus on properties of at least 250,000 square feet that are at least 21 years old—healthy buildings. Section E show that buildings that are no more than 11 years old and no less than 250,000 square feet comprise 3.0% of the national inventory. Section D indicates that buildings of similar size range and 21 years or less vintage represent 6.1% of the inventory. Ignoring vintage, buildings over 250,000 square feet are 25.7% of the national inventory—see Item F below.

Buildings created before 1980 and greater than 250,000 square feet represent 10.3% of the inventory—see section G. The largest buildings of 21-year vintage or less clearly represent a small portion of the inventory.

We show similar charts for selected MSAs. (See Exhibit 11 through 18.) For example, New York MSA's office buildings created before 1980 and greater than 250,000 square feet represent 36% of the inventory. The vintage distribution of the New York office inventory clearly indicates that New York is an older MSA, compared with 20% for Phoenix.

Exhibit 7. US office inventory: Buildings greater than 250,000 Square Feet and 11-Year vintage equal to 3.0%

United States

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	166.0	264.0	219.0	95.3	83.4	84.9	912.6	7.7%
500K - 750K	A 118.0	153.0	B 160.0	C 68.3	D 74.0	E 74.9	648.2	F 5.4%
250K - 500K	225.0	292.0	404.0	166.0	213.0	201.0	1,501.0	12.6%
0 - 250K	1,500.0	1,700.0	2,100.0	1,200.0	1,600.0	737.0	8,837.0	74.3%
Total	2,009.0	2,409.0	2,883.0	1,529.6	1,970.4	1,097.8	11,898.8	
11 years as % of total				J		3.0%		
21 years as % of total					6.1%			
31 years as % of total			I	8.9%	K			
41 yeas as % of total		H	15.5%					
Built before 1980	G	10.2%						
Total inventory greater than 250K	25.7%							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	155	219	196	84	73	70	797	0.1%
500K - 750K	215	270	279	114	123	127	1128	0.2%
250K - 500K	756	937	1217	501	652	605	4668	0.8%
0 - 250K	176,222	131,803	106,203	61,908	86,734	28,136	591,006	98.9%
Total	177,348	133,229	107,895	62,607	87,582	28,938	597,599	
11 years as % of total						4.8%		
21 years as % of total					19.5%			
31 years as % of total				30.0%				
41 yeas as % of total			48.0%					
Built before 1980		52.0%					L	
Average building size, total, mm	0.011	0.018	0.027	0.024	0.022	0.038	0.020	
Average building size, > 250K SQFT, mm	0.452	0.497	0.463	0.472	0.437	0.450		
Average building size, > 500K SQFT, mm	0.768	0.853	0.798	0.826	0.803	0.811		
Average building size, > 750K SQFT, mm	1.071	1.205	1.117	1.135	1.142	1.213		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		83.1%	62.9%	38.6%	25.8%	9.2%		

Source: Outsourced Research using COSTAR data

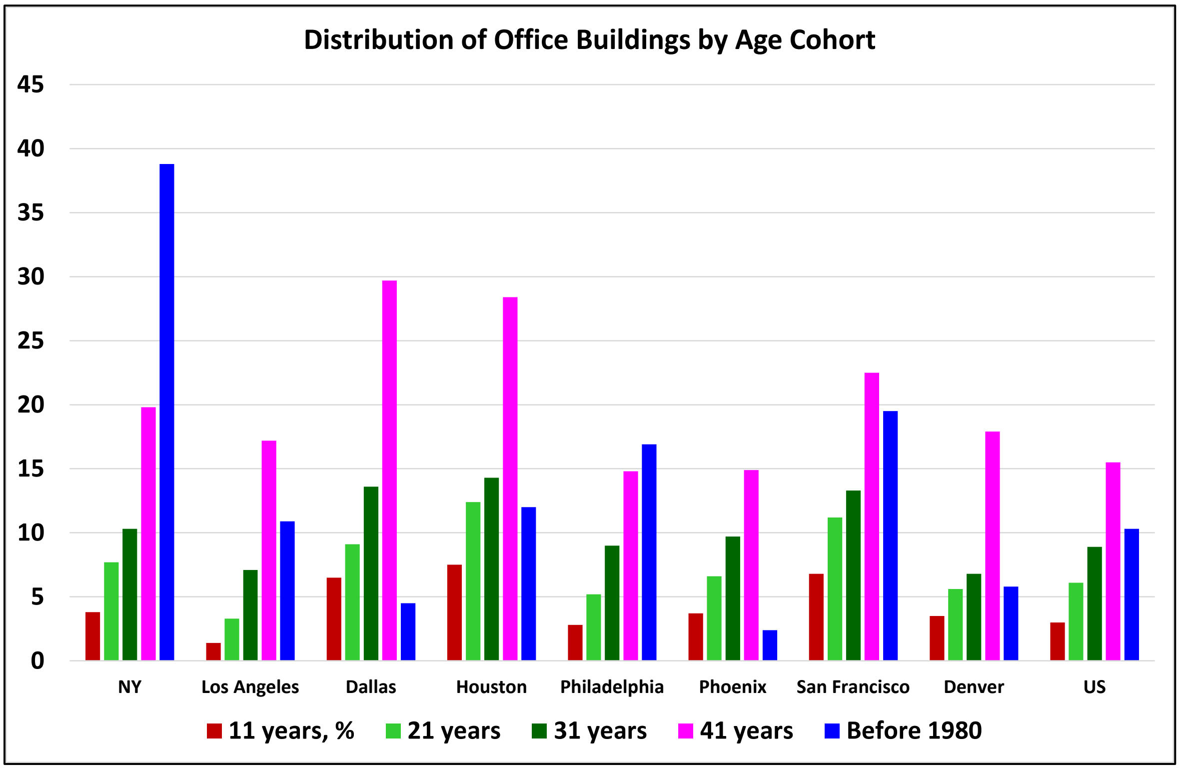
[12] We prepared Exhibits 7 through 18 on February 5, 2022 using COSTAR data for the US and selected MSAs (COSTAR Markets). At the USA level, COSTAR's "Data Export" function produced a lower US inventory estimate than the "Properties" tab. Since the Properties tab allows disaggregation of inventory data by date built and size ranges, we relied on data using the Properties tab. There was insignificant variation in the New York inventory and most other MSAs. These variances do not affect our conclusions.

The US distribution of office vintages varies by MSA, as shown below in Exhibit 8. MSA inventories built before 1980 (blue) dwarf the 41-year and earlier vintages. The 41-year vintage exceeds the before-1980 vintage for the nation.

The percentage shares of selected MSAs' 21-year vintage buildings over 250,000 square feet are as follows: New York (7.7%), San Francisco (11.2%), Los Angeles (3.3%), Philadelphia (5.2%), Houston (12.4%), Dallas (9.1%) and Phoenix (6.8%). The national average is 6.1%.

If healthy buildings are highly correlated with larger buildings of more recent vintage, then this group represents in all MSAs a small share of the office inventory. We show in Appendix B that a small shift of tenants from the more numerous older and smaller buildings to our much smaller healthy building subset could significantly increase the subset's average rent and market value.

Exhibit 8. Buildings of early vintages, 21 years or less, comprise a small share of the inventory.



Source: Outsourced Research using COSTAR data

Pricing obsolescence. We predict that tenants will sharply discriminate between energy inefficient, unhealthy and energy efficient, healthy buildings. Are the capital markets capable of pricing these distinctions? Yes, they are, and in the future, these distinctions will be even more dramatic. Ignoring building obsolescence, energy efficiency, and health will no longer be possible.

The capital markets already discriminate by certain building characteristics. For example, COSTAR ranks buildings by quality. The lowest quality property receives a COSTAR 1 designation; the best properties receive a COSTAR 5. Exhibit 9 shows that the market cap rate for COSTAR 1 exceeds COSTAR 5 properties about 200 bps to 310 bps. Recently that spread has been between 230 bps and 250 bps.

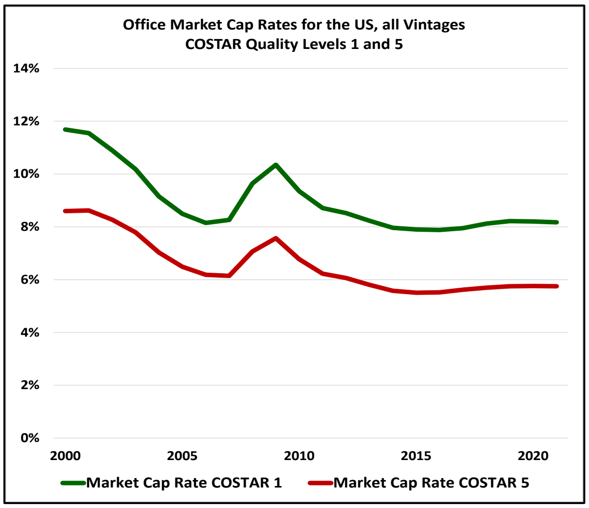
We expect the difference between the green premium and the brown discount is increasing. Cap rates will increasingly reflect this spread.

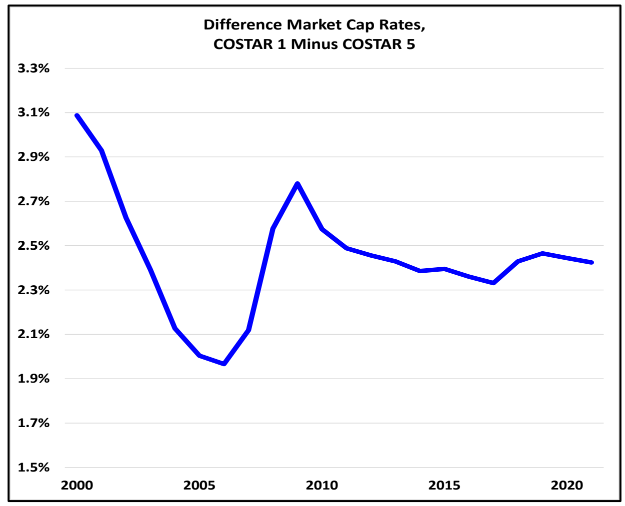
Exhibit 10 includes size, vintage as well as COSTAR quality. Market cap rates for COSTAR 4 and 5 properties are lower than the cap rates for Costar 1, 2 and 3 properties across all size ranges.

For each vintage, the cap rates of larger properties are lower than the cap rates of properties that are less than 250,000 square feet.

Building energy efficiency and health will be important metrics that capital markets price.

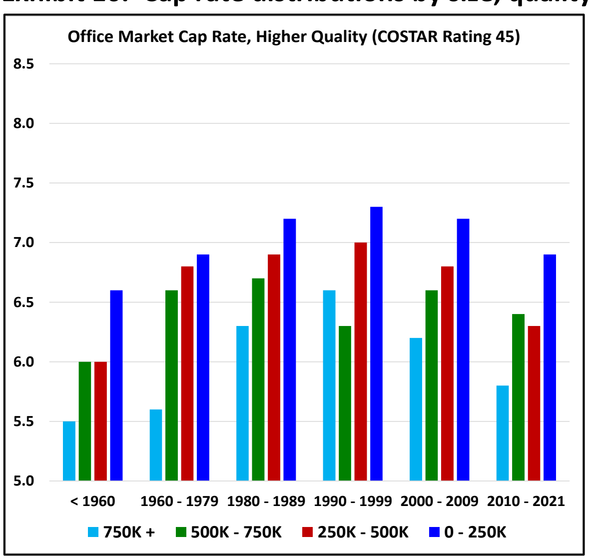
Exhibit 9. Cap rate spreads for COSTAR 1 and COSTAR 5 office properties.

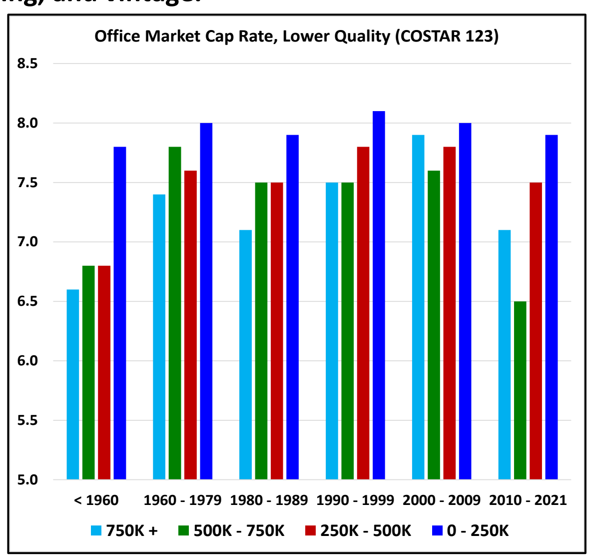




Source: Outsourced Research

Exhibit 10. Cap rate distributions by size, quality rating, and vintage.





Source: Outsourced Research

Exhibit 11. New York MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 3.8%

New York

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	92.9	98.6	43.5	14.6	27.2	20.4	297.2	32.2%
500K - 750K	43.5	19.4	18.5	4.2	3.2	4.9	93.7	10.1%
250K - 500K	77.5	25.3	26.3	4.6	5.9	9.5	149.1	16.1%
0 - 250K	194.0	59.7	66.4	18.1	23.5	22.4	384.1	41.6%
Total	407.9	203.0	154.7	41.5	59.8	57.2	924.1	
11 years as % of total						3.8%		
21 years as % of total					7.7%			
31 years as % of total				10.2%				
41 yeas as % of total			19.8%					
Built before 1980		38.7%						
Total inventory greater than 250K	58.4%							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	82	72	35	13	21	10	233	1.2%
500K - 750K	78	38	32	7	5	9	169	0.9%
250K - 500K	250	77	80	14	16	27	464	2.4%
0 - 250K	9,810	3,200	2,347	916	1,367	648	18,288	95.5%
Total	10,220	3,387	2,494	950	1,409	694	19,154	
11 years as % of total						3.6%		
21 years as % of total					11.0%			
31 years as % of total				15.9%				
41 yeas as % of total			29.0%					
Built before 1980		71.0%						
Average building size, total, mm	0.040	0.060	0.062	0.044	0.042	0.082	0.048	
Average building size, > 250K SQFT, mm	0.522	0.766	0.601	0.688	0.864	0.757		
Average building size, > 500K SQFT, mm	0.853	1.073	0.925	0.940	1.169	1.332		
Average building size, > 750K SQFT, mm	1.133	1.369	1.243	1.123	1.295	2.040		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		55.9%	33.9%	17.2%	12.7%	6.2%		

Source: Outsourced Research using COSTAR data

Exhibit 12. Denver MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 3.5%

Denver

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.0	0.9	4.8	0.0	0.0	**0.0**	5.71	3.2%
500K - 750K	0.0	4.5	6.9	0.5	0.0	**1.8**	13.7	7.8%
250K - 500K	2.1	3.5	7.7	1.6	4.1	**4.3**	23.3	13.2%
0 - 250K	10.3	26.3	41.5	15.5	26.1	13.5	133.2	75.7%
Total	**12.4**	**35.213**	**60.9**	**17.6**	**30.2**	**19.6**	**175.9**	
11 years as % of total						**3.5%**		
21 years as % of total					**5.8%**			
31 years as % of total				**7.0%**				
41 yeas as % of total			**18.0%**					
Built before 1980		**6.3%**						
Total inventory greater than 250K	**24.3%**							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0	1	4	0	0	**0**	5	0.1%
500K - 750K	0	7	11	1	0	**3**	22	0.4%
250K - 500K	6	11	23	6	13	14	73	1.3%
0 - 250K	1,368	1,488	1,114	358	728	279	5,335	98.2%
Total	**1,374**	**1,507**	**1,152**	**365**	**741**	**296**	**5,435**	
11 years as % of total						**5.4%**		
21 years as % of total					**19.1%**			
31 years as % of total				**25.8%**				
41 yeas as % of total			**47.0%**					
Built before 1980		**53.0%**						
Average building size, total, mm	0.009	0.023	0.053	0.048	0.041	0.066	0.032	
Average building size, > 250K SQFT, mm	0.350	0.469	0.511	0.300	0.315	0.359		
Average building size, > 500K SQFT, mm	NA	0.677	0.780	0.502	NA	0.600		
Average building size, > 750K SQFT, mm	NA	NA	1.200	NA	NA	NA		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**93.0%**	**72.9%**	**38.3%**	**28.3%**	**11.1%**		

Source: Outsourced Research using COSTAR data

Exhibit 13. San Francisco MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 6.8%

San Francisco

	Building Area, SQFT. MM							
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.9	11.8	4.5	0.0	0.0	**2.9**	20.1	11.1%
500K - 750K	3.4	4.2	4.2	0.7	2.9	**2.2**	17.6	9.7%
250K - 500K	7.4	7.7	8.1	3.1	5.4	7.2	38.9	21.4%
0 - 250K	39.3	14.5	18.9	9.0	13.4	9.7	104.8	57.8%
Total	**51.0**	**38.2**	**35.7**	**12.8**	**21.7**	**22.0**	**181.4**	
11 years as % of total						**6.8%**		
21 years as % of total					**11.4%**			
31 years as % of total				**13.5%**				
41 yeas as % of total			**22.7%**					
Built before 1980		**19.5%**						
Total inventory greater than 250K	**42.2%**							

	Number of Buildings							
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	1	11	5	0	0	**3**	20	0.5%
500K - 750K	6	7	7	1	5	**7**	33	0.9%
250K - 500K	22	23	26	11	17	21	120	3.2%
0 - 250K	1,976	688	412	202	225	119	3,622	95.4%
Total	**2,005**	**729**	**450**	**214**	**247**	**150**	**3,795**	
11 years as % of total						**4.0%**		
21 years as % of total					**10.5%**			
31 years as % of total				**16.1%**				
41 yeas as % of total			**28.0%**					
Built before 1980		**72.0%**						
Average building size, total, mm	0.025	0.052	0.079	0.060	0.088	0.147	0.048	
Average building size, > 250K SQFT, mm	0.404	0.578	0.442	0.317	0.377	0.397		
Average building size, > 500K SQFT, mm	0.616	0.889	0.725	0.704	0.580	0.510		
Average building size, > 750K SQFT, mm	0.913	1.073	0.900	NA	NA	0.967		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**71.9%**	**50.8%**	**31.1%**	**24.1%**	**12.1%**		

Source: Outsourced Research using COSTAR data

Exhibit 14. Philadelphia MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 2.5%

Philadelphia

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	8.4	5.3	4.0	5.1	2.1	**2.1**	27.0	9.3%
500K - 750K	5.7	8.5	5.1	1.0	0.7	**1.2**	22.2	7.7%
250K - 500K	6.7	8.0	6.0	3.9	3.2	3.9	31.7	11.0%
0 - 250K	48.8	40.5	55.3	25.9	27.9	9.8	208.2	72.0%
Total	**69.6**	**62.3**	**70.4**	**35.9**	**33.9**	17.0	**289.1**	
11 years as % of total						**2.5%**		
21 years as % of total					**4.6%**			
31 years as % of total				**8.0%**				
41 yeas as % of total			**13.3%**					
Built before 1980		**14.7%**						
Total inventory greater than 250K	**28.0%**							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	8	6	4	5	2	**2**	27	0.2%
500K - 750K	13	14	9	2	1	**2**	41	0.3%
250K - 500K	22	25	19	13	10	11	100	0.8%
0 - 250K	5,871	2,371	2,249	979	1,023	332	12,825	98.7%
Total	**5,914**	**2,416**	**2,259**	**999**	**1,036**	**347**	**12,993**	
11 years as % of total						**2.7%**		
21 years as % of total					**10.6%**			
31 years as % of total				**18.3%**				
41 yeas as % of total			**35.7%**					
Built before 1980		**64.1%**						
Average building size, total, mm	0.012	0.026	0.031	0.036	0.033	0.049	0.022	
Average building size, > 250K SQFT, mm	0.484	0.484	0.472	0.500	0.464	0.480		
Average building size, > 500K SQFT, mm	0.671	0.690	0.700	0.871	0.943	0.825		
Average building size, > 750K SQFT, mm	1.050	0.883	1.000	1.020	1.050	1.050		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**75.9%**	**54.4%**	**30.0%**	**17.6%**	**5.9%**		

Source: Outsourced Research using COSTAR data

Exhibit 15. Los Angeles MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 1.4%

Los Angeles

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.8	13.8	10.7	5.7	1.6	**0.0**	32.6	8%
500K - 750K	0.5	6.6	7.2	5.0	0.6	**1.1**	21.1	5%
250K - 500K	7.3	16.9	24.9	5.9	5.1	4.7	64.8	15%
0 - 250K	68.1	82.0	92.4	20.8	23.6	17.4	304.3	72%
Total	**76.7**	**119.3**	**135.2**	**37.4**	**30.9**	**23.2**	**422.8**	
11 years as % of total						**1.4%**		
21 years as % of total					**3.1%**			
31 years as % of total				**7.0%**				
41 yeas as % of total			**17.2%**					
Built before 1980		**10.9%**						
Total inventory greater than 250K	**28.0%**							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	1	11	10	5	2	**0**	29	0%
500K - 750K	1	12	12	8	1	**2**	36	0%
250K - 500K	28	57	74	17	17	15	208	1%
0 - 250K	7,747	4,506	3,026	874	896	563	17,612	98%
Total	**7,777**	**4,586**	**3,122**	**904**	**916**	**580**	**17,885**	
11 years as % of total						**3.2%**		
21 years as % of total					**8.4%**			
31 years as % of total				**13.4%**				
41 yeas as % of total			**30.9%**					
Built before 1980		**69.1%**						
Average building size, total, mm	0.010	0.026	0.043	0.041	0.034	0.040	0.024	
Average building size, > 250K SQFT, mm	0.287	0.466	0.446	0.553	0.367	0.341		
Average building size, > 500K SQFT, mm	0.658	0.887	0.814	0.823	0.745	0.550		
Average building size, > 750K SQFT, mm	0.800	1.255	1.070	1.140	0.800	NA		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**81.9%**	**53.6%**	**21.7%**	**12.8%**	**5.5%**		

Source: Outsourced Research using COSTAR data

Exhibit 16. Houston MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 8.0%

Houston

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.8	13.1	22.7	0.8	3.8	**7.8**	48.9	14.7%
500K - 750K	2.9	8.7	7.7	1.3	3.6	**3.6**	27.8	8.3%
250K - 500K	0.7	14.4	11.4	4.4	9.2	15.3	55.4	16.6%
0 - 250K	10.9	44.2	67.1	14.5	36.5	27.7	200.9	60.3%
Total	**15.3**	**80.4**	**108.9**	**21.0**	**53.1**	**54.4**	**333.0**	
11 years as % of total						**8.0%**		
21 years as % of total					**13.0%**			
31 years as % of total				**14.9%**				
41 yeas as % of total			**27.5%**					
Built before 1980		**12.2%**						
Total inventory greater than 250K	**39.7%**							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	1	13	18	1	4	**8**	45	0.4%
500K - 750K	6	15	13	2	6	**6**	48	0.5%
250K - 500K	4	43	51	11	29	47	185	1.8%
0 - 250K	1,688	2,467	1,911	786	1,786	1,248	9,886	97.3%
Total	**1,699**	**2,538**	**1,993**	**800**	**1,825**	**1,309**	**10,164**	
11 years as % of total						**12.9%**		
21 years as % of total					**30.8%**			
31 years as % of total				**38.7%**				
41 yeas as % of total			**58.3%**					
Built before 1980		**41.7%**						

	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total
Average building size, total, mm	0.009	0.032	0.055	0.026	0.029	0.042	0.033
Average building size, > 250K SQFT, mm	0.397	0.510	0.510	0.461	0.426	0.438	
Average building size, > 500K SQFT, mm	0.528	0.779	0.981	0.683	0.740	0.814	
Average building size, > 750K SQFT, mm	0.794	1.008	1.261	0.750	0.950	0.975	
		61 years	41 years	31 years	21 years	11 years	
Total inventory by cohort		**95.4%**	**71.3%**	**38.6%**	**32.3%**	**16.3%**	

Source: Outsourced Research using COSTAR data

Exhibit 17. Dallas MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 6.5%

Dallas

Building Area, SQFT. MM	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.0	3.9	26.6	5.0	0.0	8.1	43.6	10.8%
500K - 750K	1.1	3.9	12.1	3.4	1.8	2.8	25.1	6.2%
250K - 500K	2.1	7.2	28.2	9.1	8.7	15.5	70.8	17.5%
0 - 250K	16.5	38.2	81.6	32.1	55.7	41.6	265.7	65.6%
Total	**19.7**	**53.2**	**148.5**	**49.6**	**66.2**	**68.0**	**405.2**	
11 years as % of total						**6.5%**		
21 years as % of total					**9.1%**			
31 years as % of total				**13.4%**				
41 yeas as % of total			**29.9%**					
Built before 1980		**4.5%**						
Total inventory greater than 250K	**34.4%**							

Number of Buildings	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0	4	23	4	0	**6**	37	0.3%
500K - 750K	3	8	22	6	3	**5**	47	0.3%
250K - 500K	12	29	84	27	27	47	226	1.6%
0 - 250K	2,164	2,579	2,965	1,302	2,846	2,123	13,979	97.8%
Total	**2,179**	**2,620**	**3,094**	**1,339**	**2,876**	**2,181**	**14,289**	
11 years as % of total						**15.3%**		
21 years as % of total					**35.4%**			
31 years as % of total				**44.8%**				
41 yeas as % of total			**66.4%**					
Built before 1980		**33.6%**						
Average building size, total, mm	0.009	0.020	0.048	0.037	0.023	0.031	0.028	
Average building size, > 250K SQFT, mm	0.213	0.366	0.519	0.473	0.350	0.455		
Average building size, > 500K SQFT, mm	0.367	0.650	0.860	0.840	0.600	0.991		
Average building size, > 750K SQFT, mm	NA	0.975	1.157	1.250	NA	1.350		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**95.1%**	**82.0%**	**45.4%**	**33.1%**	**16.8%**		

Source: Outsourced Research using COSTAR data

Exhibit 18. Phoenix MSA office inventory with buildings greater than 250,000 Square Feet and 11-Year vintage equal to 3.7%

Phoenix

			Building Area, SQFT. MM					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0.0	0.9	0.0	0.9	1.0	**0.0**	2.8	1.5%
500K - 750K	0.0	0.0	2.7	1.7	0.6	**1.9**	6.9	3.6%
250K - 500K	0.6	3.2	7.2	3.3	3.6	**5.2**	23.1	12.1%
0 - 250K	5.2	19.0	40.2	22.5	54.6	16.5	158.0	82.8%
Total	**5.8**	**23.1**	**50.1**	**28.4**	**59.8**	**23.6**	**190.7**	
11 years as % of total						**3.7%**		
21 years as % of total					**6.5%**			
31 years as % of total				**9.6%**				
41 yeas as % of total			**14.7%**					
Built before 1980		**2.4%**						
Total inventory greater than 250K	**17.2%**							

			Number of Buildings					
	< 1960	1960 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2021	Total	% of Total
750K +	0	1	0	1	1	**0**	3	0.0%
500K - 750K	0	0	5	3	1	**3**	12	0.1%
250K - 500K	2	9	26	10	11	16	74	0.8%
0 - 250K	1,133	1,925	1,970	678	2,943	347	8,996	99.0%
Total	**1,135**	**1,935**	**2,001**	**692**	**2,956**	**366**	**9,085**	
11 years as % of total						**4.0%**		
21 years as % of total					**36.6%**			
31 years as % of total				**44.2%**				
41 yeas as % of total			**66.2%**					
Built before 1980		**33.8%**						
Average building size, total, mm	0.005	0.012	0.025	0.041	0.020	0.064	0.021	
Average building size, > 250K SQFT, mm	0.276	0.405	0.319	0.423	0.401	0.374		
Average building size, > 500K SQFT, mm	NA	0.853	0.540	0.656	0.805	0.633		
Average building size, > 750K SQFT, mm	NA	0.853	NA	0.925	0.996	NA		
		61 years	41 years	31 years	21 years	11 years		
Total inventory by cohort		**97.0%**	**84.9%**	**58.6%**	**43.7%**	**12.4%**		

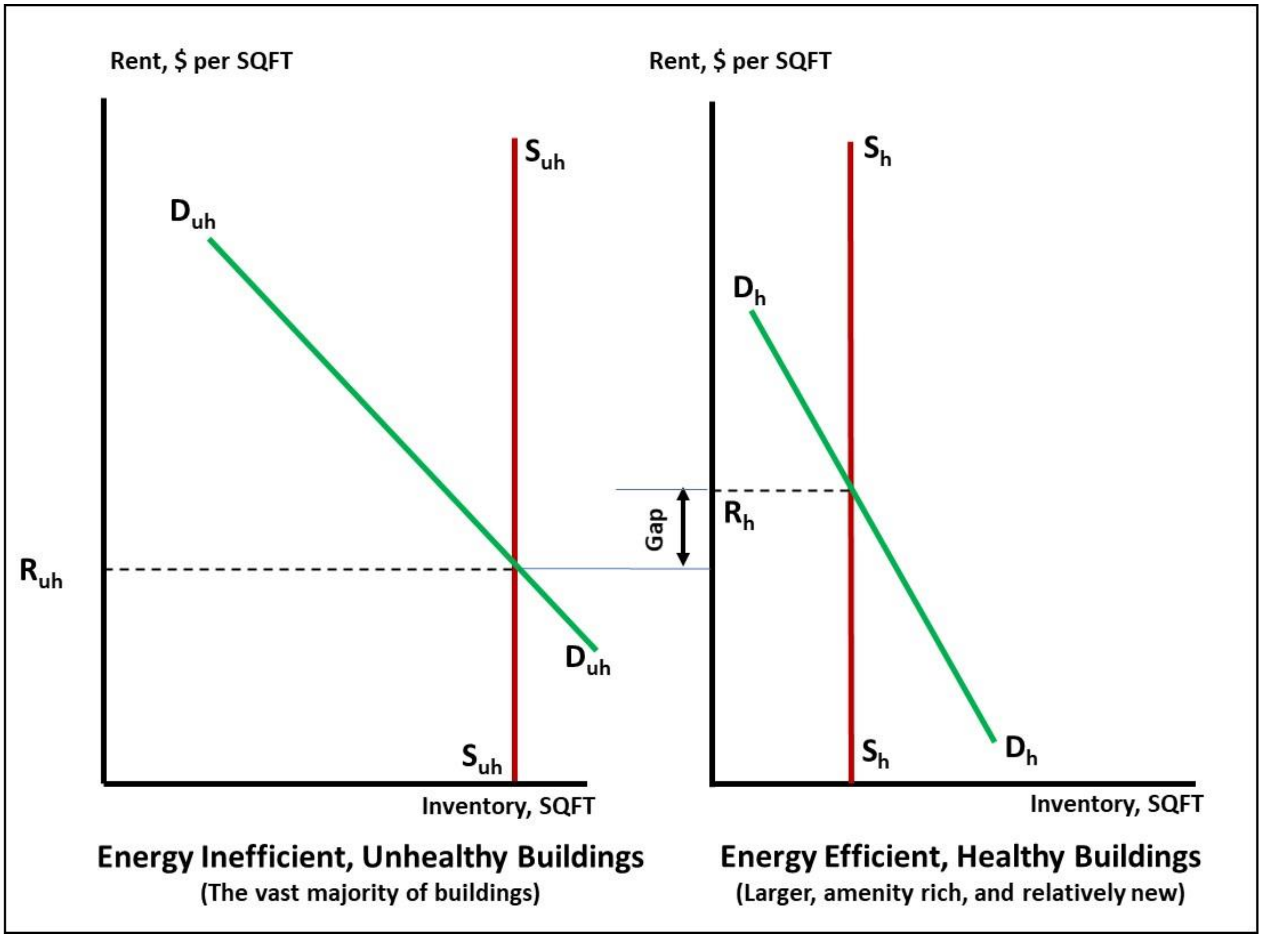
Source: Outsourced Research using COSTAR data

XIV. Appendix B: How we expect the office sector to adjust to obsolescence

How does a demand shock affect the rental rate of energy inefficient, unhealthy and energy efficient, healthy buildings? Exhibit 19 shows the initial conditions for energy inefficient, unhealthy and energy efficient, healthy buildings.

The equilibrium rent of unhealthy buildings, R_{uh}, is less than the rental rate of healthy buildings, R_h. The difference between R_h and R_{uh} is the initial rental gap, GAP.

Exhibit 19. We assume a smaller supply of energy efficient, healthy buildings, the rent for which exceeds the rent of energy inefficient, unhealthy buildings.



Source: Outsourced Research

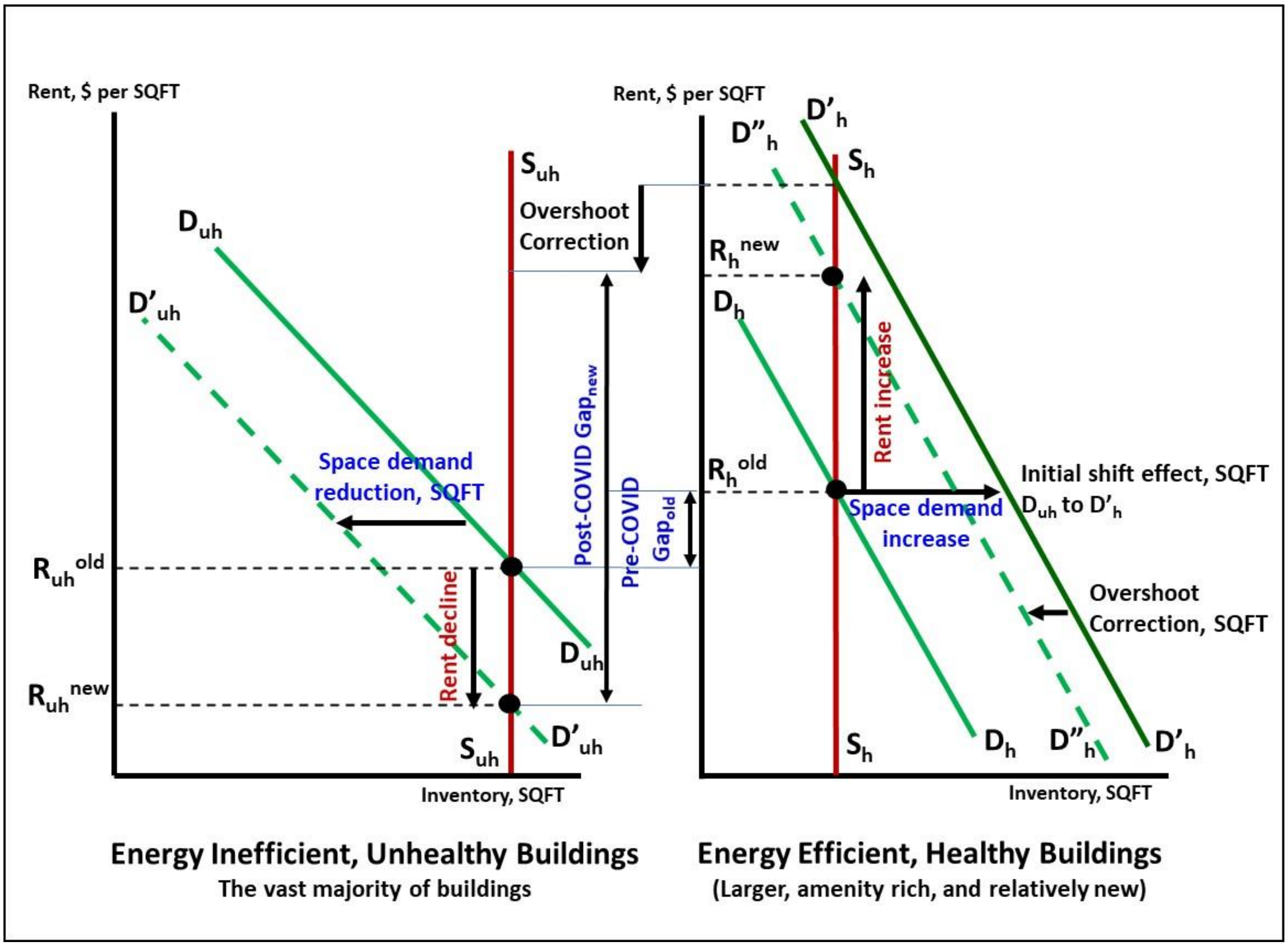
What happens if, given prevailing rents, sufficient numbers of tenants shift from unhealthy to healthy buildings. Exhibit 20 shows that the rental rate gap increases.

We assume that the supply of healthy and unhealthy buildings is perfectly inelastic in the short run. Over the longer-term, the supply adjusts to relative price changes, but the adjustment is slow. The unhealthy building demand curve $D_{uh} – D_{uh}$, shifts to $D'_{uh} – D'_{uh}$. This shift results in a decrease in the unhealthy building rental rate.

An important assumption is that the inventory of unhealthy buildings greatly exceeds the supply of healthy buildings. Thus, small proportionate changes in the demand for unhealthy space can result in significant proportionate changes in the price of inelastically supplied healthy buildings. The GAP, after correcting for overshooting in the healthy inventory, increases to $R_h^{new} - R_{uh}^{new}$. The adjustment does not stop here. The wide gap results in a dramatic repricing of healthy and unhealthy buildings. The price reduction of unhealthy buildings makes curing obsolescence more attractive, so capital eventually flows to this sector.

The prices of healthy buildings increase for two reasons: rents increase and the cap rate declines.[13]

Exhibit 20. If tenants turn away from unhealthy buildings, the increase in the rents of healthy buildings—a small subset of all office buildings—could be substantial.



Source: Outsourced Research

[13] Our analysis abstracts from the important considerations of ESG. Inclusion of ESG considerations would not change the results of this analysis.

XV. Appendix C: Work-leisure choice and worker migration

Our labor-leisure choice model helps explain the decisions of households to remain within the labor force but leave cities for the suburbs.

Workers maximize their utility subject to a budget constraint consisting of income and time. Let's assume that the risk of disease reduces the effective wage rate, which equals the pre-disease wage rate minus a COVID discount. The slope of the budget constraint in Exhibit 21, which shifts from AE to BE, is the effective wage rate, W^{eff}. The COVID discount reduces the slope of the budget line.

Households vary in their preference for leisure, income, (and even location), which we represent by utility, U.

The worker maximizes her utility subject to budget and time constraints. The budget constraint is: $pC = I + W^{eff}(24 - R)$, where R is leisure, I is income, and p is the price of consumption, C .

A shift in the budget constraint from AE to BE represents a decrease in the opportunity cost of time and a decrease in its slope. The decrease has an income and substitution effect.

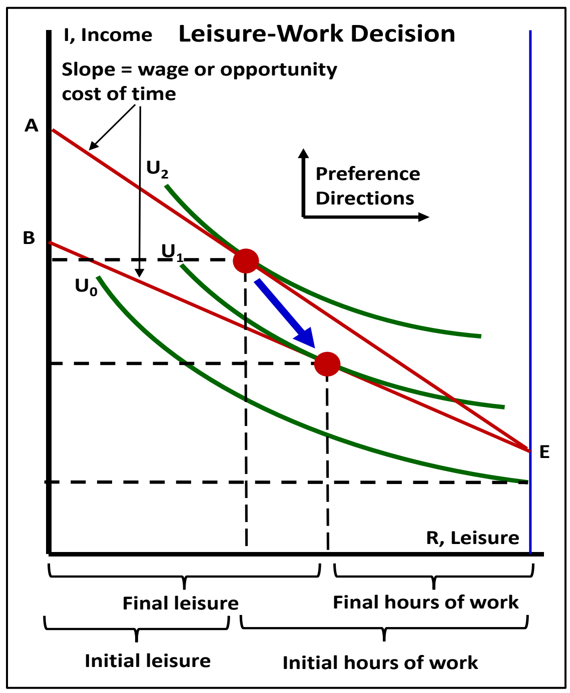
The exhibit shows that a fall in the effective wage rate <u>decreases</u> the supply of working hours and increases the amount of leisure, as long as income and leisure are normal goods. The substitution effect increases leisure while the income effect decreases leisure. The substitution effect outweighs the income effect.

Depending on the worker's preferences, the income effect can swamp the income effect, thus <u>increasing</u> the supply of labor (e.g., essential or lower skilled, lower income workers.

Enhanced models. If highly skilled workers can work from home, then we can enhance this simple model with a third variable, CBD versus suburb, and retain the tradeoff between hours worked and leisure. Working from home in the suburbs has a higher W^{eff} or a minimal COVID discount. Additionally, working from home can nearly preserve the initial leisure-work tradeoff, which provides a powerful motivation to suburbanize permanently or temporarily.

Incorporating the benefits of working in close proximity with others and decreasing, not totally eliminating the COVID discount, reduces the prevalence of working from home.

Exhibit 21. COVID can reduce workers' hours and the effective wage rate, which can induce migration of highly skilled professionals.[14]



Source: Outsourced Research

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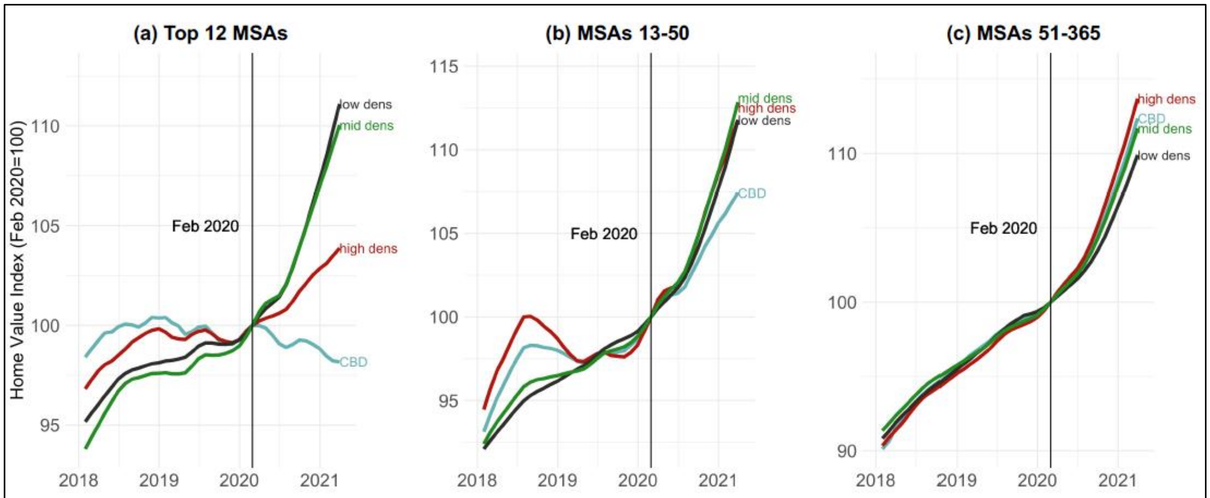
[14] We exclude consideration of worker's preferences for ESG buildings. It is our view that the inclusion of ESG would not materially change our conclusions.

We expect a hybrid solution that will significantly affect neither the overall demand for office space nor space per worker. The critical assumption is that workers will spend about one to two days WFH.

Worker migration. Exhibit 22 show that the effect of working from home on housing values and other indicators is greatest in the larger, densest MSAs. As COVID recedes or becomes endemic and manageable, many cities may partially snap back as they grope for a new equilibrium.

A decade from now, we expect that all investors, not just those living in dense cities, will shift their focus from the transient effects of COVID and turn to the longer term, difficult challenges of addressing obsolescence, energy efficiency, and creating healthier buildings.

Exhibit 22. The effect of working from home on housing values reflects MSA size and density.



Notes: The figure shows Zillow's home value index grouped by population density. Panel A pools the top 12 metros by population, panel B contains metros 13-50. and panel C gives the remaining metros (we have data on 365 in total). Zipcodes are grouped by population density or presence in a CBD. A population weighted average is taken across all zipcodes in each bucket, and each aggregated index is normalized such that Feb 2020 = 100. Density groups are given by high = top 10%, mid = 50-90th percentile, low = 0-50th percentile and populations are taken from the 2015-19 5-yr ACS. The Central Business District (CBD) is defined by taking all zipcodes with centroids contained within a 2 km radius of the CBD coordinates taken from Holian (2019). Sources: Zillow, Census Business, Holian (2019). Data: Jan 2018 - Apr 2021.

Source: Zillow, US Census Bureau

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