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Adaptive Reuse: Converting Offices to Multi-Residential Family

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Contents

Foreword and Purpose

Adaptive reuse of commercial office spaces to residential multifamily offers opportunities to ease some of the housing shortage in the US. These types of construction projects have many challenges, from zoning restrictions, financing, and also controlling construction costs. This paper explores how the Uniform Plumbing Code and Uniform Mechanical Codes impact construction affordability.

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IAPMO White Paper

Adaptive Reuse: Converting Offices to Multi-Residential Family

Executive Summary

Adaptive reuse of commercial office spaces to residential multi-family offers opportunities to ease some of the housing shortage in the US. These types of construction projects have many challenges, from zoning restrictions, financing, and also controlling construction costs. Construction costs specifically can have a disparate impact on whether an adaptive reuse project is possible, let alone successful. Therefore, flexibility during the construction process is vital to the success of an adaptive reuse project. Codes for plumbing and mechanical systems that support design versatility and science-based methods, such as the Uniform Codes, will be essential for controlling construction expenses.

Introduction

Supply and demand. It is one of the most basic economic principles. As supply goes down, demand increases, which means prices increase. Unfortunately, in the United States and Canada, the supply of homes has reduced, and low supply is a key reason why housing affordability is at its lowest level in history[1]: Per Freddie Mac, the United States has 3.8 million fewer houses than it needs[2]. Furthermore, the pace of homebuilding has still not fully recovered from the subprime mortgage crisis of 2007-08 — basically a decade of underbuilding[3]. Meanwhile, recent interest rate hikes have made homeowners reluctant to sell, contributing to the supply crunch.[4] As a result, almost half (46%) of renters are spending more than 30% of their income on rent, with 24% of renters spending more than 50% of income on rent[5].

Unfortunately, in some parts of the United States this problem is only going to become worse. As an Arizona State University Kyl Center for Water Policy study explained[6]: *"In June of 2023, the state of Arizona… [triggered] a moratorium on the issuance of permits for proposed subdivisions that would rely on local groundwater. This means that in some parts of Greater Phoenix, new housing subdivisions will not be permitted unless the developers secure water supplies other than local groundwater. Securing alternative supplies will likely require costly and complex investments in both water and infrastructure, raising concerns that new home development will be slowed, and the cost of new homes will increase, exacerbating local housing affordability problems."*

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[1] https://money.com/housing-affordability-lowest-level-in-history/

[2] https://www.freddiemac.com/perspectives/sam-khater/20210415-single-family-shortage

[3] https://www.axios.com/local/phoenix/2022/09/08/phoenix-needs-more-houses-apartments-demand

[4] https://www.investopedia.com/blame-surging-mortgage-rates-for-threadbare-for-sale-listings-7198157#:~:text=Despite%20sky-high%20home%20prices%2C%20many%20would-be%20home%20sellers,of%20the%20Federal%20Reserve's%20anti-inflation%20interest%20rate%20hikes.

[5] https://www.jchs.harvard.edu/americas-rental-housing-2022

[6] https://morrisoninstitute.asu.edu/sites/default/files/housing_affordability_and_groundwater.pdf

The United States and Canada are looking for solutions to improve housing affordability in many areas and revitalize urban cores or downtown cities. One of the potential answers presented is adaptive reuse in converting offices to residential-multi-family occupancy. This idea has been amplified post-pandemic as many professionals now work remotely ("work from home" or WFH), reducing the amount of office space needed. With transportation costs increasing, the desire to commute into the office has also declined, with many employees even being willing to switch jobs to retain the option to WFH.

When compared to pre-pandemic levels, the data show that the number of apartments resulting from adaptive reuse projects has grown more than the development of ground-up new apartments. Adaptive reuse apartments have risen 25% in the past two years compared to pre-pandemic levels. According to RentCafe[7], between 2020 and 2021 the number of adaptive reuse of offices to apartment buildings was more than 11,000. The most common adaptive reuse conversions during this time were office conversions (40%), followed by factories (15.5%), hotels (12.8%) and warehouses (9%). Since 2022, it seems as if some of the adaptive reuse market has cooled, with the total number of office-to-apartment conversions declining by 12% from previous years[8]. Additionally, according to the McKinsey Global Institute report "Empty Spaces and Hybrid Places,"[9] if all "excess office space was converted into residences, housing stock in 'superstar' cities would grow by less than 3 percent[10]." But recent news seems to indicate that another increase in adaptive reuse conversions may be occurring. New York City has unveiled an ambitious plan[11] to convert offices to housing. NYC especially has a challenge with empty offices[12]; 46 buildings are enrolled in the city's Office Conversion Accelerator program[13]. And already, since the pandemic and Hurricane Sandy, Lower Manhattan has added about 25,000 residential units[14]. While there is no easy solution to the housing issue, Adaptive Reuse of Offices for Residential is definitely one of a number of viable options.

Even though adaptive reuse has many benefits (including historical preservation, sustainability by reducing carbon emissions, and lower construction costs) there are many challenges in converting a commercial office to a residential multifamily occupancy, from financial and zoning issues to the important details of complying with building codes and making the design and installation work. That is why looking at the view from the resident and their needs and wants years in the future, while keeping an eye on the policy and construction landscape in the foreground, is so important.

[7] https://www.rentcafe.com/blog/rental-market/market-snapshots/adaptive-reuse-apartments-2022/

[8] https://www.rentcafe.com/blog/rental-market/market-snapshots/adaptive-reuse-apartments/

[9] https://www.mckinsey.com/mgi/our-research/empty-spaces-and-hybrid-places

[10] https://www.mckinsey.com/featured-insights/sustainable-inclusive-growth/chart-of-the-day/no-quick-housing-fix?cid=other-eml-chr-mip-mck&hlkid=153acb32795c4a338931dc8725a63ed3&hctky=12831642&hdpid=ee023ef9-3081-4867-9725-c02b4da09ee8

[11] https://www.nyc.gov/office-of-the-mayor/news/602-23/mayor-adams-dcp-director-garodnick-proposal-convert-vacant-offices-housing-through?utm_source=newsletter&utm_medium=email&utm_campaign=newsletter_axiosmarkets&stream=business#/0

[12] Hybrid work leaves offices empty and building owners reeling | 60 Minutes
https://www.youtube.com/watch?v=TfUhykd1Ifc

[13] https://therealdeal.com/new-york/2024/01/16/nyc-snaps-up-nearly-50-properties-in-office-to-resi-accelerator/

[14] https://www.fastcompany.com/90593504/new-york-gov-cuomo-empty-offices-should-become-housing?utm_source=newsletter&utm_medium=email&utm_campaign=newsletter_axiosmarkets&stream=business

Policy Considerations

Policy: Zoning

One of the first undertakings in adaptive reuse projects for converting an office to multifamily occupancy is to change the zoning of the building. Depending on the city, this can be a long and cumbersome process. In some jurisdictions, a change to a zoning bylaw requires public hearings, reports, and a two-thirds affirmative vote of a city council. That is why adaptive reuse is "best established as part of a master planning or strategic planning process, which considers … the needs of the area." [15] Other districts already have adaptive reuse as part of their ordinances, such as the city of Phoenix, which allows for any structure in the city prior to 2000 to be adapted for either Tier 1 (5,000 square feet), Tier 2 (5,000 to 25,000 square feet), or Tier 3 (25,000 to 100,000 square feet) reuse. In some states, the age of building plays a factor when changing the zoning of the building. For example, NYC requires adaptive reuse buildings to be older than 1977 or 1961, depending on which part of the city the building is in. Boston recently announced a conversion pilot program that allow building owners to switch from a commercial property tax to a standard residential property tax rate, and then be eligible for a rate reduction of up to 75% on the lower residential rate for a period of up to 29 years[16].

Regardless of the hurdles of zoning-change, there are opportunities in adaptive reuse, especially in making multifamily buildings a possibility in a country that generally favors single-family homes over multifamily. For example, in much of the Phoenix area, zoning and development codes promote lower-density development, effectively discouraging the creation of lower-cost housing. Many Phoenix-area municipalities zone at least 50% of their land for single-family use. However, if an office building is converted to multifamily, then land allocated for single family is not lost but rather traded with commercial land. Furthermore, if the multi-family spaces are part of a mixed-use building the reduction of commercial zoning could be abated. A building with commercial space such as retail, restaurant, grocery, or office on the ground level and with residential occupancies above has both commercial and residential occupancies. This type of creative thinking could create opportunities for more affordable housing while also encouraging community development via generating greater tax revenue per acre than conventional suburban development and reducing fiscal burdens through more efficient use of public infrastructure[17].

Policy: Financing

Financing the adaptive reuse of commercial spaces has its own distinct difficulties. Some of this is dependent on local financing options available, which are contingent on local and national policy[18]. On a local level, some municipalities offer tax abatements if a certain percentage of units within a converted building represent affordable housing[19] while other jurisdictions prohibit this practice[20]. On the broad end of the finance policy spectrum, interest rates play a significant role in making adaptive reuse projects possible. High interest rates on loans can reduce adaptive

[15] https://berkshireplanning.org/wp-content/uploads/2022/05/Toolkit-2022-Adaptive-Reuse-Zoning.pdf#:~:text=An%20adaptive%20reuse%20zoning%20bylaw%20or%20ordinance%20is,holds%20a%20public%20hearing%20and%20submits%20a%20report.

[16] https://www.gensler.com/blog/office-to-residential-conversions-in-boston

[17] https://morrisoninstitute.asu.edu/sites/default/files/housing_affordability_and_groundwater.pdf

[18] https://www.housingfinance.com/news/key-guidelines-for-developing-adaptive-reuse-projects_o

[19] https://www.bloomberg.com/news/articles/2023-07-07/what-it-actually-takes-to-turn-an-office-building-into-apartments?sref=frV97TwV

[20] https://morrisoninstitute.asu.edu/sites/default/files/housing_affordability_and_groundwater.pdf

reuse or greenfield project opportunities for developers. For example, according to one developer a 4% interest rate increasing to a 9% interest rate, in terms of debt, “puts so much of a downward force on it that it really makes it so that a lot of [adaptive reuse] projects are not able to be done right now[21].” It appears that adaptive reuse of offices to residential may become more financially viable only as office buildings devalue.

From a banking standpoint, multifamily in general is seen to be riskier than single-family homes due to the number of tenants[22] or due to the loan amounts being much higher for multifamily properties[23]. This means that interest rates in general are higher for multifamily than single family. This is where there is an opportunity for federal and state governments to work toward improving financial incentives for all multifamily construction. Such incentives can make adaptive reuse a more favorable option in increasing multi-family construction. These include the federal Historic Tax Credit program, property tax abatements, brownfield, textile, or mill tax credits, payment in lieu of taxes, and city/state grants[24a, 24b].

Much of the financial risk in adaptive reuse is due to the unknown construction risks that are uncovered only after construction starts. Therefore, for developers it is important to try to control and minimize the cost per square foot of construction. Several key factors that impact the cost per square foot includes the building purchase price, the possible rent price, and the cost of construction to convert and modernize the building from an office to a residential occupancy[25]. There are benefits of adaptive reuse by using existing land and building such as the potential to reuse existing utilities and services. Higher density housing that utilizes existing infrastructure, in general, is more efficient and can lower costs per unit while also increasing the supply of housing at lower price points than single-family homes in newly built suburban subdivisions[26]. Like any construction project the key driver in a successful adaptive reuse project is to control construction costs[27].

[21] https://www.bloomberg.com/news/articles/2023-07-07/what-it-actually-takes-to-turn-an-office-building-into-apartments?sref=frV97TwV

[22] https://lifebridgecapital.com/2022/02/16/multifamily-interest-and-cap-rates/#:~:text=Multifamily%20properties%20present%20a%20greater%20lender%20risk%20than,As%20such%2C%20that%20risk%20warrants%20higher%20interest%20rates.

[23] https://www.multifamily.loans/apartment-finance-blog/loan-ratios-in-multifamily-and-commercial-real-estate/

[24a] https://www.multihousingnews.com/adaptive-reuse-financing-game-plans/

[24b] https://www.milrose.com/insights/developers-guide-to-office-to-residential-conversions-in-chicago

[25] https://www.bloomberg.com/news/articles/2023-07-07/what-it-actually-takes-to-turn-an-office-building-into-apartments?sref=frV97TwV

[26] https://morrisoninstitute.asu.edu/sites/default/files/housing_affordability_and_groundwater.pdf

[27] IMEG website. “Office to Residential Conversion: Key Engineering Concepts to Make Your Project Successful.” https://www.imegcorp.com/library/office-to-residential-conversion-key-engineering-concepts-to-make-your-project-successful/

Construction Considerations

Flexibility is Vital

Construction costs can have a disparate impact on whether an adaptive reuse project is possible, let alone successful. Therefore, building in flexibility during the construction process is vital to the success of an adaptive reuse project. This means being flexible in evaluating location(s), being flexible in design approach in creating apartments or condominiums out of the building floor plate, and flexibility of the building structure to being modified. Flexibility of plumbing and HVAC systems will also have a major impact on the success of the project.

Building Selection

The very first construction consideration is determining the location of the existing building. Buildings located in walkable areas with lots of services and amenities are ideal[28]. This makes downtown areas — particularly with walkable neighborhoods — as especially attractive for office-to-multifamily conversions[29]. Consideration of parking to accommodate residents or any ground floor retail spaces in mixed use is also part of the determination in location.

After evaluating the location, finding the right building floor plate is the next step. The building floor plate is often dictated by the year in which the original building was constructed: the older the building the more likely it will be "long and skinny," with most offices being separated and located near a window for ventilation (especially offices built right before or after World War II, or most hotels having this configuration). When HVAC was invented, office plates went from rectangular to squarer, with HVAC allowing for the use of ductwork to provide ventilation to cubicles located "deep" into the interior. This is from where the term "deep floor plates" comes. The challenge with deep floor plates is building codes often require residential occupancies to have a window in every bedroom. This means deep floor plates provide an added difficulty in getting windows for spaces further from the building exterior. The solution is often costly: cutting a hole through the middle of the building, removing the space entirely, and either removing that volume entirely or repurposing that space volume at the top of the building in the form of more floors[30]. Amenities such as pools are considered for addition to many rooftops, as well, adding considerable weight to the structure.

Accounting for the added weight of a rooftop pool is one of many structural considerations. Validation of all other floors' existing structural floor slabs for new loads is equally necessary. After confirming loads, verifying that the structure can be modified to accommodate kitchens and bathrooms is key. Structural beams need to be located such that they do not interfere with new HVAC and plumbing systems that need to be installed. Determining if a post-tension slab was used can further complicate coring holes for ductwork and piping. Some miscellaneous structural items can include grand staircases, external sunshades, or covered walkways.

A final consideration for flexibility of space is demolishing the existing space in preparation for new construction. Ideally, demolition removes existing MEP and interior walls and leaves a blank canvas for new MEP and interior walls to be installed, also known as the new work phase; however, sometimes the demolition and new work phases overlap, also known as "mixed conversions," where renovations are done while office tenants are still in place[31]. Minimizing disturbance caused by construction noise and debris is important in these cases: giving tenants remaining in place a positive experience can help make the adaptive reuse project a success from start to finish.

[28] https://www.axios.com/local/phoenix/2022/09/08/phoenix-needs-more-houses-apartments-demand

[29] https://www.cbre.com/insights/viewpoints/office-conversions-a-second-chance-for-underutilized-space#:~:text=Conversions%20are%20especially%20attractive%20in%20dense%20markets%20with,areas%2C%20particularly%20in%20walkable%20neighborhoods%20with%20abundant%20amenities.

[30] https://www.nytimes.com/interactive/2023/03/11/upshot/office-conversions.html

[31] https://www.curbed.com/article/nyc-office-real-estate-rechler-rxr-project-kodak.html

Plumbing and Mechanical Considerations

Construction and adaptive reuse projects are estimated to save up to 20%[32,33,34] of construction costs, with the costs shifting from materials to labor[35]. Much of the overall cost of adaptive reuse is made up of mechanical (e.g., HVAC), electrical, and plumbing (MEP) systems. With much of the building remaining in place, MEP costs make up a larger percentage of construction costs in adaptive reuse projects. It is also important to adhere to such local building codes as the plumbing and mechanical codes. The *Uniform Plumbing Code (UPC®)* and *Uniform Mechanical Code (UMC®)* are developed using an American National Standards Institute (ANSI)-accredited process. The ANSI process provides flexibility for developers by allowing for greater technical discussions, which provides quicker response to new technologies. Worth noting is that some of the fastest growing urban areas — Phoenix, Austin, Houston and Las Vegas — all adopt some version of the Uniform Codes.

Flexibility of Building Codes: Plumbing

Plumbing takes on a larger percentage of multifamily construction due to the addition of more plumbing fixtures and associated piping. Therefore, plumbing codes need to provide flexibility in design and installation to control costs. The starting point for plumbing systems is the water entering the building.

When it comes to water provisions, when compared to other model plumbing codes, the *UPC* offers greater flexibility and ease to right-size water systems with the Water Demand Calculator®. Almost all model plumbing codes continue to utilize an 80-year-old sizing methodology called Hunter's Curve to size the building's water supply. Hunter's Curve was developed in 1940 and was revolutionary at the time. The probability of fixtures being on at the same time was modeled without the use of computers. Congested use was utilized to simplify the calculation process. Congested use in this case basically mimicked the water use by a sports stadium at halftime with long lines at every fixture. However, we have known for decades that most buildings do not have lines like sports stadiums at the toilets, sinks, or showers. By assuming this type of congested usage, peak flow rates estimated using the Hunter's Curve Calculation led to a large safety factor for all building types, resulting in grossly oversized piping.

Fortunately, in 2018 the International Association of Plumbing and Mechanical Officials (IAPMO), in partnership with the University of Cincinnati (UC) and the American Society of Plumbing Engineers (ASPE), released the Water Demand Calculator in Appendix M of the *UPC,* which sought to provide an updated way of sizing the water supply. The Water Demand Calculator is revolutionary because it uses real-world data to determine peak flow rates for water. The results for multifamily construction when using the Water Demand Calculator® are drastic: in general, an almost halving of the water service entrance pipe size and substantial reductions in main and branch mains in the building. In a third-party report released in 2021, potential material cost savings could be as high as 16% for multifamily[36]. This likely is even higher in present-day dollars. The Water Demand Calculator is also found to be able to save water, energy, and carbon[37].

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[32] http://yhengineering.com/the-oasis-adaptive-reuse/#:~:text=Constructing%20with%20adaptive%20reuse%20has%20more%20benefits%2C%20using,7%25%20of%20the%20total%20construction%20costs%2C%20avoiding%20demolition.

[33] https://hbre.us/the-benefits-of-adaptive-reuse/#:~:text=Calculating%20the%20costs%20of%20permits%2C%20labor%2C%20and%20materials%2C,there%20are%20no%20environmental%20problems%20along%20the%20way.

[34] https://www.ny-engineers.com/mep-engineering-services/building-commissioning-services/adaptive-reuse-and-rehabilitation

[35] https://www.mgac.com/blog/cost-drivers-of-historic-adaptive-reuse-projects/

[36] https://www.iapmo.org/media/25276/water_demand_calculator_report_summary.pdf

[37] https://www.iapmo.org/media/31497/arup_summary_report.pdf

In adaptive reuse projects, the existing water meter and building supply need to often be increased in size to meet the increased demand based on Hunter's Curve. But the greatest opportunity in adaptive reuse is the potential to not have to replace water mains at all, which occurs by using the Water Demand Calculator in lieu of Hunter's Curve. The Water Demand Calculator shows that even greater cost savings can be achieved in adaptive reuse projects due to increasing the potential to reuse existing water mains in lieu of replacing them. For example, in a recent adaptive reuse project where a hotel was converted to low-income housing, dishwashers were set to be added to each of the hotel suites to change the rooms to studio apartments. For this example, the existing hotel was served by a 3-inch water main. Based on the addition of the dishwasher main and utilizing Hunter's Curve, the 3-inch would need to be replaced with a 4-inch main, costing hundreds of thousands of dollars. However, based on the estimated peak flow rate of the Water Demand Calculator®, the 3-inch water main was more than adequate. In fact, only a 2-inch main would have been needed with the Water Demand Calculator. Using the WDC for this project helped control construction costs and affordability of a project benefitting those most in need.

This potential construction cost savings also exists for office-to-multifamily adaptive reuse projects. Many office buildings utilize flush valve water closets, while residential occupancies utilize flush tank water closets. Flush valve water closets have a much higher peak flow rate than flush tank water closets (25 GPM vs 2-3 GPM). Therefore, when converting an existing office building to a multifamily apartment or condominium, the benefit doubles: lower probability (going from Hunter's Curve to the Water Demand Calculator) and lower peak flow rates of fixtures (going from flush valve to flush tank water closets).

For example, utilizing a prototype based on a recent office-to-multifamily adaptive reuse sample project located in Phoenix, the existing 3-inch main could be reused when utilizing the Water Demand Calculator, while Hunter's Curve requires replacing it with a new 4-inch main.

> *This facility had a total of 11 floors of office converted to multifamily[38]. Assuming there was a public restroom (men's and women's) on each of the 11 floors for a total of five water closets, one urinal, and four lavatories. Assumed that all single bathrooms included tub/shower combination units, while two bathroom units included one tub/shower combination unit and one shower only. A breakdown of flow rates and pipe sizes can be found on Table 1, Table 2A, and Table 2B below:*

TABLE 1
EXISTING SAMPLE BUILDING – HUNTER'S CURVE – IPC APPENDIX E

FIXTURE TYPE	SUPPLY FIXTURE UNIT PER FIXTURE	QUANTITIES	FIXTURE UNIT TOTAL BY TYPE
Flushometer Valve Water Closet (Public)	10	55	550
3/4-Inch Flushometer Valve Urinal (Public)	5	11	55
Lavatory (Public)	2	44	88
		Fixture Unit Total =	693
		Peak Flow Rate Total =	~170 GPM
		Pipe Size (based on 4/psi per 100 LF) =	3 inches

[38] https://www.onecamelback.com/availability/bed-studio/so-rent/sd-desc

TABLE 2A
EXISTING SAMPLE BUILDING REMODEL – HUNTER'S CURVE – IPC APPENDIX E

FIXTURE TYPE	SUPPLY FIXTURE UNIT PER FIXTURE	QUANTITIES (NUMBER OF APARTMENTS)	FIXTURE UNIT TOTAL BY TYPE
1 Bedroom Full Bathroom Groups (1 Bathroom)	3.6	75	270
2 Bedroom Full Bathroom Groups (2 Bathrooms)	7.2	61	439.2
3 Bedroom Full Bathroom Groups (2 Bathrooms)	7.2	8	57.6
3 Bedroom ½ Bathroom Groups*	2.9	2	5.8
Studio Bathroom Groups	3.6	20	72
Kitchen Sinks	1.4	164	229.6
Dishwasher	1.4	164	229.6
Clothes Washing Machine	1.4	164	229.6
		Fixture Unit Total =	1533.4
		Peak Flow Rate Total =	~269.0 GPM
		Pipe Size (based on 4/psi per 100 LF) =	4 inches

*Half Bathroom Group Part of 3 Bedroom Full Bathroom Group (2 Bathrooms)

TABLE 2B
SAMPLE BUILDING REMODEL – UPC APPENDIX M WDC

FIXTURE TYPE	SUPPLY FIXTURE UNIT PER FIXTURE	QUANTITIES	FIXTURE UNIT TOTAL BY TYPE
1 Bedroom Full Bathroom Groups (1 Bathroom)	N/A	75	N/A
2 Bedroom Full Bathroom Groups (2 Bathrooms)	N/A	61	N/A
3 Bedroom Full Bathroom Groups (2 Bathrooms)	N/A	8	N/A
3 Bedroom ½ Bathroom Groups*	N/A	2	N/A
Studio Bathroom Groups	N/A	20	N/A
Kitchen Sinks	N/A	164	N/A
Dishwasher	N/A	164	N/A
Clothes Washing Machine	N/A	164	N/A
		Fixture Unit Total =	N/A
		Peak Flow Rate Total** =	46.8 GPM
		Pipe Size (based on 4/psi per 100 LF) =	2 inches

Notes:
*Half Bathroom Group Part of 3 Bedroom Full Bathroom Group (2 Bathrooms)
**Total Plumbing Fixture Quantities are as follows:
164 Units in Total
95 Combination Bath/Shower
235 Lavatories = 95 Single Bathrooom Lavatories + 2 x (69 Two Bathroom Lavatories) + 2 Half Bathroom Lavatories
69 Shower
235 Water Closets = 95 Single Bathrooom WC + 2 x (69 Two Bathroom WC) + 2 Half Bathroom WC
164 Dishwasher
164 Kitchen Sink
164 Clothes Washer

As stated previously, controlling costs is vital for a successful adaptive reuse project. Using existing plumbing piping will save on cost and labor. However, it is important that the piping installation complies with the local code requirements. Some model codes have more flexibility than others. For example, the *UPC* gives the option to use riser valves to supply water to tenants where other model plumbing codes require tenant valves[39] in multifamily buildings of varying size. For jurisdictions that adopt the *UPC*, there can be a savings of $1,300 per unit vs. where individual tenant valves are required. Therefore, to control costs, it is important to know ahead of time the plumbing provisions in your adopted plumbing code. Check with your local AHJ and Plumbing Code Amendments for tenant valve and submeter requirements. Refer to **Figure 1a** and **Figure 1b** below to see the difference in allowing riser valves in lieu of requiring tenant valves. Water submeters for each dwelling unit will change the design of the system and the amount of water piping required.

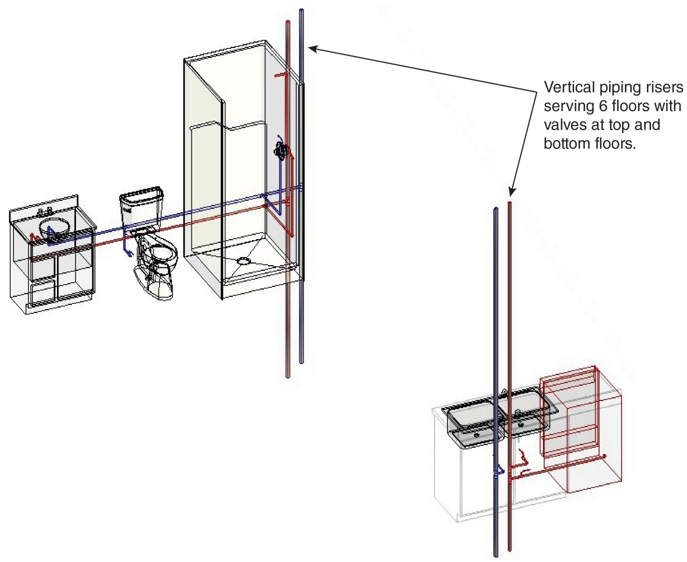


FIGURE 1A
UPC ALLOWED USE OF RISER VALVES PIPING SCHEMATIC

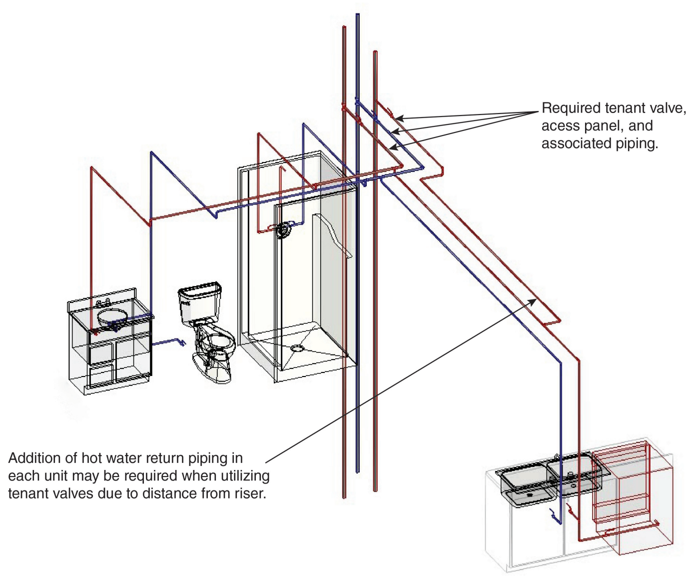


FIGURE 1B
MANDATE OF TENANT VALVES PIPING SCHEMATIC

[39] https://www.pmengineer.com/articles/94148-international-plumbing-code-change-will-require-a-shutoff-valve-to-isolate-a-tenants-water-supply

The *UPC* also includes provisions for waste and vent sizing that can impact construction affordability. To start, venting in the *UPC* (located in Chapters 7 and 9) offers engineered system design of horizontal vent systems[40]. This engineered approach allows for ease of determining capacity on individual floors of bathrooms.

Key Venting Rules for Apartments with one or more bathrooms:

- 1-1/2-inch vent for 60 feet in total developed length of which horizontal can be up to 20 feet, can have a maximum of 8 units.
- 2-inch vent for 120 feet in total developed length of which horizontal can be up to 40 feet, can have a maximum of 24 units.
- 3-inch vent for 212 feet in total developed length of which horizontal can be up to 70 feet, can have a maximum of 84 units.
- If the entire length of a vent line is upsized one nominal pipe diameter, there are no maximum length limitations.

Other *UPC* provisions that improve flexibility of design and installation of waste and vent systems are as follows:

- The possibility to vent below flood rim in the *UPC* via horizontal venting. When dealing with existing structure and new plumbing fixtures, being able to route a vent pipe below the floor provides the opportunity to avoid structural columns and reduces the need for additional chases to route vent piping.
- A typical approach in multifamily is horizontal bathroom group wet venting. The *UPC* requires the water closet be located as the most downstream fixture. There is concern in putting a water closet upstream of a bathtub as the potential of siphoning out bathtub/shower p-trap increases, thereby allowing sewer gases into the space.
- Buildings 10 or more stories in height require a yoke and parallel vent stack for a 2-stack system. Additional coring would be needed for each drainage stack, while a single-stack system would not (engineered system).

One final consideration for adaptive reuse projects is the utilization of Appendix C: Alternate Plumbing Systems. In this appendix, Table C 303.3 includes an alternate sizing methodology for drainage systems, based on the *National Standard Plumbing Code (NSPC)*. Utilizing Appendix C to compare vent and building drainage needs in our One Camelback example, we see that waste and vent sizing ends up smaller and closer to existing fixture unit values, thereby increasing the likelihood of being able to reuse existing building drains and vent penetrations, further helping reduce costs.

TABLE 3
EXISTING PROTOTYPE OFFICE – IPC CHAPTER 7

FIXTURE TYPE	DRAINAGE FIXTURE UNIT PER FIXTURE	QUANTITIES	FIXTURE UNIT TOTAL BY TYPE
Flush Valve Water Closet (Public)	4	55	220
Flush Valve Urinal (Public)	4	11	44
Lavatory (Public)	1	44	44
		Fixture Unit Total =	308
		Composite Building Drain Pipe Size (based on 1/8 inch per LF slope) =	6 inches*
		Composite Vent Pipe Size =	6 inches

*Composite Building Drain could be 5-inch, however this is an uncommon size used in industry, therefore 6-inch pipe would most likely be utilized.

[40] Per conversation with former city of Phoenix Inspector Michael Billingsley.

TABLE 4A
PROTOTYPE OFFICE TO RESIDENTIAL REMODEL – IPC CHAPTER 7

FIXTURE TYPE	DRAINAGE FIXTURE UNIT PER FIXTURE	QUANTITIES (NUMBER OF APARTMENTS)	FIXTURE UNIT TOTAL BY TYPE
1 Bedroom Full Bathroom Groups (1 Bathroom)	5	75	375
2 Bedroom Full Bathroom Groups (2 Bathrooms)	10	61	610
3 Bedroom Full Bathroom Groups (2 Bathrooms)	10	8	80
3 Bedroom ½ Bathroom Groups*	5	2	10
Studio Bathroom Groups	5	20	100
Kitchen Sinks	2	164	328
Dishwasher	2	164	328
Clothes Washing Machine	2	164	328
		Fixture Unit Total =	2149
		Composite Building Drain Pipe Size (based on 1/8 inch per LF slope) =	10 inches
		Composite Vent Pipe Size =	10 inches

*Half Bathroom Group Part of 3 Bedroom Full Bathroom Group (2 Bathrooms)

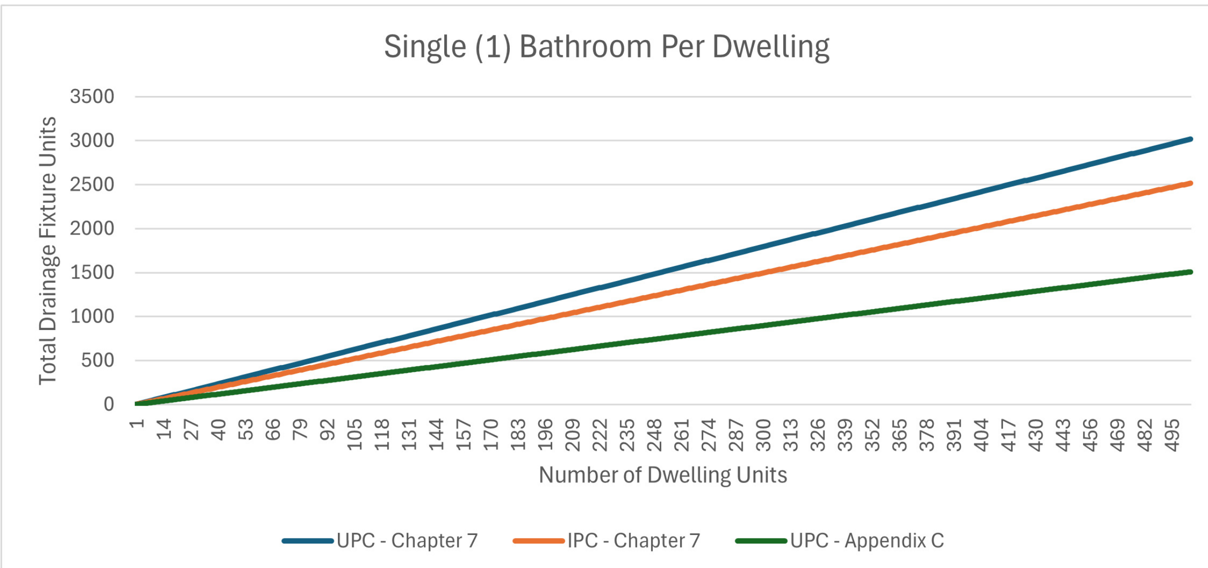
TABLE 4B
PROTOTYPE OFFICE TO RESIDENTIAL REMODEL – UPC APPENDIX C: ALTERNATE PLUMBING SYSTEMS

FIXTURE TYPE	DRAINAGE FIXTURE UNIT PER FIXTURE	QUANTITIES	FIXTURE UNIT TOTAL BY TYPE*
1 Bedroom Full Bathroom Groups (1 Bathroom)	3.0	3	9.0
1 Bedroom Full Bathroom Groups (1 Bathroom)	3.0	72	216
2 Bedroom Full Bathroom Groups (2 Bathrooms)	4.5	61	274.5
3 Bedroom Full Bathroom Groups (2 Bathrooms)	4.5	6	36
3 Bedroom Full and Half Bathroom Groups (2.5 Bathrooms)	5.0	2	10.0
Studio Bathroom Groups	3.0	20	60
Kitchen Sinks with Dishwasher	2	164	328
Clothes Washing Machine	2	164	328
		Fixture Unit Total =	1261.5
		Composite Building Drain Pipe Size (based on 1/8 inch per LF slope) =	8 inches
		Composite Vent Pipe Size =	6 inches

*Assuming this is a 164 unit apartment, you would use the column under "Serving 3 or more private use Bathroom groups" in Table C 303.3.

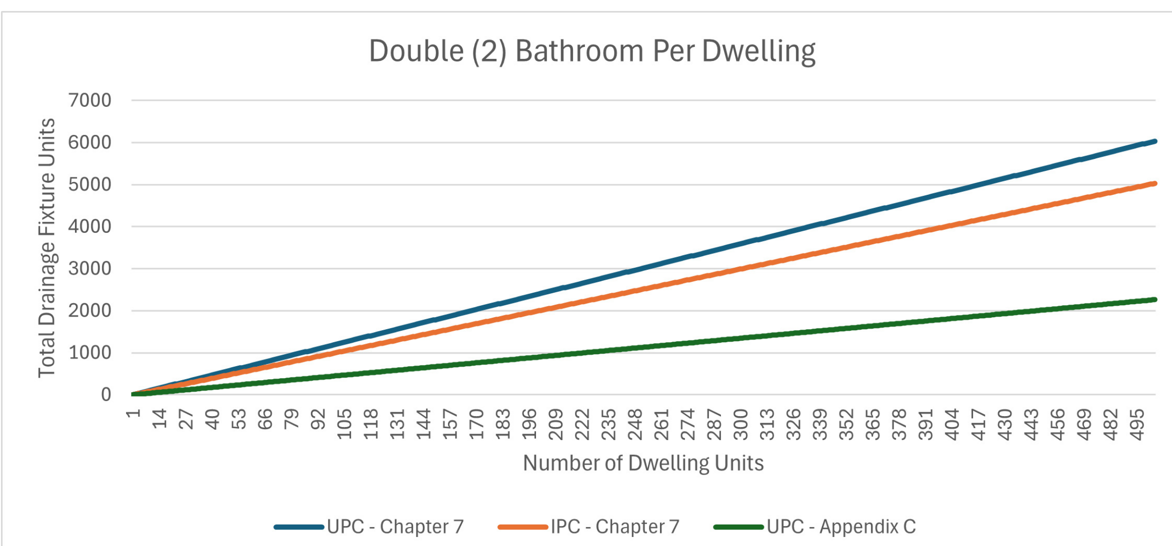
If one were to chart the difference in drainage fixture unit calculations from the various codes, the delineation between codes becomes incredibly noticeable. Refer to **Chart 1, Chart 2, and Chart 3** for an illustration in DFU value rate increase based on number of restrooms per dwelling unit. Additionally Refer to Table 5 and **Chart 4** for a comparison in Building Drainage Capacity per pipe size.

For 500 bathrooms, the difference in required sanitary pipe size reduces from 10-inch (for both *UPC* – Chapter 7 and IPC – Chapter 7) to a 6-inch (*UPC* Appendix C). Therefore, because of the potential construction cost savings and increased system performance, *UPC* Appendix C: Alternate Plumbing Systems and Appendix M: Water Demand Calculator should be considered a "must-have" for every office-to-multifamily-adaptive-reuse project.



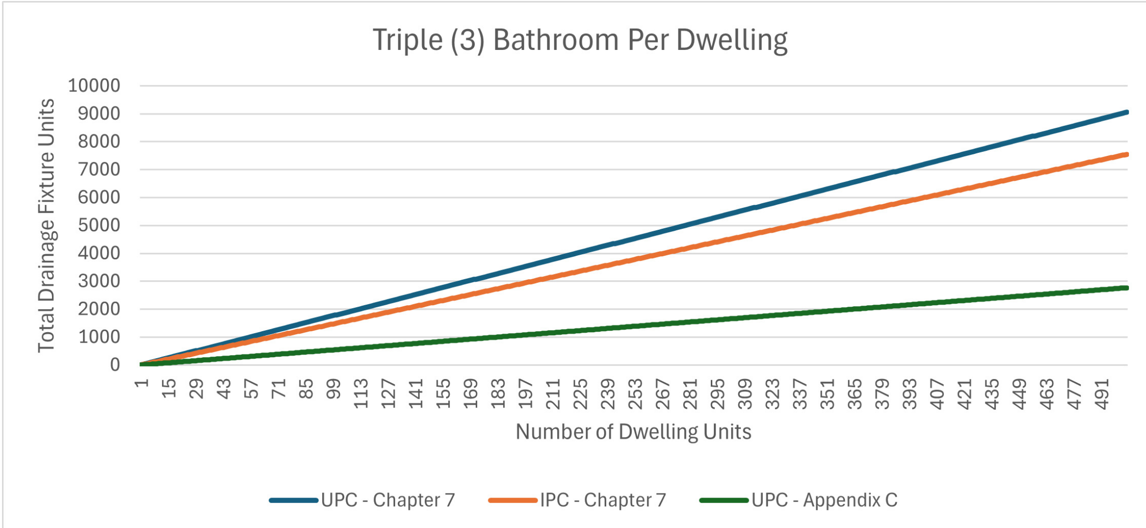
Note: Assumes 1 lavatory, 1 water closet, and 1 combination shower/tub per bathroom for a total of 6 DFU per UPC Chapter 7, 5 DFU per IPC Chapter 7, and 3 DFU per 1 Bathroom Group per Dwelling per Table C 303.2 in UPC Appendix C.

CHART 1
UPC CHAPTER 7 VS. IPC CHAPTER 7 VS. UPC APPENDIX C DFUS FOR SINGLE (1) BATHROOM PER DWELLING



Note: Assumes 1 lavatory, 1 water closet, and 1 combination shower/tub per bathroom for a total of 6 DFU per UPC Chapter 7, 5 DFU per IPC Chapter 7, and 4.5 DFU per 2 Bathroom Group per Dwelling per Table C 303.2 in UPC Appendix C.

CHART 2
UPC CHAPTER 7 VS. IPC CHAPTER 7 VS. UPC APPENDIX C DFUS FOR DOUBLE (2) BATHROOM PER DWELLING



Note: Assumes 1 lavatory, 1 water closet, and 1 combination shower/tub per bathroom for a total of 6 DFU per UPC Chapter 7, 5 DFU per IPC Chapter 7, and 5.5 DFU per 3 Bathroom Group per Dwelling per Table C 303.2 in UPC Appendix C.

CHART 3
UPC CHAPTER 7 VS. IPC CHAPTER 7 VS. UPC APPENDIX C DFUS FOR-TRIPLE (3) BATHROOM PER DWELLING

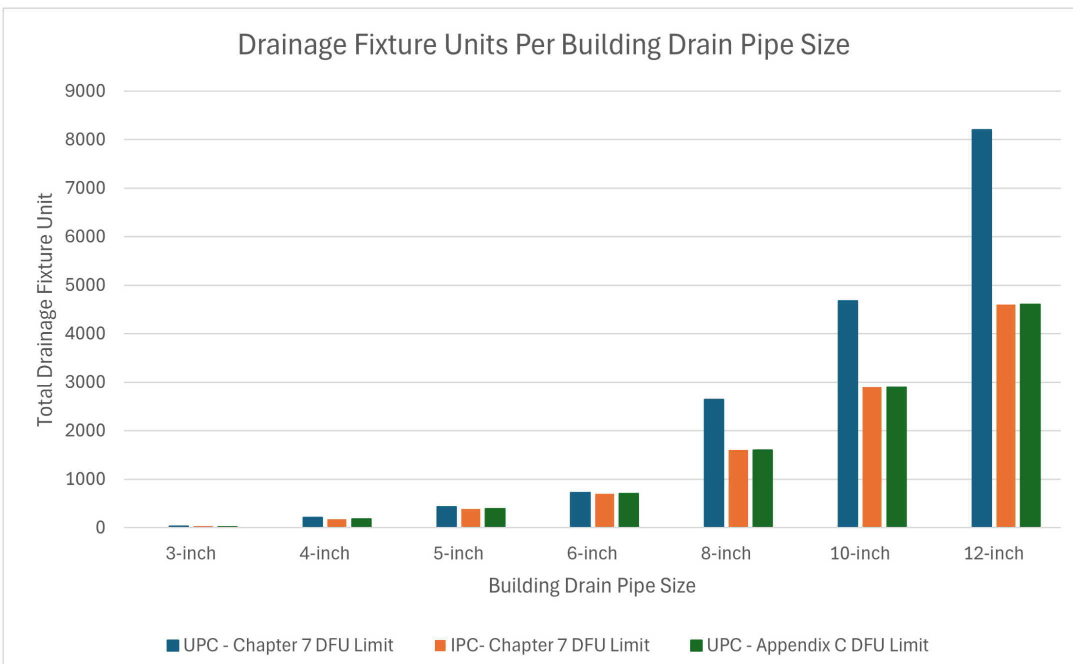


CHART 4
UPC CHAPTER 7 VS. IPC CHAPTER 7 VS. UPC APPENDIX C DRAINAGE FIXTURE UNITS PER PIPE SIZE

TABLE 5
DRAINAGE FIXTURE UNITS PER BUILDING DRAIN PIPE SIZE

Building Drain Pipe Size (1/8-inch slope per foot)	3-inch	4-inch	5-inch	6-inch	8-inch	10-inch	12-inch
UPC – Chapter 7 DFU Limit	35	216	428	720	2640	4680	8200
IPC – Chapter 7 DFU Limit	36	180	390	700	1600	2900	4600
UPC – Appendix C DFU Limit	20	180	390	700	1600	2900	4600

Flexibility of Building Codes: HVAC

A significant portion of ventilation costs accumulate as a result of when the building was constructed. With the advent of air conditioning and mechanical ventilation, office building floor plates became deeper as mechanical ventilation was used in lieu of operable windows. However, there are some mechanical ventilation requirements in codes of which those working on adaptive reuse projects should be aware:

- The ventilation air requirement formula for most model mechanical codes, including the *UMC*, is basically the same. However, the *UMC* allows natural ventilation in certain climate zones at the discretion of the AHJ, which has the potential to reduce construction and energy costs. Design considerations of the increasing likelihood of higher summer temperatures may limit the impact of this code provision.
- The *2024 UMC* has provisions for mechanical ventilation extracted from ASHRAE 62.1 (Table 402.1) for transient occupancies and for non-transient occupancies (Section 405.0). When converting from transient occupancies (e.g., hotels) to non-transient occupancies (e.g., residential), the ventilation rates differ and may need to be confirmed to provide adequate ventilation. For non-transient occupancies, the *UMC* requires mechanical ventilation to be calculated in accordance with the ventilation equation.
- The minimum ventilation rate required may be lower due to the occupancy change. However, it should not go below the minimum ventilation required for non-transient occupancies. The calculated loads should also be verified in accordance with Section 1105.1 of the *UMC*.
- For residential kitchen and bathroom exhaust, there are code requirements for volume of exhaust air and terminations restrictions that impact construction costs. However, the *UMC* does allow recirculation hoods that could save construction and operation costs by reducing the exhaust required for the building.
- While the requirement of windows in bedrooms is common in building codes, what residents prefer may be counter to this. For example, in one New York City building when prospective residents were given the option of whether or not to have windows in bedrooms, the units without as much natural light in the bedrooms were selected more quickly than units with more natural light in sleeping areas[41]. There seemed to be a preference for less natural light in their bedroom so they could sleep better. However, Section 402.2 of the *UMC* has specific requirements for natural ventilation such as ceiling height, floor area, and openings. There are cases where natural ventilation is not permitted, and mechanical ventilation is required. Where natural ventilation is not permitted, the *UMC* (Section 402.3) requires mechanical ventilation systems to include controls (manual or automatic) that enable the fan system to operate wherever the spaces served are occupied.
- Building pressurization in general will be an important ventilation consideration. Outside air ventilation requirements differ for commercial and residential: each unit needs to have dedicated outside air supply and exhaust requirements, while stairwells, elevators, and corridors require pressurization modification to maintain life-safety egress. All these changes may require replacement of existing ventilation equipment and ductwork[42].
- Other HVAC considerations: Environmental air duct terminations require shafts when exterior wall penetrations cannot be made. Remember clearances for duct work may require ceiling heights to be lowered to fit ducts.

[41] https://www.bloomberg.com/news/articles/2023-07-07/what-it-actually-takes-to-turn-an-office-building-into-apartments?sref=frV97TwV

[42] IMEG website. "Office to Residential Conversion: Key Engineering Concepts to Make Your Project Successful." https://www.imegcorp.com/library/office-to-residential-conversion-key-engineering-concepts-to-make-your-project-successful/

Water Safety

The one priority that any construction project should always have is safety. Most frequently discussed as part of safety concerns is adequate structure to support penetrations for HVAC and plumbing piping and fire-stopping of these new penetrations for life-safety. However, there are emerging concerns about conversion projects that should be addressed.

Especially for buildings that are vacant for extended periods of time, there is increased potential for water to become stagnant in piping distribution for plumbing fixtures. As that water ages, the disinfectant dissipates, and the conditions for waterborne pathogen amplification increase. To mitigate this risk for waterborne disease there are two documents of which developers, building owners, and contractors should be aware:

1. ***The IAPMO/AWWA Manual of Safe Closure and Reopening of Buildings*** — This manual covers risk management practices for all potable and non-potable water supply systems, water-supplied mechanical systems (cooling towers), wet fire suppression systems, and decorative water feature systems post-construction, during normal operation, when closing, during interruption to normal operation (system shutdown), and reopening all building occupancy types except for single- and two-family residential buildings. It is intended to provide expert guidance on building water system safety and provides sound and effective risk management practices for preparing water systems when buildings must be shut down or put into low use modes, "exercising" building water systems during periods of no or low use and evaluating and preparing water systems for reopening.

2. ***The IAPMO Manual of Construction Practices for Potable Water*** – Systematic water management during construction of new buildings (including significant additions to the envelope of an existing building) can reduce the risk that the building water system begins its service life contaminated with pathogenic organisms such as Legionella pneumophila (the etiological agent responsible for most cases of Legionnaires' disease) and can reduce the risk of infections of contractors and others at or near the site during the construction process. This standard outlines a process for developing guidance for contractors and subcontractors installing and managing building water systems during construction. This guideline plays a crucial role in reducing the risk of waterborne disease and improving the well-being of building occupants and was created to establish the improved water systems baselines for occupancy.

3. ***IAPMO/ESPRI Manual of Water Quality for Plumbing Industry Professionals and Building Managers*** - This publication provides basic guidance to help plumbing system design engineers, building owners, and water system managers obtain important information from their water suppliers (public water systems; water suppliers or purveyors) to help them design, install, and manage potable water systems that maintain water quality all the way to the end users while simultaneously protecting the pipes, fittings, fixtures, and other components that make up these systems.

Together these documents can provide enhanced public health practices in the realm of water safety.

Summary

Not only can adaptive reuse help communities address their housing shortages, but selecting and installing the right systems can do so economically. As architect John Lister, AIA, said:

> *"The most efficient building in the world is the one that's already built due to one thing: embodied reuse. Rather than starting from scratch I would pick the adaptive reuse. Adaptive reuse dynamic is getting easier every day — the materials and products and the methods and the systems that get you there were on the fringes but are becoming more mainstream. As economies of scale increase for adaptive reuse, these projects will streamline, and costs will come down. The more adaptive reuse professionals do, the more efficient and cost effective these projects become."*

As America wrestles with housing shortages in the foreseeable future, codes and standards like the *UPC* and *UMC* increase resiliency, safety, sustainability and affordability. Design flexibility and science-based approaches will be key to solving this multifaceted problem while also controlling costs. As this white paper shows, the Uniform Codes offer the greatest opportunity to do so.

Additional Research

Additional items of research on this topic could include bathroom and kitchen configurations to optimize efficiency, vacuum water closets to reduce water use, reusing stacks, co-living with central shared bathrooms, and opportunities to minimize core sleeving with PT slabs, which were not addressed as part of this white paper but are topics identified as worthy of additional review.

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