Department of Civil & Architectural Engineering
SUREAL - Built Environment Team

Presents

Phase IIA: Water Conservation Analysis

Multi-family water consumption modeling and water conservation measure analysis

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We reserve the right to make edits or changes to the data and report submitted.

Executive Summary

The idea of water becoming a scarce resource has started to plague the minds of researchers and organizations alike. The University of Miami and the International Code Council released a report titled "**Water Conservation and Codes: Leveraging Global Water-Efficient Building Standards to Avert Shortfalls**" early 2024 detailing the necessity and expectancy of adopting the water conservation measures listed in the 2021 International Water Conservation Code Provisions (IWCCP) for single-family homes and multi-family dwelling units such as duplexes and townhomes. Through the focus of four cities across ASHRAE zones, the discussion of water savings became clear. The following water conservation measures that applied were:

- Implementation of water-efficient plumbing fixtures;
- Rainwater harvesting, treatment, storage, and reuse;
- Grey water treatment, storage, and reuse; and
- HVAC condensate catchment, treatment, storage, and reuse.

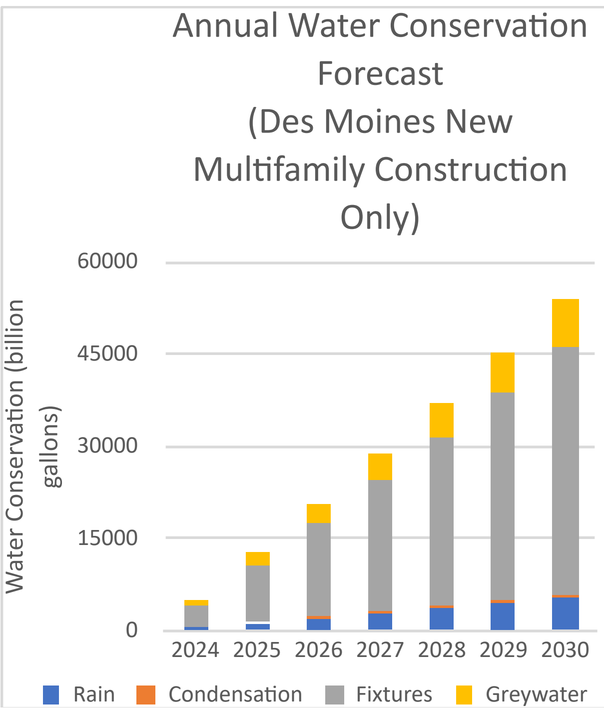
Within each city, it was discovered that there is a substantial amount of potential savings through water conservation. As a result, this study serves as a follow up to the prior as it investigates whether these same conservation methods are applicable to scaled-up multi-family properties, specifically garden-style/low-rise buildings, mid-rise buildings, and high-rise buildings. Applying the same framework created in Phase I, the total annual potential aggregate water conservation over seven years for each newly constructed building typology in the four cities are as follows:

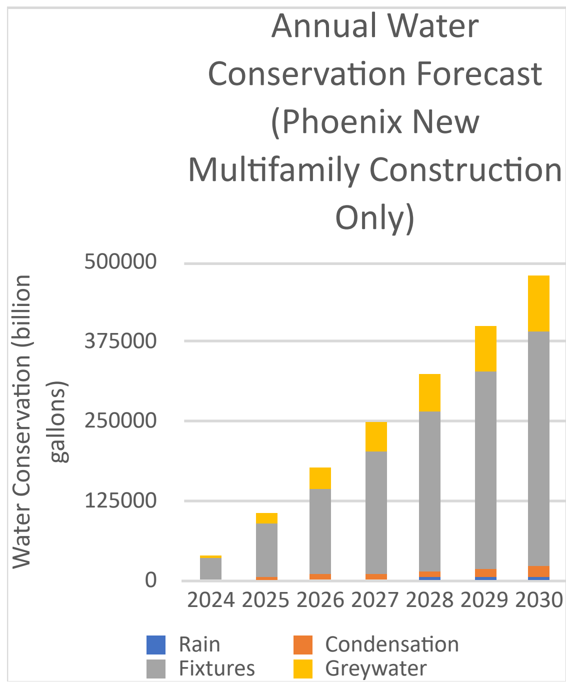
Garden-style/Low-rise:
Houston, Texas – 559.2 billion gallons;
Phoenix, Arizona – 351.9 billion gallons;
Las Vegas, Nevada – 191.3 billion gallons; and
Des Moines, Iowa – 44.8 billion gallons

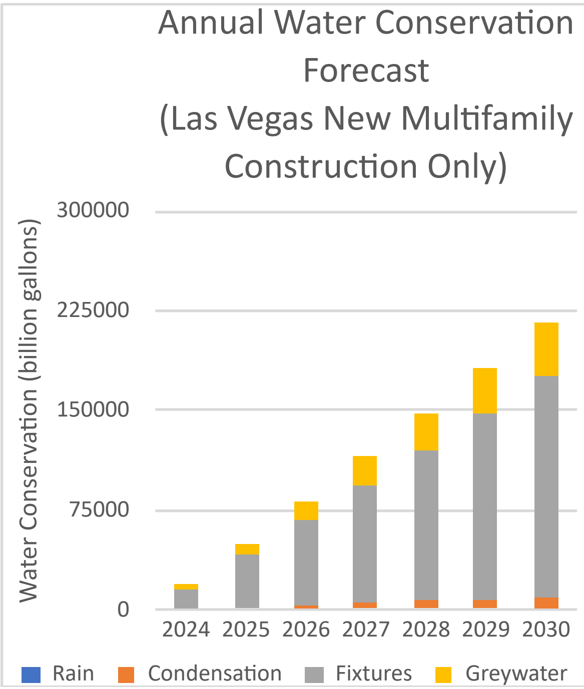
Mid-rise:
Houston, Texas – 124.8 billion gallons;
Phoenix, Arizona – 56.0 billion gallons;
Las Vegas, Nevada – 19.1 billion gallons; and
Des Moines, Iowa – 8.7 billion gallons

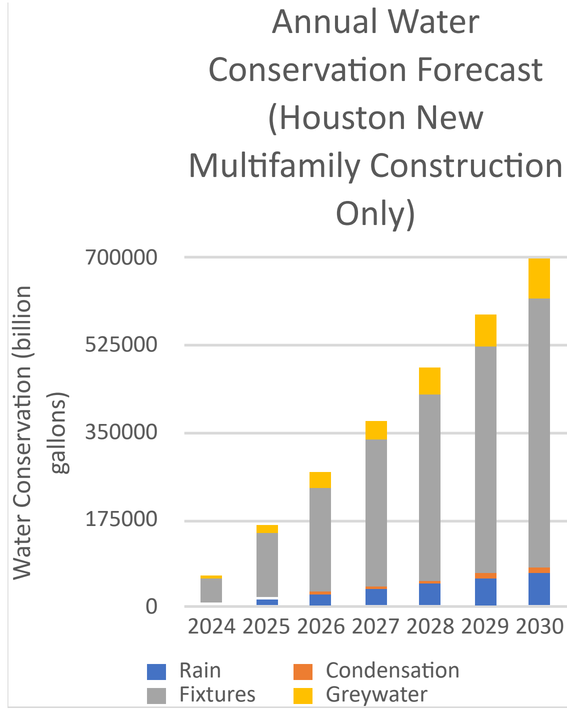
High-rise:
Houston, Texas – 13.9 billion gallons;
Phoenix, Arizona – 72.0 billion gallons;
Las Vegas, Nevada – 5.5 billion gallons; and
Des Moines, Iowa – 0.6 billion gallons
The approximate total potential aggregate water conservation for each city are as follows: Houston, Texas – **697.9** billion gallons; Phoenix, Arizona – **479.9** billion gallons; Las Vegas, Nevada – **215.9** billion gallons; and Des Moines, Iowa - **54.1** billion gallons.

A visual summary of the potential water savings for all building typologies within each city are shown below:









All four cities exhibit tremendous ability to conserve water. Remarkably, these quantities are only confined to newly constructed building typologies and will increase immensely with the renovation of existing properties.

As noted throughout this report, while these measures produce significant change, it is important to address each city individually to ensure they maximize benefits for the specific context in which they are implemented.

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1. Introduction to Phase IIA

Overview of Previous Report

As a part of Phase I, the University of Miami's SUREAL Engineering Lab in conjunction with EXP Services, Inc. published a report entitled: **Water Conservation and Codes: Leveraging Global Water-Efficient Building Standards to Avert Shortfalls**. The purpose of this report was to identify the necessity behind updating standards and highlight code provisions that would address the critical needs surrounding water and its sustainability and management throughout the built environment.

In the Phase I report, the focus was geared towards single-family residential homes and the multifamily dwelling units depicted through the formal layouts of duplexes and townhomes. With an average home consisting of approximately three bedrooms, two and a half baths, and other necessities such as a washer/dryer, and dishwasher, it was hypothesized that the use of water efficient fixtures, greywater harvesting, rainwater harvesting, and condensate harvesting from HVAC systems may be the most effective water conservation provisions in the four cities examined as part of the Phase I study:

Houston, Texas
Phoenix, Arizona
Las Vegas, Nevada
Des Moines, Iowa

At the conclusion of Phase I, after determining baseline potable and non-potable water use, the analysis showed potential water savings for one-and two-family dwellings in the four cities examined based on adoption of the noted water conservation strategies as outlined within the 2021 International Water Conservation Code Provisions (IWCCP).

Recognizing that some but not all of these strategies may be additive and that some may be more optimal for different climate zones and geographies than others, the Phase I report also included recommended combined approaches for the four cities studied.

For Phase IIA, this project investigates the scaled-up benefits of implementing these same water conservation measures for households living in multi-family buildings.

Discussion of Multi-Family Construction

According to the National Association of Home Builders, multi-family construction has been quickly on the rise – making up approximately 31.4 percent of today's housing needs. Providing shelter for the various backgrounds of the American people – students, elderly, and low-income, this vast real estate development and construction sector can meet the needs of growing population in many global cities. A notable factor to the design and placement of these residential building types is their location in urban, densely populated areas. The increasing needs and accessibility to essential community life support services such as grocery stores, shopping centers, health care centers and other similar amenities have also resulted in the emergence of unique mixed-use occupancies, bringing multi-family and commercial occupancies under one roof. As more individuals dwell in a confined footprint, the water consumption and energy demands increase significantly, placing a much heavier burden on regional infrastructure utilities, thus highlighting the significance of the noted water conservation provisions in growing urban communities.

Multi-family construction can be depicted into several building typologies ranging from duplexes to mixed-used facilities. As part of the Phase IIA scope, three multi-family building typologies were defined among the cityscapes within each of the four cities – "garden-style/low-rise buildings," "mid-rise buildings," and "high-rise buildings," with the hope to create a gateway in addressing water conservation on a pronounced scale.

The evaluation of each building typology is as follows:

Garden-Style and Low-Rise Buildings

Upon surveying all garden-style and low-rise buildings in each city studied, this building typology has been categorized as consisting of an average of 20 dwelling units, with a maximum of three stories in height. Similarly designed across the country into "O", "U", and "L" shapes, this building typology is considered to be "garden-style" or "courtyard" apartments where multiple multi-family buildings are designed to surround a parking area, designated green space or courtyard for amenities such as pools and landscaping features to be utilized and revered, respectively. With a range of one-bedroom units to four-bedroom units, the average square footage consists of roughly 875 square feet among the units.

Figure I: Typical Layout of Garden-Style/Low-Rise Buildings (Las Vegas)

Mid-Rise Buildings

Mid-Rise buildings were categorized as consisting of over 20 units but contained within the limitations of eight stories in height as part of the Phase IIA investigations. Similarly designed across the country into dense, boxed shapes, this building typology has varied options of containing rentable commercial retail spaces, such as restaurants, offices, grocery stores, and garages within a certain parcel of land based on the local zoning ordinances. With a range of one-bedroom units to three-bedroom units, the average size consists of also roughly 875 square feet among the units.

Figure II: Typical Layout of Mid-Rise Buildings (Phoenix)

High-Rise Buildings

High-rise buildings were categorized as consisting of over 20 units contained in buildings with an average height of 20 stories in this study. Following the concept of the mid-rise buildings but on a larger footprint, similarly, designed across the country into dense, boxed shapes, this building typology also offers more varied options for its' occupants, bringing some of the essential amenities such as rentable commercial retail spaces including restaurants, offices, grocery stores, and garages under one roof on larger parcel of land based on the local zoning ordinances. With a range of one-bedroom units to three-bedroom units, the average size also consists of roughly 875 square feet among the units.

Figure III: Typical Layout of High-Rise Buildings (Des Moines)

Discussion of Data Collection and Methodological approach undertaken during this study.

While additional data sources have been introduced, the methodology, compilation and analysis of data carried out during this phase is reflective of the framework previously established for the same four cities in Phase I.

The assumptions made during this phase are briefly described below:

Number of dwelling units – Although similar, each city has their own building typologies, zoning ordinances, and economic growth and development regulations unique to their populations needs. Thus, the number of dwelling units for each building typology within each city was estimated based upon the data attained from the United States Census Bureau and CoStar, a commercial real estate database.

To define the building typologies further, based on the survey data gathered from CoStar, each multi-family building typology was averaged as follows:

- Garden-Style/Low-Rise: 3 stories
- Mid-Rise: 7 stories
- High-Rise: 20 stories

Within this report, these building typologies are evaluated as properties and not counted as individualized buildings. The data obtained from CoStar has multi-family construction denoted as properties. Properties are denoted as having multiple buildings under one ownership. Moreover, it should be noted that one property could contain as low as one building or have more than 10. The information received from CoStar data regarding the total number of dwelling units is synonymous to the data obtained from local jurisdictions that's provided through the United States Census.

Commercial buildings with more transient residential occupancies such as hotels, dormitories, and co-ops were excluded when categorizing and averaging the multi-family buildings under this study.

Water use or consumption has risen exponentially over the recent decades; in 2015, 325 million individuals consumed water in the United States. As previously documented in Phase I, a baseline is needed to compute the average water consumption within each dwelling unit considered in each of the multi-family building typologies examined under this phase of study. Based on the survey of data gathered, while the household size and average number of dwelling units changed across the four cities examined, the multi-family building typologies remained consistent, although in varying composition, across each city.

Consistent with the Phase I study approach, water consumption has been categorized as either potable or non-potable. Potable water meets public health standards for drinking, cooking, and personal bathing, as defined by public health regulations or local authorities. Non-potable water, unsuitable for human consumption, is not treated to drinking water standards. Currently, uses of non-potable water vary significantly across different regions and regulatory frameworks and may be used for water closets, urinals, irrigation, and HVAC makeup water.

The following average household sizes were established based on multi-family occupancy population demographics obtained from Census data, coupled with multi-family housing stock available as documented by CoStar in each city.

Houston, Texas: **2.52** people per home
Phoenix, Arizona: **2.68** people per home
Las Vegas, Nevada: **2.65** people per home
Des Moines, Iowa: **2.34** people per home

The tables provided under Sections 2, 3 and 4 below represent the estimated baseline consumption for dwelling units in the three different types of multi-family buildings in each of the four cities following the *code minimum* provisions for new residential construction in each respective city. Several assumptions were made to develop the baseline water consumption profile; please refer to the data below and included in the report appendices for additional information.

2. Baseline Water Consumption per City for Garden-Style/Low-Rise Properties

The following baseline consumptions are based on two-bedroom, two-bathroom dwelling units in garden-style/low-rise buildings. It should be noted that the reported water consumption values are influenced by significant variations in property structure, size, and regional characteristics. For example, properties in Houston, which often include larger multi-building complexes and water-intensive features, exhibit much higher average water consumption compared to properties in Phoenix, where smaller property structures and arid climate considerations drive lower usage. These differences are essential to understanding and comparing the data meaningfully.

2.1. Average Multi-Family Property – Houston, Texas

The average household size in Houston, Texas is 2.52 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a garden-style/low-rise property in Houston, Texas is 739 units.

Houston, Texas – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		12291.05
2	Shower Head	X		46557.00
1	Kitchen Sink Faucet	X		40970.16
2	Water Closet		X	14302.31
1	Clothes – Washer	X		35383.32
1	Dishwasher	X		7821.58
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	157710.41

Table 1: Average Baseline Household Water Consumption per Day per Multi-Family Property in Houston

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 143,023 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 14,687 gallons or 10% of the total daily consumption.

2.2. Average Multi-Family Property – Phoenix, Arizona

The average household size in Phoenix, Arizona is 2.68 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a garden-style/low-rise property in Phoenix, Arizona is 161 units.

Phoenix, Arizona – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		2847.77
2	Shower Head	X		10787.00
1	Kitchen Sink Faucet	X		9492.56
2	Water Closet		X	3313.77

1	Clothes – Washer	X		8198.12
1	Dishwasher	X		1812.22
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	36836.43

Table 2: Average Baseline Household Water Consumption per Day per Multi-Family Property in Phoenix

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 33,318 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 3,518 gallons or 10% of the total daily consumption.

2.3. Average Multi-Family Property – Las Vegas, Nevada

The average household size in Las Vegas, Nevada is 2.65 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a garden-style/low-rise property in Houston, Texas is 190 units.

Las Vegas, Nevada – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		3323.10
2	Shower Head	X		12587.50
1	Kitchen Sink Faucet	X		11077.00
2	Water Closet		X	3866.88
1	Clothes – Washer	X		9566.50
1	Dishwasher	X		2114.70
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	42920.68

Table 3: Average Baseline Household Water Consumption per Day per Multi-Family Property in Las Vegas

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 38,669 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 4,251 gallons or 10% of the total daily consumption.

2.4. Average Multi-Family Property – Des Moines, Iowa

The average household size in Des Moines, IA is 2.34 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a garden-style/low-rise property in Houston, Texas is 98 units.

Des Moines, Iowa – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		1513.51
2	Shower Head	X		5733.00
1	Kitchen Sink Faucet	X		5045.04
2	Water Closet		X	1761.18
1	Clothes – Washer	X		4357.08
1	Dishwasher	X		963.14
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	19757.95

Table 4: Average Baseline Household Water Consumption per Day per Multi-Family Property in Des Moines

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 17,611 gallons or 89% of the total daily consumption. Total daily non-potable consumption is approximately 2,146 gallons or 11% of the total daily consumption.

3. Baseline Water Consumption per City for Mid-Rise Properties

The following baseline consumptions are based on two-bedroom, two-bathroom dwelling units in mid-rise buildings.

3.1. Average Multi-Family Property – Houston, Texas

The average household size in Houston, Texas is 2.52 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a mid-rise property in Houston, Texas is 247 units.

Houston, Texas – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		4108.10
2	Shower Head	X		15561.00
1	Kitchen Sink Faucet	X		13693.68
2	Water Closet		X	4780.34
1	Clothes – Washer	X		11826.36
1	Dishwasher	X		2614.25
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	52968.73

Table 5: Baseline Household Water Consumption per Day for Multi-Family Property in Houston

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 47,803 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 5,165 gallons or 10% of the total daily consumption.

3.2. Average Multi-Family Property – Phoenix, Arizona

The average household size in Phoenix, Arizona is 2.68 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a mid-rise property in Phoenix, Arizona is 217 units.

Phoenix, Arizona – Multi-Family Property
Baseline Household Water Consumption per Day

Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		3838.30
2	Shower Head	X		14539.00
1	Kitchen Sink Faucet	X		12794.32
2	Water Closet		X	4466.38
1	Clothes – Washer	X		11049.64
1	Dishwasher	X		2442.55
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	49515.19

Table 6: Baseline Household Water Consumption per Day for Multi-Family Property in Phoenix

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 44,663 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 4,851 gallons or 10% of the total daily consumption.

3.3. Average Multi-Family Property – Las Vegas, Nevada

The average household size in Las Vegas, Nevada is 2.65 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a mid-rise property in Las Vegas, Nevada is 217 units.

Las Vegas, Nevada – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		3795.33
2	Shower Head	X		14376.25
1	Kitchen Sink Faucet	X		12651.10
2	Water Closet		X	4416.38
1	Clothes – Washer	X		10925.95
1	Dishwasher	X		2415.21
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	48965.22

Table 7: Baseline Household Water Consumption per Day for Multi-Family Property in Las Vegas

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 44,163 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 4,801 gallons or 10% of the total daily consumption.

3.4. Average Multi-Family Property – Des Moines, Iowa

The average household size in Des Moines, IA is 2.34 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a mid-rise property in Des Moines, Iowa is 106 units.

Des Moines, Iowa – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		1637.06
2	Shower Head	X		6201.00
1	Kitchen Sink Faucet	X		5456.88
2	Water Closet		X	1904.95
1	Clothes – Washer	X		4712.76
1	Dishwasher	X		1041.77
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	21339.42

Table 8: Baseline Household Water Consumption per Day for Multi-Family Property in Des Moines

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 19,049 gallons or 89% of the total daily consumption. Total daily non-potable consumption is approximately 2,289 gallons or 11% of the total daily consumption.

4. Baseline Water Consumption per City for High-Rise Properties

The following baseline consumptions are based on two-bedroom, two-bathroom dwelling units in high-rise buildings.

4.1. Average Multi-Family Property – Houston, Texas

The average household size in Houston, Texas is 2.52 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a high-rise property in Houston, Texas is 308 units.

Houston, Texas – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		5122.66
2	Shower Head	X		19404.00
1	Kitchen Sink Faucet	X		17075.52
2	Water Closet	X	X	5960.91
1	Clothes – Washer	X		14747.04
1	Dishwasher	X		3259.87
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	65955.00

Table 9: Baseline Household Water Consumption per Day for Multi-Family Property in Houston

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 59,609 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 6,345 gallons or 10% of the total daily consumption.

4.2. Average Multi-Family Property– Phoenix, Arizona

The average household size in Phoenix, Arizona is 2.68 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a high-rise property in Phoenix, Arizona is 269 units.

Phoenix, Arizona – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day

2	Lavatory Faucet	X		4758.07
2	Shower Head	X		18023.00
1	Kitchen Sink Faucet	X		15860.24
2	Water Closet		X	5536.67
1	Clothes – Washer	X		13697.48
1	Dishwasher	X		3027.86
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	61288.32

Table 10: Baseline Household Water Consumption per Day for Multi-Family Property in Phoenix

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 55,366 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 5,921 gallons or 10% of the total daily consumption.

4.3. Average Multi-Family Property – Las Vegas, Nevada

The average household size in Las Vegas, Nevada is 2.65 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a high-rise property in Las Vegas is 57 units.

Las Vegas, Nevada – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		996.93
2	Shower Head	X		3776.25
1	Kitchen Sink Faucet	X		3323.10
2	Water Closet		X	1160.06
1	Clothes – Washer	X		2869.95
1	Dishwasher	X		634.41
-	Hose Bibbs	X	X	N/A
	Irrigation only		X	385.00
			Total:	13145.70

Table 11: Baseline Household Water Consumption per Day for Multi-Family Property in Las Vegas

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 11,600 gallons or 88% of the total daily consumption. Total daily non-potable consumption is approximately 1,545 gallons or 12% of the total daily consumption.

4.4. Average Multi-Family Property – Des Moines, Iowa

The average household size in Des Moines, IA is 2.34 people per home (U.S. Census Bureau 2023 American Community Survey 1-Year Estimate). The average number of dwelling units for a high-rise property in Houston, Texas is 152 units.

Des Moines, Iowa – Multi-Family Property				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
2	Lavatory Faucet	X		2347.49
2	Shower Head	X		8892.00
1	Kitchen Sink Faucet	X		7824.96
2	Water Closet		X	2731.62
1	Clothes – Washer	X		6757.92
1	Dishwasher	X		1493.86
-	Hose Bibbs		X	N/A
	Irrigation only		X	385.00
			Total:	30432.85

Table 12: Baseline Household Water Consumption per Day for Multi-Family Property in Des Moines

If all potential non-potable water consumptions are separated for supply by an alternate water source: Total daily potable water consumption is approximately 27,316 gallons or 90% of the total daily consumption. Total daily non-potable consumption is approximately 3,116 gallons or 10% of the total daily consumption.

5. Potential Supplemental Water Sources for Residential Occupancies

As noted in Phase I, the benefits of using on-site non-potable water are vast as it creates new accessible sources to water for utilization especially in water scarce regions and climates, thus enabling economic growth and development for the generations to come. Reclaimed water is treated wastewater that meets the codes, regulations, and requirements for the public's health that can be reused. Reclaimed water is also called recycled water. For example, by capturing and treating water sources such as greywater on site, the treated water can be reused aside from the site it was collected on and can be distributed to other local parcels when incentivized by the locally governing water utilities.

Condensate harvesting is another example of onsite water recovery and reuse system. Condensation in residential units is due to the formation of water on cooling coils from air-conditioning units within a property, which is significantly pronounced in hot, humid tropical and subtropical climate zones. The produced water is typically dispersed to outside of the home for dispersion into ground through natural percolation or in other instances, connected to storm water disposal systems in urban city settings.

Non-potable rainwater collection and distribution systems are created from the capturing, storing, and treatment of rainwater falling from rain events from roofing surfaces and collection devices. This water is then used for other non-potable uses.

Under current adverse climate conditions in the noted climate zones, frequent storm and flood events often render the natural percolation of stormwater ineffective, while condensation contributions further overburdens stormwater management protocols in such regions.

5.1. Rainwater Baseline Data

As documented in Phase I report, rainwater data was compiled from National Oceanic and Atmospheric Administration (NOAA, 2024) weather data in monthly intervals for each city. Five-year averages from 2019 – 2023 were calculated and used in the modeling analysis. 80% collection efficiency was established for rainwater harvesting, based on the findings documented by a Rainwater Harvesting Systems Technology Review study conducted by the Federal Energy Management Program of U.S. Department of Energy, which ranged the collection efficiency as 75% - 90%.

Rainwater harvesting is posed through the collection of rainwater from the roofing system of a building. When determining the rainwater baseline for the selected building typologies, the discussion of the building's footprint and the climate zone was introduced. Garden-style/low-rise buildings are considered to have a larger building footprint as many of the dwelling units spread across the parcel of land. The dwelling units in mid-rise and high-rise buildings are vertically stacked and are contained within a smaller building footprint, allowing multiple buildings to occupy a single area.

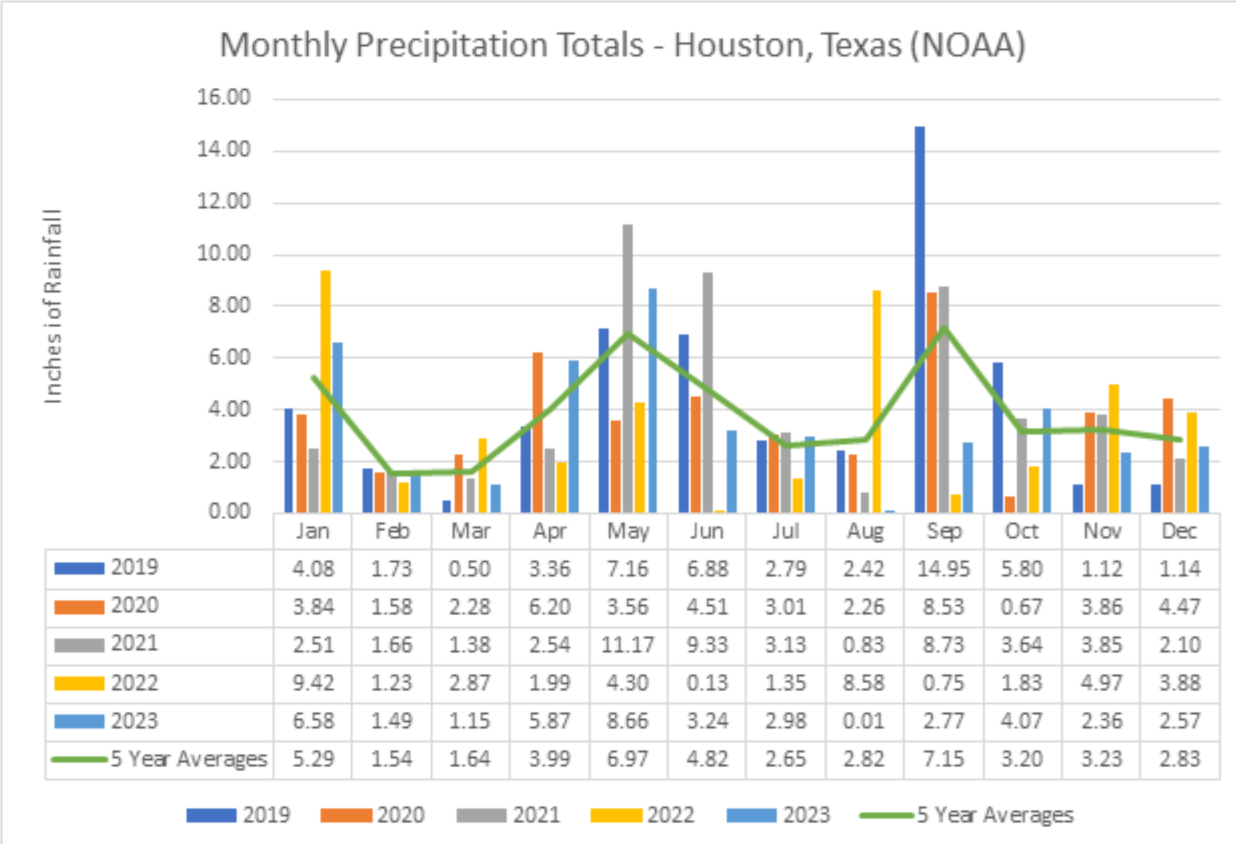
With ASHRAE zones in place, not all cities and states are affected equally. The climate zone indicates the weather conditions a city may experience. Warmer regions generally receive less rainfall compared to colder regions, except in tropical and sub-tropical climate zones.

Storage tank size/volume and non-potable water demand would be the most critical factors for multi-family rainwater harvesting systems. While mid-rise and high-rise multi-family building typologies may have limited roof collection surface area and limited footprint for storage tank and treatment systems, they often have high demand for non-potable water due to higher occupant densities. Such systems can provide non-potable water for indoor water closet flushing and limited amount for exterior landscaping purposes considering the small building footprint. On the other hand, garden-style/low-rise building typologies may offer opportunities for higher collection volumes due to availability of larger roof collection surface area, but lower demand for indoor non-potable water use due to lower population density per building and significantly higher demand for outdoor irrigation use due to larger parcel footprint typically associated with this building typology.

The centralized system would include filtration and disinfection equipment, storage tank, booster pump with hydromechanical tank, controls, and distribution piping from the outlet of the tank to supply all water closets and irrigation systems. As this non-potable system is not considered reliable to always meet the usage demand, interconnection of a reliable water source such as municipal water is also required with a backflow preventer to protect the municipal water supply.

Sections below detail the analysis and results; monthly rainfall collection profiles were developed using the NOAA weather data, collection surface area, and efficiency factors. Comparing the monthly non-potable demand consumption to the available rainwater collected and stored provided the estimated monthly and annual water savings. The rainwater collection systems for all three multi-family building typologies utilized the same calculation methodology. While each system was modeled to maximize the rainwater harvesting savings potential per building typology in each city, the quantified benefits varied across building typologies and geographic regions, therefore, highlighting the significance and relevance of rainwater harvesting as an effective water conservation approach.

5.1.1. Average Multi-Family Property – Houston, Texas



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	4.08	1.73	0.50	3.36	7.16	6.88	2.79	2.42	14.95	5.80	1.12	1.14
2020	3.84	1.58	2.28	6.20	3.56	4.51	3.01	2.26	8.53	0.67	3.86	4.47
2021	2.51	1.66	1.38	2.54	11.17	9.33	3.13	0.83	8.73	3.64	3.85	2.10
2022	9.42	1.23	2.87	1.99	4.30	0.13	1.35	8.58	0.75	1.83	4.97	3.88
2023	6.58	1.49	1.15	5.87	8.66	3.24	2.98	0.01	2.77	4.07	2.36	2.57
5 Year Averages	5.29	1.54	1.64	3.99	6.97	4.82	2.65	2.82	7.15	3.20	3.23	2.83

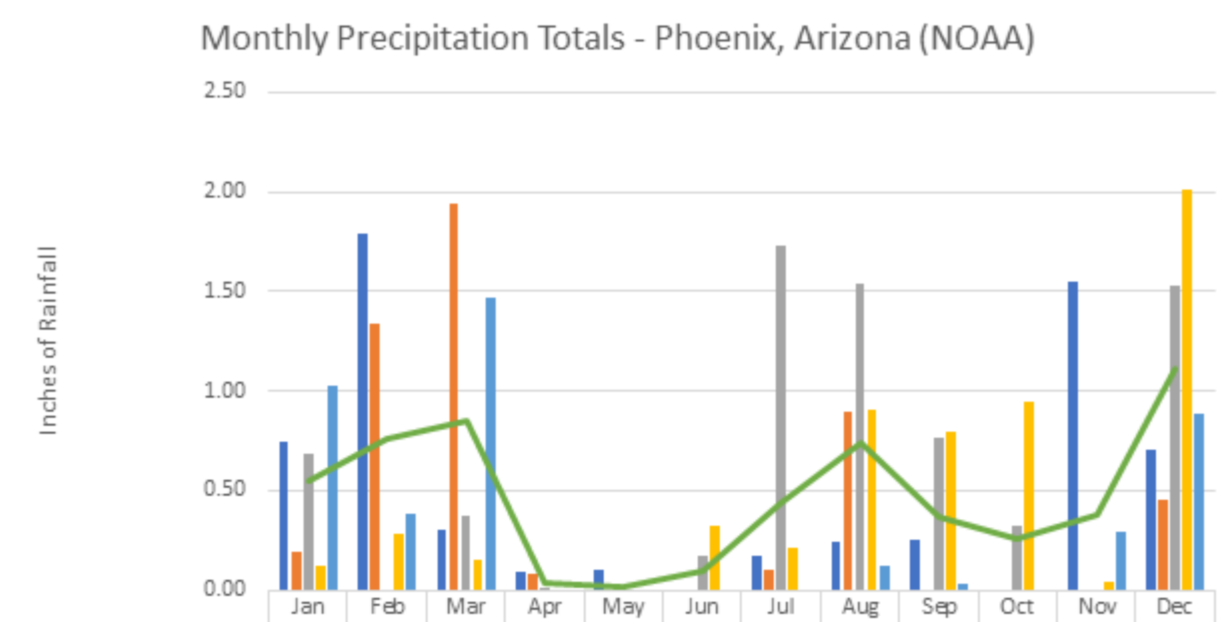
Figure IV: Monthly Precipitation Totals for Houston

The 5-year average annual rainfall in Houston, Texas was estimated to be 46.124 inches per year with a collection efficiency of 80%. Using building data as published by CoStar, the average approximate building roof areas for a property and its average number of dwelling units for each building typology have been calculated as follows:

Garden-style/low-rise building – 215,755 square feet; 739 dwelling units
Mid-rise building – 30, 967 square feet; 247 dwelling units
High-rise building – 13, 534 square feet; 308 dwelling units

Based on these tabulations, these building typologies have a maximum annual water harvesting potential of approximately 4,935,961 gallons, 708,462 gallons, and 309,641 gallons per building, respectively.

5.1.2. Average Multi-Family Property – Phoenix, Arizona



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	0.74	1.79	0.30	0.09	0.10	0.00	0.17	0.24	0.25	0.00	1.55	0.70
2020	0.19	1.34	1.94	0.08	0.00	0.00	0.10	0.90	0.00	0.00	0.00	0.45
2021	0.68	0.00	0.37	0.01	0.00	0.17	1.73	1.54	0.76	0.32	0.00	1.53
2022	0.12	0.28	0.15	0.00	0.00	0.32	0.21	0.91	0.79	0.95	0.04	2.01
2023	1.03	0.38	1.47	0.00	0.00	0.00	0.00	0.12	0.03	0.00	0.29	0.89
5 Year Averages	0.55	0.76	0.85	0.04	0.02	0.10	0.44	0.74	0.37	0.25	0.38	1.12

2019 2020 2021 2022 2023 5 Year Averages

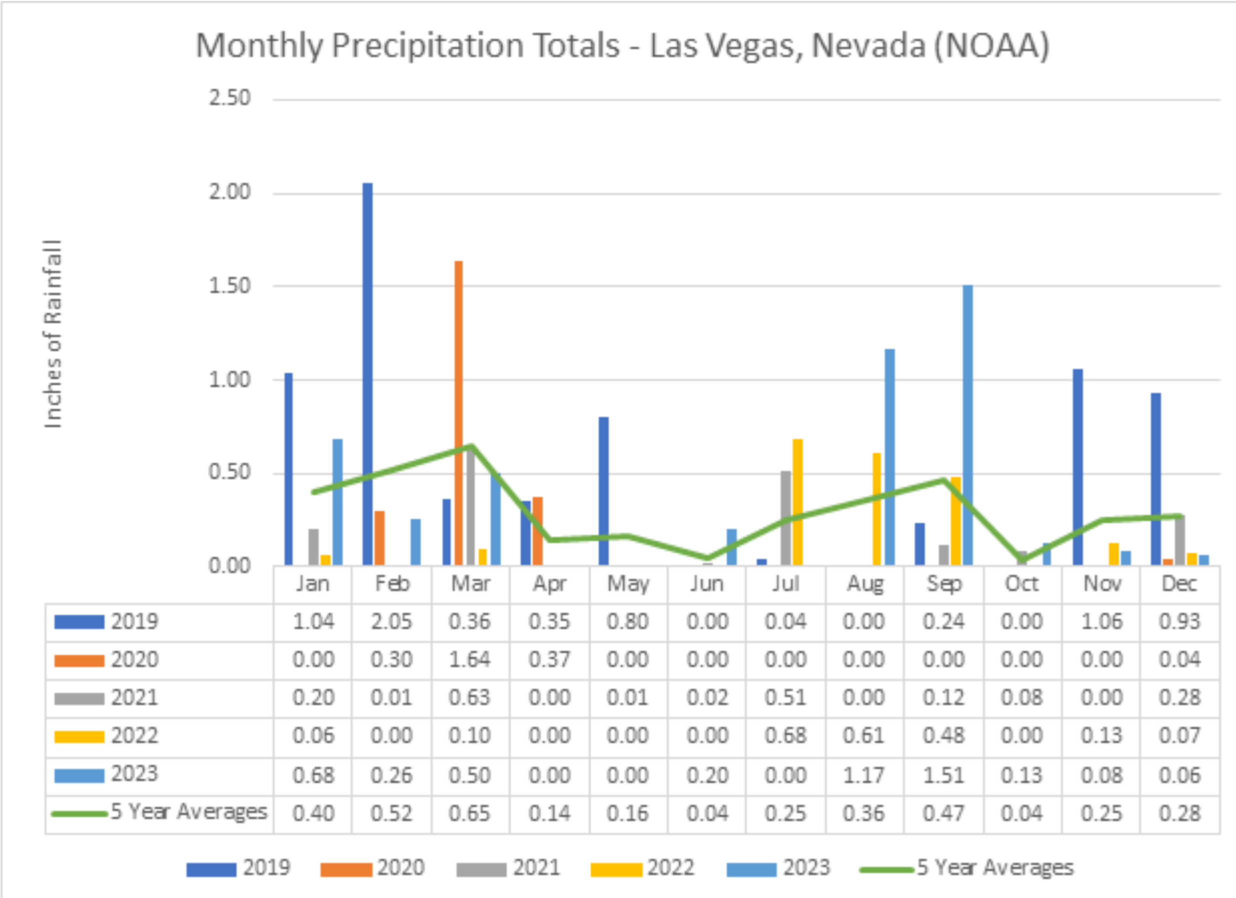
Figure V: Monthly Precipitation Totals for Phoenix

The 5-year average annual rainfall in Phoenix, Arizona was estimated to be 5.606 inches per year with a collection efficiency of 80%. Using building data as published by CoStar, the average approximate building roof areas for a property and its average number of dwelling units for each building typology have been calculated as follows:

Garden-style/low-rise building – 47,005 square feet; 161 dwelling units
Mid-rise building – 27,206 square feet; 217 dwelling units
High-rise building – 11, 820 square feet; 269 dwelling units

Based on these tabulations, these building typologies have a maximum annual water harvesting potential of approximately 130,700 gallons, 75,649 gallons, and 32,868 gallons per building, respectively.

5.1.3. Average Multi-Family Property – Las Vegas, Nevada



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	1.04	2.05	0.36	0.35	0.80	0.00	0.04	0.00	0.24	0.00	1.06	0.93
2020	0.00	0.30	1.64	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
2021	0.20	0.01	0.63	0.00	0.01	0.02	0.51	0.00	0.12	0.08	0.00	0.28
2022	0.06	0.00	0.10	0.00	0.00	0.00	0.68	0.61	0.48	0.00	0.13	0.07
2023	0.68	0.26	0.50	0.00	0.00	0.20	0.00	1.17	1.51	0.13	0.08	0.06
5 Year Averages	0.40	0.52	0.65	0.14	0.16	0.04	0.25	0.36	0.47	0.04	0.25	0.28

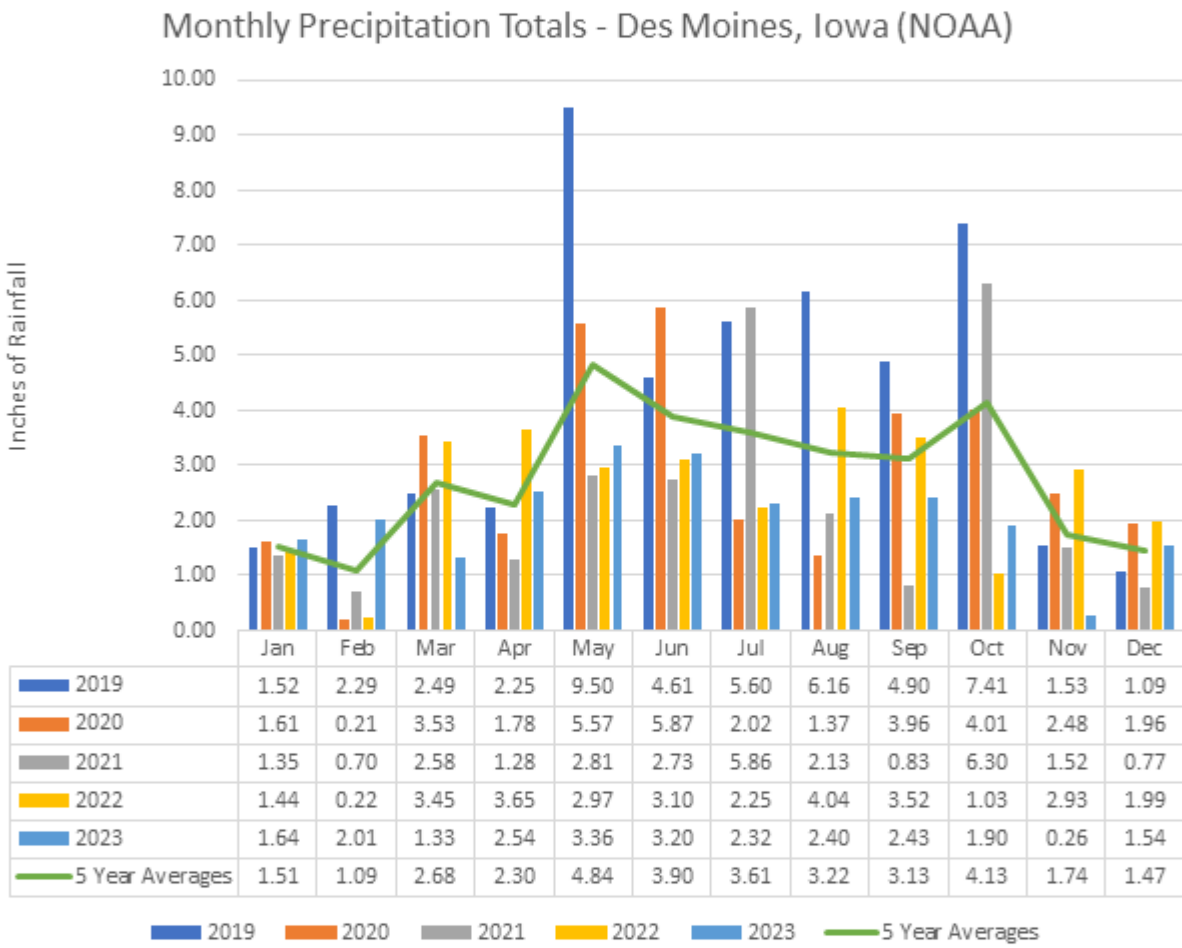
Figure VI: Monthly Precipitation Totals for Las Vegas

The 5-year average annual rainfall in Las Vegas, Nevada was estimated to be3.560 inches per year with a collection efficiency of 80%. Using building data as published by CoStar, the average approximate building roof areas for a property and its average number of dwelling units for each building typology have been calculated as follows:

Garden-style/low-rise building - 55, 471 square feet; 190 dwelling units
Mid-rise building – 27,206 square feet; 217 dwelling units
High-rise building – 2, 504 square feet; 57 dwelling units

Based on these tabulations, these building typologies have a maximum annual water harvesting potential of approximately 97,947 gallons, 48,038 gallons, and 4,422 gallons per building, respectively.

5.1.4. Average Multi-Family Property – Des Moines, Iowa



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	1.52	2.29	2.49	2.25	9.50	4.61	5.60	6.16	4.90	7.41	1.53	1.09
2020	1.61	0.21	3.53	1.78	5.57	5.87	2.02	1.37	3.96	4.01	2.48	1.96
2021	1.35	0.70	2.58	1.28	2.81	2.73	5.86	2.13	0.83	6.30	1.52	0.77
2022	1.44	0.22	3.45	3.65	2.97	3.10	2.25	4.04	3.52	1.03	2.93	1.99
2023	1.64	2.01	1.33	2.54	3.36	3.20	2.32	2.40	2.43	1.90	0.26	1.54
5 Year Averages	1.51	1.09	2.68	2.30	4.84	3.90	3.61	3.22	3.13	4.13	1.74	1.47

Figure VII: Monthly Precipitation Totals for Des Moines

The 5-year average annual rainfall in Des Moines, Iowa was estimated to be 33.620 inches per year with a collection efficiency of 80%. Using building data as published by CoStar, the average approximate building roof areas for a property and its average number of dwelling units for each building typology have been calculated as follows:

Garden-style/low-rise building – 28, 611 square feet; 98 dwelling units
Mid-rise building – 13, 289 square feet; 106 dwelling units
High-rise building – 6, 679 square feet; 152 dwelling units

Based on these tabulations, these building typologies have a maximum annual water harvesting potential of approximately 477,115 gallons, 221,613 gallons, and 111,383 gallons per building, respectively.

5.2. Baseline Condensation Data

Following the same procedure as Phase I study, condensation data was developed by estimating the maximum household cooling using industry standards for capacity per square foot. The cooling capacity values would reflect traditional construction methods and insulation levels anticipated for each region. Cooling degree weather data for each city was then compiled and based on outside air temperatures, cooling load diversity factors were applied, and the corresponding cooling ton-hours were calculated. Using the formulas to calculate the psychometric of the initial and final conditions of air based on the methodology outlined in the ASHRAE 2021 Handbook, condensation rate ranging in 0.10 to 0.30 gallons per cooling ton-hour is typically achieved (Guz, K. 2005). In this study, condensation production was then calculated utilizing an estimated average condensation rate of 0.20 gallons for every cooling ton-hour.

Condensate collection potential varies and is dependent upon the size and operation load of the air conditioning system, ambient temperature, and humidity. This study focuses on exemplifying the potential benefits for condensate harvesting in relevant climate zones for the three multi-family building typologies considered in this study. Condensate is considered free water and is produced when the need for water irrigation is high. Condensate water is considered a high-quality source of water, similar to distilled water, the pH is neutral to slightly acidic and the temperature is low.

This study emphasizes the difference between single-family and multi-family units as the capacity and number of air conditioning systems in use. Collection benefits, in fact, increase as the population density and thermal comfort demand in multi-family building typologies may be higher as more dwelling units are concentrated within each of the three building typologies. However, its overall impact may vary based on the climate zone the building resides in.

5.2.1. Average Multi-Family Property – Houston, Texas

Based on the average size of residential dwelling units in multi-family building typologies considered as documented through census data and CoStar market data, the household HVAC cooling capacity has been estimated as 2 tons. The following is then estimated as the condensation production volume per year per building for each building typology:

Garden-style/low-rise building – 866,530 gallons
Mid-rise building – 24,629 gallons
High-rise building – 361,152 gallons

Houston, Texas						
Baseline Condensate Totals						
Month	**Cooling Degree Days @65 deg F. Base Temp.**	**Monthly Ave. High Temp. (deg F.)**	**Cooling Load Diversity**	**Cooling Tons**	**Cooling Ton-Hours**	**HVAC Condensate (gal)**
January	5	62	0.20	0.4	2	0
February	69	67	0.25	0.5	35	7
March	165	74	0.35	0.7	115	23
April	181	80	0.45	0.9	163	33
May	327	86	0.65	1.3	425	85
June	593	91	0.80	1.6	948	190
July	716	95	0.90	1.8	1,288	258
August	762	95	1.00	2.0	1,524	305
September	630	90	0.80	1.6	1,007	201
October	301	82	0.50	1.0	301	60
November	57	71	0.35	0.7	40	8
December	23	64	0.30	0.6	14	3
					Annual Total	**1,173**

Table 13: Baseline Condensation Totals – Houston, Texas

5.2.2 Average Multi-Family Property – Phoenix, Arizona

Based on the average size of residential dwelling units in multi-family building typologies considered as documented through census data and CoStar market data, the household HVAC cooling capacity has been estimated as 2 tons. The following is then estimated as the condensation production volume per year per building for ach building typology:

Garden-style/low-rise building – 264,224 gallons
Mid-rise building – 34,461 gallons
High-rise building – 441,467 gallons

Pheonix, Arizona						
Baseline Condensate Totals						
Month	**Cooling Degree Days @65 deg F. Base Temp.**	**Monthly Ave. High Temp. (deg F.)**	**Cooling Load Diversity**	**Cooling Tons**	**Cooling Ton-Hours**	**HVAC Condensate (gal)**
January	21	78.2	0.35	0.7	15	3
February	18	82.1	0.50	1.0	18	4
March	58	90.4	0.80	1.6	93	19
April	267	99	0.95	1.9	507	101
May	425	105.7	1.00	2.0	849	170
June	620	112.7	1.00	2.0	1,240	248
July	897	114.6	1.00	2.0	1,793	359
August	740	113.2	1.00	2.0	1,480	296
September	620	108.9	1.00	2.0	1,239	248
October	370	100.7	1.00	2.0	740	148
November	120	88.9	0.80	1.6	192	38
December	42	77.7	0.45	0.9	38	8
					Annual Total	**1,641**

Table 14: Baseline Condensation Totals – Phoenix, Arizona

5.2.3 Average Multi-Family Property – Las Vegas, Nevada

Based on the average size of residential dwelling units in multi-family building typologies considered as documented through census data and CoStar market data, the household HVAC cooling capacity has been estimated as 2 tons. The following is then estimated as the condensation production volume per year per building for each building typology:

Garden-style/low-rise building – 293,360 gallons
Mid-rise building – 32,431 gallons
High-rise building – 88,008 gallons

Las Vegas Area, NV						
Baseline Condensate Totals						
Month	**Cooling Degree Days @65 deg F. Base Temp.**	**Monthly Ave. High Temp. (deg F.)**	**Cooling Load Diversity**	**Cooling Tons**	**Cooling Ton-Hours**	**HVAC Condensate (gal)**
January	4	68.7	0.40	0.8	4	1
February	2	74.2	0.50	1.0	2	0
March	9	84.3	0.65	1.3	11	2
April	223	93.6	0.90	1.8	402	80
May	456	101.8	1.00	2.0	912	182
June	573	110.1	1.00	2.0	1,146	229
July	1,052	112.9	1.00	2.0	2,105	421
August	796	110.3	1.00	2.0	1,592	318
September	507	105	1.00	2.0	1,013	203
October	276	94.6	0.90	1.8	496	99

November	37	80.6	0.50	1.0	37	7
December	3	67.9	0.40	0.8	2	0
					Annual Total	**1,544**

Table 15: Baseline Condensation Totals – Las Vegas, Nevada

5.2.4 Average Multi-Family Property – Des Moines, Iowa

Based on the average size of residential dwelling units in multi-family building typologies considered as documented through census data and CoStar market data, the household HVAC cooling capacity has been estimated as 2 tons. The following is then estimated as the condensation production volume per year per building for each building typology:

Garden-style/low-rise building – 44,884 gallons
Mid-rise building – 48,548 gallons
High-rise building – 69,616 gallons

Des Moines, Iowa						
Baseline Condensate Totals						
Month	**Cooling Degree Days @65 deg F. Base Temp.**	**Monthly Ave. High Temp. (deg F.)**	**Cooling Load Diversity**	**Cooling Tons**	**Cooling Ton-Hours**	**HVAC Condensate (gal)**
January	0	30	0.00	0.0	0	0
February	0	35	0.00	0.0	0	0
March	2	49	0.00	0.0	0	0
April	38	62	0.45	0.9	34	7
May	142	73	0.65	1.3	184	37
June	286	82	0.80	1.6	457	91

July	342	86	0.90	1.8	615	123
August	348	84	1.00	2.0	696	139
September	196	77	0.80	1.6	313	63
October	54	64	0.50	1.0	54	11
November	2	48	0.00	0.0	0	0
December	0	35	0.00	0.0	0	0
					Annual Total	**471**

Table 16: Baseline Condensation Totals – Des Moines, Iowa

6. Water Conservation Through Water Efficient Plumbing Fixture Use

As previously determined in Phase I, the implementation of low flow, water-efficient fixtures would contribute to the reduction of water consumption in single-family homes. This approach has also been utilized for residential dwelling units in multi-family construction as well.

The following tables represent the tabulated consumption volumes for the average number of dwelling units within a garden-style/ low-rise property in each subject city respectively.

6.1.Garden-Style/ Low-Rise Properties

Water Efficient Plumbing Fixtures: Houston Area, Texas											
Multi-Family Unit											
Average Houshold Size = 2.52		| Average number of dwelling units per prop.= 739									
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons											
Houston Amendments to the 2015 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property		
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	16.63	gpd	12291.05	gpd	
Shower Head	2.50	gpm	10.0	min	25.00	gpd	63.00	gpd	46557.00	gpd	
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	55.44	gpd	40970.16	gpd	
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	14302.31	gpd	
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	14041.00	gpd	
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	3103.80	gpd	
Gallons per Unit per Day							177.63	gpd			
Gallons per Unit per Year							64,833.34	gpy			
Gallons per Multi-Family Residential Property per Day									131265.32	gpd	
Gallons per Multi-Family Residential Property per Year									47911841.22	gpy	

Table 17: Multi-Family Building per Dwelling Unit and Aggregated Total *Baseline Code Minimum Consumption Volumes – Houston*

Water Efficient Plumbing Fixtures: Houston Area, Texas										
Multi-Family Unit										
Average Houshold Size = 2.52		| Average number of dwelling units per prop.= 739								
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.34	gpd	8380.26	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	50.40	gpd	37245.60	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	45.36	gpd	33521.04	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	14302.31	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	10346.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	2364.80	gpd
Gallons per Unit per Day							143.65	gpd		
Gallons per Unit per Year							52,433.56	gpy		
Gallons per Multi-Family Residential Property per Day									106160.01	gpd
Gallons per Multi-Family Residential Property per Year									38748403.80	gpy

Table 18: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Houston

Water Efficient Plumbing Fixtures: Phoenix, Arizona										
Multi-Family Unit										
Average Houshold Size = 2.68		I Average number of dwelling units per prop.= 161								
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Phoenix Amendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.69	gpd	2847.77	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	67.00	gpd	10787.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.96	gpd	9492.56	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	3313.77	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	3059.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	676.20	gpd
Gallons per Unit per Day							187.43	gpd		
Gallons per Unit per Year							68,412.10	gpy		
Gallons per Multi-Family Residential Property per Day									30176.29	gpd
Gallons per Multi-Family Residential Property per Year									11014347.46	gpy

Table 19: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Phoenix

Water Efficient Plumbing Fixtures: Phoenix, Arizona										
Multi-Family Unit										
Average Houshold Size = 2.68		I Average number of dwelling units per prop.= 161								
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	12.06	gpd	1941.66	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.60	gpd	8629.60	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	48.24	gpd	7766.64	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	3313.77	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	2254.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	515.20	gpd
Gallons per Unit per Day							151.68	gpd		
Gallons per Unit per Year							55,364.08	gpy		
Gallons per Multi-Family Residential Property per Day									24420.87	gpd
Gallons per Multi-Family Residential Property per Year									8913616.24	gpy

Table 20: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Phoenix

Water Efficient Plumbing Fixtures: Las Vegas, Nevada											
Multi-Family Unit											
Average Houshold Size =	2.65	I Average number of dwelling units per prop.=				190					
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons											
Las Vegas Amendments to the 2018 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property		
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.49	gpd	3323.10	gpd	
Shower Head	2.50	gpm	10.0	min	25.00	gpd	66.25	gpd	12587.50	gpd	
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.30	gpd	11077.00	gpd	
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	3866.88	gpd	
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	3610.00	gpd	
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	798.00	gpd	
Gallons per Unit per Day							185.59	gpd			
Gallons per Unit per Year							67,741.08	gpy			
Gallons per Multi-Family Residential Property per Day									35262.48	gpd	
Gallons per Multi-Family Residential Property per Year									12870805.20	gpy	

Table 21: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Las Vegas

Water Efficient Plumbing Fixtures: Las Vegas, Nevada										
Multi-Family Unit										
Average Houshold Size =	2.65	I Average number of dwelling units per prop.=				190				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.93	gpd	2265.75	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.00	gpd	10070.00	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	47.70	gpd	9063.00	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	3866.88	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	2660.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	608.00	gpd
Gallons per Unit per Day							150.18	gpd		
Gallons per Unit per Year							54,814.61	gpy		
Gallons per Multi-Family Residential Property per Day									28533.63	gpd
Gallons per Multi-Family Residential Property per Year									10414774.95	gpy

Table 22: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Las Vegas

Water Efficient Plumbing Fixtures: Des Moines, Iowa										
Multi-Family Unit										
Average Houshold Size =		2.34	I Average number of dwelling units per prop.=				98			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Des Moines Amendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	15.44	gpd	1513.51	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	58.50	gpd	5733.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	51.48	gpd	5045.04	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	1761.18	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	1862.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	411.60	gpd
Gallons per Unit per Day							166.60	gpd		
Gallons per Unit per Year							60,807.25	gpy		
Gallons per Multi-Family Residential Property per Day									16326.33	gpd
Gallons per Multi-Family Residential Property per Year									5959110.30	gpy

Table 23: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Des Moines

Water Efficient Plumbing Fixtures: Des Moines, Iowa										
Multi-Family Unit										
Average Houshold Size =		2.34	I Average number of dwelling units per prop.=				98			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	10.53	gpd	1031.94	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	46.80	gpd	4586.40	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	42.12	gpd	4127.76	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	1761.18	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	1372.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	313.60	gpd
Gallons per Unit per Day							134.62	gpd		
Gallons per Unit per Year							49,136.74	gpy		
Gallons per Multi-Family Residential Property per Day									13192.88	gpd
Gallons per Multi-Family Residential Property per Year									4815400.32	gpy

Table 24: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Des Moines

2. Mid-Rise Properties

The following tables represent the tabulated consumption volumes for the average number of dwelling units within a mid-rise property in each subject city respectively.

Water Efficient Plumbing Fixtures: Houston Area, Texas										
Multi-Family Unit										
Average Houshold Size =	2.52		l Average number of dwelling units per prop.=				247			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Houston Amendments to the 2015 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	16.63	gpd	4108.10	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	63.00	gpd	15561.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	55.44	gpd	13693.68	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	4780.34	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	4693.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	1037.40	gpd
					Gallons per Unit per Day		177.63	gpd		
					Gallons per Unit per Year		64,833.34	gpy		
						Gallons per Multi-Family Residential Property per Day			43873.52	gpd
						Gallons per Multi-Family Residential Property per Year			16013835.97	gpy

Table 25: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Houston

Water Efficient Plumbing Fixtures: Houston Area, Texas										
Multi-Family Unit										
Average Houshold Size =	2.52		l Average number of dwelling units per prop.				247			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.34	gpd	2800.98	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	50.40	gpd	12448.80	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	45.36	gpd	11203.92	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	4780.34	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	3458.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	790.40	gpd
					Gallons per Unit per Day		143.65	gpd		
					Gallons per Unit per Year		52,433.56	gpy		
						Gallons per Multi-Family Residential Property per Day			35482.44	gpd
						Gallons per Multi-Family Residential Property per Year			12951090.31	gpy

Table 26: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Houston

Water Efficient Plumbing Fixtures: Phoenix, Arizona											
Multi-Family Unit											
Average Houshold Size = 2.68			l Average number of dwelling units per prop.= 217								
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons											
Phoenix Amendments to the 2018 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.69	gpd	3838.30	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	67.00	gpd	14539.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.96	gpd	12794.32	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	4466.38	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	4123.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	911.40	gpd
Gallons per Unit per Day							187.43	gpd		
Gallons per Unit per Year							68,412.10	gpy		
Gallons per Multi-Family Residential Property per Day									40672.40	gpd
Gallons per Multi-Family Residential Property per Year									14845424.83	gpy

Table 27: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Phoenix

Water Efficient Plumbing Fixtures: Phoenix, Arizona										
Multi-Family Unit										
Average Houshold Size = 2.68			l Average number of dwelling units per prop.= 217							
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	12.06	gpd	2617.02	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.60	gpd	11631.20	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	48.24	gpd	10468.08	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	4466.38	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	3038.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	694.40	gpd
Gallons per Unit per Day							151.68	gpd		
Gallons per Unit per Year							55,364.08	gpy		
Gallons per Multi-Family Residential Property per Day									32915.08	gpd
Gallons per Multi-Family Residential Property per Year									12014004.49	gpy

Table 28: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Phoenix

Water Efficient Plumbing Fixtures: Las Vegas, Nevada											
Multi-Family Unit											
Average Houshold Size =	2.65		l Average number of dwelling units per prop.=				217				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons											
Las Vegas Amendments to the 2018 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property		
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.49	gpd	3795.33	gpd	
Shower Head	2.50	gpm	10.0	min	25.00	gpd	66.25	gpd	14376.25	gpd	
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.30	gpd	12651.10	gpd	
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	4416.38	gpd	
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	4123.00	gpd	
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	911.40	gpd	
Gallons per Unit per Day							185.59	gpd			
Gallons per Unit per Year							67,741.08	gpy			
Gallons per Multi-Family Residential Property per Day									40273.46	gpd	
Gallons per Multi-Family Residential Property per Year									14699814.36	gpy	

Table 29: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Las Vegas

Water Efficient Plumbing Fixtures: Las Vegas, Nevada										
Multi-Family Unit										
Average Houshold Size =	2.65		l Average number of dwelling units per prop.=				217			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.93	gpd	2587.73	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.00	gpd	11501.00	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	47.70	gpd	10350.90	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	4416.38	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	3038.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	694.40	gpd
Gallons per Unit per Day							150.18	gpd		
Gallons per Unit per Year							54,814.61	gpy		
Gallons per Multi-Family Residential Property per Day									32588.41	gpd
Gallons per Multi-Family Residential Property per Year									11894769.29	gpy

Table 30: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Las Vegas

Water Efficient Plumbing Fixtures: Des Moines, Iowa										
Multi-Family Unit										
Average Houshold Size =		2.34	l Average number of dwelling units per prop.=			106				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Des Moines Amendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	15.44	gpd	1637.06	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	58.50	gpd	6201.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	51.48	gpd	5456.88	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	1904.95	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	2014.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	445.20	gpd
Gallons per Unit per Day							166.60	gpd		
Gallons per Unit per Year							60,807.25	gpy		
Gallons per Multi-Family Residential Property per Day									17659.09	gpd
Gallons per Multi-Family Residential Property per Year									6445568.29	gpy

Table 31: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Des Moines

Water Efficient Plumbing Fixtures: Des Moines, Iowa										
Multi-Family Unit										
Average Houshold Size =		2.34	l Average number of dwelling units per prop.=			106				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	10.53	gpd	1116.18	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	46.80	gpd	4960.80	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	42.12	gpd	4464.72	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	1904.95	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	1484.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	339.20	gpd
Gallons per Unit per Day							134.62	gpd		
Gallons per Unit per Year							49,136.74	gpy		
Gallons per Multi-Family Residential Property per Day									14269.85	gpd
Gallons per Multi-Family Residential Property per Year									5208494.23	gpy

Table 32: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Des Moines

3. High-Rise Properties

The following tables represent the tabulated consumption volumes for the average number of dwelling units within a high-rise property in each subject city respectively.

Water Efficient Plumbing Fixtures: Houston Area, Texas										
Multi-Family Unit										
Average Houshold Size =	2.52		l Average number of dwelling units per prop.=				308			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Houston Amendments to the 2015 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	16.63	gpd	5122.66	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	63.00	gpd	19404.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	55.44	gpd	17075.52	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	5960.91	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	5852.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	1293.60	gpd
Gallons per Unit per Day							177.63	gpd		
Gallons per Unit per Year							64,833.34	gpy		
Gallons per Multi-Family Residential Property per Day									54708.68	gpd
Gallons per Multi-Family Residential Property per Year									19968669.95	gpy

Table 33: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Houston

Water Efficient Plumbing Fixtures: Houston Area, Texas										
Multi-Family Unit										
Average Houshold Size =	2.52		l Average number of dwelling units per prop.=				308			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.34	gpd	3492.72	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	50.40	gpd	15523.20	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	45.36	gpd	13970.88	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	5960.91	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	4312.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	985.60	gpd
Gallons per Unit per Day							143.65	gpd		
Gallons per Unit per Year							52,433.56	gpy		
Gallons per Multi-Family Residential Property per Day									44245.31	gpd
Gallons per Multi-Family Residential Property per Year									16149537.71	gpy

Table 34: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Houston

Water Efficient Plumbing Fixtures: Phoenix, Arizona										
Multi-Family Unit										
Average Houshold Size =		**2.68**		**l Average number of dwelling units per prop.=**			**269**			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Phoenix Amendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate or Consumption**		**Estimated Usage per Day**		**Gallons per Person per Day**		**Gallons per Household per Day**		**Gallons per Property**	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.69	gpd	4758.07	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	67.00	gpd	18023.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.96	gpd	15860.24	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	5536.67	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	5111.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	1129.80	gpd
Gallons per Unit per Day							**187.43**	**gpd**		
Gallons per Unit per Year							**68,412.10**	**gpy**		
Gallons per Multi-Family Residential Property per Day									**50418.78**	**gpd**
Gallons per Multi-Family Residential Property per Year									**18402853.82**	**gpy**

Table 35: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Phoenix

Water Efficient Plumbing Fixtures: Phoenix, Arizona										
Multi-Family Unit										
Average Houshold Size =		**2.68**		**l Average number of dwelling units per prop.=**			**269**			
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate or Consumption**		**Estimated Usage per Day**		**Gallons per Person per Day**		**Gallons per Household per Day**		**Gallons per Property**	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	12.06	gpd	3244.14	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.60	gpd	14418.40	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	48.24	gpd	12976.56	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	5536.67	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	3766.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	860.80	gpd
Gallons per Unit per Day							**151.68**	**gpd**		
Gallons per Unit per Year							**55,364.08**	**gpy**		
Gallons per Multi-Family Residential Property per Day									**40802.57**	**gpd**
Gallons per Multi-Family Residential Property per Year									**14892936.44**	**gpy**

Table 36: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Phoenix

Water Efficient Plumbing Fixtures: Las Vegas, Nevada										
Multi-Family Unit										
Average Houshold Size =	2.65		I Average number of dwelling units per prop.=			57				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
Las Vegas Amendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.49	gpd	996.93	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	66.25	gpd	3776.25	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.30	gpd	3323.10	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	1160.06	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	1083.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	239.40	gpd
						Gallons per Unit per Day	185.59	gpd		
						Gallons per Unit per Year	67,741.08	gpy		
								Gallons per Multi-Family Residential Property per Day	10578.74	gpd
								Gallons per Multi-Family Residential Property per Year	3861241.56	gpy

Table 37: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes - Las Vegas

Water Efficient Plumbing Fixtures: Las Vegas, Nevada										
Multi-Family Unit										
Average Houshold Size =	2.65		I Average number of dwelling units per prop.=			57				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.93	gpd	679.73	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.00	gpd	3021.00	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	47.70	gpd	2718.90	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	1160.06	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	798.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	182.40	gpd
						Gallons per Unit per Day	150.18	gpd		
						Gallons per Unit per Year	54,814.61	gpy		
								Gallons per Multi-Family Residential Property per Day	8560.09	gpd
								Gallons per Multi-Family Residential Property per Year	3124432.49	gpy

Table 38: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Las Vegas

Water Efficient Plumbing Fixtures: Des Moines, Iowa											
Multi-Family Unit											
Average Houshold Size =	2.34	l Average number of dwelling units per prop.=				152					
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons											
Des Moines Amendments to the 2018 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property		
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	15.44	gpd	2347.49	gpd	
Shower Head	2.50	gpm	10.0	min	25.00	gpd	58.50	gpd	8892.00	gpd	
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	51.48	gpd	7824.96	gpd	
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	2731.62	gpd	
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	2888.00	gpd	
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	638.40	gpd	
Gallons per Unit per Day							166.60	gpd			
Gallons per Unit per Year							60,807.25	gpy			
Gallons per Multi-Family Residential Property per Day									25322.47	gpd	
Gallons per Multi-Family Residential Property per Year									9242701.70	gpy	

Table 39: Multi-Family Building per Dwelling Unit and Aggregated Total Baseline Code Minimum Consumption Volumes – Des Moines

Water Efficient Plumbing Fixtures: Des Moines, Iowa										
Multi-Family Unit										
Average Houshold Size =	2.34	l Average number of dwelling units per prop.=				152				
Average American Water Consumption per Person per Day is Approximately 80-100 Gallons										
2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Property	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	10.53	gpd	1600.56	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	46.80	gpd	7113.60	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	42.12	gpd	6402.24	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	2731.62	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	2128.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	486.40	gpd
Gallons per Unit per Day							134.62	gpd		
Gallons per Unit per Year							49,136.74	gpy		
Gallons per Multi-Family Residential Property per Day									20462.42	gpd
Gallons per Multi-Family Residential Property per Year									7468784.18	gpy

Table 40: Multi-Family Building per Dwelling Unit and Aggregated Total Consumption Volumes Based on Proposed Water Conservation Provision – Des Moines

7. Hot Water Systems

Service hot water systems including water heaters, hot water pipe insulation, heated water circulation piping and temperature maintenance systems requirements are provided to minimize the volume of water which may cool within the distribution piping. Any volume of hot water which has cooled within the piping system is typically wasted by running the plumbing fixture to flush the cooled water out to allow for the hot water to be expelled from the fixture outlet at the desired temperature.

The impact on residential plumbing systems, aside from centralized hot water systems in multi-family buildings, is minimal due to the inherently small pipe sizes and short lengths of run within single-family homes or multi-family dwelling units with local water heaters. The IWCCP, aims to further limit the maximum water volume within piping between the hot water source and the fixtures of 64 oz. for systems with a water heater and 24 oz. systems with a circulation loop or an electrically heat-traced pipe. These measures are expected to yield water conservation benefits. However, as noted in earlier sections of this report, hot water systems and piping network optimization benefits were intentionally excluded from this phase of the study. These aspects will be explored in greater detail, including their energy conservation benefits, in subsequent phases of this investigation.

8. Rainwater Harvesting

Rainwater collection and distribution systems sized for maximum rainfall potential harvesting are provided to offset the non-potable site consumption. Minimal filtration systems or treatment is required since all rainwater collection systems serve non-potable fixtures. While rainfall totals vary greatly by region, this measure can still offer water conservation in most locations. The equipment investment and intended usage of rainwater would increase in regions with higher annual rainfall totals. Rainwater in most regions is considered to be relatively pure, with low mineral content, however contamination can occur from the catchment surface materials or environmental deposits forming or expelled onto the catchment surface. This makes rainwater a viable candidate for potable water if treated properly, similar to well water. If regulations were developed and enforced for individual water filtration and purification systems to produce potable water from captured rainwater, this approach could be highly beneficial in climates with moderate annual rainfall rates. However, due to the unpredictability and inconsistency of rainfall, such systems should not be relied upon as the sole source of water and would require interconnection with a generally uninterruptable water supply to serve as a backup. Storage tank size/volume would be the most limiting factor for a residential rainwater harvesting system. A large system would likely require a large volume exterior above or below grade storage tank.

The three building typologies discussed in this report involve large systems, characterized by building roof collection surfaces exceeding 7,500 square feet are respective to each city and its population.

The large systems would serve non-potable water for indoor water closet flushing and exterior landscaping purposes. The system would include the filtration and disinfection equipment, storage tank, booster pump with hydromechanical tank, controls, and distribution piping from the outlet of the tank to supply all water closets and irrigation systems. The non-potable water closet supply water would be a central system throughout the building. As this non-potable system is not considered reliable to always meet the usage demand, interconnection of a reliable water source such as municipal water is also required with a backflow preventer to protect the municipal water supply.

Monthly rainfall collection profiles were developed using the NOAA weather data, collection surface area, and efficiency factors. Comparing the monthly non-potable demand consumption to the available rainwater collected and stored provided the estimated monthly and annual water savings. The small and large rainwater collection systems utilized the same calculation methodology. Each system was modeled to maximize the rainwater harvesting savings potential per city.

8.1.Houston, Texas

Garden/Low-Rise	
Roof Area (sq. ft.)	215,755
Rain water collected (gal)	4,935,936
Rain water consumed (gal)	21,005,274
Water Savings per Year (gal)	4,935,936

Mid-Rise	
Roof Area (sq. ft.)	30,967
Rain water collected (gal)	708,448
Rain water consumed (gal)	7,114,520
Water Savings per Year (gal)	708,448

High-Rise	
Roof Area (sq. ft.)	13,534
Rain water collected (gal)	309,624
Rain water consumed (gal)	8,836,748
Water Savings per Year (gal	309,624

Houston, TX - Garden/Low-Rise

Month	Rainwater Consumption			Rainwater Harvesting					Estimated Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	1,767,200	11,935	1,779,135	5.286	215,755	0.62	0.8	565,679	565,679
February	1,653,187	11,165	1,664,352	1.538	215,755	0.62	0.8	164,588	164,588
March	1,767,200	11,935	1,779,135	1.636	215,755	0.62	0.8	175,076	175,076
April	1,710,194	11,550	1,721,744	3.992	215,755	0.62	0.8	427,202	427,202
May	1,767,200	11,935	1,779,135	6.97	215,755	0.62	0.8	745,891	745,891
June	1,710,194	11,550	1,721,744	4.818	215,755	0.62	0.8	515,596	515,596
July	1,767,200	11,935	1,779,135	2.652	215,755	0.62	0.8	283,802	283,802
August	1,767,200	11,935	1,779,135	2.82	215,755	0.62	0.8	301,781	301,781
September	1,710,194	11,550	1,721,744	7.146	215,755	0.62	0.8	764,725	764,725
October	1,767,200	11,935	1,779,135	3.202	215,755	0.62	0.8	342,660	342,660
November	1,710,194	11,550	1,721,744	3.232	215,755	0.62	0.8	345,871	345,871
December	1,767,200	11,935	1,779,135	2.832	215,755	0.62	0.8	303,065	303,065
			21,005,274					4,935,936	4,935,936

Houston, TX - Mid-Rise

Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	590,661	11,935	602,596	5.286	30,967	0.62	0.8	81,191	81,191
February	552,554	11,165	563,719	1.538	30,967	0.62	0.8	23,623	23,623
March	590,661	11,935	602,596	1.636	30,967	0.62	0.8	25,128	25,128
April	571,607	11,550	583,157	3.992	30,967	0.62	0.8	61,316	61,316
May	590,661	11,935	602,596	6.97	30,967	0.62	0.8	107,057	107,057
June	571,607	11,550	583,157	4.818	30,967	0.62	0.8	74,003	74,003
July	590,661	11,935	602,596	2.652	30,967	0.62	0.8	40,734	40,734
August	590,661	11,935	602,596	2.82	30,967	0.62	0.8	43,314	43,314
September	571,607	11,550	583,157	7.146	30,967	0.62	0.8	109,760	109,760
October	590,661	11,935	602,596	3.202	30,967	0.62	0.8	49,182	49,182
November	571,607	11,550	583,157	3.232	30,967	0.62	0.8	49,642	49,642
December	590,661	11,935	602,596	2.832	30,967	0.62	0.8	43,498	43,498
			7,114,520					708,448	708,448

Houston, TX - High-Rise									
Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	736,533	11,935	748,468	5.286	13,534	0.62	0.8	35,484	35,484
February	689,014	11,165	700,179	1.538	13,534	0.62	0.8	10,324	10,324
March	736,533	11,935	748,468	1.636	13,534	0.62	0.8	10,982	10,982
April	712,774	11,550	724,324	3.992	13,534	0.62	0.8	26,798	26,798
May	736,533	11,935	748,468	6.97	13,534	0.62	0.8	46,789	46,789
June	712,774	11,550	724,324	4.818	13,534	0.62	0.8	32,343	32,343
July	736,533	11,935	748,468	2.652	13,534	0.62	0.8	17,803	17,803
August	736,533	11,935	748,468	2.82	13,534	0.62	0.8	18,930	18,930
September	712,774	11,550	724,324	7.146	13,534	0.62	0.8	47,970	47,970
October	736,533	11,935	748,468	3.202	13,534	0.62	0.8	21,495	21,495
November	712,774	11,550	724,324	3.232	13,534	0.62	0.8	21,696	21,696
December	736,533	11,935	748,468	2.832	13,534	0.62	0.8	19,011	19,011
			8,836,748					309,624	309,624

Table 41: Rain Harvesting Collection Systems – Houston

Maximum potential rainwater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 23% annually.

Maximum potential rainwater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 10% annually.

Maximum potential rainwater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 4% annually.

2. Phoenix, Arizona

Garden/ Low-Rise	
Roof Area (sq. ft.)	47,005
Rain water collected (gal)	130,701
Rain water consumed (gal)	1,674,165
Water Savings per Year (gal)	130,701

Mid-Rise	
Roof Area (sq. ft.)	27,206
Rain water collected (gal)	75,648
Rain water consumed (gal)	2,207,470
Water Savings per Year (gal)	75,648

High-Ris	
Roof Area (sq. ft.)	11,820
Rain water collected (gal)	32,866
Rain water consumed (gal)	2,702,683
Water Savings per Year (gal	32,866

Phoenix, AZ - Garden/ Low-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Estimated Water Savings (gal)
January	129,866	11,935	141,801	0.552	47,005	0.62	0.8	12,870	12,870
February	121,487	11,165	132,652	0.758	47,005	0.62	0.8	17,672	17,672
March	129,866	11,935	141,801	0.846	47,005	0.62	0.8	19,724	19,724
April	125,677	11,550	137,227	0.036	47,005	0.62	0.8	839	839
May	129,866	11,935	141,801	0.02	47,005	0.62	0.8	466	466
June	125,677	11,550	137,227	0.098	47,005	0.62	0.8	2,285	2,285
July	129,866	11,935	141,801	0.442	47,005	0.62	0.8	10,305	10,305
August	129,866	11,935	141,801	0.742	47,005	0.62	0.8	17,299	17,299
September	125,677	11,550	137,227	0.366	47,005	0.62	0.8	8,533	8,533
October	129,866	11,935	141,801	0.254	47,005	0.62	0.8	5,922	5,922
November	125,677	11,550	137,227	0.376	47,005	0.62	0.8	8,766	8,766
December	129,866	11,935	141,801	1.116	47,005	0.62	0.8	26,019	26,019
			1,674,165					130,701	130,701

Phoenix, AZ - Mid-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Water Savings (gal)
January	175,037	11,935	186,972	0.552	27,206	0.62	0.8	7,449	7,449
February	163,744	11,165	174,909	0.758	27,206	0.62	0.8	10,229	10,229
March	175,037	11,935	186,972	0.846	27,206	0.62	0.8	11,416	11,416
April	169,390	11,550	180,940	0.036	27,206	0.62	0.8	486	486
May	175,037	11,935	186,972	0.02	27,206	0.62	0.8	270	270
June	169,390	11,550	180,940	0.098	27,206	0.62	0.8	1,322	1,322
July	175,037	11,935	186,972	0.442	27,206	0.62	0.8	5,964	5,964
August	175,037	11,935	186,972	0.742	27,206	0.62	0.8	10,013	10,013
September	169,390	11,550	180,940	0.366	27,206	0.62	0.8	4,939	4,939
October	175,037	11,935	186,972	0.254	27,206	0.62	0.8	3,428	3,428
November	169,390	11,550	180,940	0.376	27,206	0.62	0.8	5,074	5,074
December	175,037	11,935	186,972	1.116	27,206	0.62	0.8	15,060	15,060
			2,207,470					75,648	75,648

Phoenix, AZ - High-Rise									
Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	216,981	11,935	228,916	0.552	11,820	0.62	0.8	3,236	3,236
February	202,982	11,165	214,147	0.758	11,820	0.62	0.8	4,444	4,444
March	216,981	11,935	228,916	0.846	11,820	0.62	0.8	4,960	4,960
April	209,981	11,550	221,531	0.036	11,820	0.62	0.8	211	211
May	216,981	11,935	228,916	0.02	11,820	0.62	0.8	117	117
June	209,981	11,550	221,531	0.098	11,820	0.62	0.8	575	575
July	216,981	11,935	228,916	0.442	11,820	0.62	0.8	2,591	2,591
August	216,981	11,935	228,916	0.742	11,820	0.62	0.8	4,350	4,350
September	209,981	11,550	221,531	0.366	11,820	0.62	0.8	2,146	2,146
October	216,981	11,935	228,916	0.254	11,820	0.62	0.8	1,489	1,489
November	209,981	11,550	221,531	0.376	11,820	0.62	0.8	2,204	2,204
December	216,981	11,935	228,916	1.116	11,820	0.62	0.8	6,543	6,543
			2,702,683					32,866	32,866

Table 42: Rain Harvesting Collection Systems – Phoenix

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 8% annually.

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 4% annually.

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 1% annually.

3. Las Vegas, Nevada

Garden/ Low-Rise	
Roof Area (sq. ft.)	55,471
Rain water collected (gal)	97,948
Rain water consumed (gal)	1,989,979
Water Savings per Year (gal)	97,948

Mid-Rise	
Roof Area (sq. ft.)	27,206
Rain water collected (gal)	48,039
Rain water consumed (gal)	2,252,741
Water Savings per Year (gal)	48,039

High-Rise	
Roof Area (sq. ft.)	2,504
Rain water collected (gal)	4,421
Rain water consumed (gal)	695,631
Water Savings per Year (gal	4,421

Las Vegas, NV - Garden/ Low-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Estimated Water Savings (gal)
January	156,615	11,935	168,550	0.396	55,471	0.62	0.8	10,895	10,895
February	146,511	11,165	157,676	0.524	55,471	0.62	0.8	14,417	14,417
March	156,615	11,935	168,550	0.646	55,471	0.62	0.8	17,774	17,774
April	151,563	11,550	163,113	0.144	55,471	0.62	0.8	3,962	3,962
May	156,615	11,935	168,550	0.162	55,471	0.62	0.8	4,457	4,457
June	151,563	11,550	163,113	0.044	55,471	0.62	0.8	1,211	1,211
July	156,615	11,935	168,550	0.246	55,471	0.62	0.8	6,768	6,768
August	156,615	11,935	168,550	0.356	55,471	0.62	0.8	9,795	9,795
September	151,563	11,550	163,113	0.47	55,471	0.62	0.8	12,931	12,931
October	156,615	11,935	168,550	0.042	55,471	0.62	0.8	1,156	1,156
November	151,563	11,550	163,113	0.254	55,471	0.62	0.8	6,988	6,988
December	156,615	11,935	168,550	0.276	55,471	0.62	0.8	7,594	7,594
			1,989,979					97,948	97,948

Las Vegas, NV- Mid-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Water Savings (gal)
January	178,871	11,935	190,806	0.396	27,206	0.62	0.8	5,344	5,344
February	167,331	11,165	178,496	0.524	27,206	0.62	0.8	7,071	7,071
March	178,871	11,935	190,806	0.646	27,206	0.62	0.8	8,717	8,717
April	173,101	11,550	184,651	0.144	27,206	0.62	0.8	1,943	1,943
May	178,871	11,935	190,806	0.162	27,206	0.62	0.8	2,186	2,186
June	173,101	11,550	184,651	0.044	27,206	0.62	0.8	594	594
July	178,871	11,935	190,806	0.246	27,206	0.62	0.8	3,320	3,320
August	178,871	11,935	190,806	0.356	27,206	0.62	0.8	4,804	4,804
September	173,101	11,550	184,651	0.47	27,206	0.62	0.8	6,342	6,342
October	178,871	11,935	190,806	0.042	27,206	0.62	0.8	567	567
November	173,101	11,550	184,651	0.254	27,206	0.62	0.8	3,428	3,428
December	178,871	11,935	190,806	0.276	27,206	0.62	0.8	3,724	3,724
			2,252,741					48,039	48,039

Las Vegas, NV- High-Rise									
Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	46,985	11,935	58,920	0.396	2,504	0.62	0.8	492	492
February	43,953	11,165	55,118	0.524	2,504	0.62	0.8	651	651
March	46,985	11,935	58,920	0.646	2,504	0.62	0.8	802	802
April	45,469	11,550	57,019	0.144	2,504	0.62	0.8	179	179
May	46,985	11,935	58,920	0.162	2,504	0.62	0.8	201	201
June	45,469	11,550	57,019	0.044	2,504	0.62	0.8	55	55
July	46,985	11,935	58,920	0.246	2,504	0.62	0.8	306	306
August	46,985	11,935	58,920	0.356	2,504	0.62	0.8	442	442
September	45,469	11,550	57,019	0.47	2,504	0.62	0.8	584	584
October	46,985	11,935	58,920	0.042	2,504	0.62	0.8	52	52
November	45,469	11,550	57,019	0.254	2,504	0.62	0.8	315	315
December	46,985	11,935	58,920	0.276	2,504	0.62	0.8	343	343
			695,631					4,421	4,421

Table 43: Rain Harvesting Collection Systems – Las Vegas

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 5% annually.

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 2% annually.

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 0.6% annually.

4. Des Moines, Iowa

Garden/ Low-Rise	
Roof Area (sq. ft.)	28,611
Rain water collected (gal)	477,103
Rain water consumed (gal)	967,309
Water Savings per Year (gal)	477,103

Mid-Rise	
Roof Area (sq. ft.)	13,289
Rain water collected (gal)	221,601
Rain water consumed (gal)	1,034,770
Water Savings per Year (gal)	221,601

High-Rise	
Roof Area (sq. ft.)	6,679
Rain water collected (gal)	111,376
Rain water consumed (gal)	1,422,671
Water Savings per Year (gal	111,376

Des Moines, IA - Garden/ Low-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Estimated Water Savings (gal)
January	69,996	11,935	81,931	1.512	28,611	0.62	0.8	21,457	21,457
February	65,480	11,165	76,645	1.086	28,611	0.62	0.8	15,411	15,411
March	69,996	11,935	81,931	2.676	28,611	0.62	0.8	37,975	37,975
April	67,738	11,550	79,288	2.3	28,611	0.62	0.8	32,639	32,639
May	69,996	11,935	81,931	4.842	28,611	0.62	0.8	68,713	68,713
June	67,738	11,550	79,288	3.902	28,611	0.62	0.8	55,374	55,374
July	69,996	11,935	81,931	3.61	28,611	0.62	0.8	51,230	51,230
August	69,996	11,935	81,931	3.22	28,611	0.62	0.8	45,695	45,695
September	67,738	11,550	79,288	3.128	28,611	0.62	0.8	44,390	44,390
October	69,996	11,935	81,931	4.13	28,611	0.62	0.8	58,609	58,609
November	67,738	11,550	79,288	1.744	28,611	0.62	0.8	24,749	24,749
December	69,996	11,935	81,931	1.47	28,611	0.62	0.8	20,861	20,861
			967,309					477,103	477,103

Des Moines, IA - Mid-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Water Savings (gal)
January	75,709	11,935	87,644	1.512	13,289	0.62	0.8	9,966	9,966
February	70,825	11,165	81,990	1.086	13,289	0.62	0.8	7,158	7,158
March	75,709	11,935	87,644	2.676	13,289	0.62	0.8	17,638	17,638
April	73,267	11,550	84,817	2.3	13,289	0.62	0.8	15,160	15,160
May	75,709	11,935	87,644	4.842	13,289	0.62	0.8	31,915	31,915
June	73,267	11,550	84,817	3.902	13,289	0.62	0.8	25,719	25,719
July	75,709	11,935	87,644	3.61	13,289	0.62	0.8	23,795	23,795
August	75,709	11,935	87,644	3.22	13,289	0.62	0.8	21,224	21,224
September	73,267	11,550	84,817	3.128	13,289	0.62	0.8	20,618	20,618
October	75,709	11,935	87,644	4.13	13,289	0.62	0.8	27,222	27,222
November	73,267	11,550	84,817	1.744	13,289	0.62	0.8	11,495	11,495
December	75,709	11,935	87,644	1.47	13,289	0.62	0.8	9,689	9,689
			1,034,770					221,601	221,601

Des Moines, IA - High-Rise									
	Rainwater Consumption			Rainwater Harvesting					
Month	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	Water Savings (gal)
January	108,564	11,935	120,499	1.512	6,679	0.62	0.8	5,009	5,009
February	101,560	11,165	112,725	1.086	6,679	0.62	0.8	3,598	3,598
March	108,564	11,935	120,499	2.676	6,679	0.62	0.8	8,865	8,865
April	105,062	11,550	116,612	2.3	6,679	0.62	0.8	7,619	7,619
May	108,564	11,935	120,499	4.842	6,679	0.62	0.8	16,041	16,041
June	105,062	11,550	116,612	3.902	6,679	0.62	0.8	12,926	12,926
July	108,564	11,935	120,499	3.61	6,679	0.62	0.8	11,959	11,959
August	108,564	11,935	120,499	3.22	6,679	0.62	0.8	10,667	10,667
September	105,062	11,550	116,612	3.128	6,679	0.62	0.8	10,362	10,362
October	108,564	11,935	120,499	4.13	6,679	0.62	0.8	13,682	13,682
November	105,062	11,550	116,612	1.744	6,679	0.62	0.8	5,777	5,777
December	108,564	11,935	120,499	1.47	6,679	0.62	0.8	4,870	4,870
			1,422,671					111,376	111,376

Table 44: Rain Harvesting Collection Systems – Des Moines

Maximum potential rainwater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 49% annually.

Maximum potential rainwater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 21% annually.

Maximum potential rainwater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 8% annually.

The landscape irrigation consumption would vary greatly based on property size, homeowner lifestyles and plant species used in landscaping. Large diversity in irrigation estimates directly impacts the potable to non-potable site profiles and therefore percent reductions of municipal water for non-potable uses.

In summary, as demonstrated by the analysis above for the four subject cities, harvested rainwater can be an alternate water supply stream meeting the non-potable water demands. Of course, proper water balance computations will need to be undertaken by the design engineers in coordination with landscape architects when assessing design approaches.

9. Grey Water Harvesting

Grey water can be characterized as water from the following plumbing fixtures: lavatories, showers, tubs, and washing machines. Although these fixtures are generally used on a daily basis, it may not be practical to harvest 100 percent of the greywater generated as losses may occur. Losses, such as greywater entering the anaerobic state (Al-Jayyousi, 2003), are one of many occurrences that would prohibit the collection of the total amount of greywater obtained; similarly based on unique architectural design features, it may not always be cost effective and practical to capture every gray water fixture in the harvesting piping network, which may result in reduced collection efficiencies. Within this study, a conservative approach was taken where the assumption that 75 percent of the total potential for greywater from plumbing fixtures was harvested. In addition, as detailed in section 5.2 of this report, condensation produced by HVAC systems can also be categorized as a gray water source, contributing to total gray water harvesting potential in a building. Therefore, when investigating total gray water harvesting potential for the building typologies discussed in this report, in addition to gray water from plumbing fixture, condensation water with a harvest efficiency of 90 percent was also included as tabulated for each city in the sections below. Considering that it may not always be feasible or cost effective to harvest 100 percent of the condensation water produced based on architectural design and construction features, 90 percent was used as a reasonable assumption.

Grey water harvesting and distribution systems sized for maximum harvesting potential are provided to offset the non-potable site consumption. Minimal filtration systems or treatment is required since all rainwater collection systems serve non-potable fixtures.

The three building typologies discussed herein this report are large systems as the number of dwelling units with each property is respective to each city and its population.

The large systems would serve non-potable water closets only and landscape irrigation. The system would include drain piping from each fixture (bathtub, showers, lavatories, laundry tub, and HVAC equipment) to be directed to an onsite storage tank. A filtration and disinfection system, and pump would provide code minimum treatment in Compliance with NSF 350. Distribution piping from the outlet of the tank, through a pressure booster pump with a hydromechanical tank would be extended into the home to serve all water closets with supply water. A supply branch pipe would also be extended and connected into supply piping that serves landscape irrigation.

Monthly grey water consumption and grey water harvesting profiles were developed using the previously established single and or multi-family baselines. Both systems were modeled to maximize the grey water harvesting savings potential.

Comparing the baseline grey water consumption to the available grey water collected and stored provided the estimated monthly and annual water savings. The grey water systems models produced the following results:

9.1.Houston, Texas

Garden/Low-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	Water Savings (gal)
January	443,372	11,935	455,307	2,259,560	1,694,670	559	503	1,695,173	1,695,173
February	414,767	11,165	425,932	2,113,782	1,585,337	8,962	8,066	1,593,403	1,593,403
March	443,372	11,935	455,307	2,259,560	1,694,670	29,838	26,854	1,721,524	1,721,524
April	429,069	11,550	440,619	2,186,671	1,640,004	42,157	37,942	1,677,945	1,677,945
May	443,372	11,935	455,307	2,259,560	1,694,670	109,952	98,957	1,793,627	1,793,627
June	429,069	11,550	440,619	2,186,671	1,640,004	245,283	220,755	1,860,758	1,860,758
July	443,372	11,935	455,307	2,259,560	1,694,670	333,255	299,930	1,994,600	1,994,600
August	443,372	11,935	455,307	2,259,560	1,694,670	394,286	354,857	2,049,528	2,049,528
September	429,069	11,550	440,619	2,186,671	1,640,004	260,512	234,461	1,874,465	1,874,465
October	443,372	11,935	455,307	2,259,560	1,694,670	77,957	70,161	1,764,832	1,764,832
November	429,069	11,550	440,619	2,186,671	1,640,004	10,338	9,304	1,649,308	1,649,308
December	443,372	11,935	455,307	2,259,560	1,694,670	3,616	3,254	1,697,925	1,697,925
		Annual Total	**5,375,556**				**Annual Total**	**21,373,088**	**21,373,088**

Mid-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	Water Savings (gal)
January	148,191	11,935	160,126	755,225	566,419	187	168	566,587	566,587
February	138,630	11,165	149,795	706,501	529,876	2,995	2,696	532,572	532,572
March	148,191	11,935	160,126	755,225	566,419	9,973	8,976	575,395	575,395
April	143,410	11,550	154,960	730,863	548,147	14,090	12,681	560,829	560,829
May	148,191	11,935	160,126	755,225	566,419	36,750	33,075	599,494	599,494
June	143,410	11,550	154,960	730,863	548,147	81,982	73,784	621,931	621,931
July	148,191	11,935	160,126	755,225	566,419	111,386	100,247	666,666	666,666
August	148,191	11,935	160,126	755,225	566,419	131,784	118,606	685,025	685,025
September	143,410	11,550	154,960	730,863	548,147	87,072	78,365	626,513	626,513
October	148,191	11,935	160,126	755,225	566,419	26,056	23,450	589,869	589,869
November	143,410	11,550	154,960	730,863	548,147	3,455	3,110	551,257	551,257
December	148,191	11,935	160,126	755,225	566,419	1,209	1,088	567,507	567,507
		Annual Total	**1,890,514**				**Annual Total**	**7,143,644**	**7,143,644**

High-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	Water Savings (gal)
January	184,788	11,935	196,723	941,738	706,304	233	210	706,513	706,513
February	172,866	11,165	184,031	880,981	660,736	3,735	3,362	664,098	664,098
March	184,788	11,935	196,723	941,738	706,304	12,436	11,192	717,496	717,496
April	178,827	11,550	190,377	911,360	683,520	17,570	15,813	699,333	699,333
May	184,788	11,935	196,723	941,738	706,304	45,826	41,243	747,547	747,547
June	178,827	11,550	190,377	911,360	683,520	102,229	92,006	775,526	775,526
July	184,788	11,935	196,723	941,738	706,304	138,894	125,004	831,308	831,308
August	184,788	11,935	196,723	941,738	706,304	164,330	147,897	854,201	854,201
September	178,827	11,550	190,377	911,360	683,520	108,576	97,719	781,238	781,238
October	184,788	11,935	196,723	941,738	706,304	32,491	29,242	735,546	735,546
November	178,827	11,550	190,377	911,360	683,520	4,309	3,878	687,398	687,398
December	184,788	11,935	196,723	941,738	706,304	1,507	1,356	707,660	707,660
		Annual Total	**2,322,603**				**Annual Total**	**8,907,863**	**8,907,863**

Table 45: Greywater Harvesting Collection Systems – Houston

Maximum potential greywater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property with an additional surplus of approximately 16.0 million gallons annually.

Maximum potential greywater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property with an additional surplus of approximately 5.3 million gallons annually.

Maximum potential greywater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property with an additional surplus of approximately 6.6 million gallons annually.

2. Phoenix, Arizona

Garden/ Low-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Mulit-Family Grey Water Consumption (gal)**	**Grey water from plumbing fixtures collected (75% efficiency)**	**HVAC Condensate (gal)**	**HVAC condensate collected (90% efficiency)**	**Grey water + HVAC harvested (gal)**	**Water Savings (gal)**
January	128,408	11,935	140,343	517,507	388,130	820	738	388,869	388,869
February	120,124	11,165	131,289	484,119	363,089	1,020	918	364,007	364,007
March	128,408	11,935	140,343	517,507	388,130	5,220	4,698	392,828	392,828
April	124,266	11,550	135,816	500,813	375,610	28,597	25,737	401,347	401,347
May	128,408	11,935	140,343	517,507	388,130	47,852	43,067	431,197	431,197
June	124,266	11,550	135,816	500,813	375,610	69,885	62,897	438,507	438,507
July	128,408	11,935	140,343	517,507	388,130	101,036	90,932	479,062	479,062
August	128,408	11,935	140,343	517,507	388,130	83,421	75,078	463,209	463,209
September	124,266	11,550	135,816	500,813	375,610	69,829	62,846	438,456	438,456
October	128,408	11,935	140,343	517,507	388,130	41,722	37,549	425,679	425,679
November	124,266	11,550	135,816	500,813	375,610	10,801	9,721	385,331	385,331
December	128,408	11,935	140,343	517,507	388,130	2,130	1,917	390,047	390,047
		Annual Total	**1,656,958**				**Annual Total**	**4,998,539**	**4,998,539**

Mid-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Mulit-Family Grey Water Consumption (gal)**	**Grey water from plumbing fixtures collected (75% efficiency)**	**HVAC Condensate (gal)**	**HVAC condensate collected (90% efficiency)**	**Grey water + HVAC harvested (gal)**	**Water Savings (gal)**
January	173,072	11,935	185,007	697,509	523,132	1,106	995	524,127	524,127
February	161,906	11,165	173,071	652,509	489,381	1,375	1,237	490,619	490,619
March	173,072	11,935	185,007	697,509	523,132	7,036	6,332	529,464	529,464
April	167,489	11,550	179,039	675,009	506,257	38,544	34,689	540,946	540,946
May	173,072	11,935	185,007	697,509	523,132	64,497	58,047	581,179	581,179
June	167,489	11,550	179,039	675,009	506,257	94,193	84,774	591,031	591,031
July	173,072	11,935	185,007	697,509	523,132	136,178	122,561	645,692	645,692
August	173,072	11,935	185,007	697,509	523,132	112,436	101,193	624,325	624,325
September	167,489	11,550	179,039	675,009	506,257	94,117	84,706	590,962	590,962
October	173,072	11,935	185,007	697,509	523,132	56,233	50,610	573,742	573,742
November	167,489	11,550	179,039	675,009	506,257	14,558	13,102	519,359	519,359
December	173,072	11,935	185,007	697,509	523,132	2,871	2,584	525,716	525,716
		Annual Total	**2,184,279**				**Annual Total**	**6,737,161**	**6,737,161**

High-Rise									
	Grey Water Consumption			Grey Water Harvesting					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Mulit-Family Grey Water Consumption (gal)**	**Grey water from plumbing fixtures collected (75% efficiency)**	**HVAC Condensate (gal)**	**HVAC condensate collected (90% efficiency)**	**Grey water + HVAC harvested (gal)**	**Water Savings (gal)**
January	214,546	11,935	226,481	864,654	648,491	1,371	1,234	649,724	649,724
February	200,704	11,165	211,869	808,870	606,653	1,704	1,534	608,186	608,186
March	214,546	11,935	226,481	864,654	648,491	8,722	7,850	656,341	656,341
April	207,625	11,550	219,175	836,762	627,572	47,780	43,002	670,574	670,574
May	214,546	11,935	226,481	864,654	648,491	79,952	71,957	720,448	720,448
June	207,625	11,550	219,175	836,762	627,572	116,765	105,088	732,660	732,660
July	214,546	11,935	226,481	864,654	648,491	168,811	151,930	800,421	800,421
August	214,546	11,935	226,481	864,654	648,491	139,380	125,442	773,932	773,932
September	207,625	11,550	219,175	836,762	627,572	116,671	105,004	732,575	732,575
October	214,546	11,935	226,481	864,654	648,491	69,709	62,738	711,228	711,228
November	207,625	11,550	219,175	836,762	627,572	18,047	16,242	643,814	643,814
December	214,546	11,935	226,481	864,654	648,491	3,559	3,203	651,694	651,694
		Annual Total	**2,673,935**				**Annual Total**	**8,351,596**	**8,351,596**

Table 46: Greywater Harvesting Collection Systems – Phoenix

Maximum potential greywater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property with an additional surplus of approximately 3.3 million gallons annually.

Maximum potential greywater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property with an additional surplus of approximately 4.6 million gallons annually.

Maximum potential greywater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property with an additional surplus of approximately 5.7 million gallons annually.

3. Las Vegas, Nevada

Garden/Low-Rise									
Month	Grey Water Consumption			Grey Water Harvesting					Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	
January	149,842	11,935	161,777	605,139	453,854	234	211	454,065	454,065
February	140,174	11,165	151,339	566,097	424,573	120	108	424,681	424,681
March	149,842	11,935	161,777	605,139	453,854	752	677	454,531	454,531
April	145,008	11,550	156,558	585,618	439,214	26,741	24,067	463,280	463,280
May	149,842	11,935	161,777	605,139	453,854	60,621	54,559	508,413	508,413
June	145,008	11,550	156,558	585,618	439,214	76,182	68,564	507,778	507,778
July	149,842	11,935	161,777	605,139	453,854	139,956	125,960	579,814	579,814
August	149,842	11,935	161,777	605,139	453,854	105,855	95,269	549,123	549,123
September	145,008	11,550	156,558	585,618	439,214	67,378	60,640	499,854	499,854
October	149,842	11,935	161,777	605,139	453,854	32,989	29,690	483,544	483,544
November	145,008	11,550	156,558	585,618	439,214	2,467	2,220	441,434	441,434
December	149,842	11,935	161,777	605,139	453,854	154	139	453,993	453,993
		Annual Total	**1,910,008**				**Annual Total**	**5,820,510**	**5,820,510**

Mid-Rise									
Month	Grey Water Consumption			Grey Water Harvesting					Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	
January	171,135	11,935	183,070	691,132	518,349	267	241	518,590	518,590
February	160,094	11,165	171,259	646,543	484,907	137	123	485,030	485,030
March	171,135	11,935	183,070	691,132	518,349	859	773	519,122	519,122
April	165,614	11,550	177,164	668,837	501,628	30,541	27,487	529,115	529,115
May	171,135	11,935	183,070	691,132	518,349	69,236	62,312	580,661	580,661
June	165,614	11,550	177,164	668,837	501,628	87,008	78,307	579,936	579,936
July	171,135	11,935	183,070	691,132	518,349	159,844	143,860	662,209	662,209
August	171,135	11,935	183,070	691,132	518,349	120,897	108,807	627,156	627,156
September	165,614	11,550	177,164	668,837	501,628	76,953	69,257	570,885	570,885
October	171,135	11,935	183,070	691,132	518,349	37,677	33,910	552,259	552,259
November	165,614	11,550	177,164	668,837	501,628	2,818	2,536	504,164	504,164
December	171,135	11,935	183,070	691,132	518,349	176	159	518,508	518,508
		Annual Total	**2,161,406**				**Annual Total**	**6,647,635**	**6,647,635**

High-Rise									
Month	Grey Water Consumption			Grey Water Harvesting					Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)	
January	44,952	11,935	56,887	181,542	136,156	70	63	136,219	136,219
February	42,052	11,165	53,217	169,829	127,372	36	32	127,404	127,404
March	44,952	11,935	56,887	181,542	136,156	226	203	136,359	136,359
April	43,502	11,550	55,052	175,685	131,764	8,022	7,220	138,984	138,984
May	44,952	11,935	56,887	181,542	136,156	18,186	16,368	152,524	152,524
June	43,502	11,550	55,052	175,685	131,764	22,855	20,569	152,333	152,333
July	44,952	11,935	56,887	181,542	136,156	41,987	37,788	173,944	173,944
August	44,952	11,935	56,887	181,542	136,156	31,756	28,581	164,737	164,737
September	43,502	11,550	55,052	175,685	131,764	20,213	18,192	149,956	149,956
October	44,952	11,935	56,887	181,542	136,156	9,897	8,907	145,063	145,063
November	43,502	11,550	55,052	175,685	131,764	740	666	132,430	132,430
December	44,952	11,935	56,887	181,542	136,156	46	42	136,198	136,198
		Annual Total	**671,639**				**Annual Total**	**1,746,153**	**1,746,153**

Table 47: Greywater Harvesting Collection Systems – Las Vegas

Maximum potential greywater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property with an additional surplus of approximately 3.9 million gallons annually.

Maximum potential greywater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property with an additional surplus of approximately 4.5 million gallons annually.

Maximum potential greywater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property with an additional surplus of approximately 1.1 million gallons annually.

4. Des Moines, Iowa

Garden/Low-Rise										
Month	Grey Water Consumption			Grey Water Harvesting						Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)		
January	68,246	11,935	80,181	282,364	211,773	0	0	211,773		211,773
February	63,843	11,165	75,008	264,147	198,110	0	0	198,110		198,110
March	68,246	11,935	80,181	282,364	211,773	0	0	211,773		211,773
April	66,044	11,550	77,594	273,255	204,942	965	868	205,810		205,810
May	68,246	11,935	80,181	282,364	211,773	5,273	4,745	216,518		216,518
June	66,044	11,550	77,594	273,255	204,942	13,075	11,768	216,709		216,709
July	68,246	11,935	80,181	282,364	211,773	17,591	15,832	227,605		227,605
August	68,246	11,935	80,181	282,364	211,773	19,900	17,910	229,683		229,683
September	66,044	11,550	77,594	273,255	204,942	8,959	8,063	213,005		213,005
October	68,246	11,935	80,181	282,364	211,773	1,552	1,397	213,170		213,170
November	66,044	11,550	77,594	273,255	204,942	0	0	204,942		204,942
December	68,246	11,935	80,181	282,364	211,773	0	0	211,773		211,773
		Annual Total	**946,649**				**Annual Total**	**2,560,869**		**2,560,869**

Mid-Rise										
Month	Grey Water Consumption			Grey Water Harvesting						Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)		
January	73,817	11,935	85,752	305,414	229,060	0	0	229,060		229,060
February	69,054	11,165	80,219	285,710	214,282	0	0	214,282		214,282
March	73,817	11,935	85,752	305,414	229,060	0	0	229,060		229,060
April	71,436	11,550	82,986	295,562	221,671	1,043	939	222,611		222,611
May	73,817	11,935	85,752	305,414	229,060	5,703	5,133	234,193		234,193
June	71,436	11,550	82,986	295,562	221,671	14,143	12,728	234,400		234,400
July	73,817	11,935	85,752	305,414	229,060	19,027	17,124	246,185		246,185
August	73,817	11,935	85,752	305,414	229,060	21,524	19,372	248,432		248,432
September	71,436	11,550	82,986	295,562	221,671	9,691	8,721	230,393		230,393
October	73,817	11,935	85,752	305,414	229,060	1,679	1,511	230,571		230,571
November	71,436	11,550	82,986	295,562	221,671	0	0	221,671		221,671
December	73,817	11,935	85,752	305,414	229,060	0	0	229,060		229,060
		Annual Total	**1,012,423**				**Annual Total**	**2,769,920**		**2,769,920**

High-Rise										
Month	Grey Water Consumption			Grey Water Harvesting						Water Savings (gal)
	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water from plumbing fixtures collected (75% efficiency)	HVAC Condensate (gal)	HVAC condensate collected (90% efficiency)	Grey water + HVAC harvested (gal)		
January	105,850	11,935	117,785	437,952	328,464	0	0	328,464		328,464
February	99,021	11,165	110,186	409,697	307,273	0	0	307,273		307,273
March	105,850	11,935	117,785	437,952	328,464	0	0	328,464		328,464
April	102,436	11,550	113,986	423,825	317,868	1,496	1,347	319,215		319,215
May	105,850	11,935	117,785	437,952	328,464	8,178	7,360	335,824		335,824
June	102,436	11,550	113,986	423,825	317,868	20,280	18,252	336,120		336,120
July	105,850	11,935	117,785	437,952	328,464	27,284	24,555	353,019		353,019
August	105,850	11,935	117,785	437,952	328,464	30,865	27,778	356,242		356,242
September	102,436	11,550	113,986	423,825	317,868	13,896	12,506	330,375		330,375
October	105,850	11,935	117,785	437,952	328,464	2,407	2,167	330,631		330,631
November	102,436	11,550	113,986	423,825	317,868	0	0	317,868		317,868
December	105,850	11,935	117,785	437,952	328,464	0	0	328,464		328,464
		Annual Total	**1,390,627**				**Annual Total**	**3,971,961**		**3,971,961**

Table 48: Greywater Harvesting Collection Systems – Des Moines

Maximum potential greywater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for garden-style/low-rise multi-family residential property with an additional surplus of approximately 1.6 million gallons annually.

Maximum potential greywater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for mid-rise multi-family residential property with an additional surplus of approximately 1.8 million gallons annually.

Maximum potential greywater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for high-rise multi-family residential property with an additional surplus of approximately 2.6 million gallons annually.

Based on the analysis demonstrated in sections 6.3-Rainwater Harvesting and 6.4-Greywater harvesting, it is important to highlight that there is strong potential for implementing these measures individually or collectively depending on multiple regionally and design specific factors.

The landscape irrigation consumption may vary greatly based on property size, homeowner lifestyles and plant species and landscape design implemented. Large diversity in irrigation estimates directly impact the potable to non-potable site profiles and therefore the projected surplus of grey water captured for non-potable uses. Therefore, harvesting storage and treatment capacities can be optimized with proper water balance computations at each property to produce the most favorable conservation outcomes.

10. Scaling to City-Scale: Water Conservation Outcomes

The water conservation gains calculated for each typology of multi-family residential properties are scaled up to obtain citywide conservation outcomes using numerical modeling that incorporates city-specific census data on occupancy and the existing housing stock, as well as forecasts of future new homes. However, it's important to note that it is not plausible to expect all homes in a city to adopt these provisions simultaneously or instantaneously. Instead, in our calculations, we assume that all new properties constructed in the future will adhere to the IWCCP, while a portion of existing homes will gradually adopt them through renovations over time. Historical data for newly constructed properties from 2018 to June 2024 obtained from the CoStar commercial real estate platform was utilized to obtain a 6-year forecast of the future trajectory of multi-family properties employing the exponential smoothing (ETS) algorithm for each city under this study. This data showed a clear understanding as to the varying dynamics of multifamily construction within a city such as the number of occupied and vacant dwelling units and number of properties, for example.

The resulting new construction trajectories for each city are depicted in the graphs below. These forecasts serve as key input in computing the future projections of the water conservation volumes achievable through compliance with IWCCP at citywide scales in various geographic locations with different climatic and geological characteristics.

1. Garden-Style/ Low-Rise Properties

In Phase I, the assessment of conservation measures implemented within single-family residences and the outlook of each selected city determined that it is paramount to assess the trend of applying these code provisions at a larger scale to elect if the benefits would exist and are applicable in the future. The same methodology is administered as the forecasts for new garden-style/low-rise properties in each city as shown below. This statement will be applicable in sections 10.2 Mid-Rise Buildings and 10.3 High-Rise Buildings as well.

As previously noted in the Phase I report, the assumption of all properties applying these provisions is not conducive. Thus, the forecasting performed for each city and each building typology will show the adoption of these measures each quarter until the year 2030 by new properties and the inclusion of one percent and five percent of the renovated buildings.

As for the Annual Water Conservation Forecast graphs, the quantities of each measure are retained within the specified color block of the graph and not compounded or shown as an overlay.

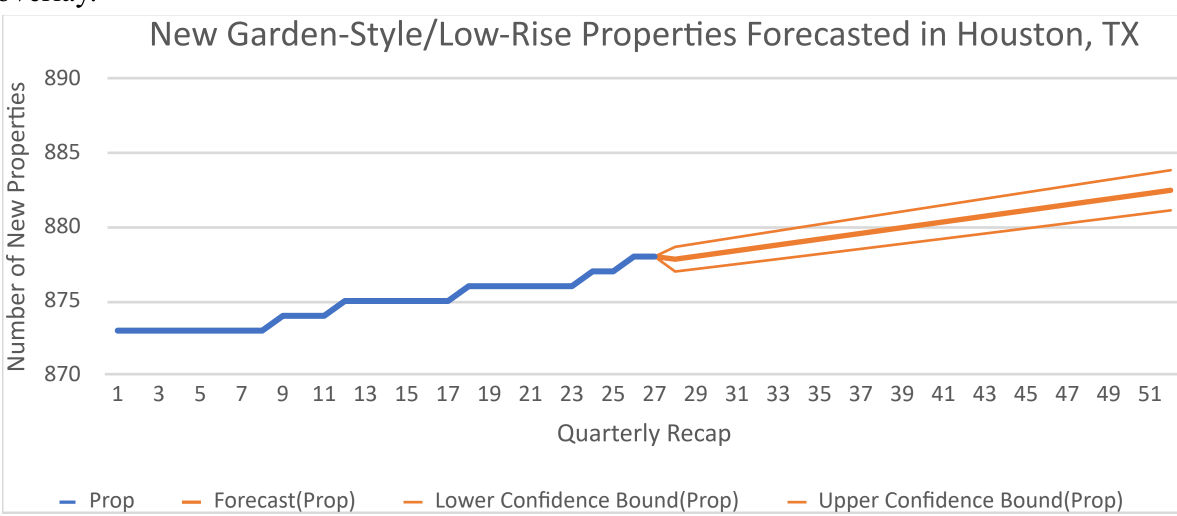


Figure VIII: Historic New Garden-Style/Low-Rise Properties Construction Trend and Projected Future Trajectory – Houston

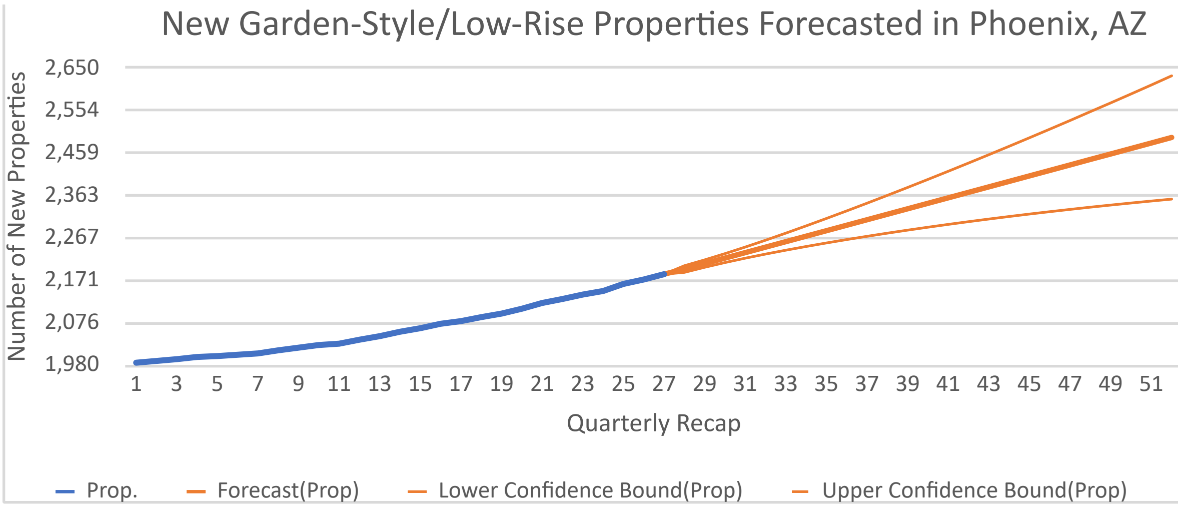


Figure VIV: Historic New Garden-Style/Low-Rise Properties Construction Trend and Projected Future Trajectory – Phoenix

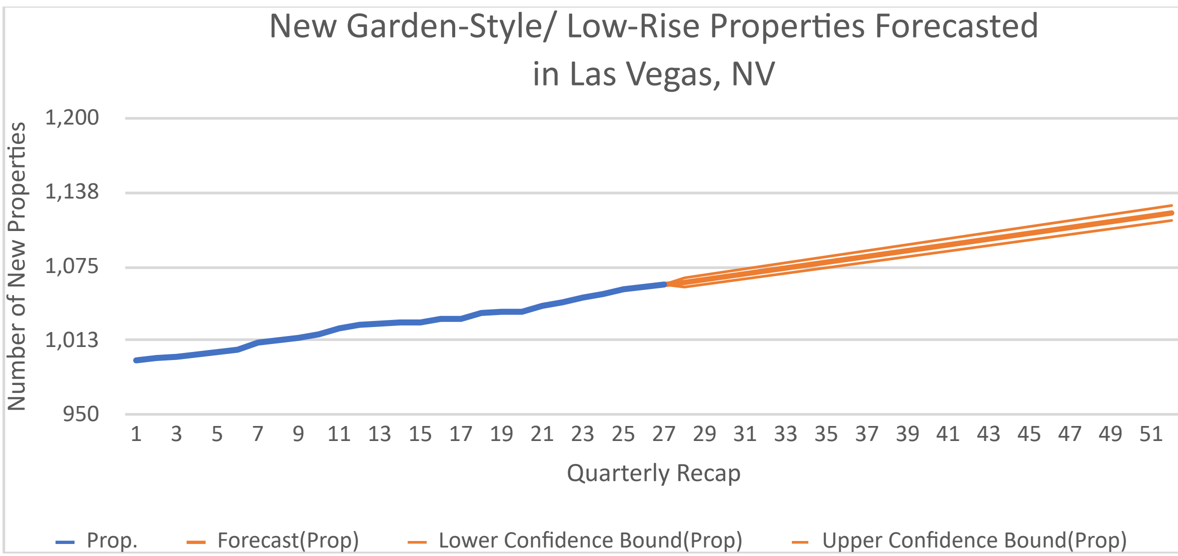


Figure X: Historic New Garden-Style/Low-Rise Properties Construction Trend and Projected Future Trajectory - Las Vegas

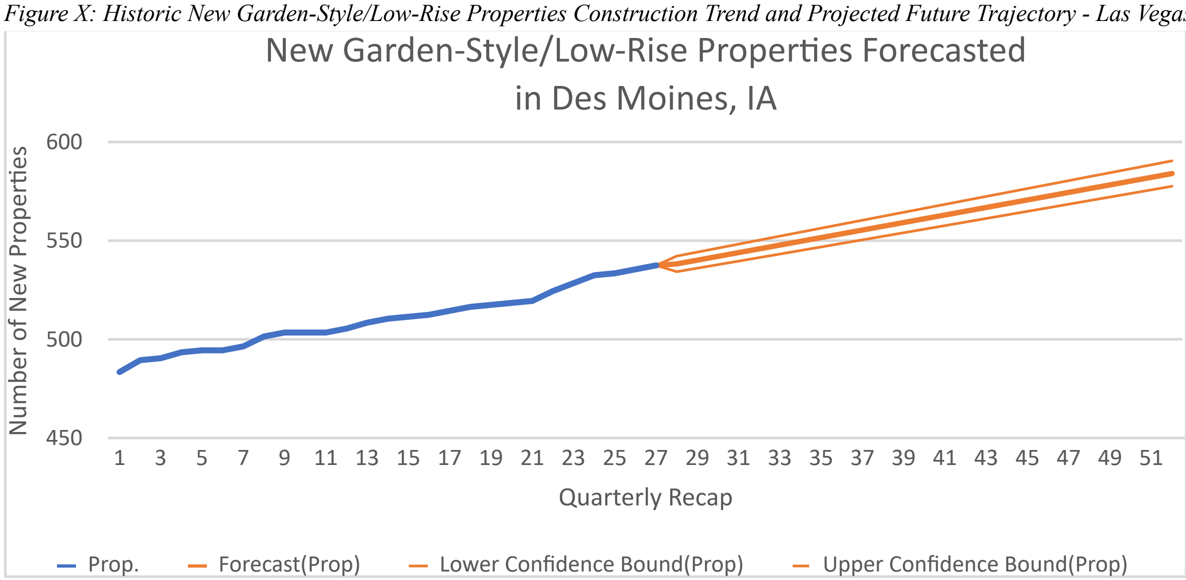


Figure XI: Historic New Garden/Low-Rise Properties Construction Trend and Projected Future Trajectory - Des Moines

1.1. Houston

Below, Figure XII displays the annual aggregate water conservation forecast for garden-style/low-rise properties in the city of Houston where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new garden-style/low-rise properties, the aggregate water conservation quantities are projected to be approximately 52.6 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 559.2 billion gallons.

If all new constructed garden-style/low-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 192.3 billion gallons. By year 7, the total aggregate amount would approximately 1,508.3 billion gallons.

Similarly, if all newly constructed garden-style/low-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 751.2 billion gallons. By year 7, the total aggregate amount would approximately 4,773.9 billion gallons.

As noted in the forecast, the implementation of water conservation measures can be seen as a benefit as the upward trend proves that they can become a greater asset to the city.

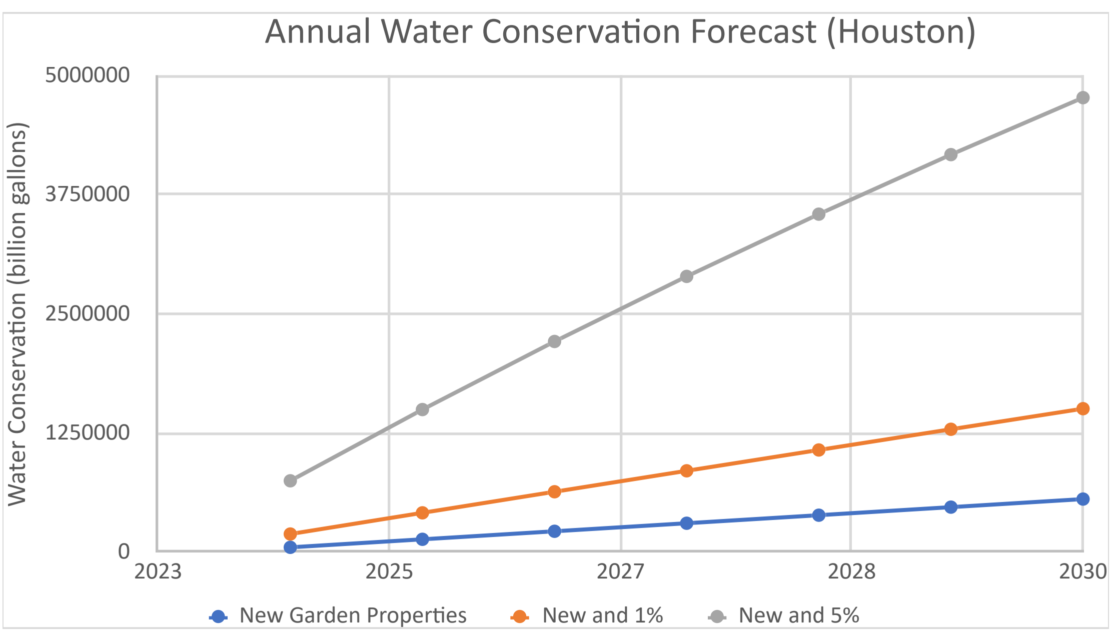


Figure XII: Annual Aggregate Water Conservation Forecast for Garden-Style/Low-Rise Properties in Houston

In the following two figures, the categorization of these measures is shown in a color-coded manner where the assessment of each measure can be assessed to the prior and forthcoming projected year. Moreover, these comprehensive predictions allow for an evaluation of which strategies are best suitable for this building typology in the city of Houston.

With the main adoption of the implementation of water-efficient fixtures in garden-style/low-rise buildings, the city of Houston would be able to meet their needs. Due to these provisions being based on human interaction, it is favorable to conclude that the involvement of the community is necessary to achieve the preservation of water.

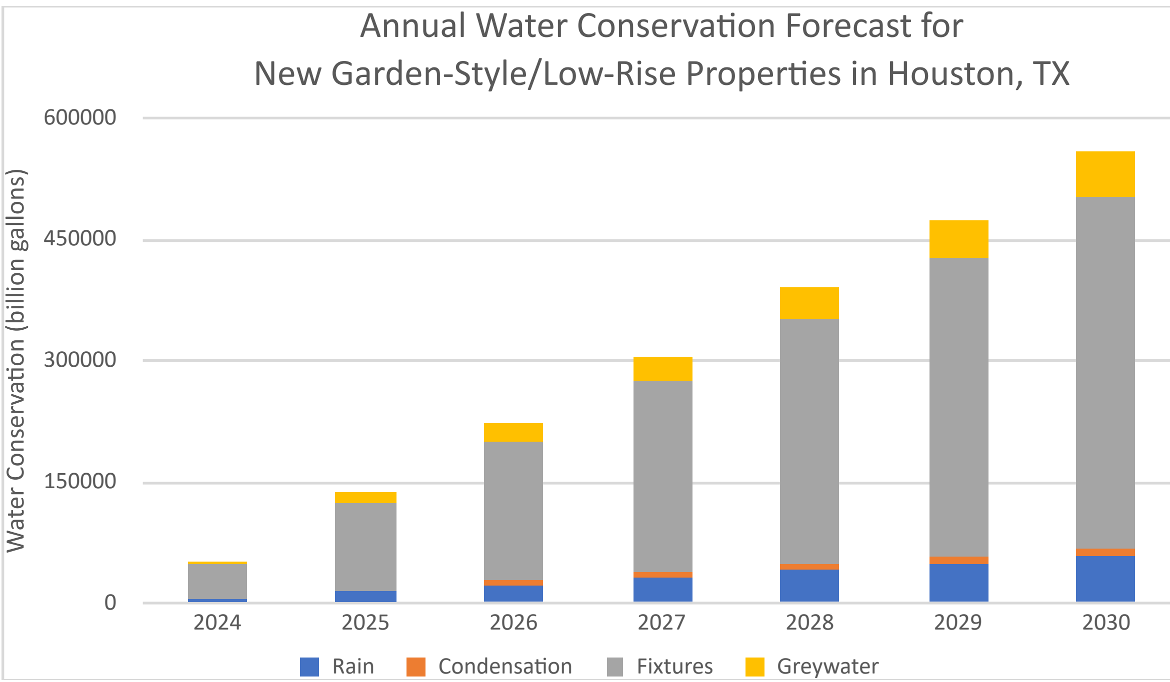


Figure XIII: Annual Water Conservation Forecast - Houston

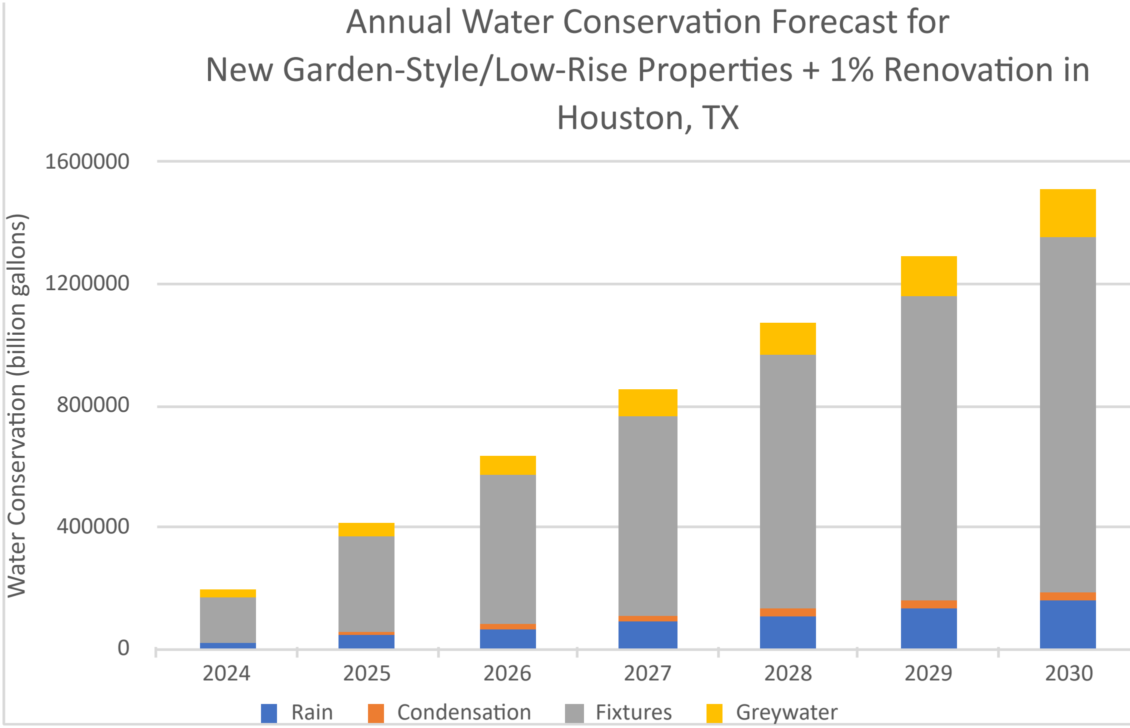


Figure XIV: Annual Water Conservation Forecast - Houston

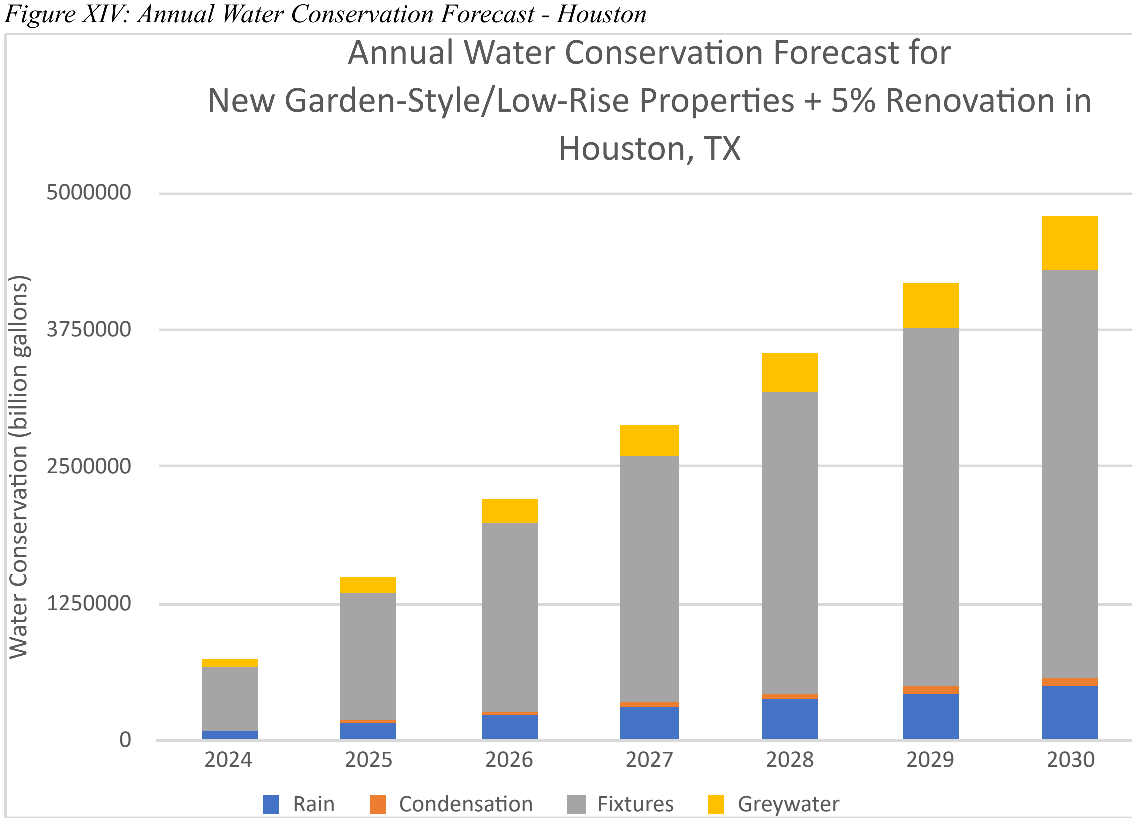


Figure XV: Annual Water Conservation Forecast - Houston

1.2. Phoenix

Below, Figure XVI displays the annual aggregate water conservation forecast for garden-style/ low-rise properties in the city of Phoenix where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new garden-style/ low-rise properties, the aggregate water conservation quantities are projected to be approximately 31.1 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 351.9 billion gallons.

If all new constructed garden-style/low-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 49.5 billion gallons. By year 7, the total aggregate amount would approximately 476.5 billion gallons. Similarly, if all new constructed garden-style/low-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 122.8 billion gallons. By year 7, the total aggregate amount would approximately 905.1 billion gallons.

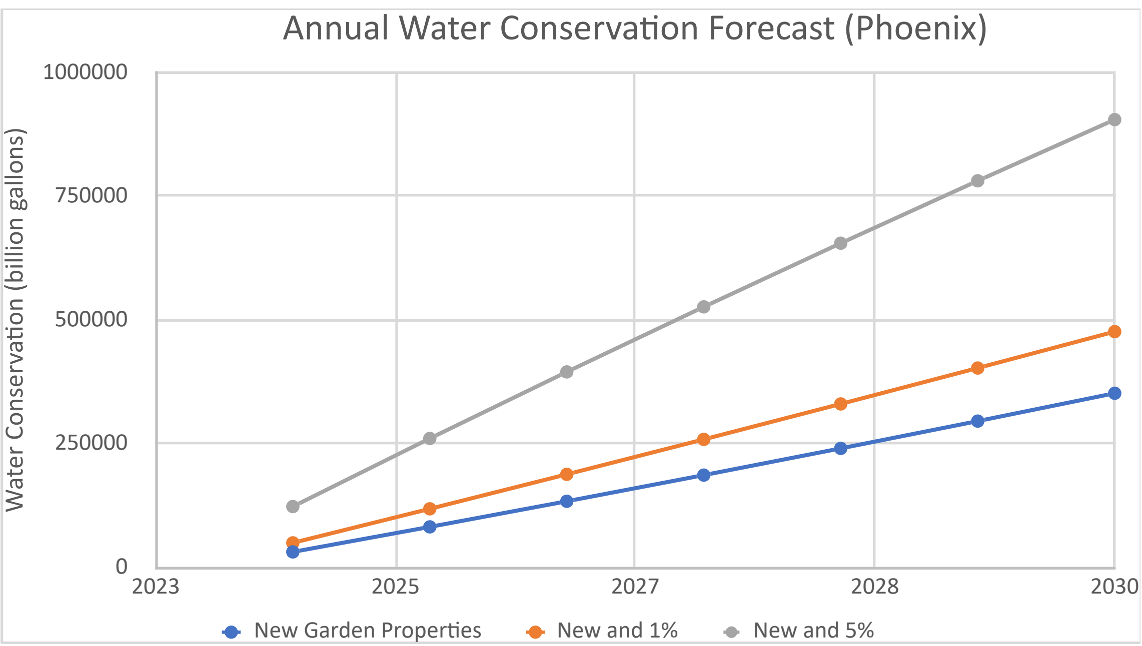


Figure XVI: Annual Aggregate Water Conservation Forecast for Garden-Style/Low-Rise Buildings in Phoenix

The following figures show that the adoption of the implementation of water-efficient fixtures in garden-style/low-rise buildings would be most beneficial for the city of Phoenix.

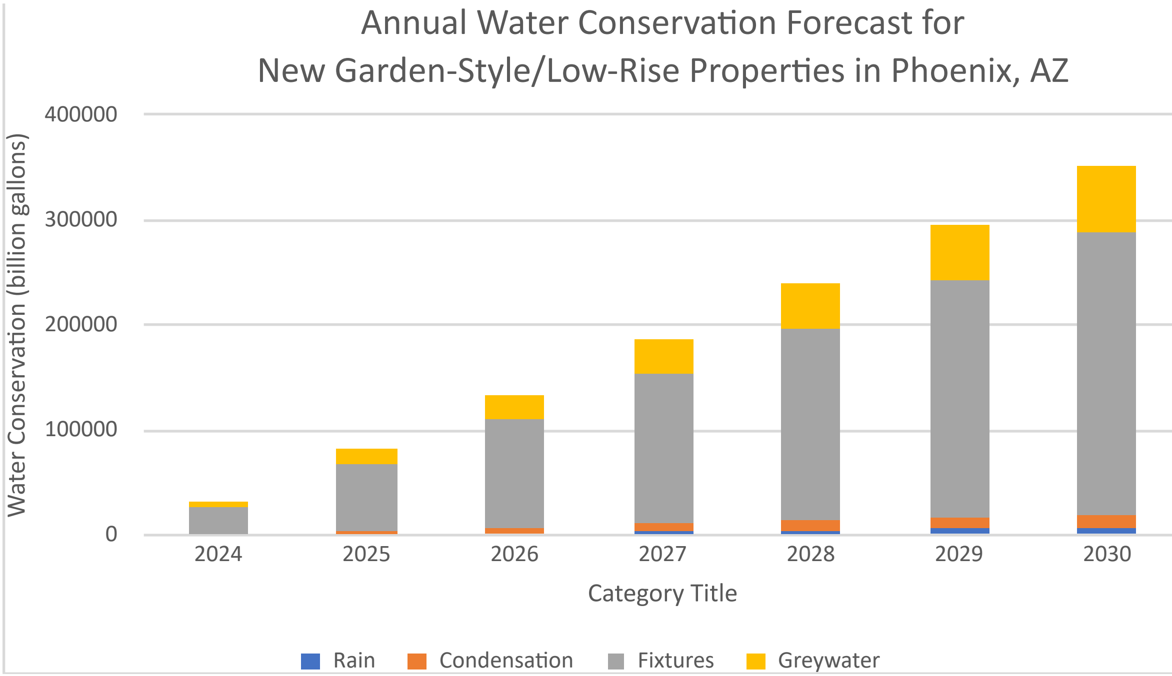


Figure XVII: Annual Water Conservation Forecast – Phoenix

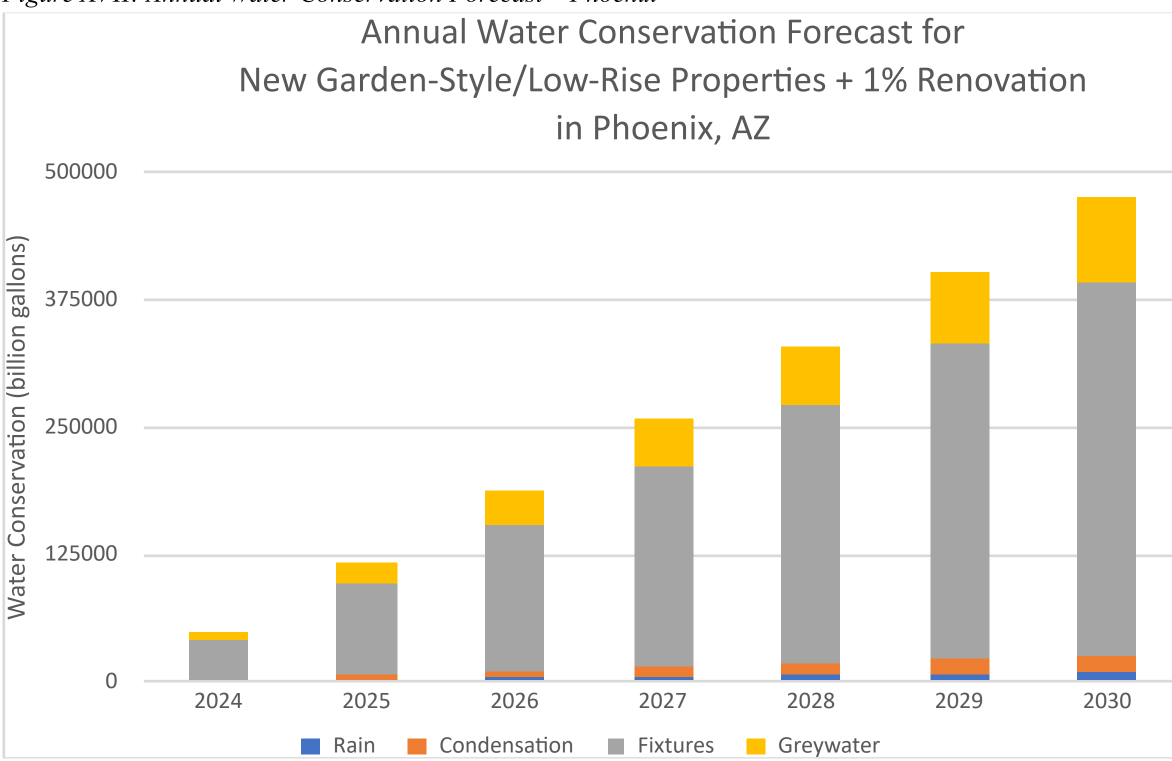


Figure XVIII: Annual Water Conservation Forecast – Phoenix

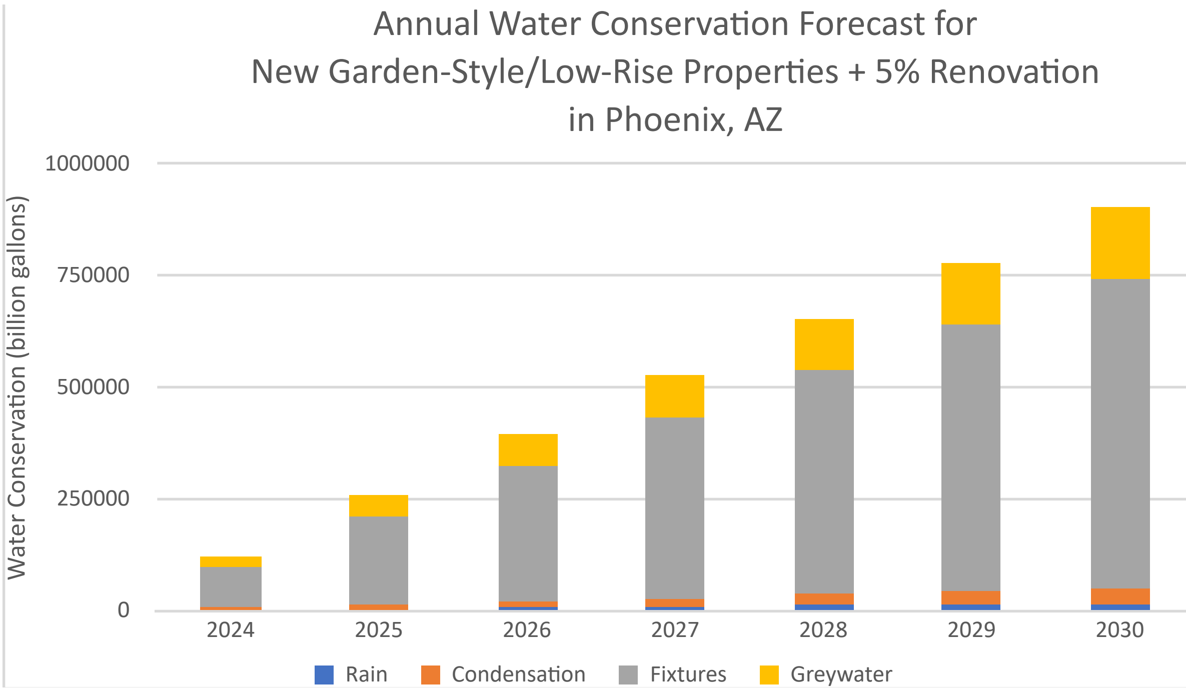


Figure XIX: Annual Water Conservation Forecast – Phoenix

1.3. Las Vegas

Below, Figure XX displays the annual aggregate water conservation forecast for garden-style/ low-rise properties in the city of Las Vegas where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new garden-style/ low-rise properties, the aggregate water conservation quantities are projected to be approximately 17.6 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 191.3 billion gallons.

If all newly constructed garden-style/low-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 29.7 billion gallons. By year 7, the total aggregate amount would be approximately 273.8 billion gallons.

Similarly, if all new constructed garden-style/low-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 78.3 billion gallons. By year 7, the total aggregate amount would be approximately 557.8 billion gallons.

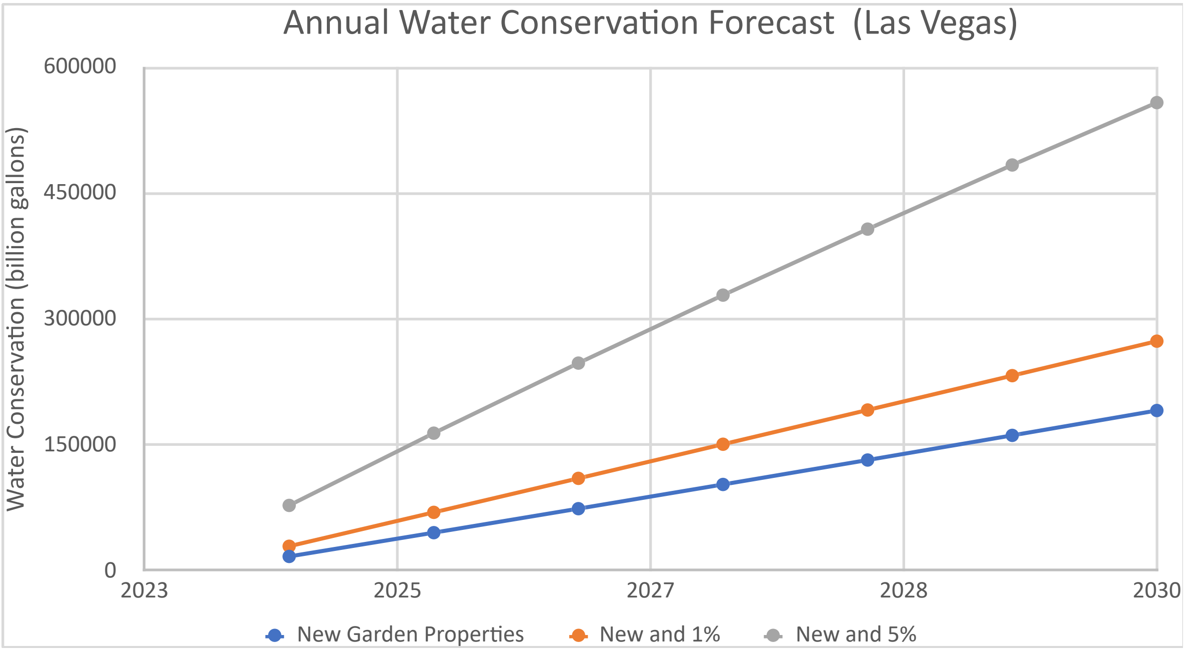


Figure XX: Annual Aggregate Water Conservation Forecast for Garden-Style/Low-Rise Buildings in Las Vegas

The following figures show that the main adoption of the implementation of water-efficient fixtures in garden-style/low-rise buildings would benefit the city of Las Vegas.

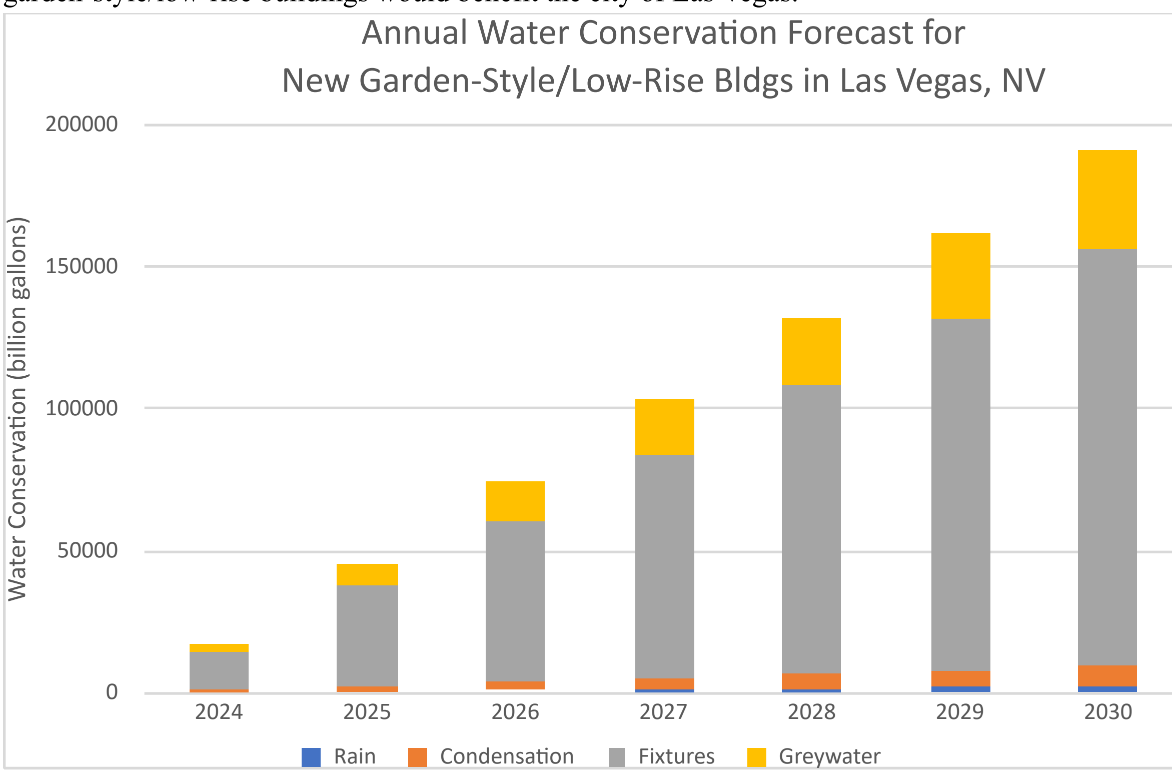


Figure XXI: Annual Water Conservation Forecast – Las Vegas

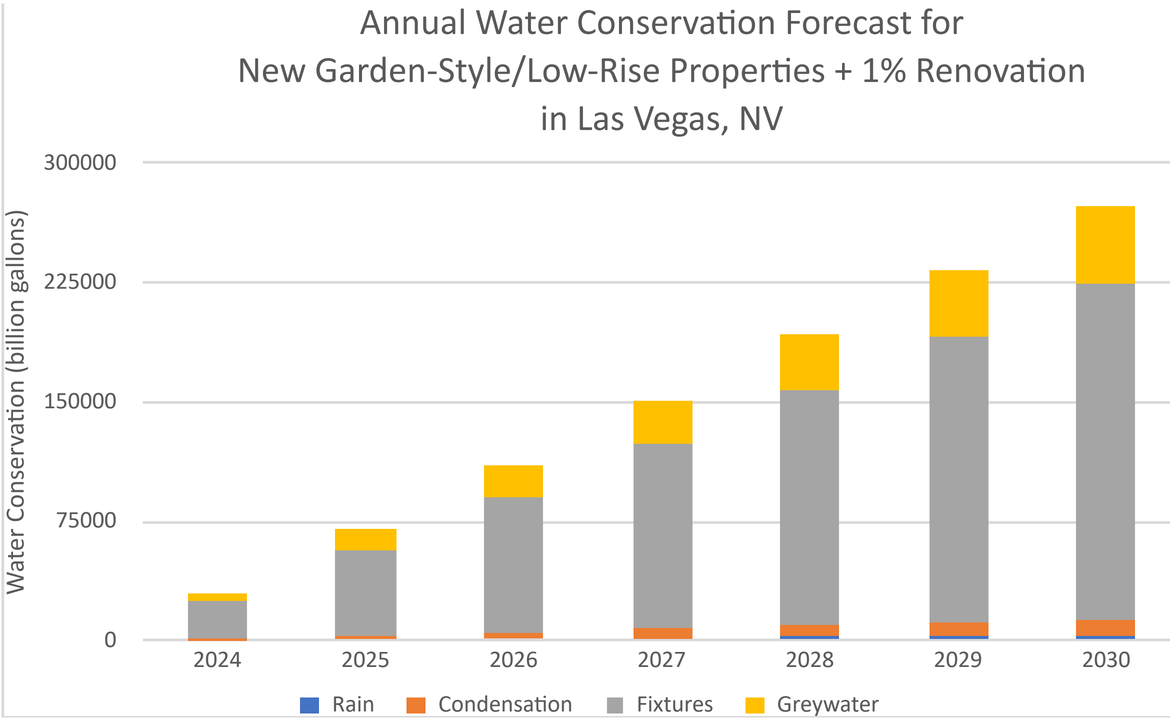


Figure XXII: Annual Water Conservation Forecast – Las Vegas

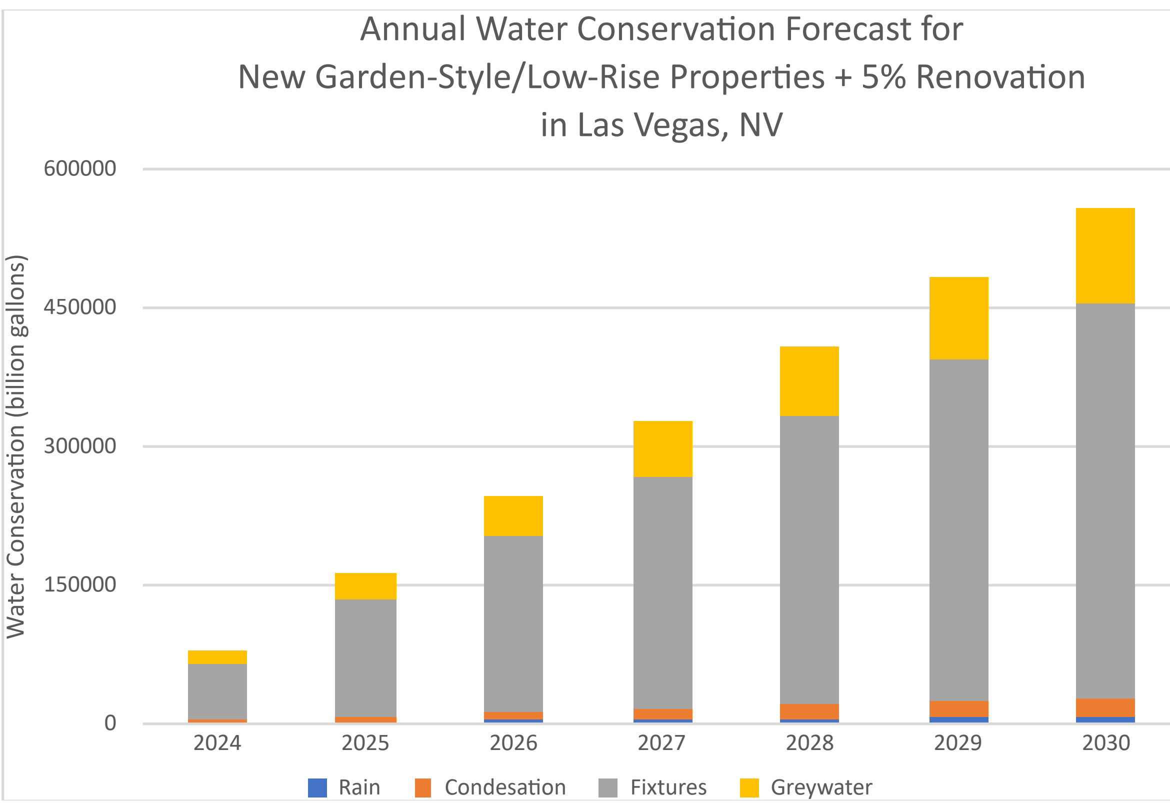


Figure XXIII: Annual Water Conservation Forecast – Las Vegas

1.4. Des Moines

Below, Figure XXIV displays the annual aggregate water conservation forecast for garden-style/ low-rise properties in the city of Des Moines where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new garden-style/ low-rise properties, the aggregate water conservation quantities are projected to be approximately 4.1 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 44.8 billion gallons.

If all newly constructed garden-style/low-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 5.6 billion gallons. By year 7, the total aggregate amount would approximately 54.9 billion gallons.

Similarly, if all new constructed garden-style/low-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 11.5 billion gallons. By year 7, the total aggregate amount would be approximately 89.7 billion gallons.

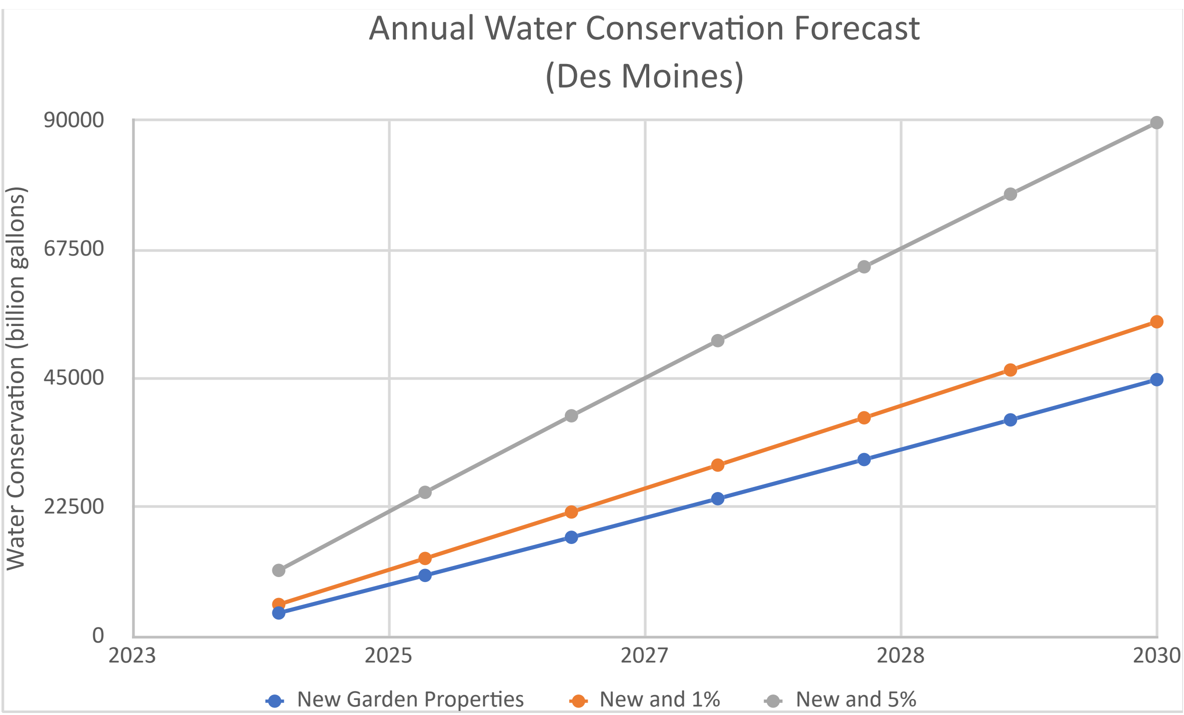


Figure XXIV: Annual Aggregate Water Conservation Forecast for Garden-Style/Low-Rise Buildings in Des Moines

The following figures show that the main adoption of the implementation of water-efficient fixtures in garden-style/low-rise buildings would mostly benefit the city of Des Moines.

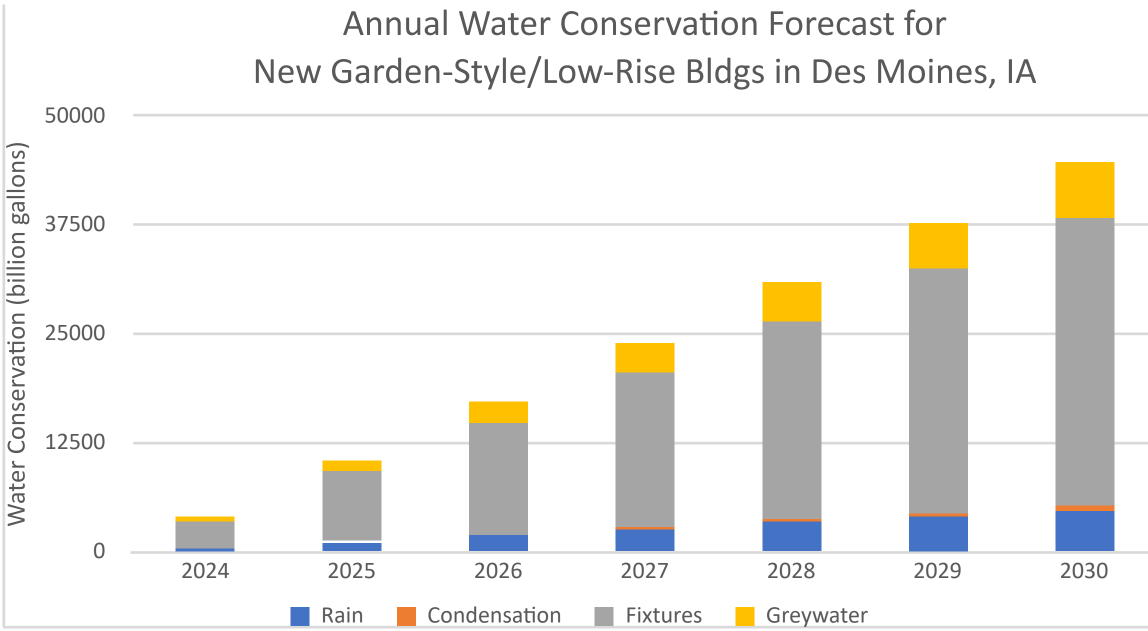


Figure XXV: Annual Water Conservation Forecast – Des Moines

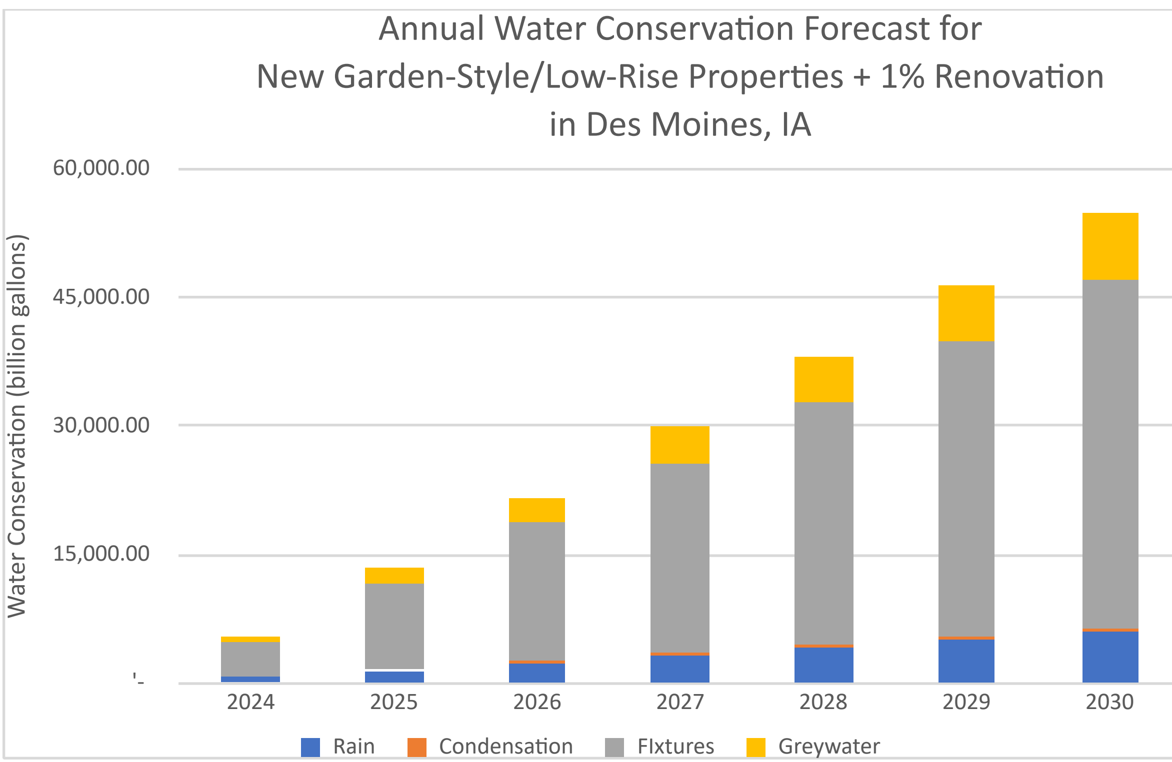


Figure XXVI: Annual Water Conservation Forecast – Des Moines

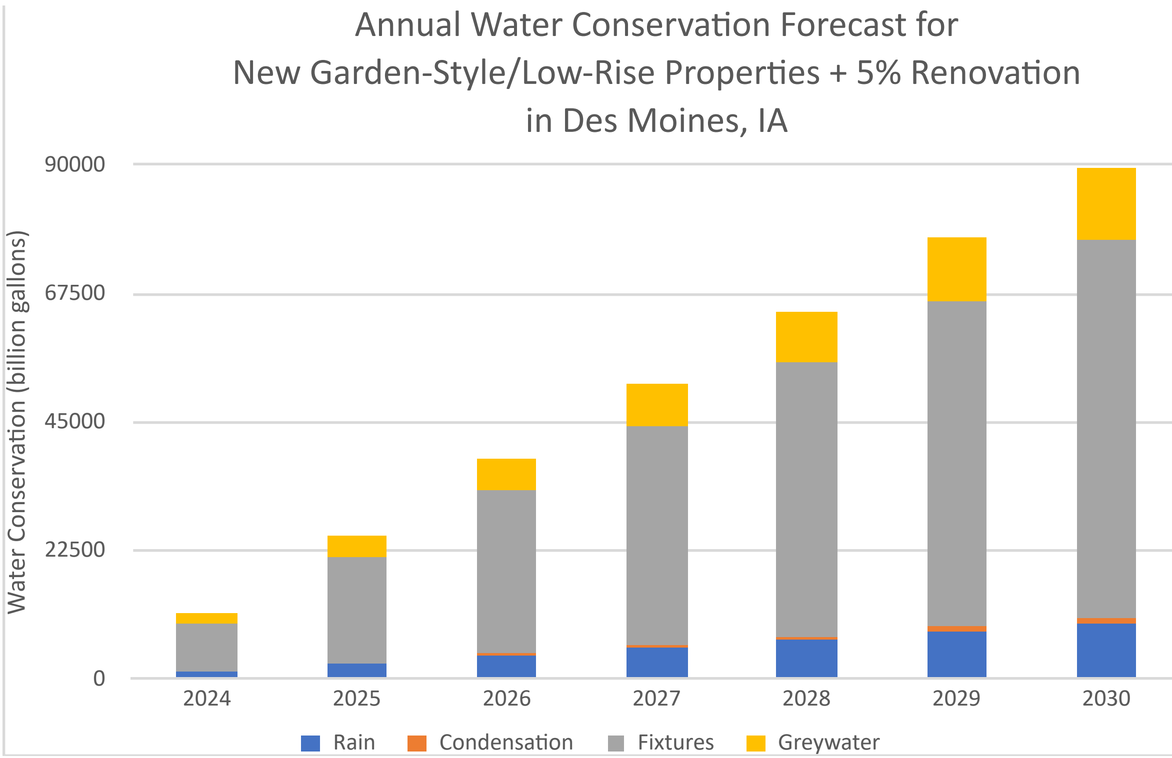


Figure XXVII: Annual Water Conservation Forecast – Des Moines

In all four cities, condensate harvesting was not optimal and showed to be nominal. However, although not comparable, greywater harvesting and rainfall harvesting could be alternative sources as well.

2. Mid-Rise Properties

Below, forecasting of mid-rise properties within each city are shown as well as the adoption of these measures each quarter until the year 2030 by new buildings and the inclusion of one percent and five percent of the renovated buildings.

As for the Annual Water Conservation Forecast graphs, the quantities of each measure are retained within the specified color block of the graph and not compounded or shown as an overlay.

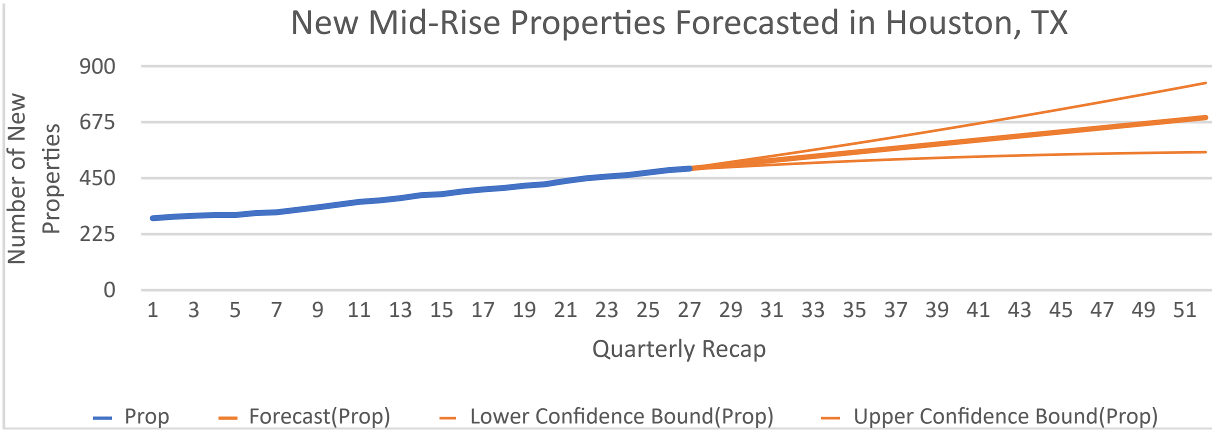


Figure XXVIII: Historic New Mid-Rise Properties Construction Trend and Projected Future Trajectory – Houston

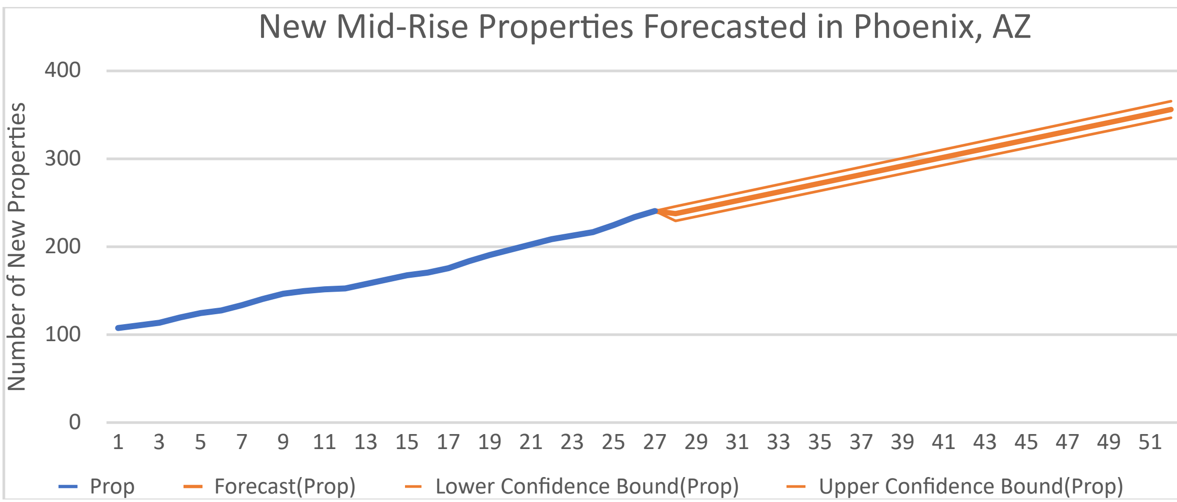


Figure XXIX: Historic New Mid-Rise Properties Construction Trend and Projected Future Trajectory – Phoenix

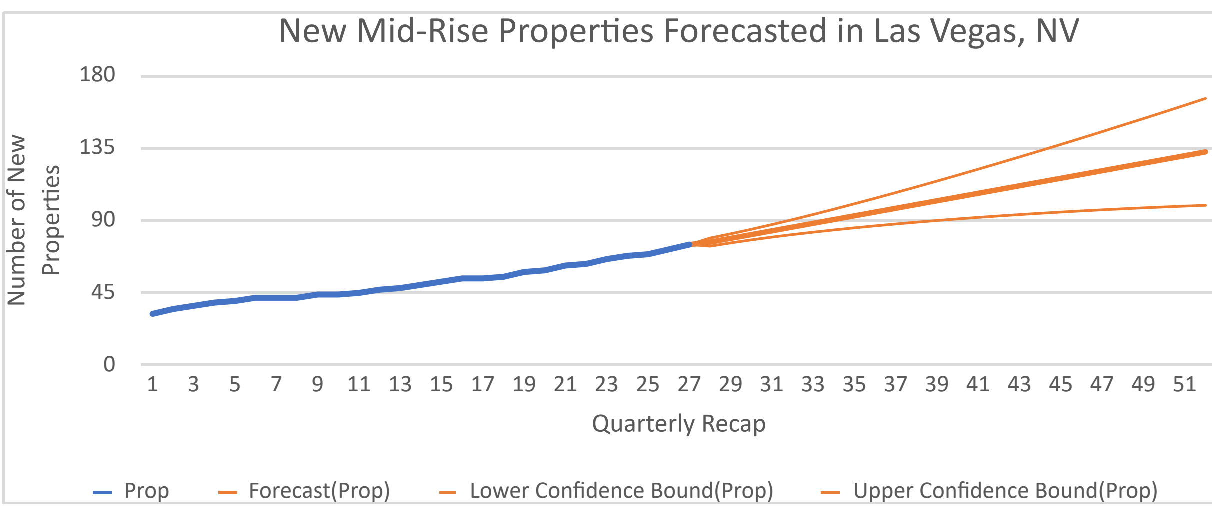
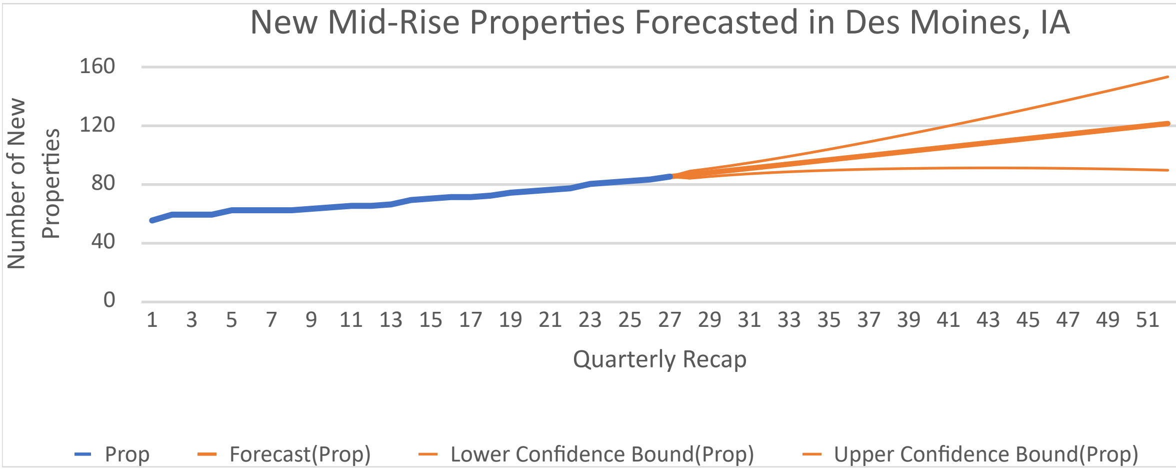


Figure XXX: Historic New Mid-Rise Properties Construction Trend and Projected Future Trajectory – Las Vegas

Figure XXXI: Historic New Mid-Rise Properties Construction Trend and Projected Future Trajectory – Des Moines



2.1. Houston

Below, Figure XXXII displays the annual aggregate water conservation forecast for mid-rise properties in the city of Houston where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new mid-rise properties, the aggregate water conservation quantities are projected to be approximately 9.8 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 124.8 billion gallons.

If all newly constructed mid-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 18.6 billion gallons. By year 7, the total aggregate amount would approximately 184.1 billion gallons. Similarly, if all new constructed mid-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 53.5 billion gallons. By year 7, the total aggregate amount would approximately 388.2 billion gallons.

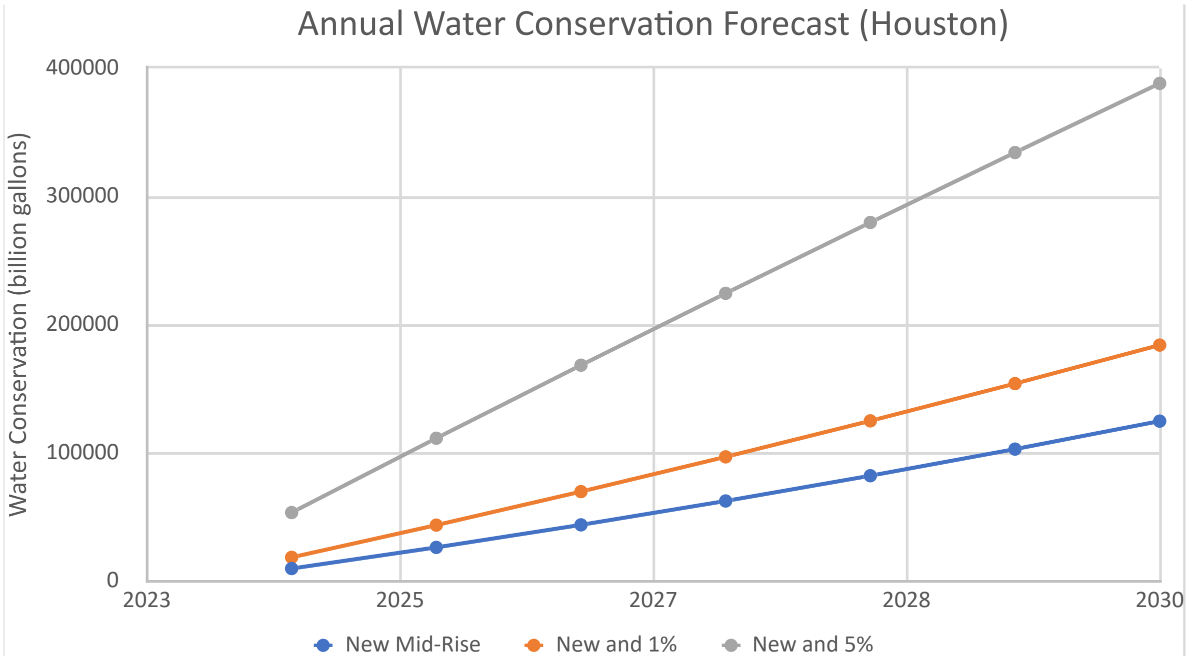


Figure XXXII: Houston Scaled-up Water Conservation Analysis

The following figures show that the main adoption of implementation of water-efficient fixtures would be of most significance to the city of Houston.

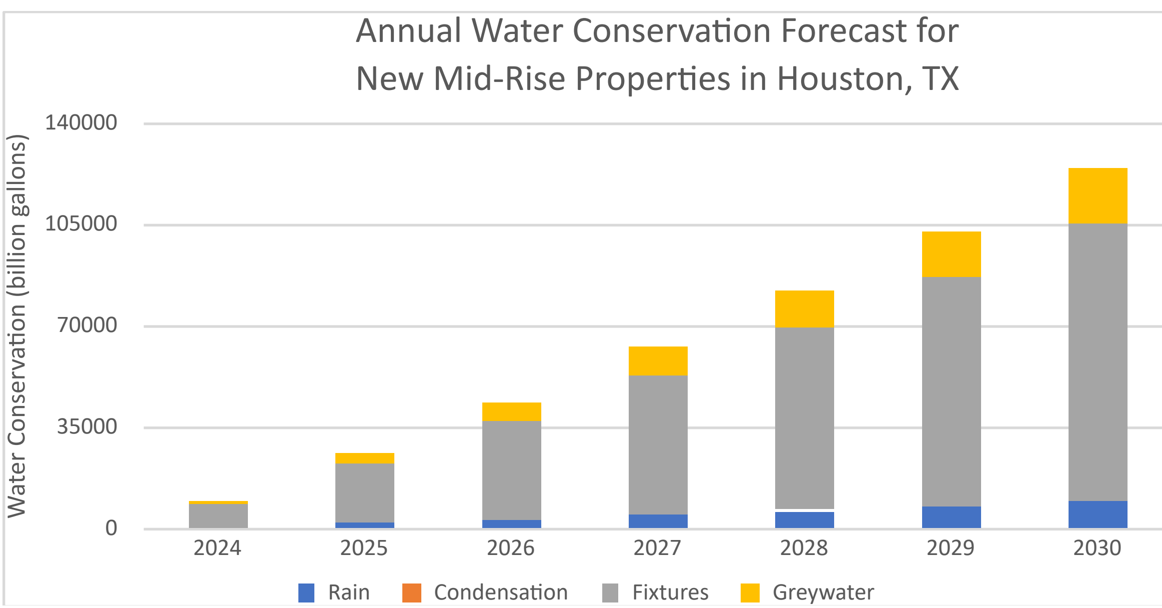


Figure XXXIII: Annual Water Conservation Forecast – Houston

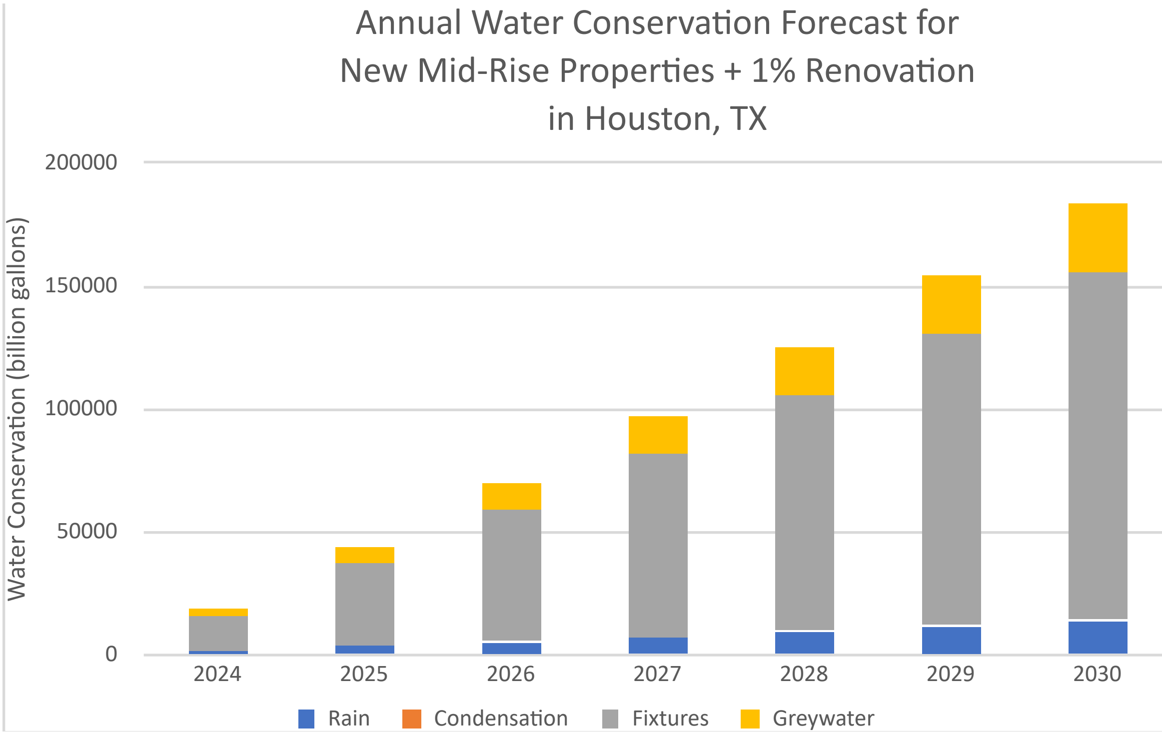


Figure XXXIV: Annual Water Conservation Forecast – Houston

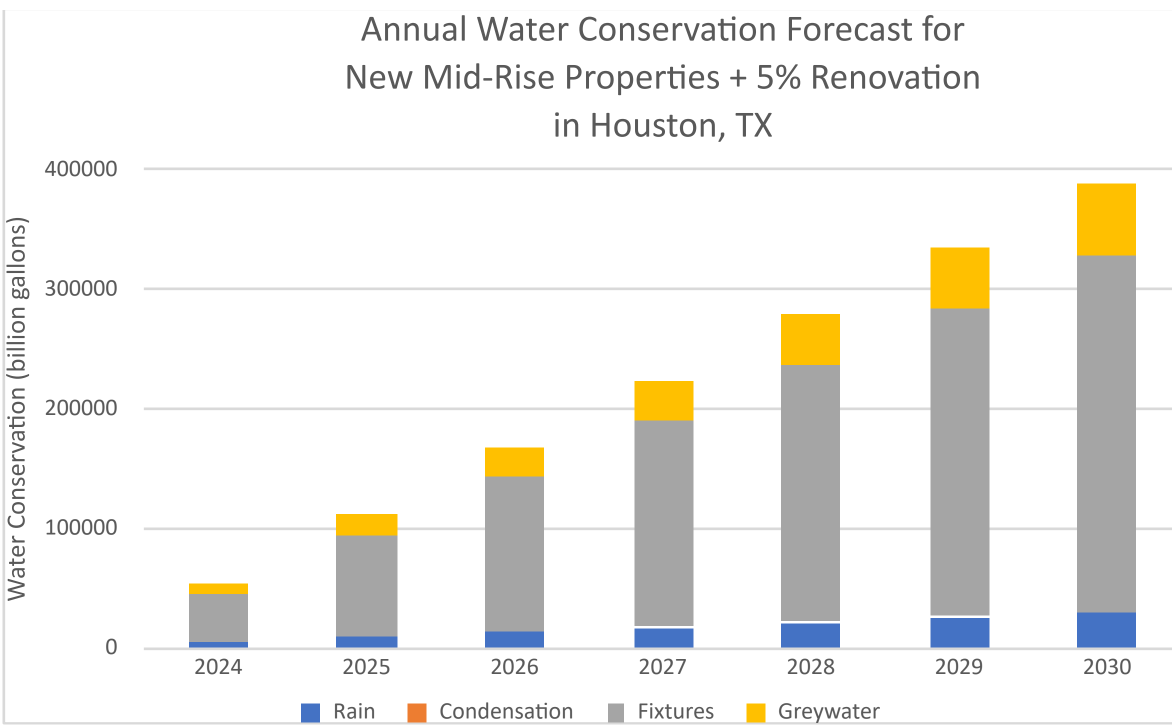


Figure XXXV: Annual Water Conservation Forecast – Houston

2.2. Phoenix

Below, Figure XXXVI displays the annual aggregate water conservation forecast for mid-rise properties in the city of Phoenix where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new mid-rise properties, the aggregate water conservation quantities are projected to be approximately 4.3 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 56.0 billion gallons.

If all newly constructed mid-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 7.6 billion gallons. By year 7, the total aggregate amount would be approximately 78.9 billion gallons.

Similarly, if all new constructed mid-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 21.1 billion gallons. By year 7, the total aggregate amount would approximately 157.6 billion gallons.

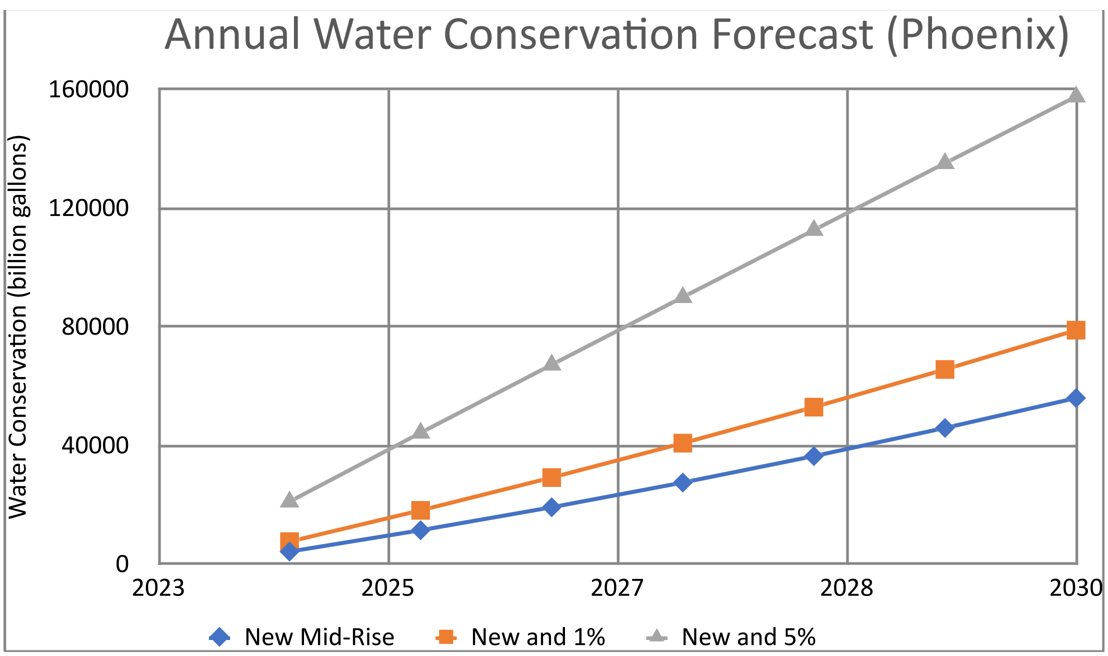


Figure XXXVI: Phoenix Scaled-up Water Conservation Analysis

The following figures show that the main adoption of implementation of water-efficient fixtures and greywater harvesting would benefit the city of Phoenix.

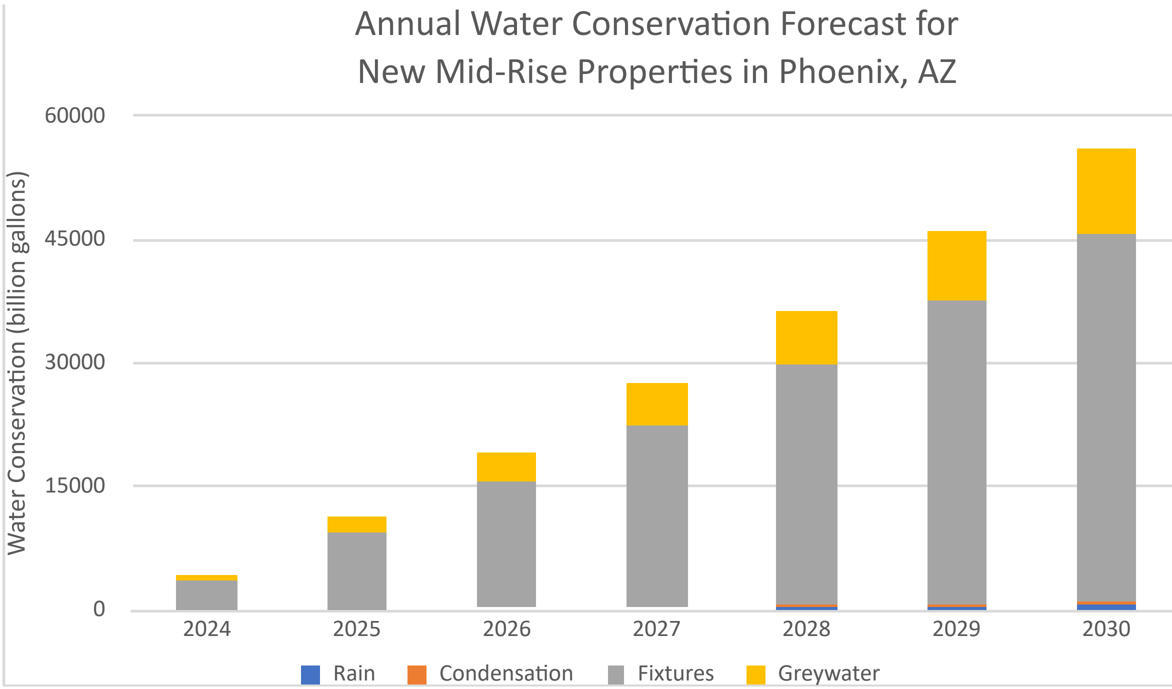


Figure XXXVII: Annual Water Conservation Forecast – Phoenix

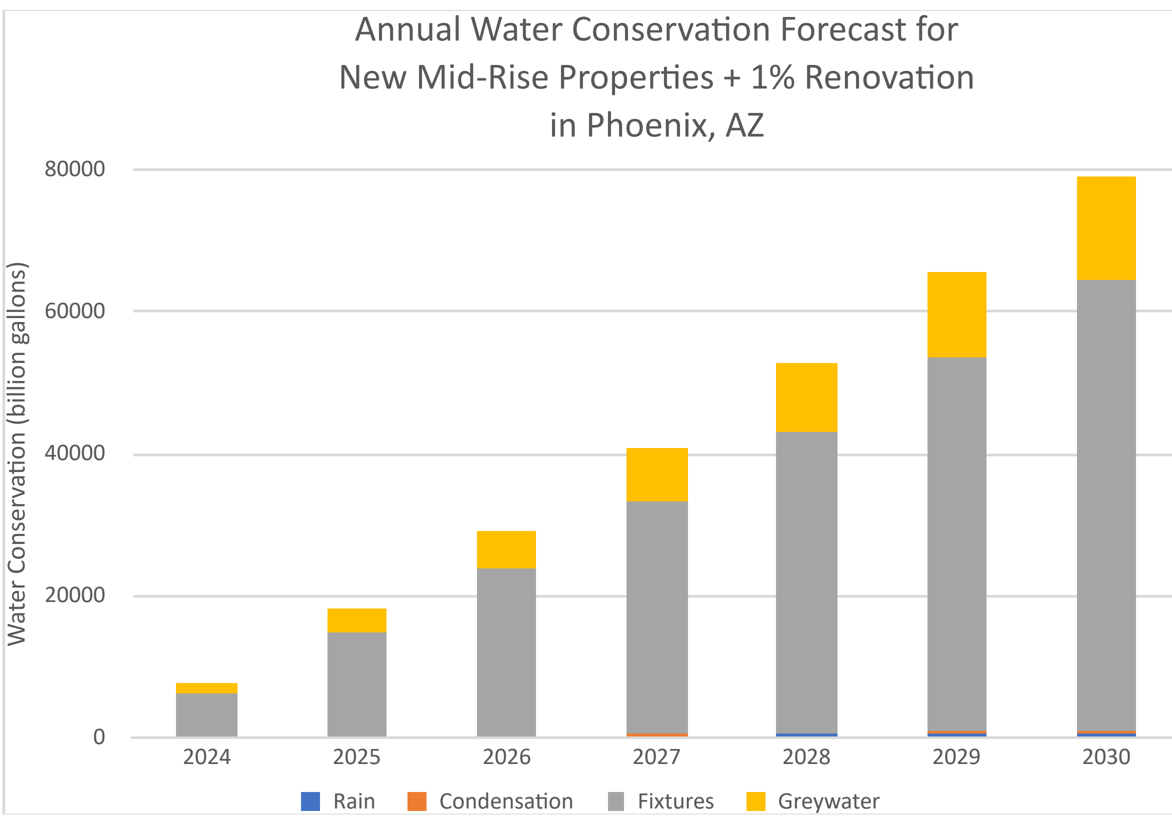


Figure XXXVIII: Annual Water Conservation Forecast – Phoenix

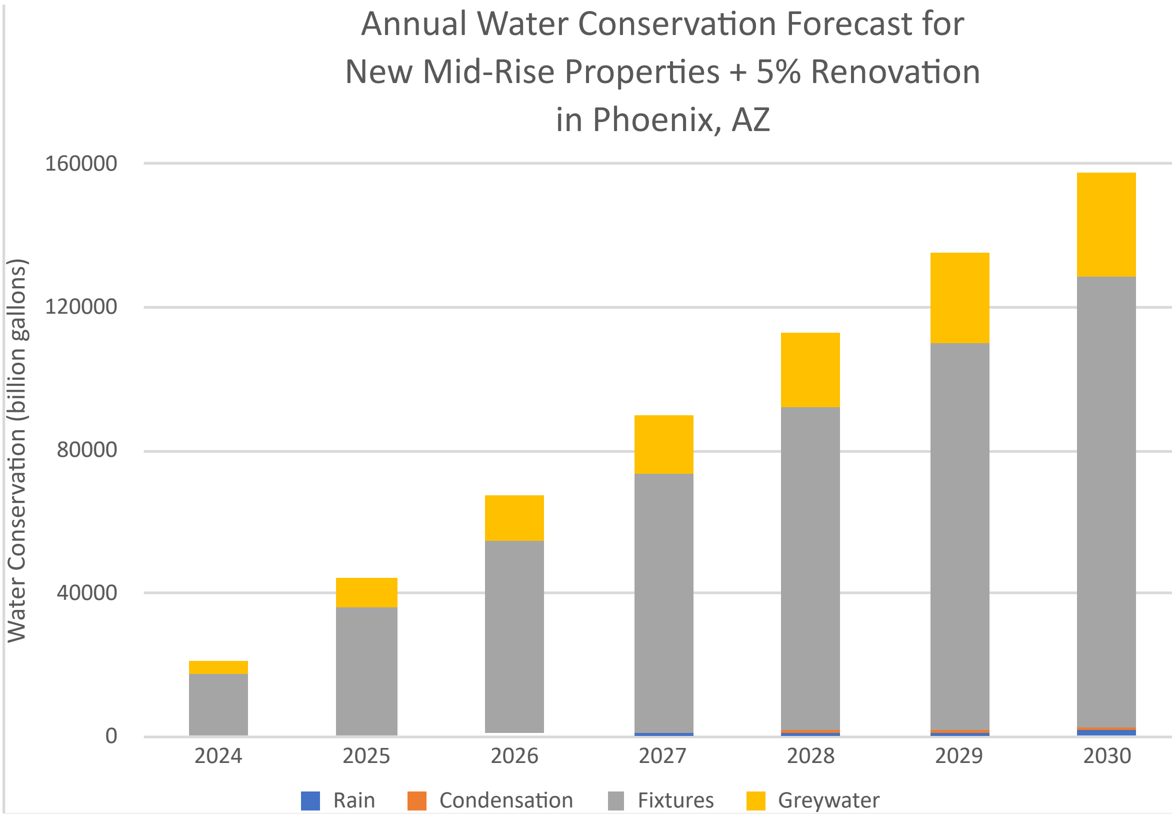


Figure XXXIX: Annual Water Conservation Forecast – Phoenix

2.3. Las Vegas

Below, Figure XL displays the annual aggregate water conservation forecast for mid-rise properties in the city of Las Vegas where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new mid-rise properties, the aggregate water conservation quantities are projected to be approximately 1.3 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 19.1 billion gallons.

If all new constructed mid-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 2.3 billion gallons. By year 7, the total aggregate amount would be approximately 25.7 billion gallons.

Similarly, if all newly constructed mid-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 6.2 billion gallons. By year 7, the total aggregate amount would be approximately 48.3 billion gallons.

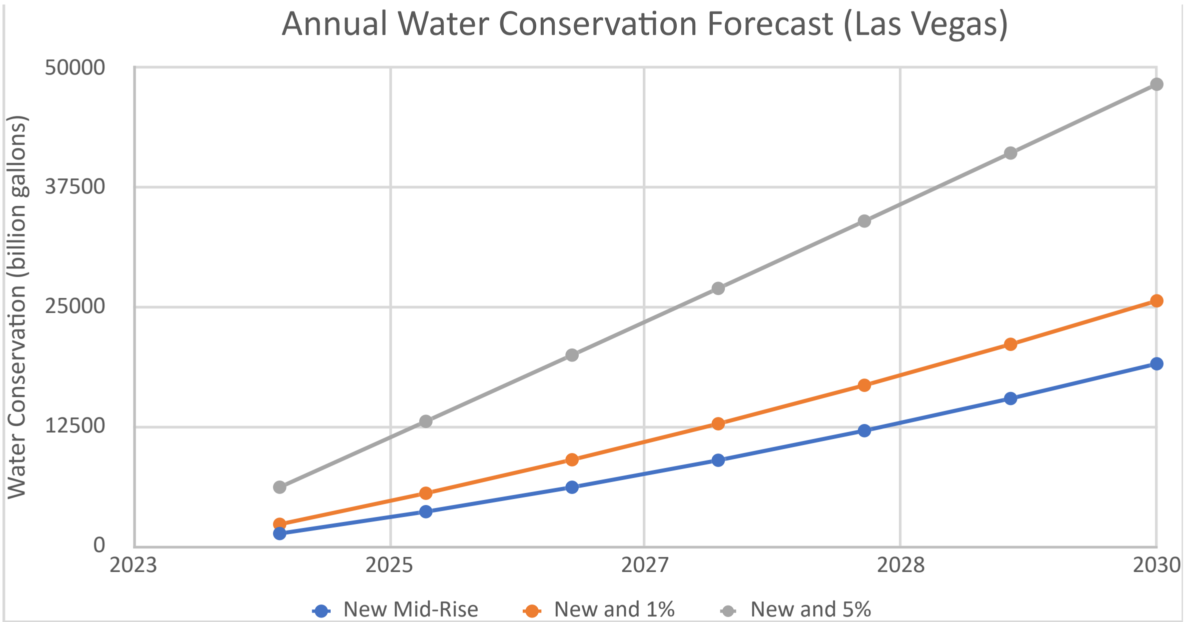


Figure XL: Las Vegas Scaled-up Water Conservation Analysis

The following figures show that the adoption of implementation of water-efficient fixtures and greywater harvesting would benefit the city of Las Vegas.

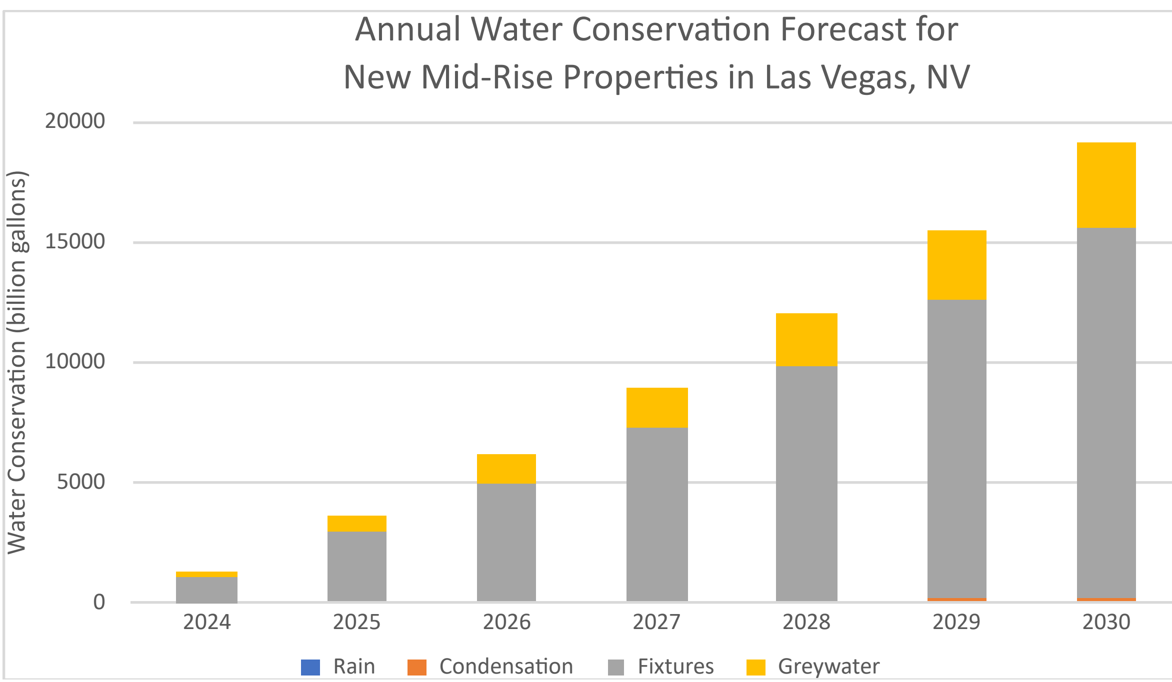


Figure XLI: Annual Water Conservation Forecast – Las Vegas

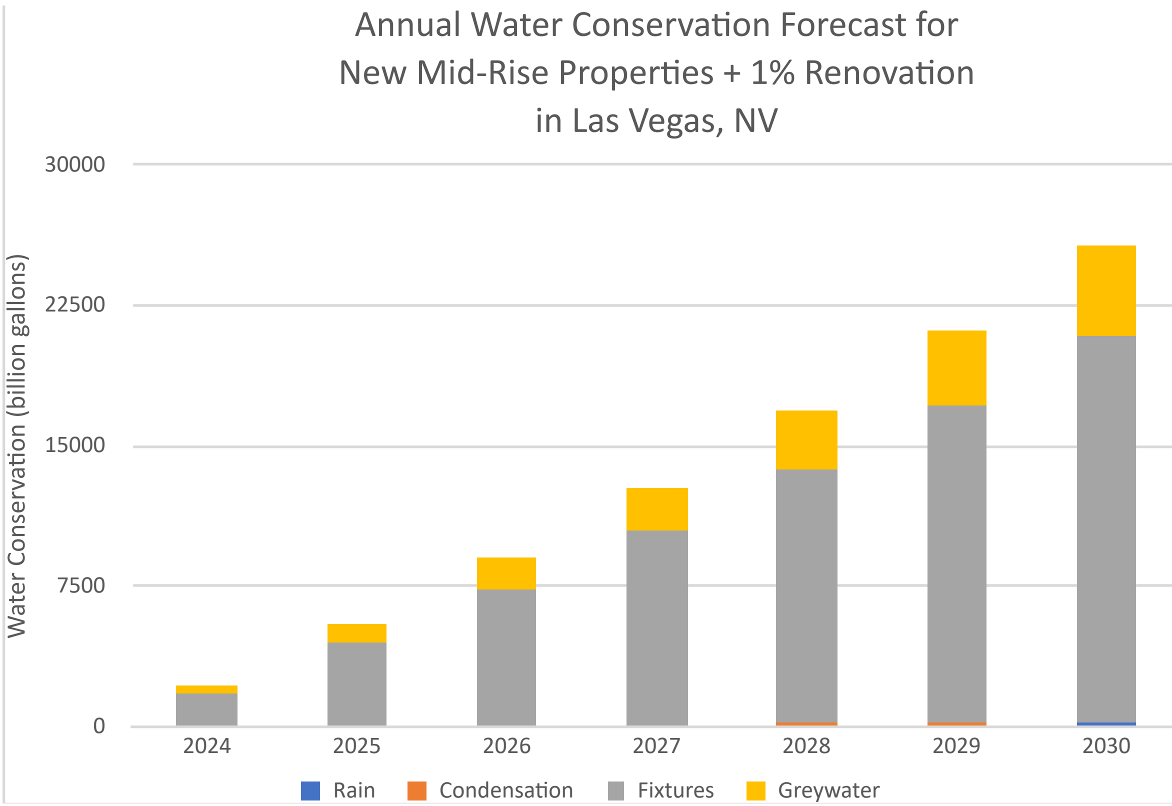


Figure XLII: Annual Water Conservation Forecast – Las Vegas

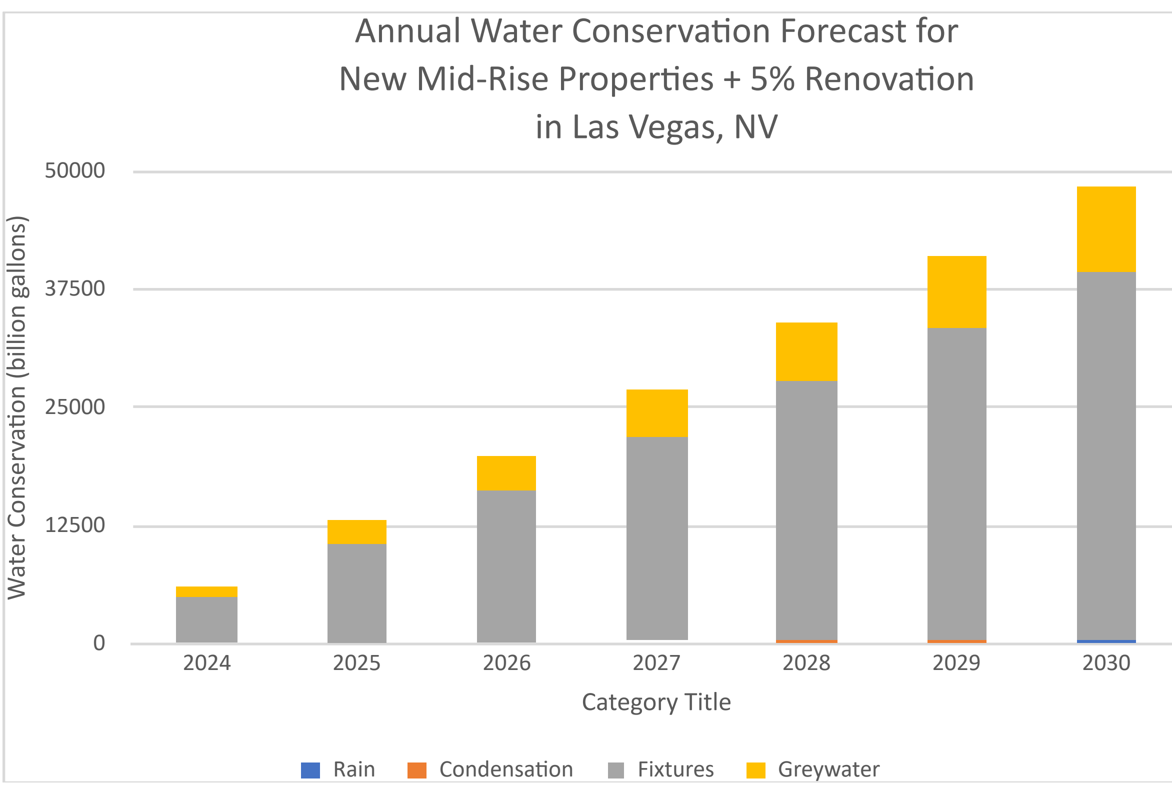


Figure XLIII: Annual Water Conservation Forecast – Las Vegas

2.4. Des Moines

Below, Figure XLIV displays the annual aggregate water conservation forecast for mid-rise properties in the city of Des Moines where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new mid-rise properties, the aggregate water conservation quantities are projected to be approximately 0.7 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 8.7 billion gallons.

If all newly constructed mid-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 0.9 billion gallons. By year 7, the total aggregate amount would be approximately 10.4 billion gallons.

Similarly, if all new constructed mid-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 2.0 billion gallons. By year 7, the total aggregate amount would be approximately 16.4 billion gallons.

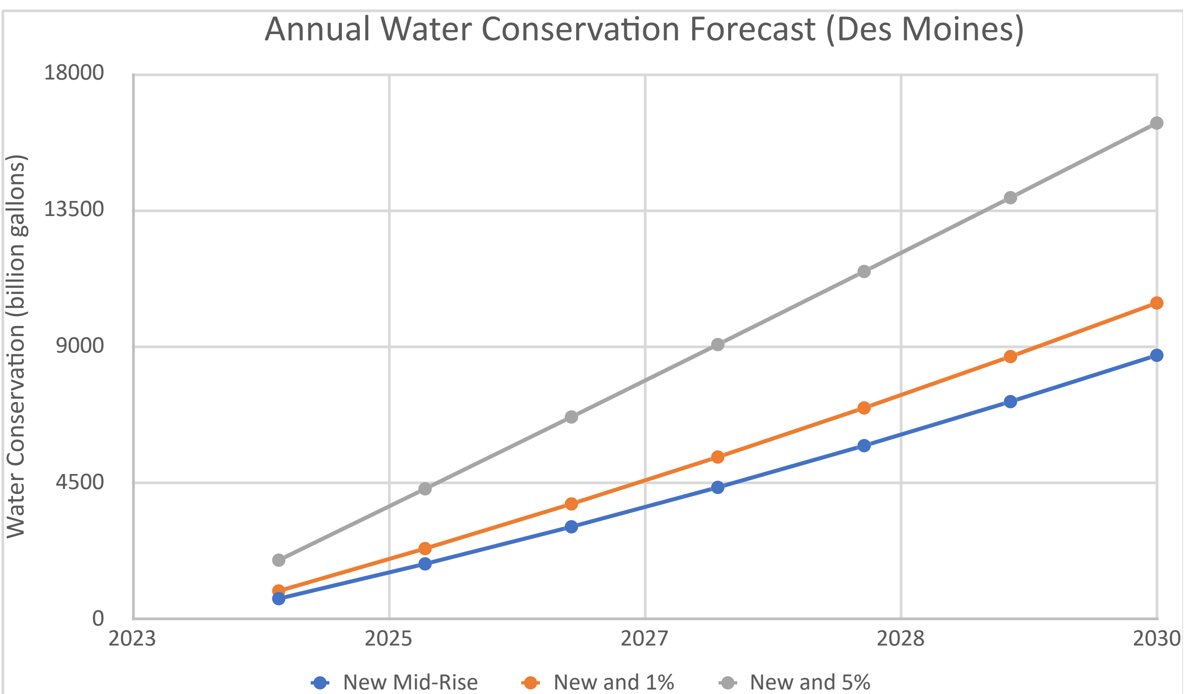


Figure XLIV: Des Moines Scaled-up Water Conservation Analysis

The following figures show that the adoption of implementation of water-efficient fixtures followed by greywater harvesting would benefit the city of Des Moines.

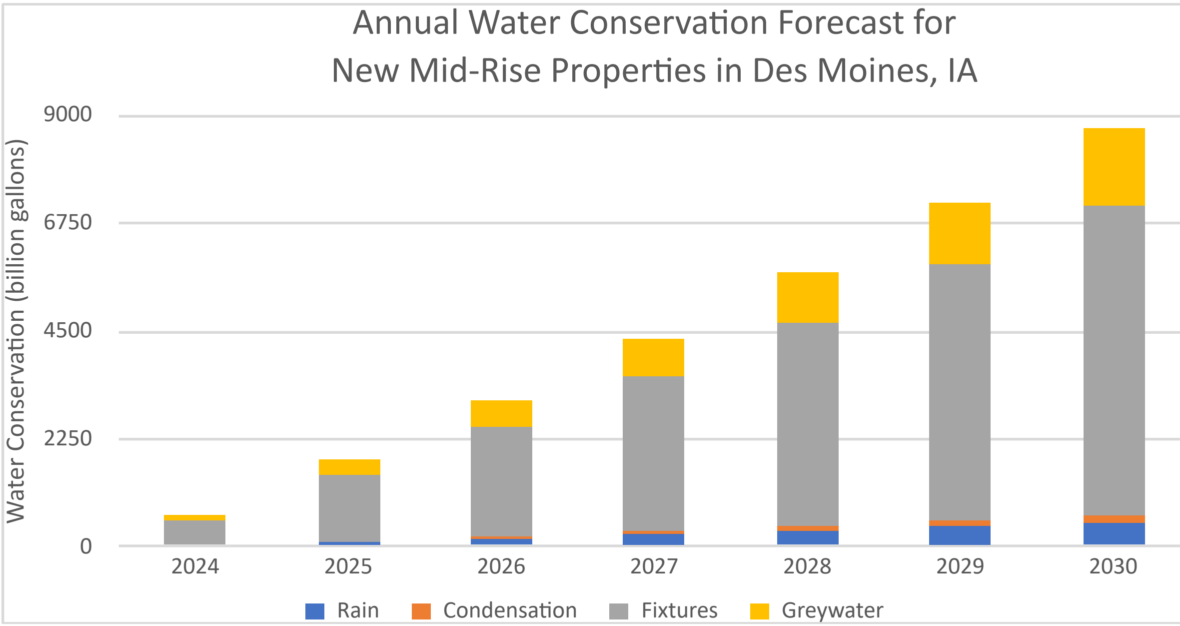


Figure XLV: Annual Water Conservation Forecast – Des Moines

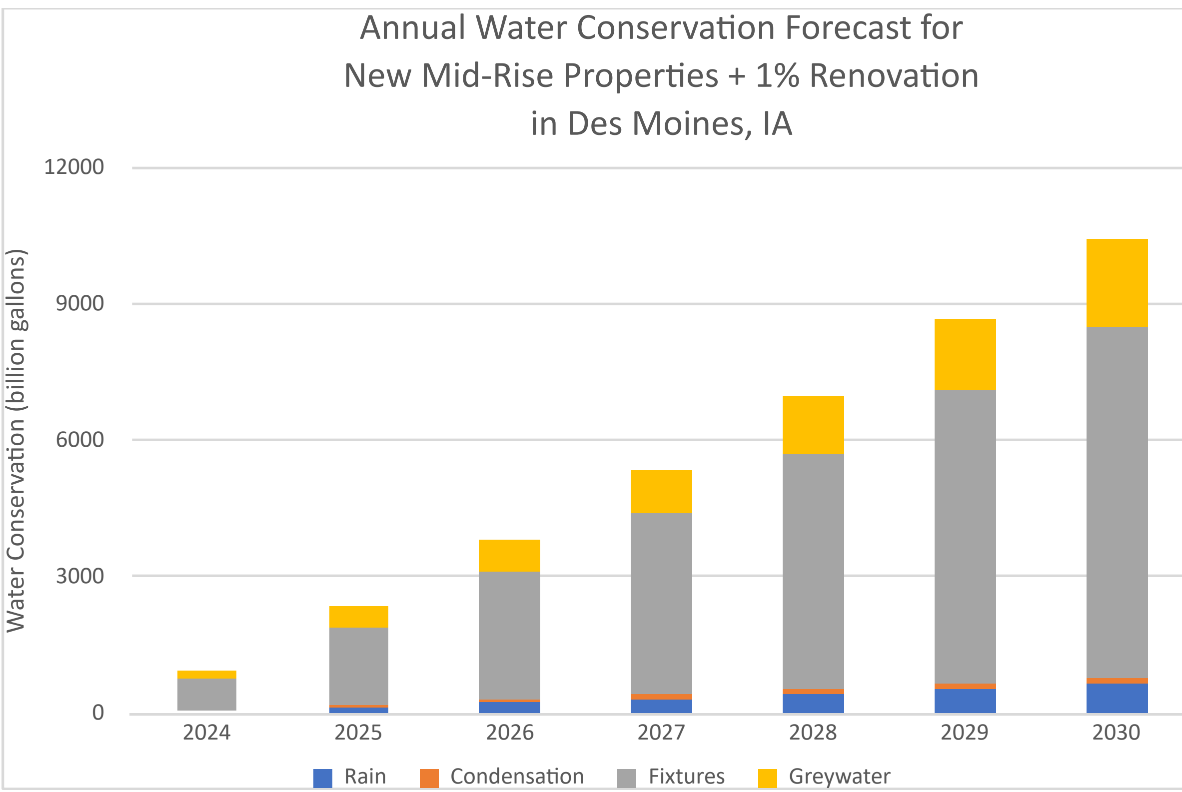


Figure XLVI: Annual Water Conservation Forecast – Des Moines

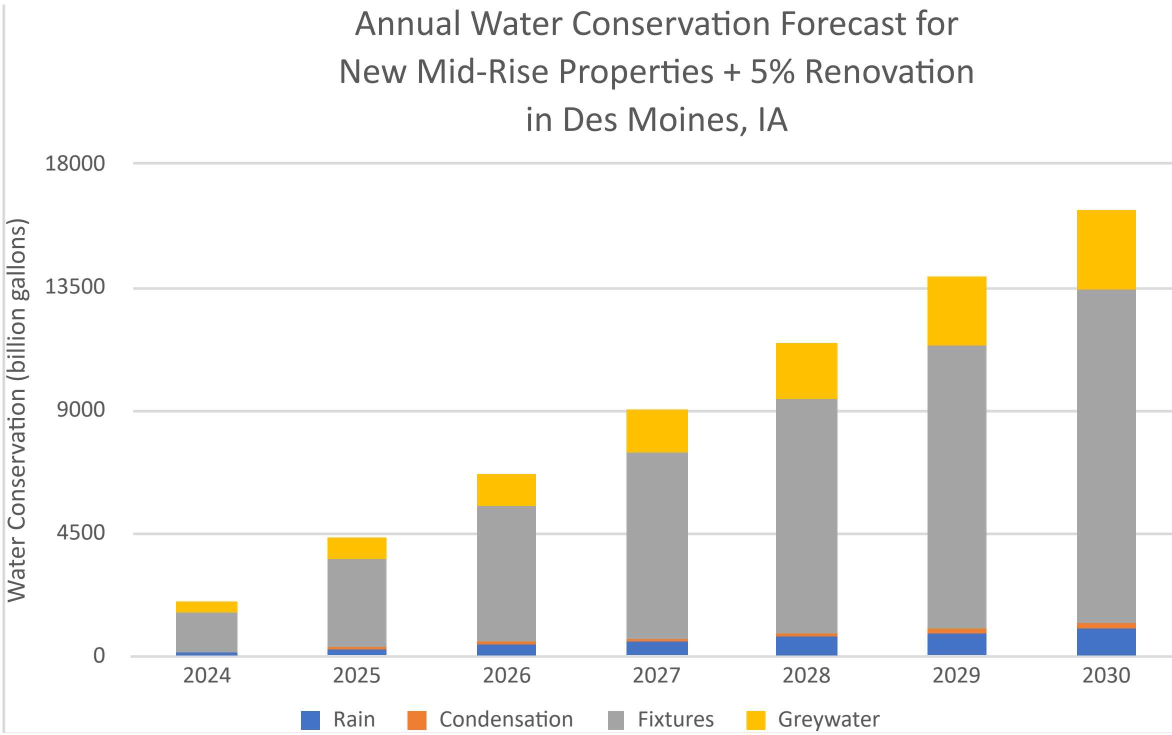


Figure XLVII: Annual Water Conservation Forecast – Des Moines

3. High-Rise Properties

Below, forecasting of high-rise properties within each city are shown as well as the adoption of these measures each quarter until the year 2030 by new buildings and the inclusion of one percent and five percent of the renovated buildings.

As for the Annual Water Conservation Forecast graphs, the quantities of each measure are retained within the specified color block of the graph and not compounded or shown as an overlay.

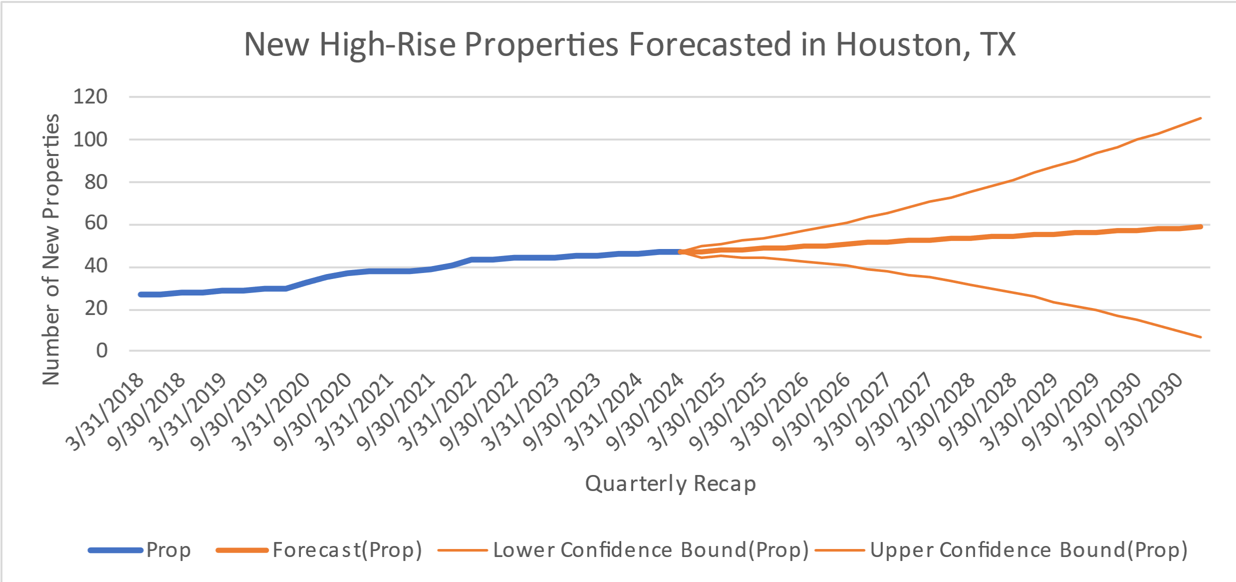


Figure XLVIII: Historic New High-Rise Buildings Construction Trend and Projected Future Trajectory – Houston

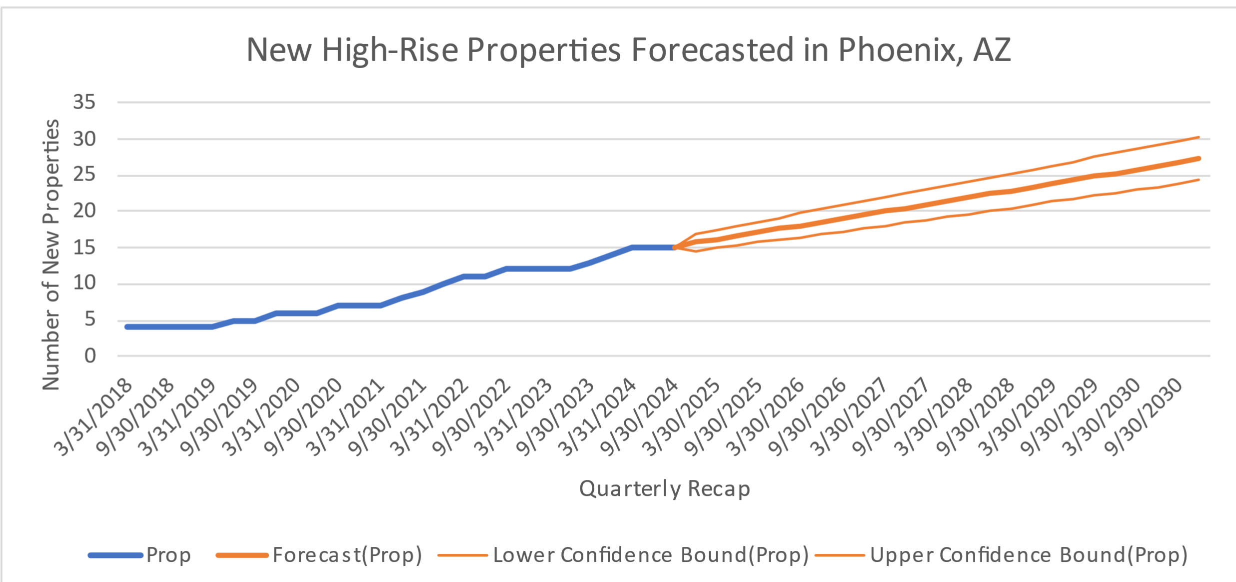


Figure XLIX: Historic New High-Rise Buildings Construction Trend and Projected Future Trajectory – Phoenix

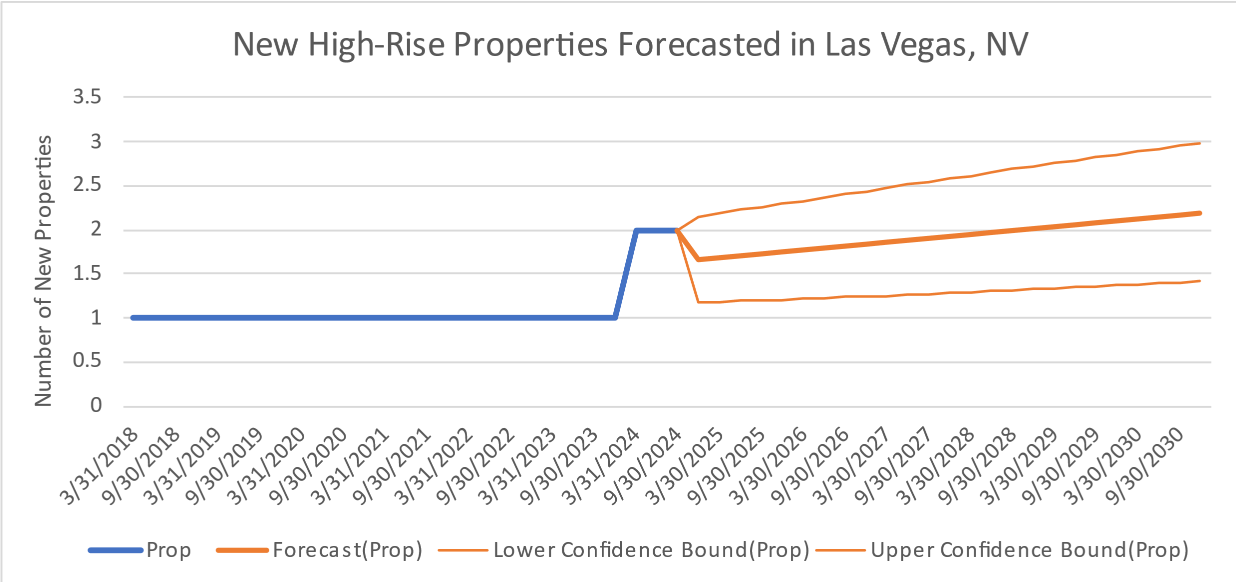


Figure L: Historic New High-Rise Buildings Construction Trend and Projected Future Trajectory – Las Vegas

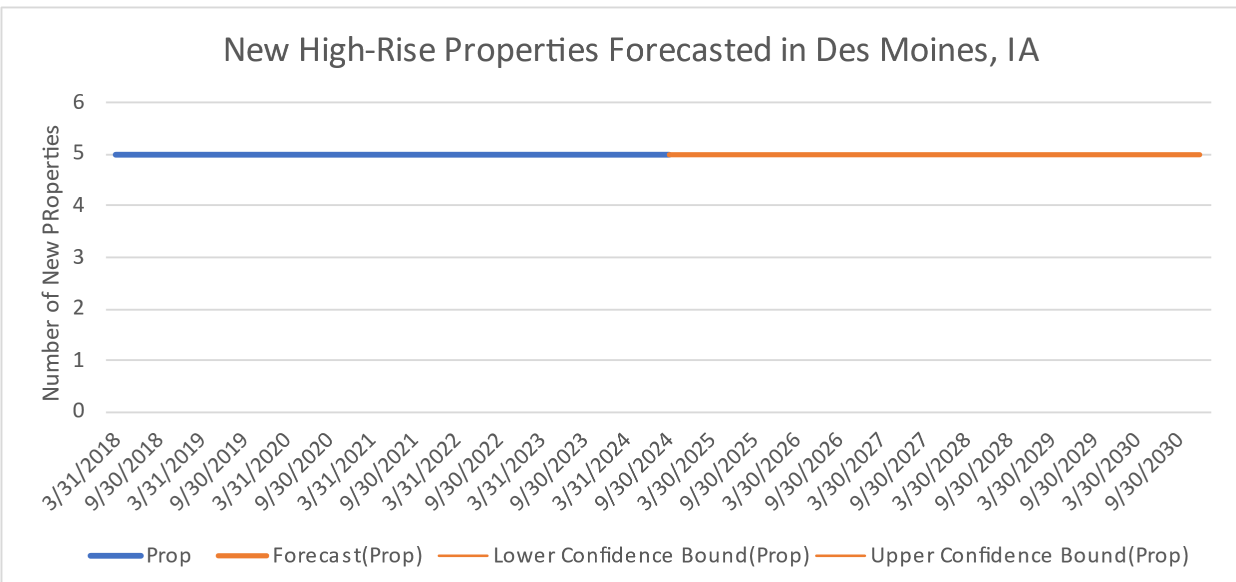


Figure LI: Historic New High-Rise Buildings Construction Trend and Projected Future Trajectory – Des Moines

3.1. Houston

Below, Figure LII displays the annual aggregate water conservation forecast for high-rise properties in the city of Houston where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new high-rise properties, the aggregate water conservation quantities are projected to be approximately 1.2 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 13.9 billion gallons.

If all new constructed high-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 2.5 billion gallons. By year 7, the total aggregate amount would be approximately 22.7 billion gallons.

Similarly, if all newly constructed mid-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 7.7 billion gallons. By year 7, the total aggregate amount would be approximately 53.1 billion gallons.

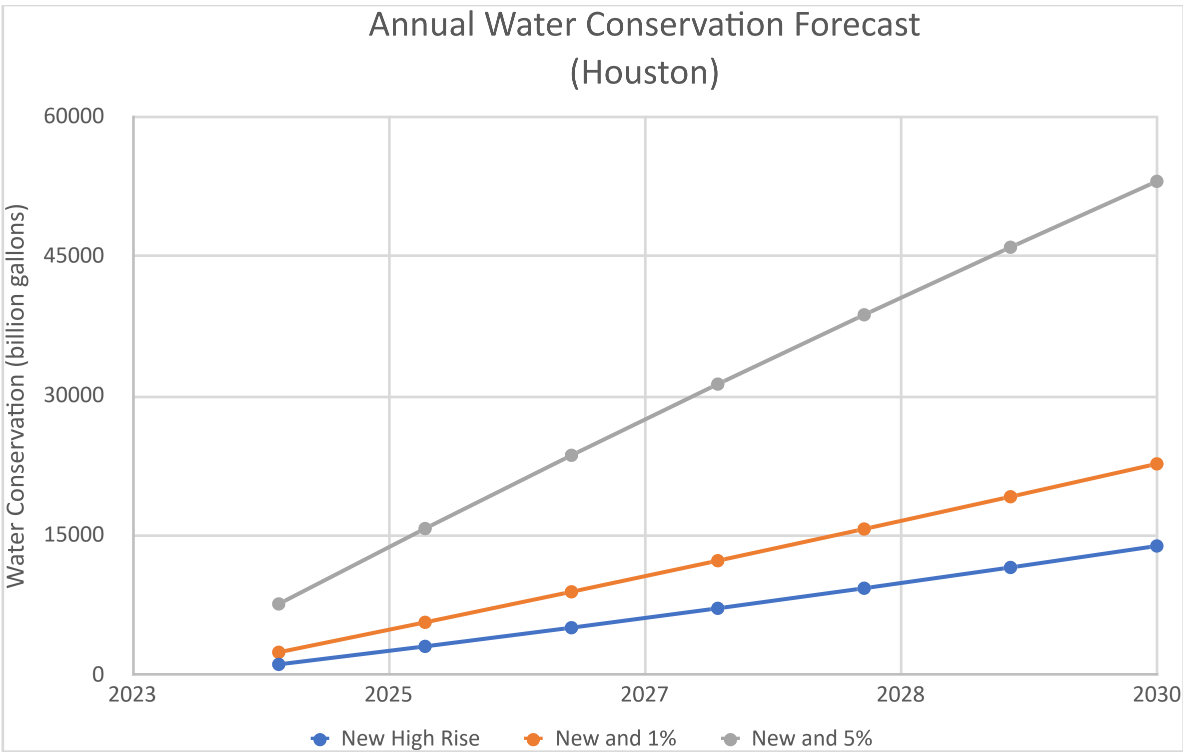


Figure LII: Houston Scaled-up Water Conservation Analysis

The following figures show that the main adoption of the implementation of water-efficient fixtures followed by greywater harvesting would pose to be of significant benefits to the city of Houston.

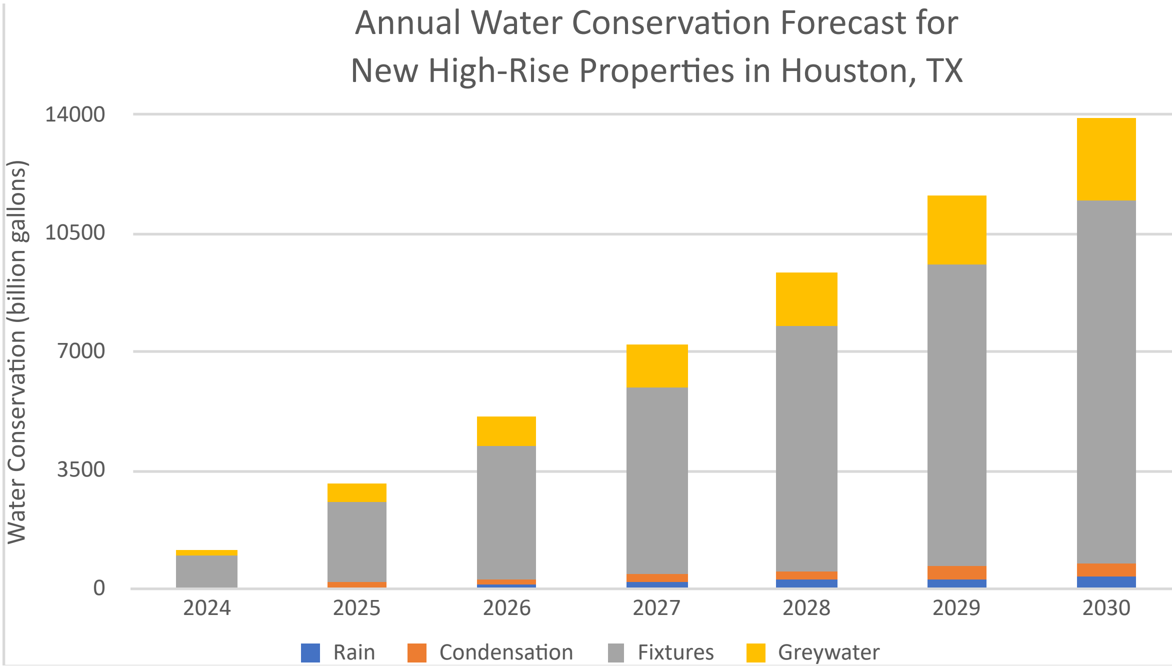


Figure LIII: Annual Water Conservation Forecast – Houston

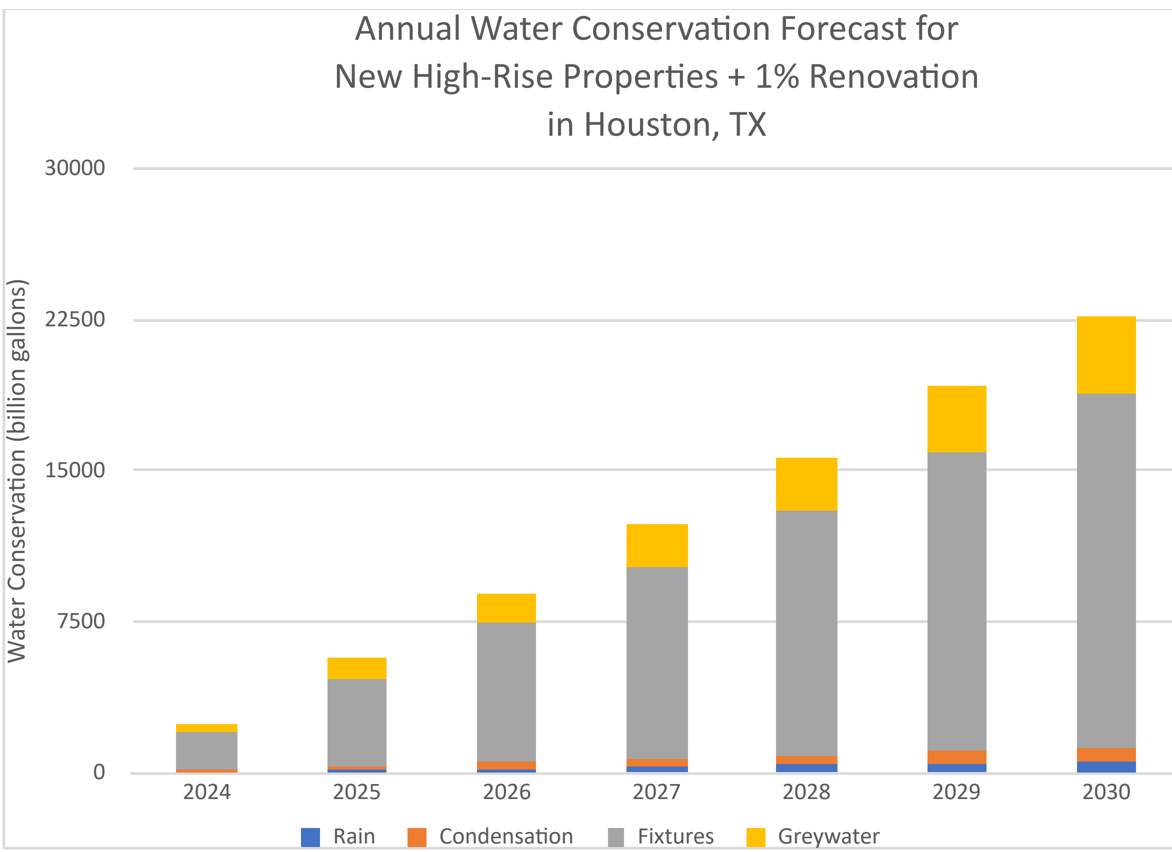


Figure LIV: Annual Water Conservation Forecast – Houston

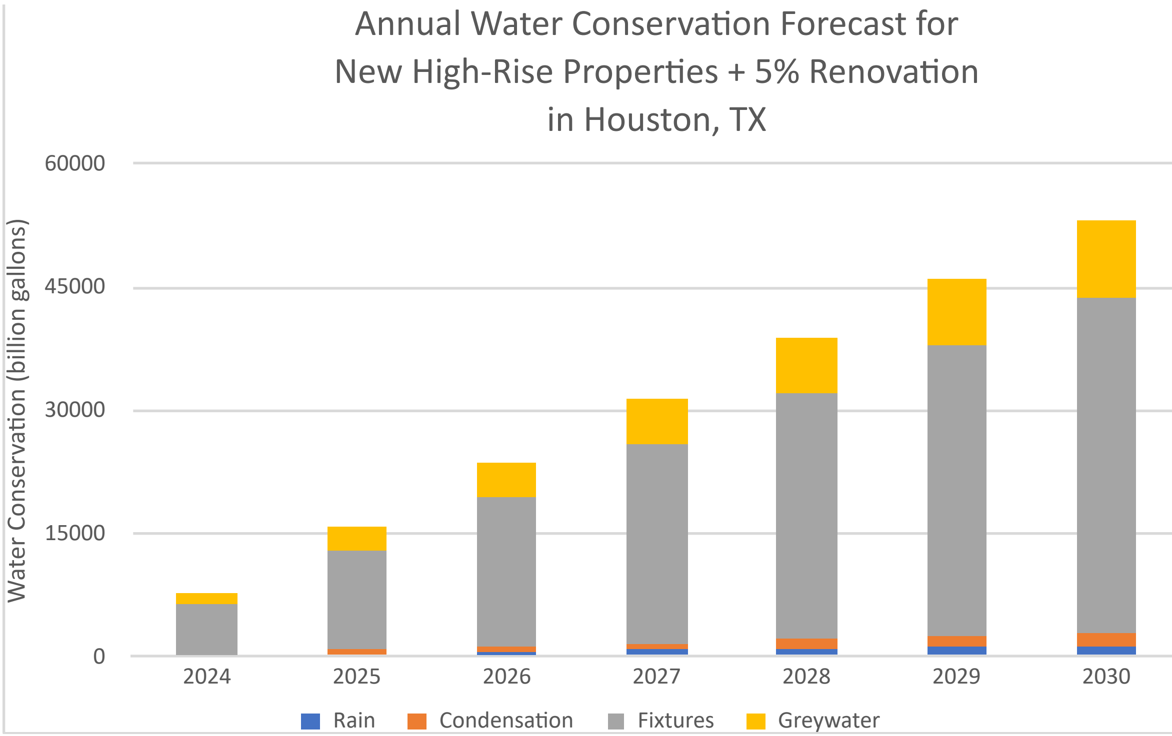


Figure LV: Annual Water Conservation Forecast – Houston

3.2. Phoenix

Below, Figure LVI displays the annual aggregate water conservation forecast for high-rise properties in the city of Phoenix where all three scenarios are considered. Based upon the adoption of water conservation measures by only new high-rise properties, the aggregate water conservation quantities are projected to be approximately 5.5 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 72.0 billion gallons.

If all new constructed high-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 5.8 billion gallons. By year 7, the total aggregate amount would be approximately 74.0 billion gallons.

Similarly, if all newly constructed high-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 7.0 billion gallons. By year 7, the total aggregate amount would be approximately 80.8 billion gallons.

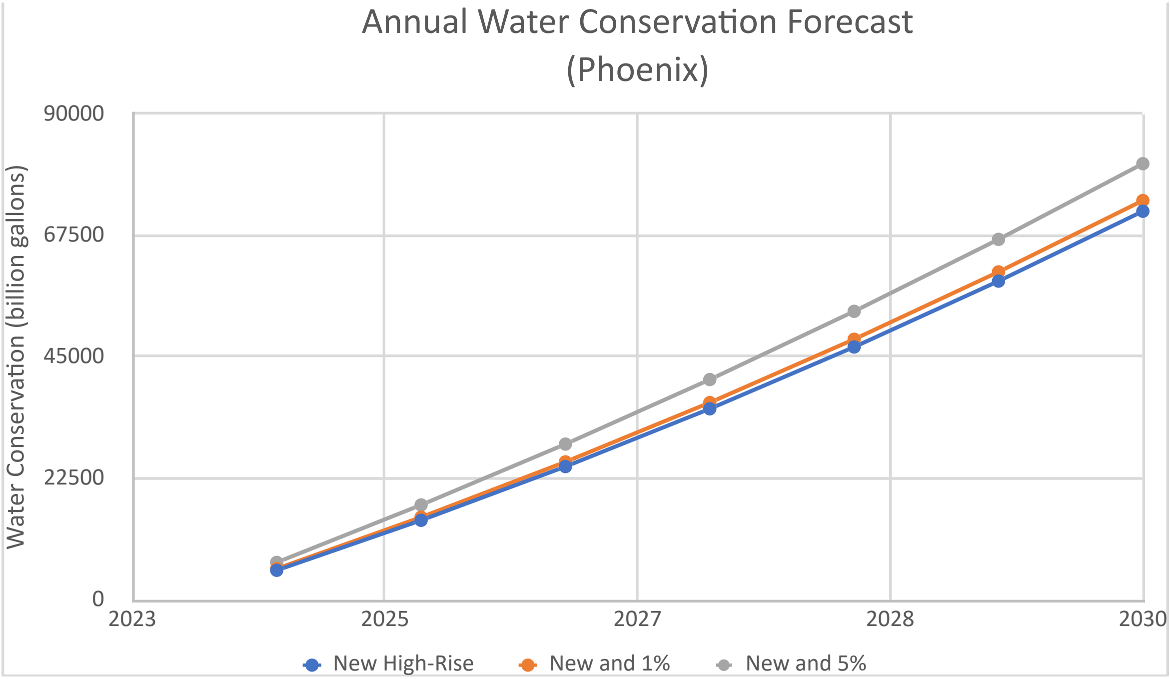


Figure LVI: Phoenix Scaled-up Water Conservation Analysis

The following figures show that the adoption implementation of water-efficient fixtures and greywater harvesting would benefit the city of Phoenix. Condensate harvesting proves to be of benefit as well.

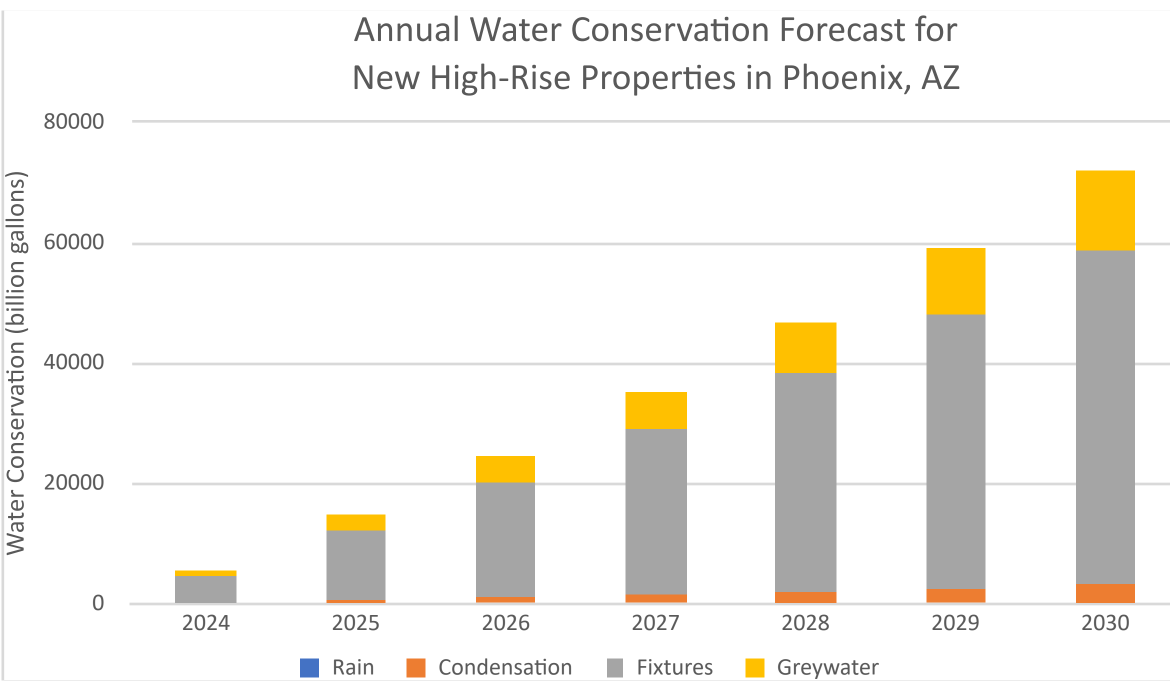


Figure LVII: Annual Water Conservation Forecast – Phoenix

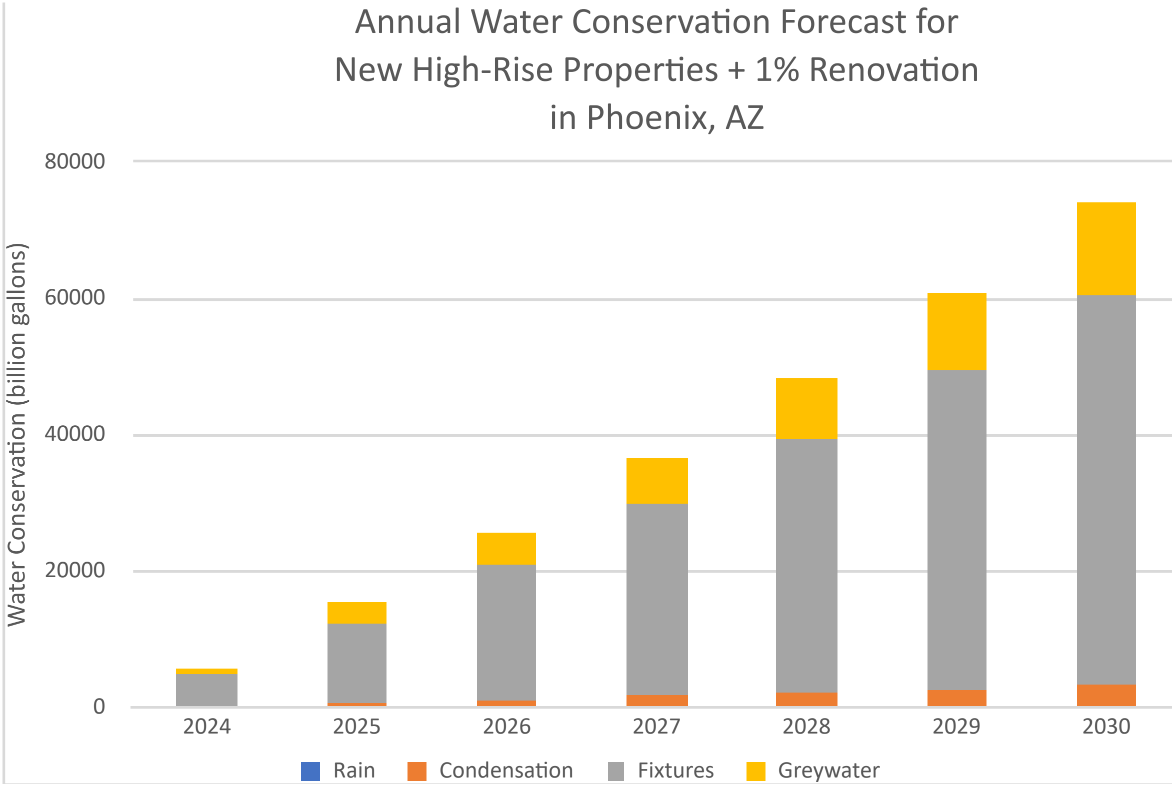


Figure LVIII: Annual Water Conservation Forecast – Phoenix

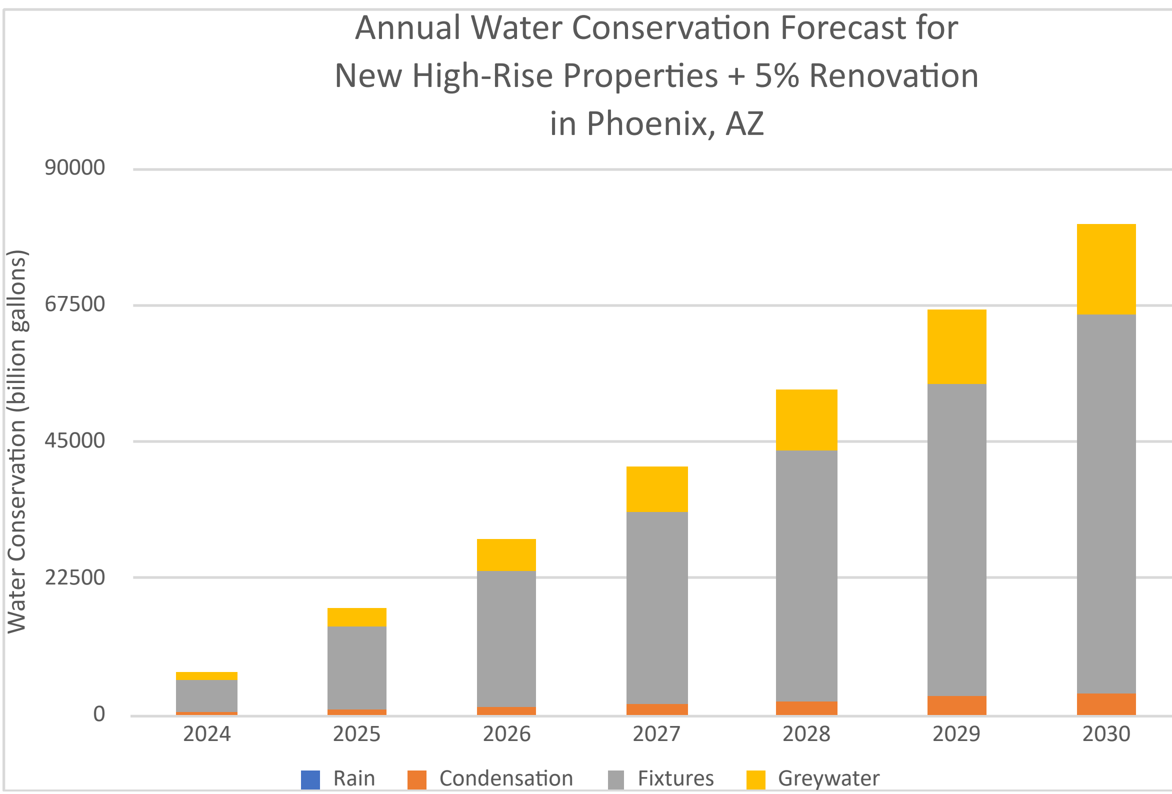


Figure LIX: Annual Water Conservation Forecast – Phoenix

3.3. Las Vegas

Below, Figure LX displays the annual aggregate water conservation forecast for high-rise properties in the city of Las Vegas where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new high-rise properties, the aggregate water conservation quantities are projected to be approximately 0.4 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 5.5 billion gallons.

If all newly constructed high-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately the same at 0.4 billion gallons, and for year 7, the total aggregate amount would be approximately the same 5.5 billion gallons.

Similarly, the results would be approximately the same with 5% of existing properties and new constructed properties adopting these measures.

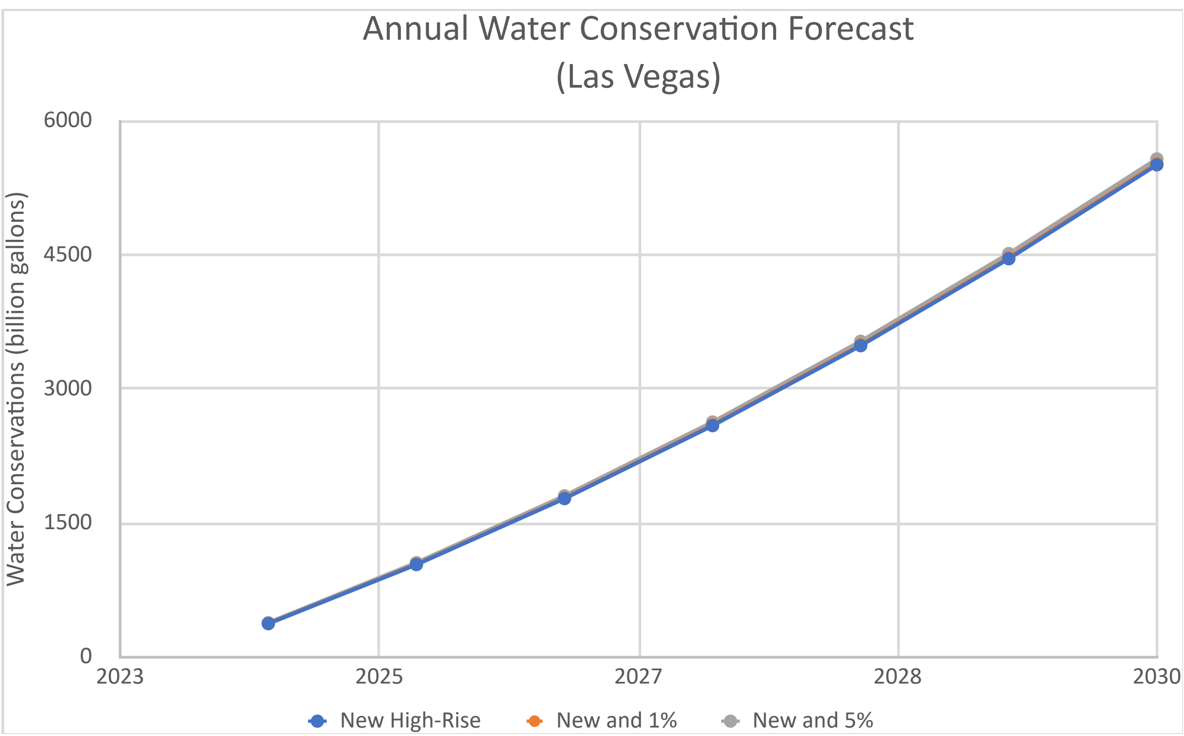


Figure LX: Las Vegas Scaled-up Water Conservation Analysis

The following figures show that the adoption of implementation of water-efficient fixtures and greywater harvesting would benefit the city of Las Vegas. Condensate harvesting also shows to assist in conservation efforts.

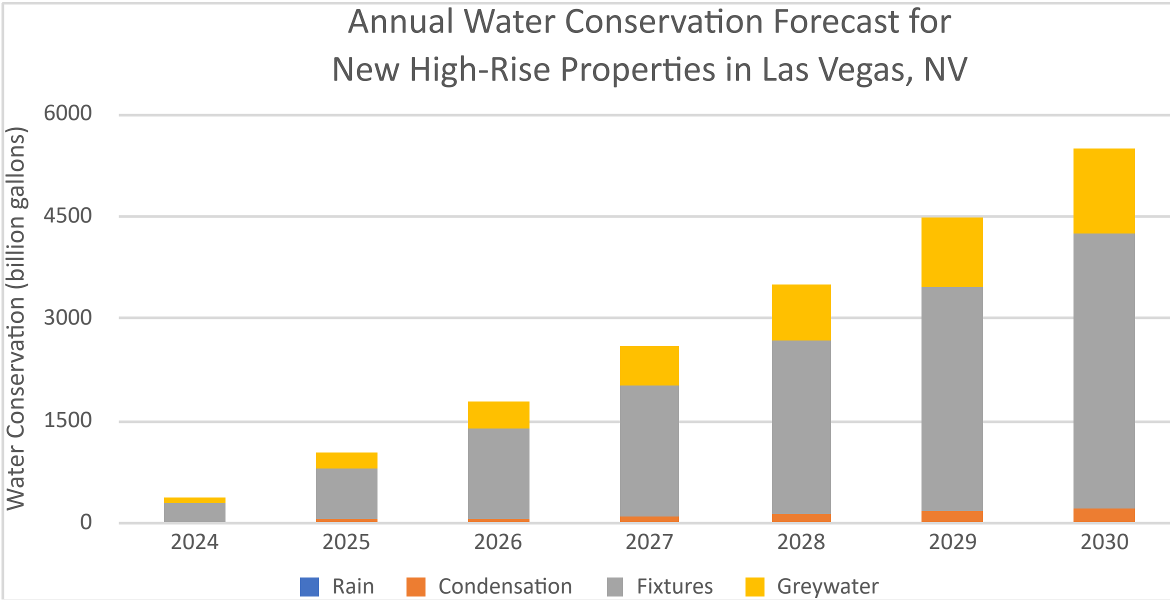


Figure LXI: Annual Water Conservation Forecast – Las Vegas

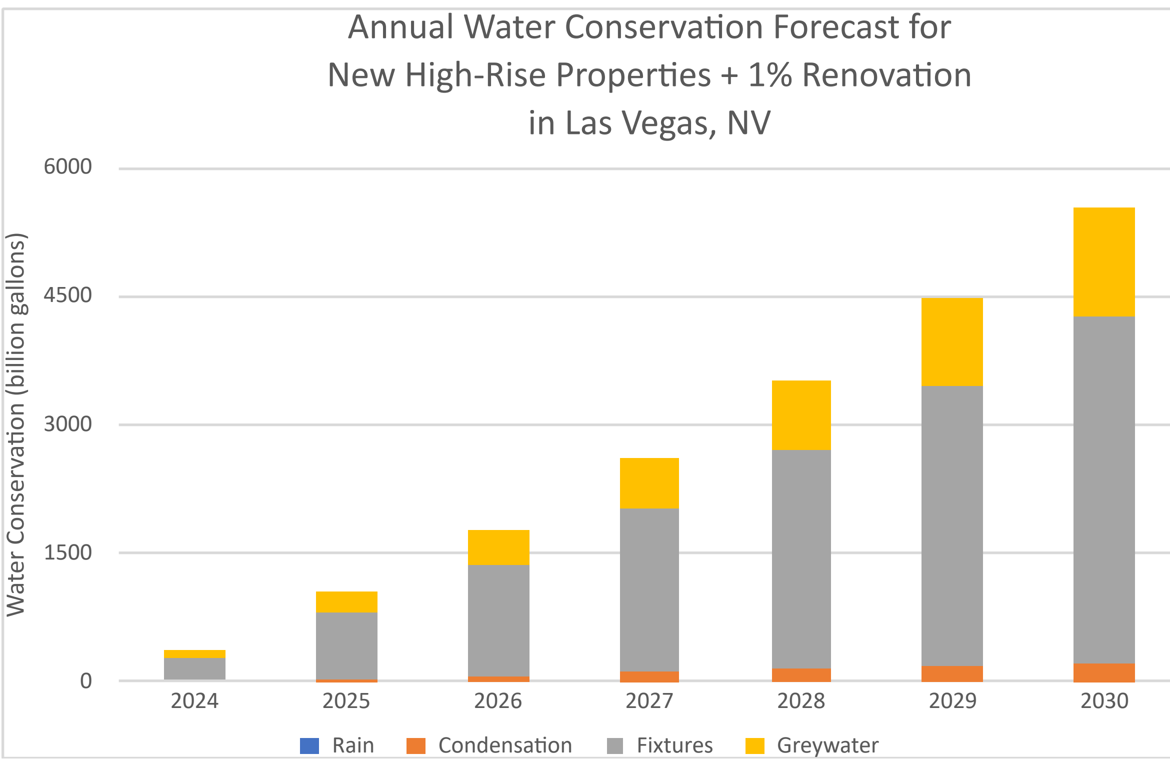


Figure LXII: Annual Water Conservation Forecast – Las Vegas

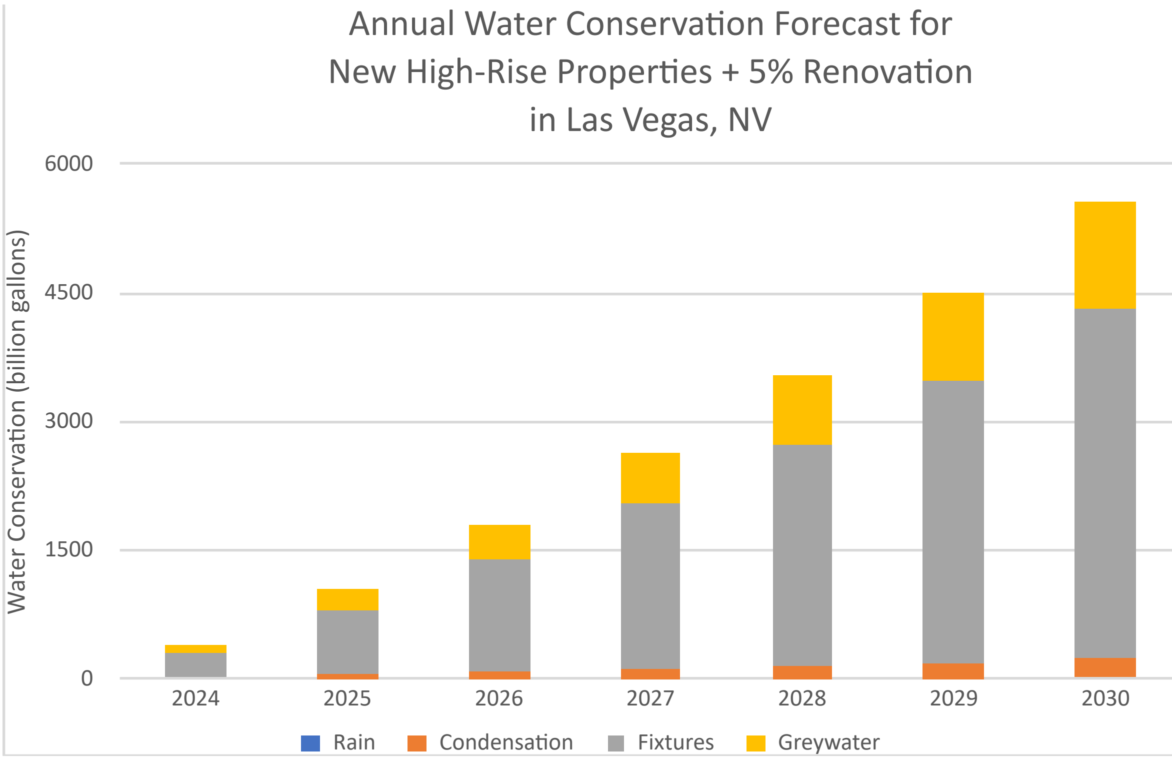


Figure LXIII: Annual Water Conservation Forecast – Las Vegas

3.4. Des Moines

Below, Figure LXIV displays the annual aggregate water conservation forecast for high-rise properties in the city of Des Moines where all three scenarios are considered. Based upon the adoption of the water conservation measures by only new high-rise properties, the aggregate water conservation quantities are projected to be approximately 0.06 billion gallons in Year 1 (2024). By year 7 (2030), the aggregate total will become approximately 0.6 billion gallons.

If all newly constructed high-rise properties adopt these measures along with 1% of existing properties, the annual water conservation amount for year 1 would be approximately 0.09 billion gallons. By year 7, the total aggregate amount would be approximately 0.8 billion gallons.

Similarly, if all newly constructed high-rise properties adopt these measures along with 5% of existing properties, the annual water conservation amount for year 1 would be approximately 0.2 billion gallons. By year 7, the total aggregate amount would be approximately 1.6 billion gallons.

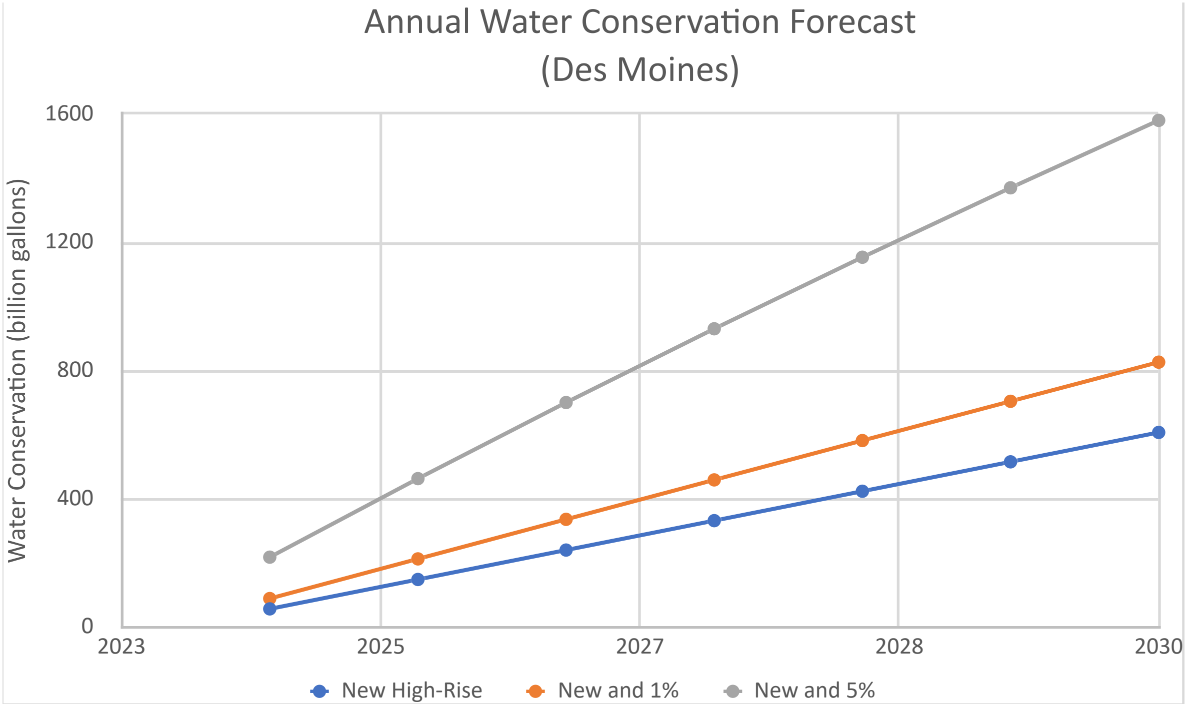


Figure LXIV: Des Moines Scaled-up Water Conservation Analysis

The following figures show that the adoption of implementation of water-efficient fixtures followed by greywater harvesting would benefit the city of Des Moines.

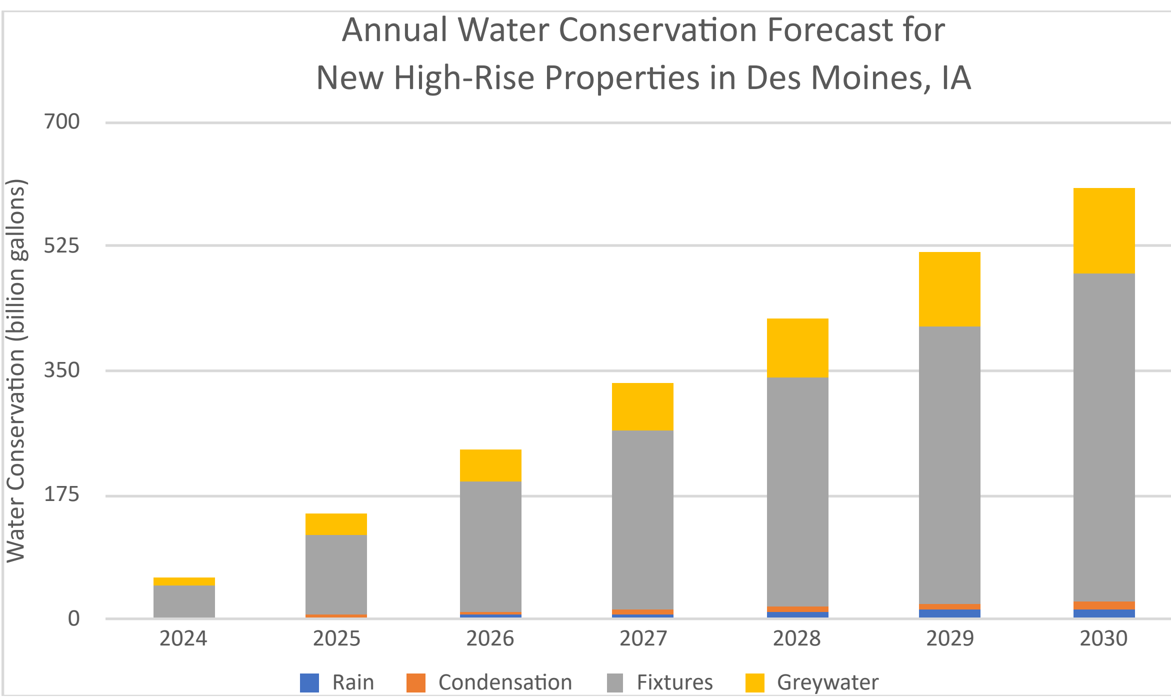


Figure LXV: Annual Water Conservation Forecast – Des Moines

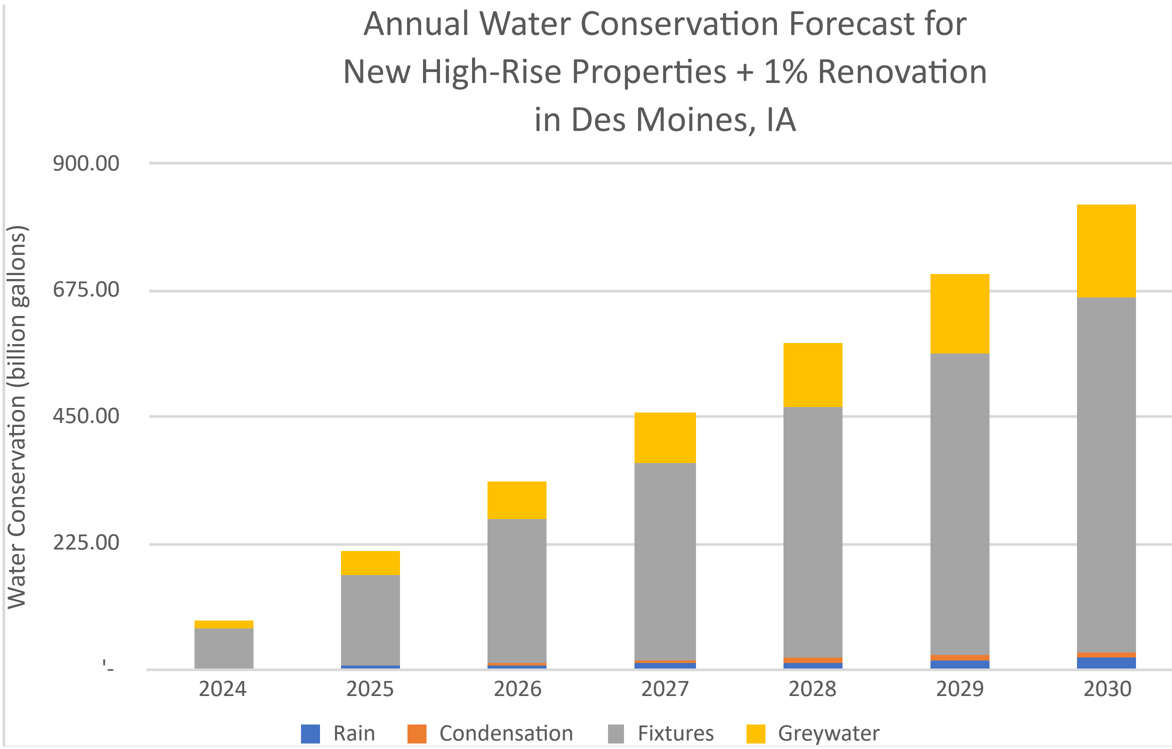


Figure LXVI: Annual Water Conservation Forecast – Des Moines

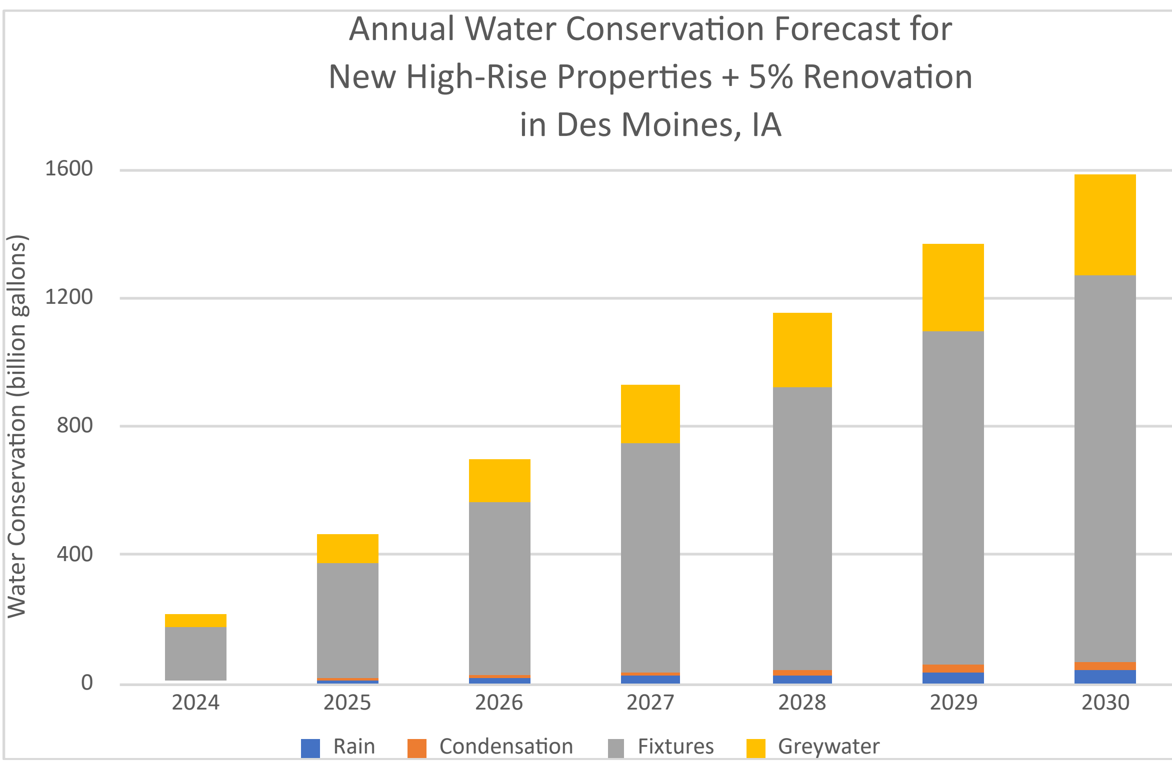


Figure LXVII: Annual Water Conservation Forecast – Des Moines

11. Conclusions

Although a continuation from Phase I, Phase IIA of this study was vast in nature as it did not only address the needs within specific cities but also the ever-evolving nature of multi-family construction and the applicability and adaptation to each building typology reflected.

The utilization of the four water conservation measures: rainwater harvesting, condensate harvesting from HVAC systems, the implementation of water-efficient fixtures, and greywater harvesting proved to be viable methods to harness water within each building typology and respective city.

Comparison between Building Typologies

The capabilities of conservation performed by residents and tenants residing in garden-style/ low-rise buildings are not the same or parallel to tenants in mid-rise and high-rise buildings. It was evident that the higher the occupant density, the more certain measures played an intricate part. For example, garden-style/low-rise properties have a smaller occupancy as compared to mid-rise and high-rise properties. With this being the case, conservation measures such as greywater harvesting and condensation harvesting would prove to be more prudent and beneficial. Whereas mid-rise and high-rise properties do not yield tremendous results from these two measures as the occupant densities skews the impact these measures can make.

The conservation measures proved to be of drastic importance in garden-style/low-rise buildings as the roof area and number of occupants work in tandem to provide the strongest chance of conserving water utilizing most, if not all, provisions. Whereas, due to the smaller building footprint and roof area seen in mid-rise and high-rise buildings, the provision of rainwater harvesting would not be a beneficial provision to implement.

The analysis and benefits of these conservation efforts discriminate against building typologies as garden-style/low-rise buildings yield far greater results across all cities than mid-rise and high-rise buildings. It is also proven that due to the increase of occupants within each building typology, the implementation of water-efficient fixtures is paramount. However, it should be noted that the provisions are inequitable as they cannot benefit all cities across the ASHRAE zones.

Comparison between Cities

Houston and Des Moines are the only two cities that benefit noticeably from the implementation of rainwater harvesting throughout all building typologies. Due to these cities receiving heavier rainfall as reviewed earlier in this report, the data is analogous.

Similarly, Las Vegas and Phoenix are the only two cities that exhibit a substantial gain using condensate harvesting from HVAC systems across all building typologies. It is presumed that due to the very dry, hot climate, these cities can gain an advantage through implementing this measure.

All cities, however, benefit from the implementation of water-efficient fixtures and greywater harvesting throughout all building typologies. As previously mentioned, the increase in occupants contributes to the overall impact of the conservation methods. In this case, the more dwelling units a building has, the more occupants residing. This only furthers solidify the data that was generated.

Although it would not be a hinderance to implement all conservation measures, it is safe to presume that each city should focus on employing greywater harvesting and the implementation of water-efficient fixture moving forward.

Comparison between Measures

It should be noted that achieving water conservation is not only possible through the utilization of all measures. As mentioned above, these conservation measures are subjected to building typologies and can vary among cities. Although these measures appear "stacked" for visualization purposes, each of these measures or only one can be implemented in each city or building type based upon its necessity. For example, the benefits of implementing water-efficient fixtures and greywater harvesting in high rise properties in Las Vegas would be higher as opposed to only implementing greywater harvesting in that city. It doesn't negate the impact created. This further justifies the need to assess each city separately and apart to identify the most important measures to be employed.

Summary

In cities alike, the demand for water conservation through the conservation measures show to increase as the number of dwelling units vary across city and building types.

The conscientious efforts to conserve water within each building typology and city should be addressed prior to groundbreaking as it is not safe to assume that all residents, landlords, and tenants would abide by code provisions required by the IWCCP.

Moreover, the assessment of each city and the three building typologies wherein proved a critical point in analysis that "one size does not fit all", and that conservation measures should be addressed to each scenario and not serve as a "blanket" for city-wide ordinance.

Furthermore, the decision to conserve water in each city is possible, but a thorough analysis should be performed in a manner that addresses the city's specific needs. As the need continues to grow, strategic measures should be analyzed to ensure we are working towards a sustainable future.

12. References

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