

Water Use in the Multi-family Housing Sector

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Presentation Overview

- Background on WRF 4554
- Data sources
- Water use comparisons
- Examples of modeling variability in water use
- Summary and conclusions

The Multifamily Housing Sector

- About 25% percent of housing (or about 33 million residences) in the U.S
- Share of multifamily dwellings increasing in some areas
- Multifamily housing dominant residential sector in some denser urban areas
- Many areas plan to direct future development or “densify”

Water Research Foundation Project 4554

Water Use in the Multifamily Housing Sector

- Narrow knowledge gaps
- Develop, demonstrate, and recommend analytical strategies for:
 - Estimating multifamily water use
 - Categorizing multifamily properties
 - Forecasting and evaluating water use patterns

Defining what is “Multi-family”

- Everything other than traditional single-family detached homes
 - Any residential property w/2+ units
 - Master-metered residential properties
 - General practice to lump MF into general residential or commercial customer classes
- “...detached, semidetached, row house, or multi-family structures with 5 or more units.”

Ownership/Tenure
Rental
Apartments
Duplex
Multiplex
Individually Owned
Condominiums
Townhouses
Jointly Owned
Cooperatives

What “Multifamily” looks like



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Selected Research Questions

- To what extent does multifamily water use differ from single-family use?
- Does water use differ among subclasses of multifamily sector?
- What factors influence water use in the multifamily sector and major sub-classes?
 - Does greater development density lead to less use?
 - What are the effects of given property features?
 - Can we inform forecasting and evaluation efforts?

Data Collection

- Secondary information only
- Water use - properties and/or classes
- Number of dwelling units (scale measure)
- Property sub-classification schemes
- Property characteristics
- Other potentially influential variables
 - Price
 - Socioeconomic
 - Climatic

Utility Partners

- Denver Water
- New York City
Department of
Environmental Protection
- Phoenix Water Services
- San Diego County Water
Authority
- Tampa Bay Water



Other Key Data Sources

- U.S. Census
 - American Housing Survey
 - American Community Survey
- New York University Furman Center
- Fannie Mae

What the US Census tells us

- Increase in share of population living in multiple unit structures
- Rental tenure dominates
- Lower incomes
- Smaller households
- Younger householders
- Proportionally fewer (in unit) clothes washers and dish washers (especially renter-occupied)

Comparison of Unit Usage Rates (gallons per dwelling unit per day)

Utility	Multi-family Sector (Composite)	
	Units	Mean use per unit
Denver (2014)	192,560	133
New York City (2014)	2,143,108*	170
Phoenix (2014)	181,101	182
San Diego County (2012)	423,788	164
Tampa Bay Water (2014)	280,865	117
*Excludes properties designated as One-Family Dwelling or Mixed Residential/Commercial		

Range of ~65 gpd

Comparison of Unit Usage Rates (gallons per dwelling unit per day)

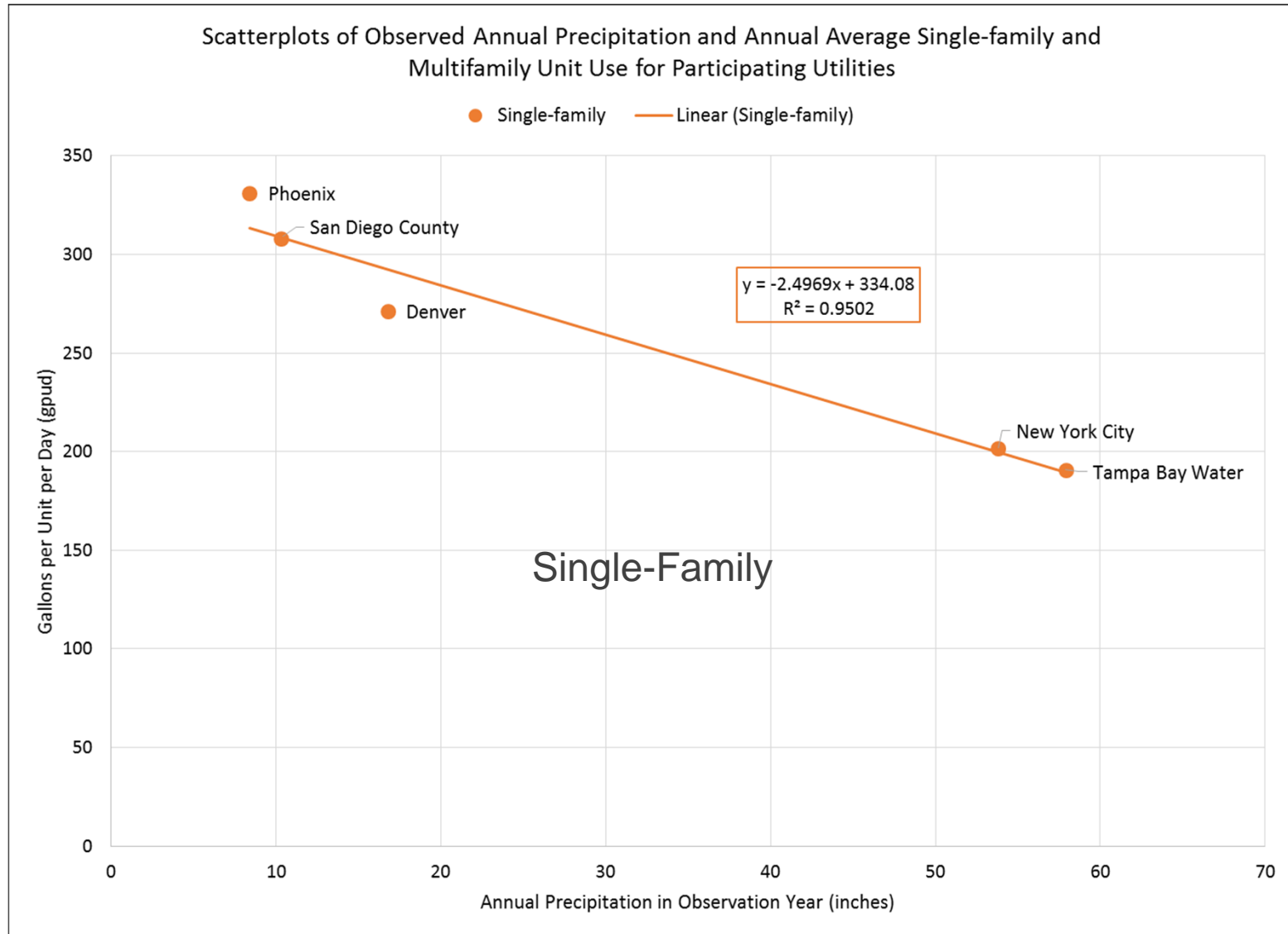
Utility	Multi-family Sector (Composite)		Single-Family Sector		Ratio SF Mean to MF Mean
	Units	Mean use per unit	Units	Mean use per unit	
Denver (2014)	192,560	133	202,367	271	2.0
New York City (2014)	2,143,108*	170	315,246	202	1.2
Phoenix (2014)	181,101	182	305,341	331	1.8
San Diego County (2012)	423,788	164	670,692	308	1.9
Tampa Bay Water (2014)	280,865	117	404,903	191	1.6

Range of ~140 gpd

MF < SF
in all cases

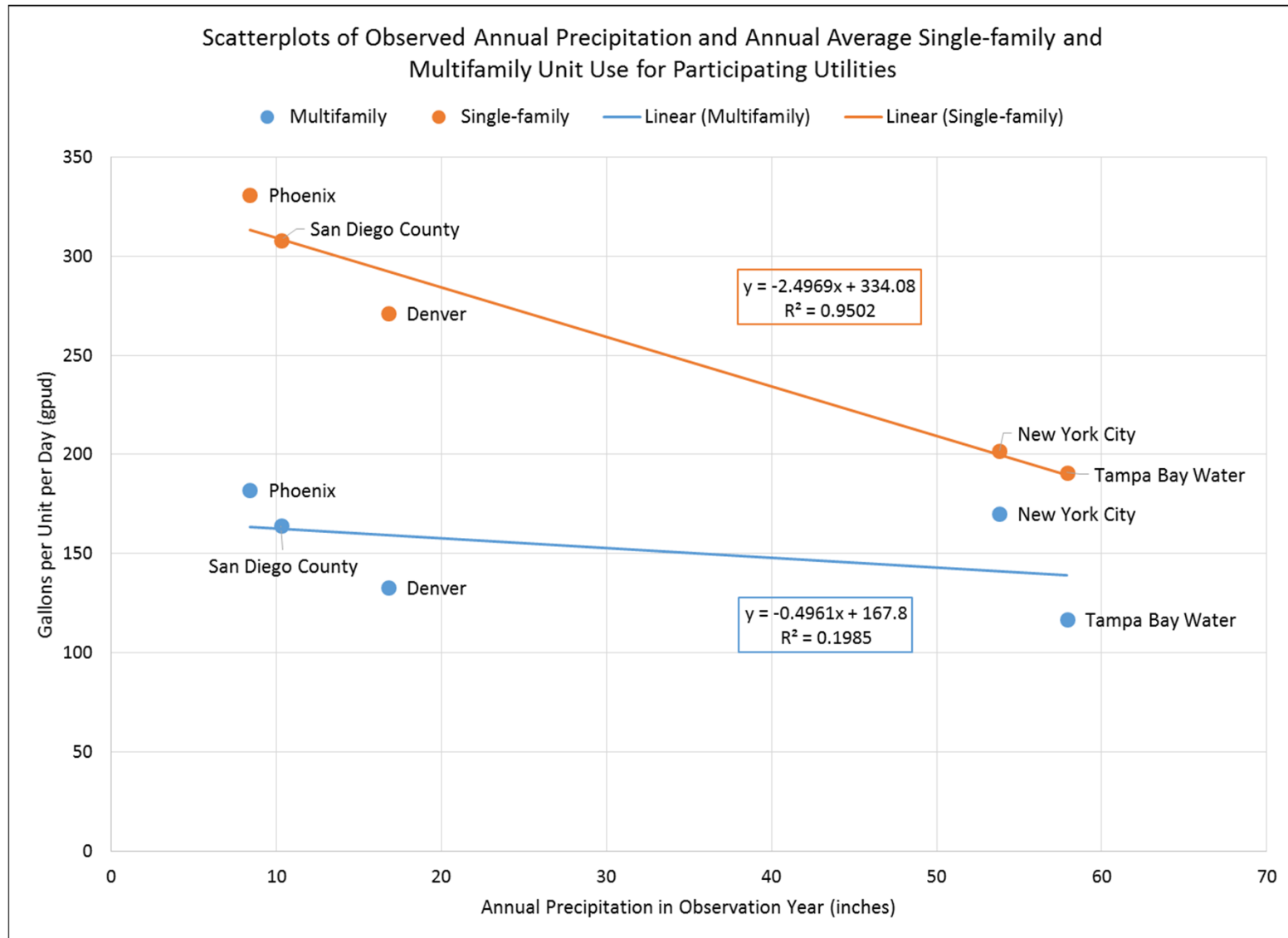
*Excludes properties designated as One-Family Residential/Commercial

Annual Precipitation and Average Unit Use



Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

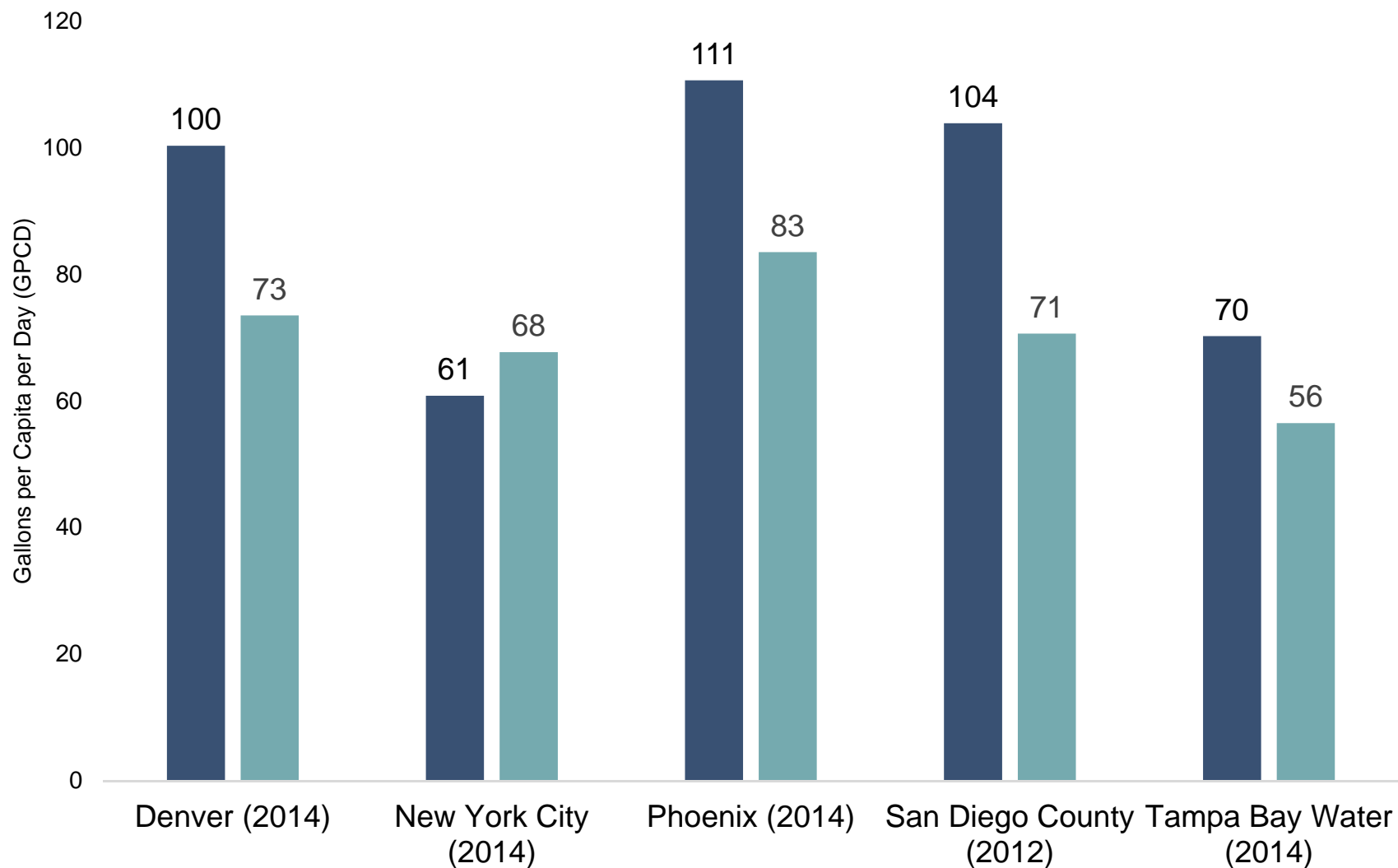
Annual Precipitation and Average Unit Use



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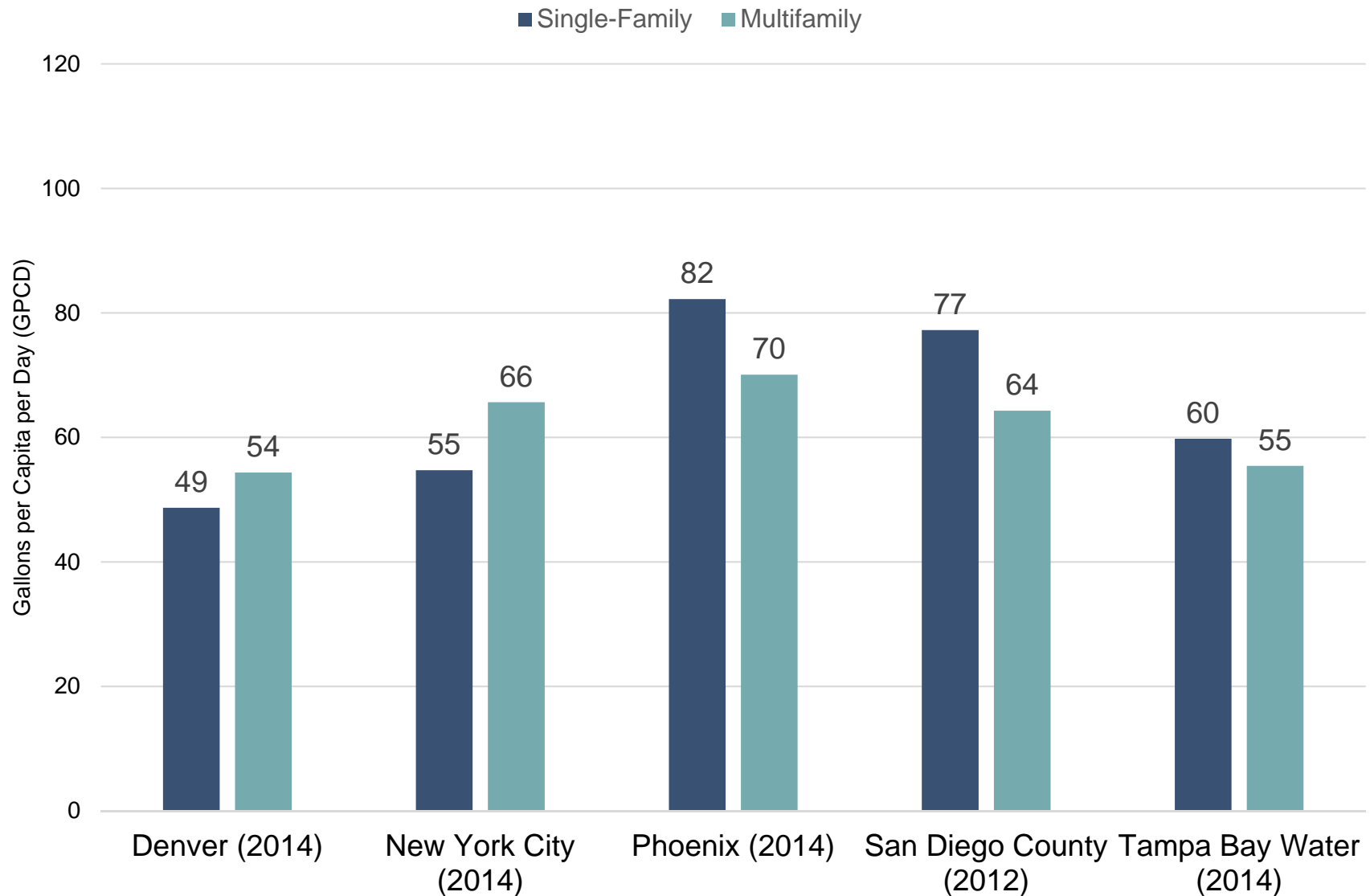
Estimated Average Annual Water Use **Per Capita** for Five Water Systems
(gallons per capita per day)

■ Single-Family ■ Multifamily



Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

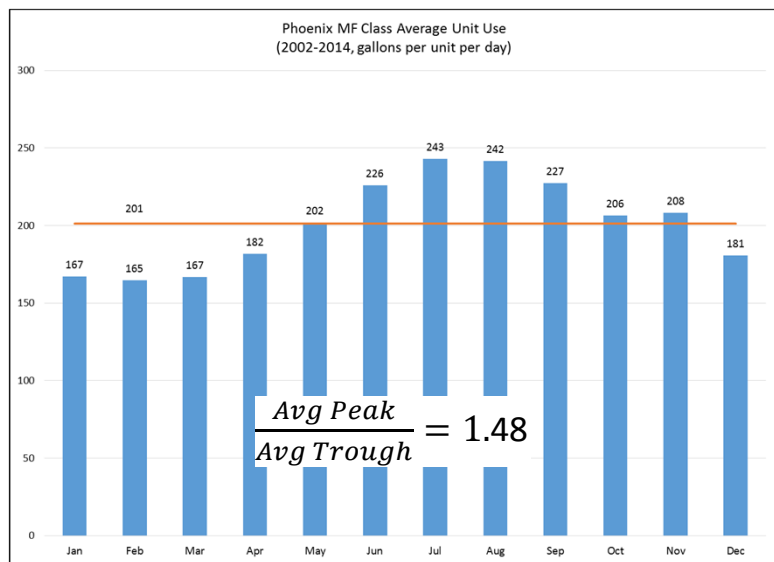
Estimated Average **"Min-Month"** Water Use **Per Capita** for Five Water Systems (gallons per capita per day)



Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

Examples of Multi-family Seasonal Usage Patterns

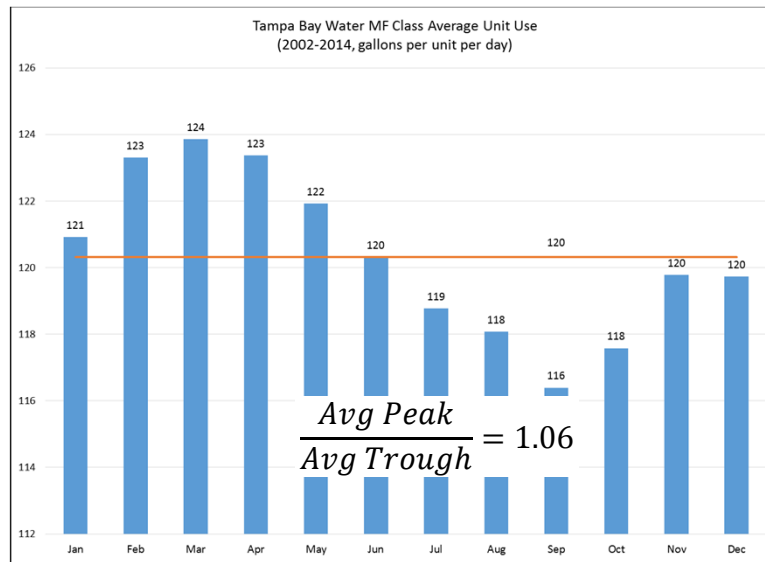
Phoenix (2002-2014)



“Common” Seasonal Pattern

- Summer peak
- Winter Trough


Tampa Bay Water (2002-2014)



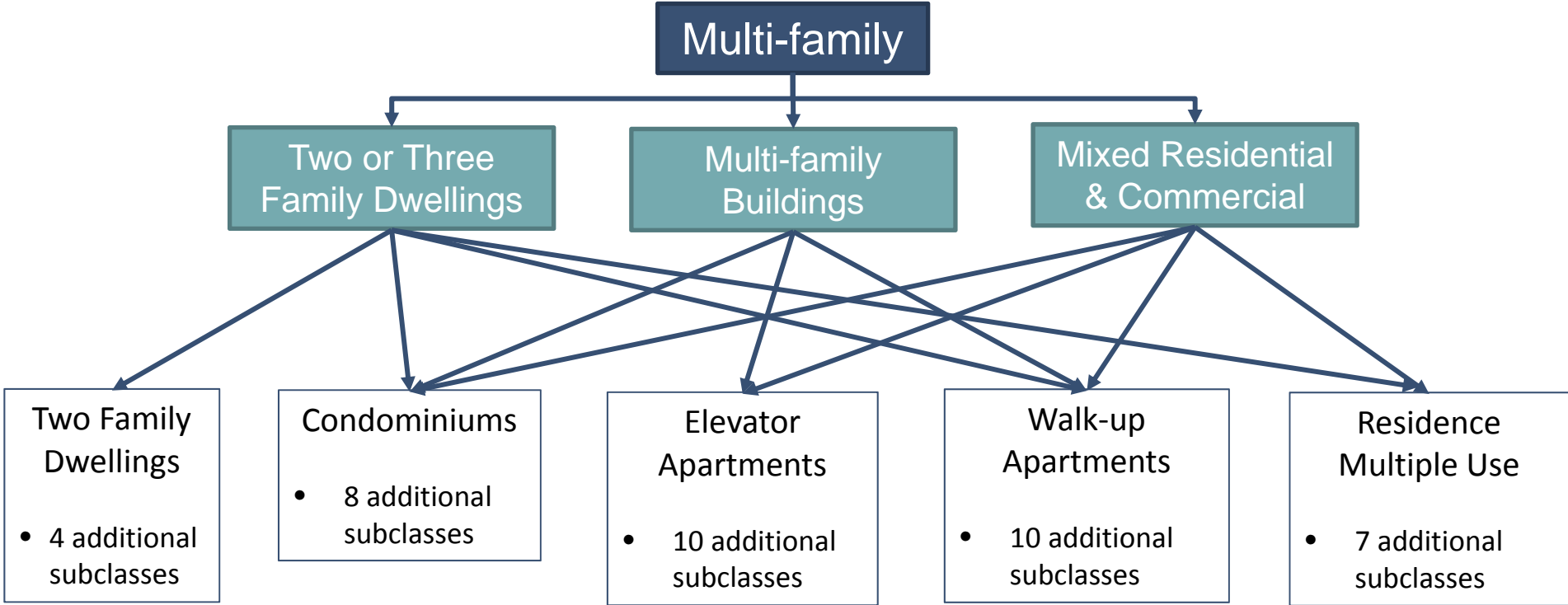
Unique Seasonal Pattern

- Spring is dry season
- “Snowbirds”/Spring Break

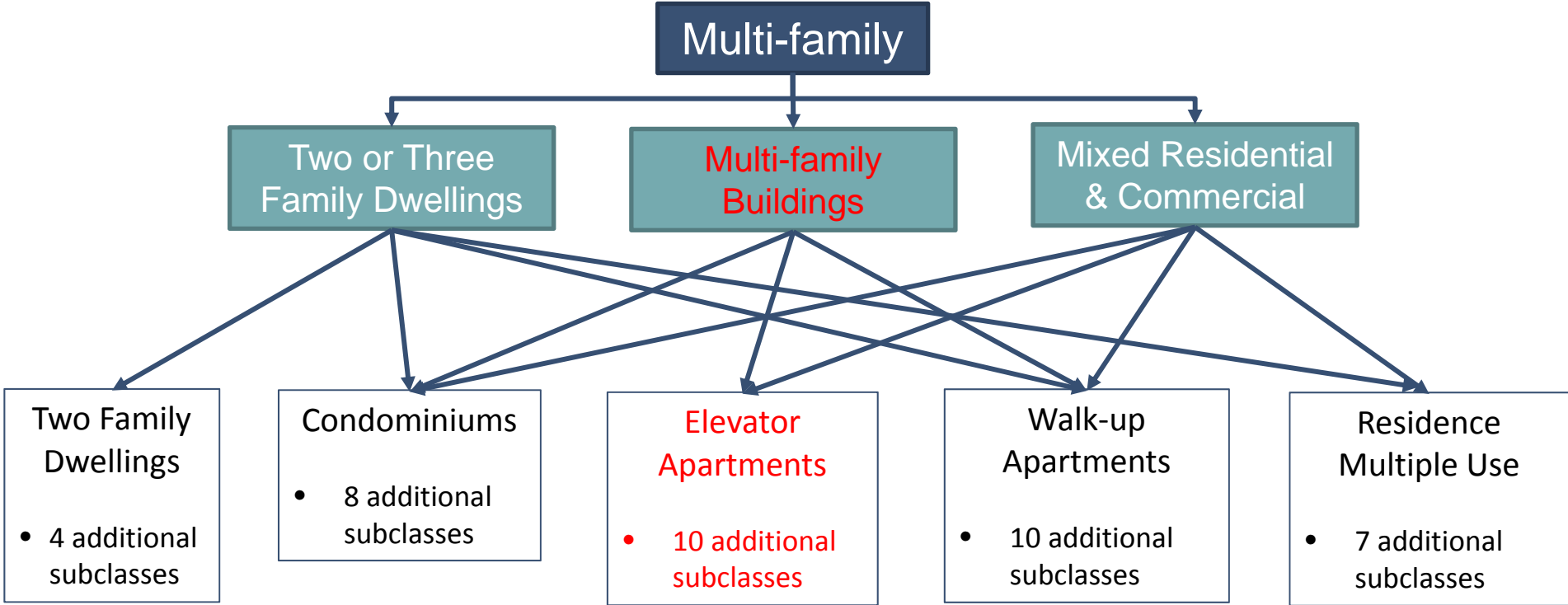
Evaluation of Sub-Classification

- Do average usage patterns differ significantly based on definitional groupings?
 - Analysis depended on use of “external” and linkable data for classification schemes
 - Sub-classification was found to affect sample statistics in all case analyses
 - Differences in definitions/classification criteria prevented meaningful cross-utility comparisons
- 

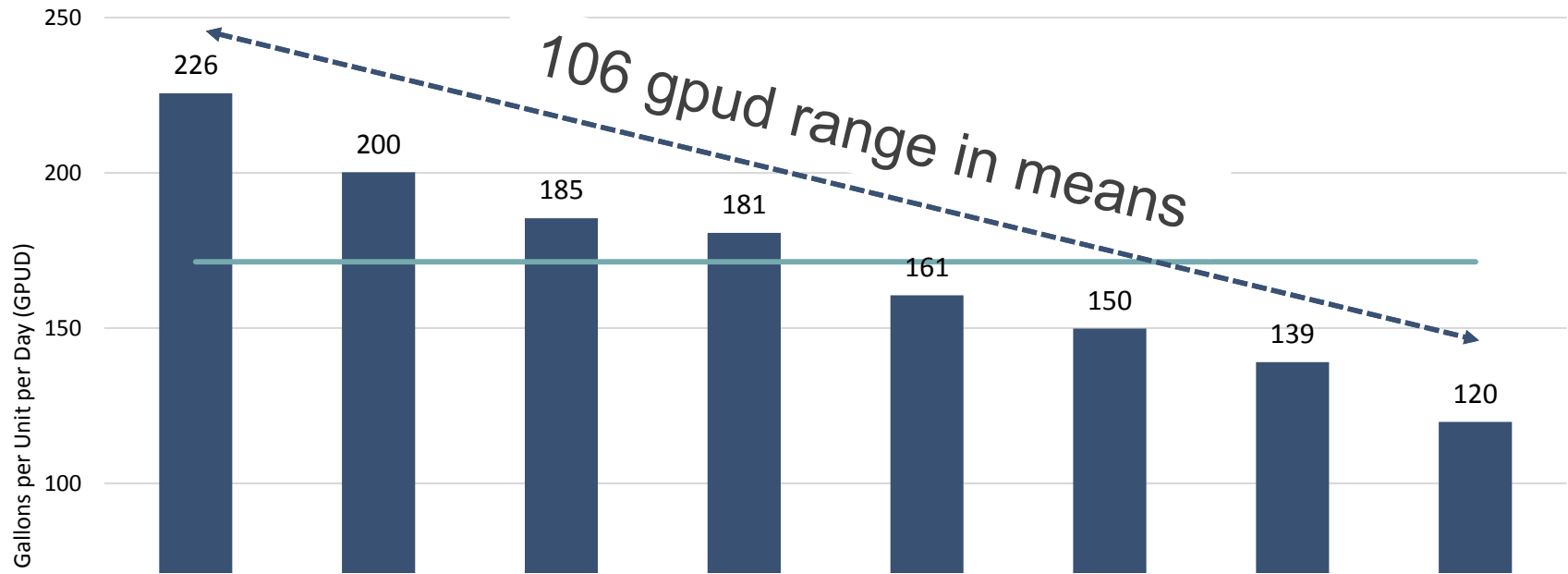
New York City Classifications



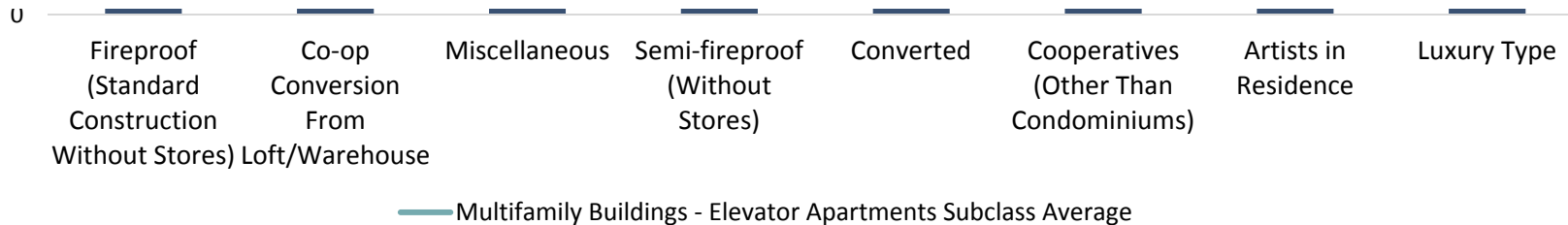
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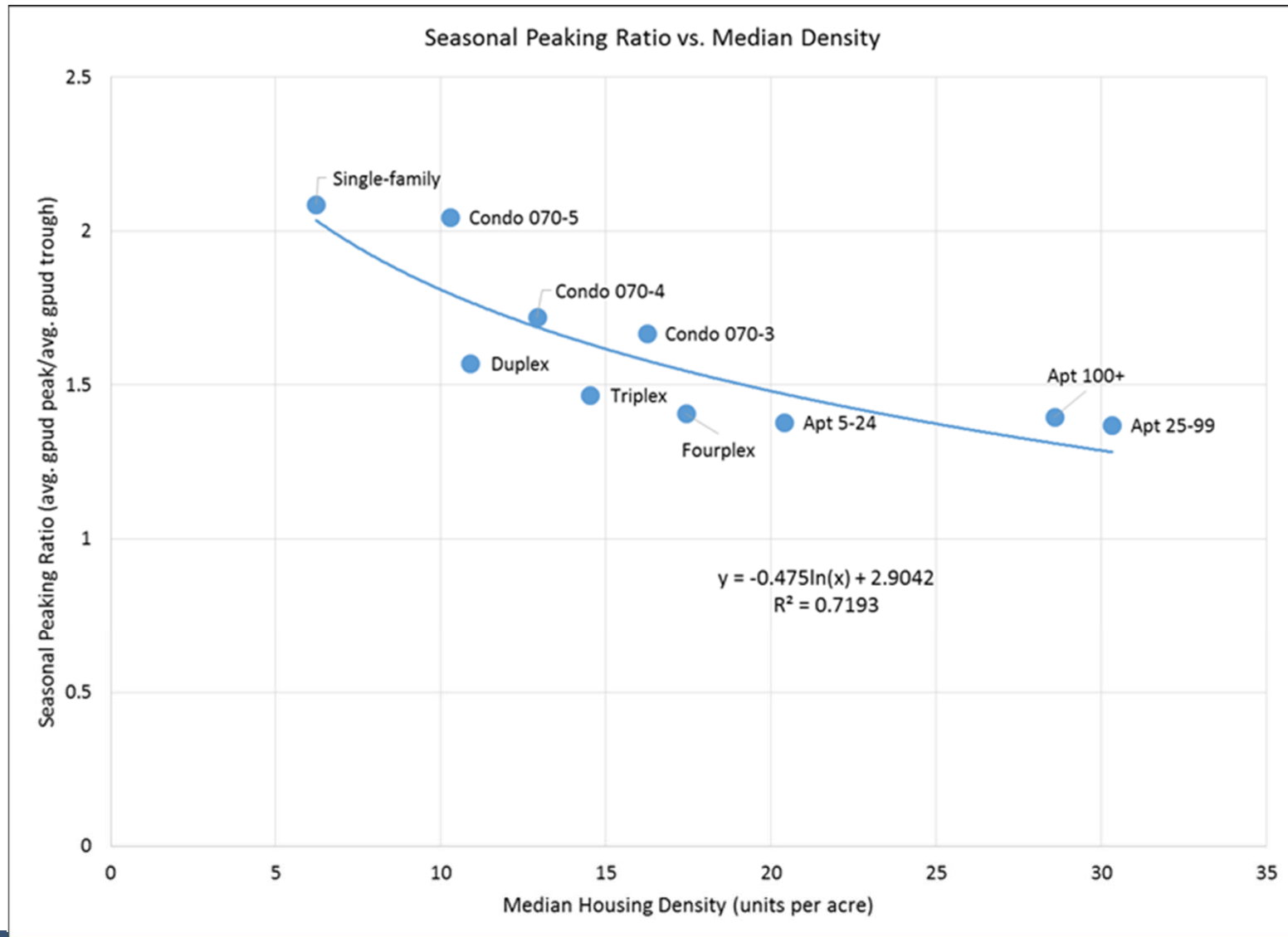
New York City Mean 2014 Unit Use for Building Sub-Classes within "Elevator Apartments" Building and "Multi-family Buildings" Land Use Tax Class (GPUD)



Cannot easily infer reasons for differences based on class names alone

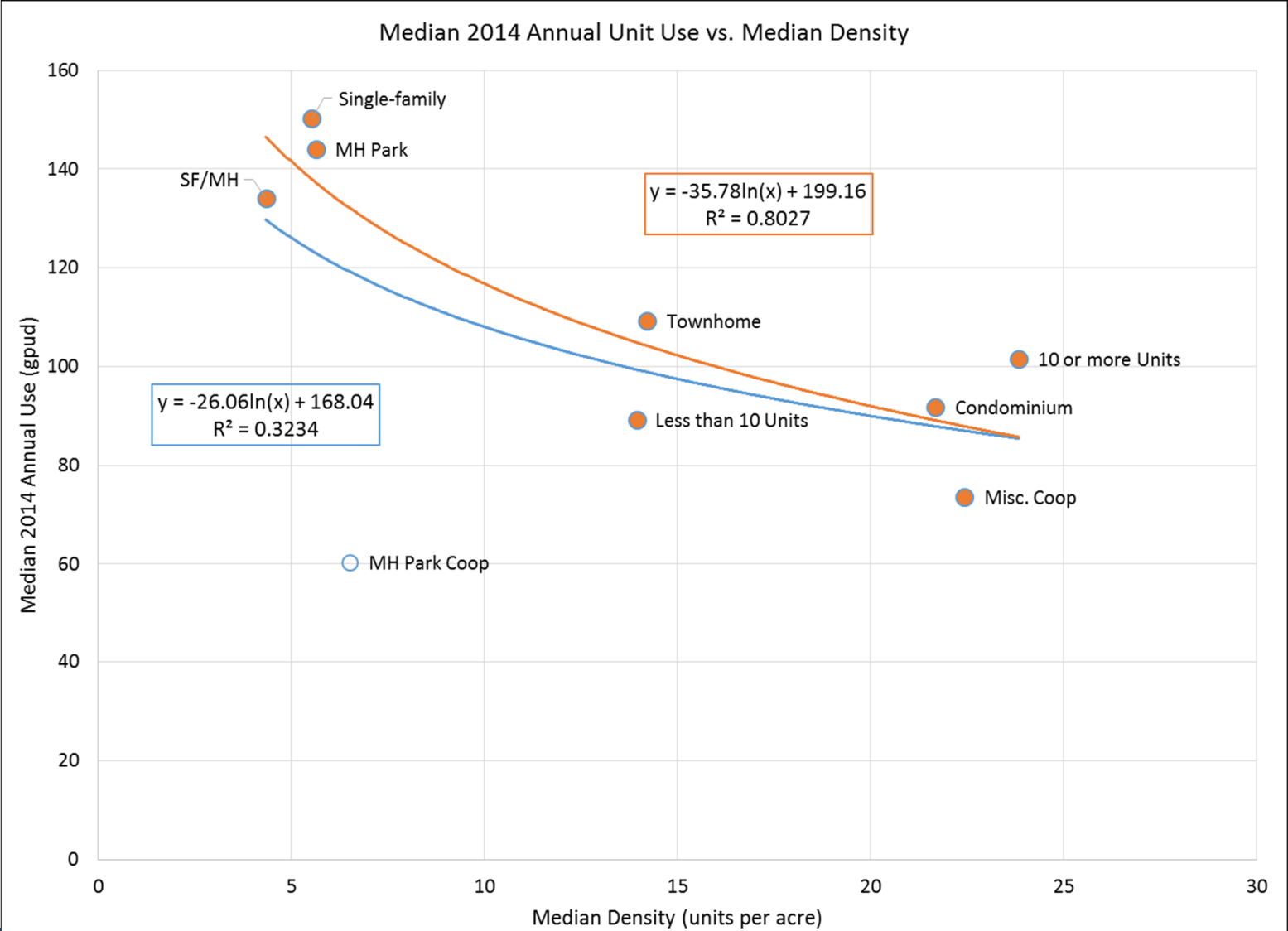


Seasonal Peaking and Housing Density by Sub-class (Phoenix)



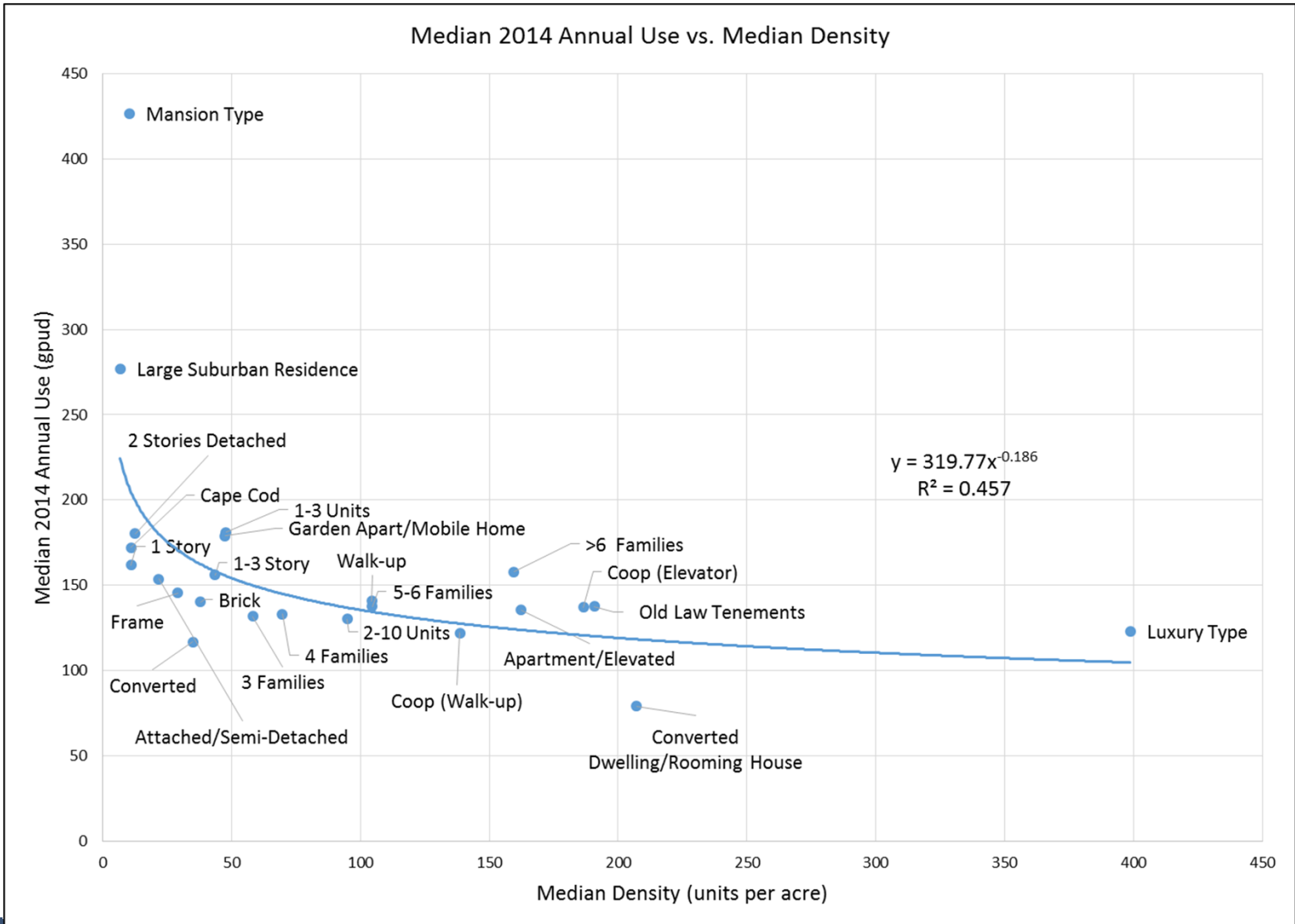
Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

Median Unit Use and Housing Density by Sub-class (Tampa Bay Water)



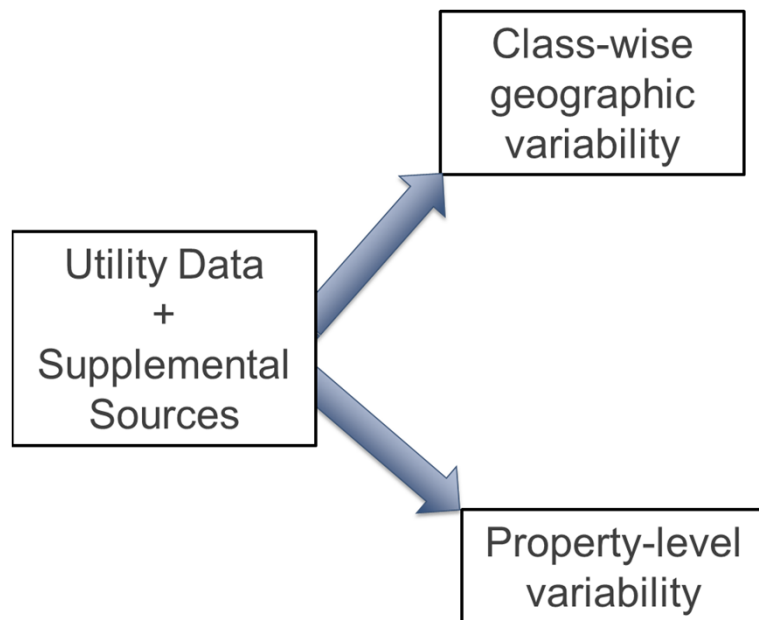
Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

Median Unit Use and Housing Density by Sub-class (New York City)



Source: Kiefer, J. and L. Krentz. 2018. *Water Use in the Multi-Family Housing Sector*. Project #4554. Denver, Colo.: Water Research Foundation.

Assessment of Multifamily Demand Determinants



- San Diego County
 - Tampa Bay Water
 - New York City
-
- 2012 Fannie Mae Multifamily Market Research Energy and Water Survey
 - Tampa Bay Water
 - Phoenix
 - New York City
 - Denver

Multi-family Class-level Forecast Model (San Diego County)

- Balanced panel model of water use, socioeconomics, weather, and climate
- 22 agencies, 120 months each

Variable	Estimated Multi-family Elasticity
Marginal Price for Water (inflation-adjusted)	-0.14
Median Household Income (inflation-adjusted)	+0.07
Housing Density (housing units per acre)	-0.30
Household Size	+0.56

Multi-family Class-level Forecast Model (San Diego County)

- Balanced panel model of water use, socioeconomics, weather, and climate
- 22 agencies, 120 months each

Variable	Estimated Multi-family Elasticity		Estimated Single-Family Elasticity
Marginal Price for Water (inflation-adjusted)	-0.14	<	-0.23
Median Household Income (inflation-adjusted)	+0.07	<	+0.54
Housing Density (housing units per acre)	-0.30		-0.31
Household Size	+0.56	>	+0.44

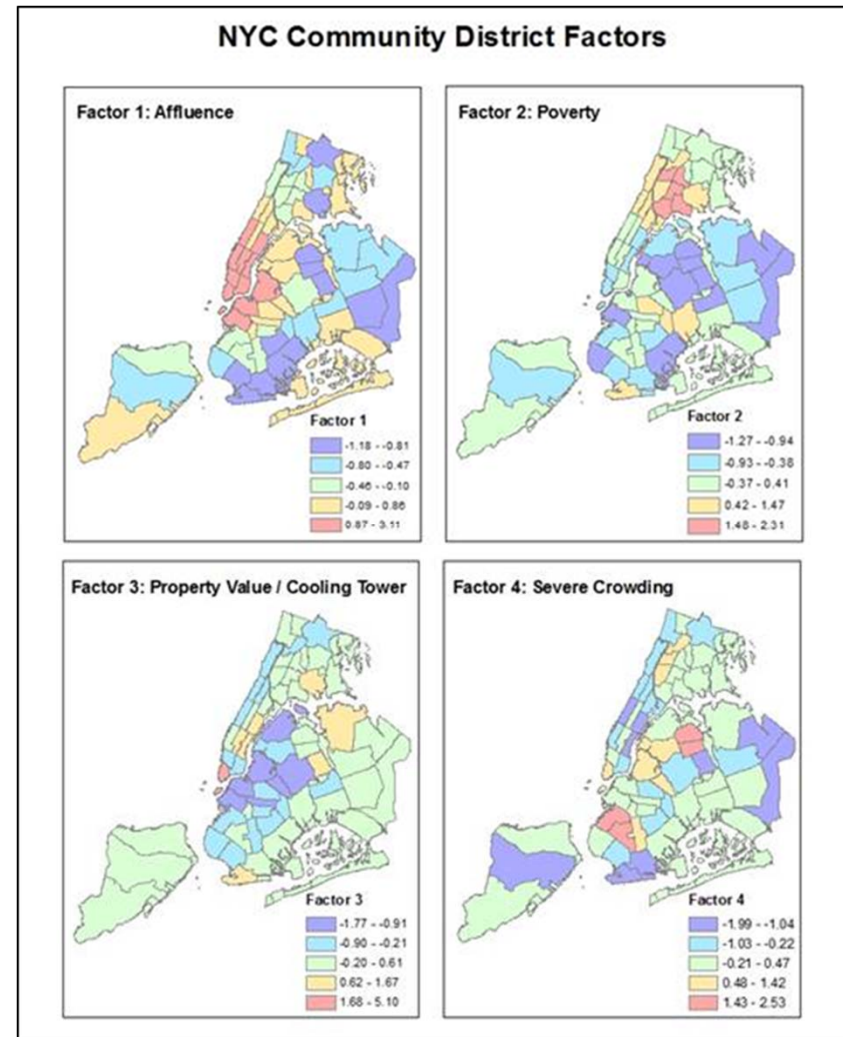
Factor Analysis of NYC Community Districts

Socioeconomic data from NYU Furman Center available for 57 metrics across 59 Community Districts (64 metrics total)

1. Aggregate premise level water use data to community district level
2. Condense demographic metrics into fewer “thematic” factors
3. Evaluate median water use per dwelling unit with respect to factor scores

Factor Analysis of NYC Community Districts


Thematic Factor	Estimated Effect of 1 unit change in factor score
“Affluence”	-18 gpud
“Poverty”	+23 gpud
“Property Value/Cooling Towers”	+8 gpud
“Severe Crowding”	+15 gpud



Property-level Assessments (Fannie Mae Survey)

- Sample of 955 multi-family properties for 2012 categorized by broad region
- Regression analysis of cross-sectional data on multi-family property features, accounting for region

Variable	Estimated Elasticity or Effect
Average Cost of Water	-0.26
Presence of Pool	+10%
Tenant Pays for Water	-17%
Property Receives Govt Subsidy	-12%
Property Built ≥ 2001	-16%
Senior Living Facility	-18%



Level
+
Mechanism

Property-level Assessments (Utility-provided)

Matrix of Property-Level Data Provided							
System	Units	Lot Size	Year Built	Assessed Value	Presence of Pool(s)	Presence of Reclaimed Water	Presence of Cooling Tower(s)
Denver	X	X (pervious area)	X				
New York City	X	X	X	X			X
Phoenix	X	X	X		X (Apt only)		X (Apt only)
Tampa Bay Water	X	X	X	X	X	X	



System	Class	Density (Units/Acre) Elasticity	Assessed Value Elasticity	Effect of Pool(s)	Effect of Reclaimed Water	Effect of Cooling Tower(s)	Age Profile
Denver (2015)	Multi-family Total	-0.18					
Tampa Bay Water (2010-2014 average)	Multi-family Total	-0.14	0.10	+9.4%	-20.5%	Access to alternative has effect demands	
	Condo	-0.14	0.09	+7.8%	-18.2%		
	Townhouse	-0.06	0.21	+13.0%			
	Less than 10 Units	-0.05					
	10 or More Units	-0.21					
Phoenix (2010-2014 average)	Multi-family Total	-0.44					+++
	Apartment	-0.45		+20.3%		+28.7%	+++
	Condo	-0.54					+-
	Multiplex	-0.23					+++
New York City (2014)	Condominiums	-0.14				+18.4%	+++
	Elevator Apartments	-0.20	-0.04			+15.7%	+++
	Walk-up Apartments	-0.08	-0.01			+5.8%	+++

All density effects are statistically significant
 Effects of income proxy are mixed

Pools increase water use

Impact of cooling towers proportionally larger in the desert

Summary & Conclusions

- Water use per unit in the Multi-family sector is generally lower than water use per unit in the Single-family sector
- The gap between SF and MF unit usage rates narrows when accounting for household size and seasonality
- For a given climate, generally lower seasonal use in the MF sector relative to SF

Summary & Conclusions

- Development density is statistically important
- More units per acre (i.e., higher unit density) - lower unit usage rates
- Results are consistent with
 - Notion of shared outdoor (and other) uses
 - Less irrigated area

Summary & Conclusions

- Two main effects from densification
 - Between class: MF is denser than SF
 - Within class: more dense MF, generally less water use (per dwelling unit)

Summary & Conclusions

- Water use in the MF sector is also influenced by
 - Property features (water end uses, age)
 - Socioeconomics
 - Price
- The estimated effects of water use determinants tend to vary by geographic area
 - Underlying climate
 - Sector/subclass structure

Summary & Conclusions

- The ability to obtain information on housing units is essential for accounting for scale
- Obtaining information on units typically permits additional classification options
- Sub-classification can affect sample statistics and modeling relationships – this may matter for certain planning and evaluation purposes

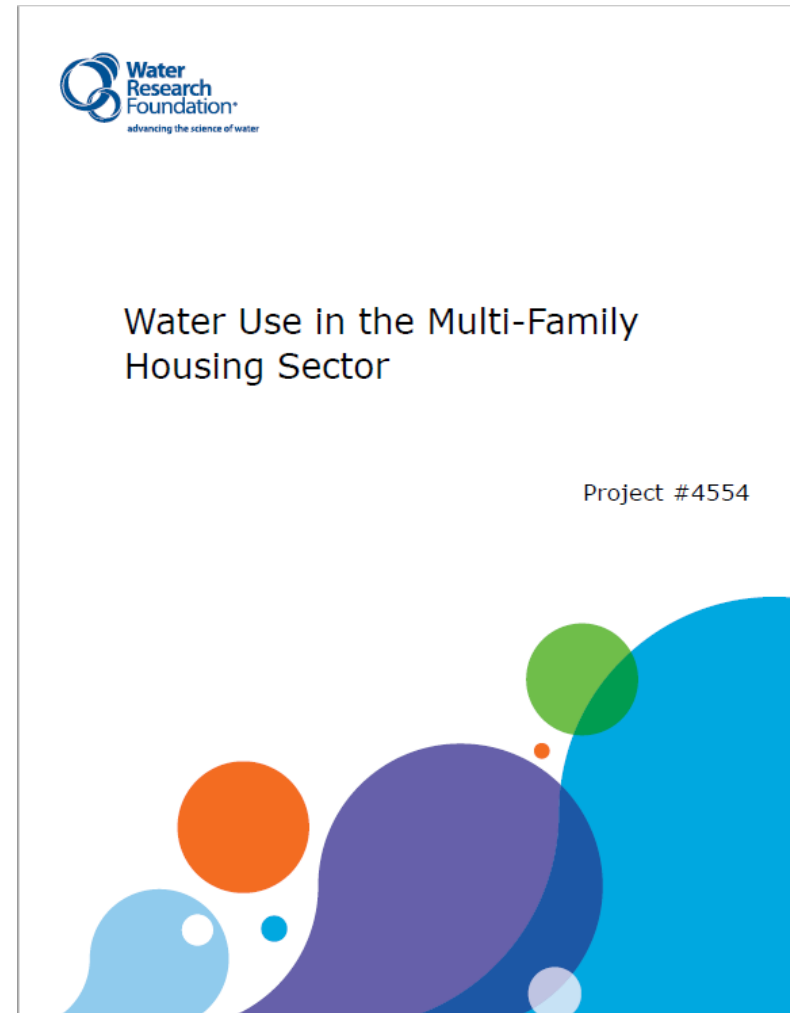
Recommendations

- Keep a watchful eye on housing trends
- Recognize potential impacts of densification and other development policies
- Test for statistical associations with key variables for the purposes of forecasting and profiling
- Seek more uniformity and consistency in classifying and sub-classifying multi-family
 - Better metrics
 - More robust comparisons

Thank You!

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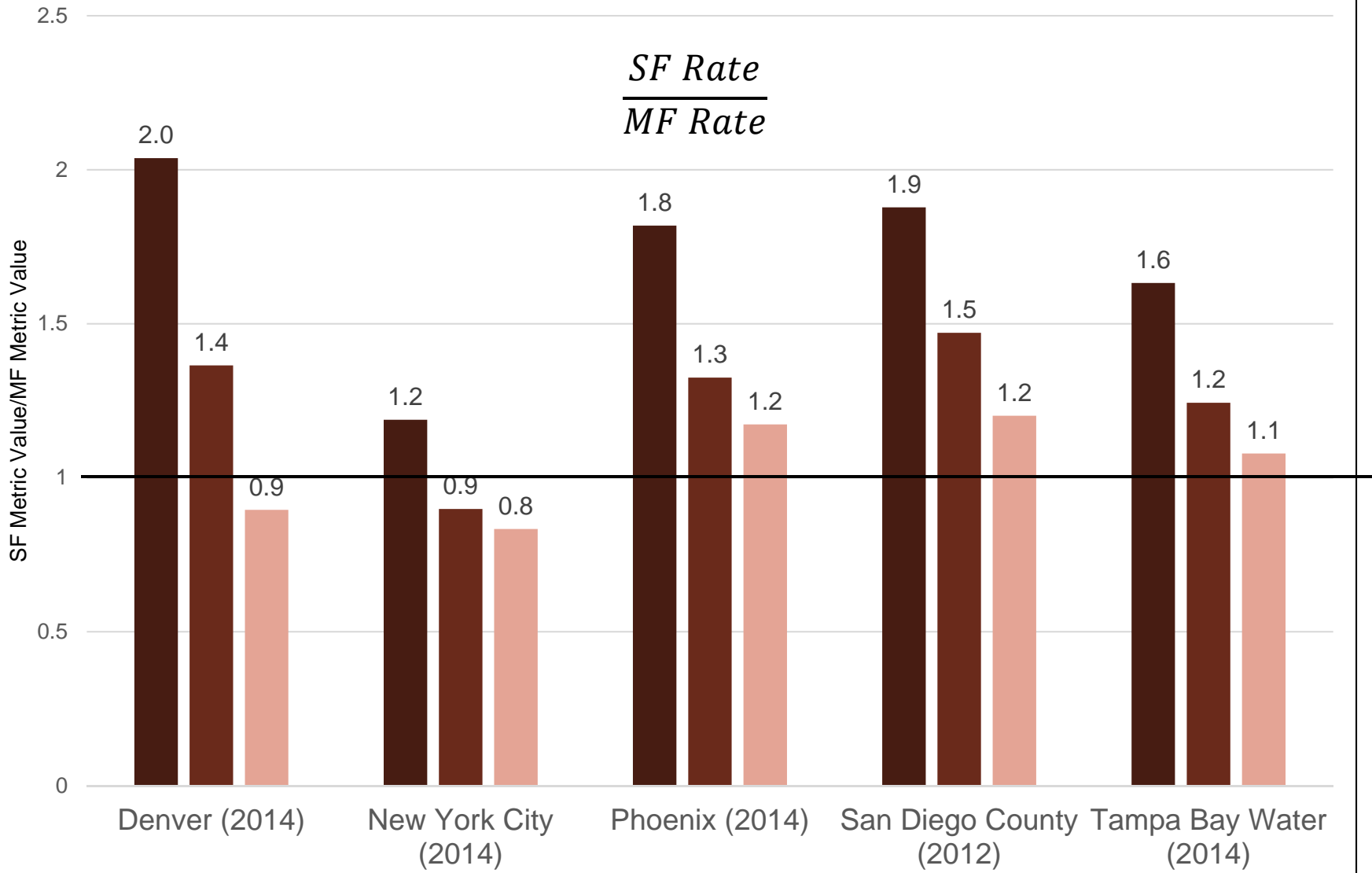
Extra Support Slides

What the US Census tells us

- Increase in share of population living in multiple unit structures
- Rental tenure dominates
- Lower incomes
- Smaller households
- Younger householders
- Proportionally fewer (in unit) clothes washers and dish washers (especially renter-occupied)

Ratio of Single-Family to Multifamily Usage Rate Estimates for Five Water Systems

■ Ratio Annual Use per Unit
 ■ Ratio Annual Use per Capita
 ■ Ratio "Min-Month" Use per Capita



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Tampa Bay Water (2014)	280,865	117	97

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Relatively weak association with climate differences

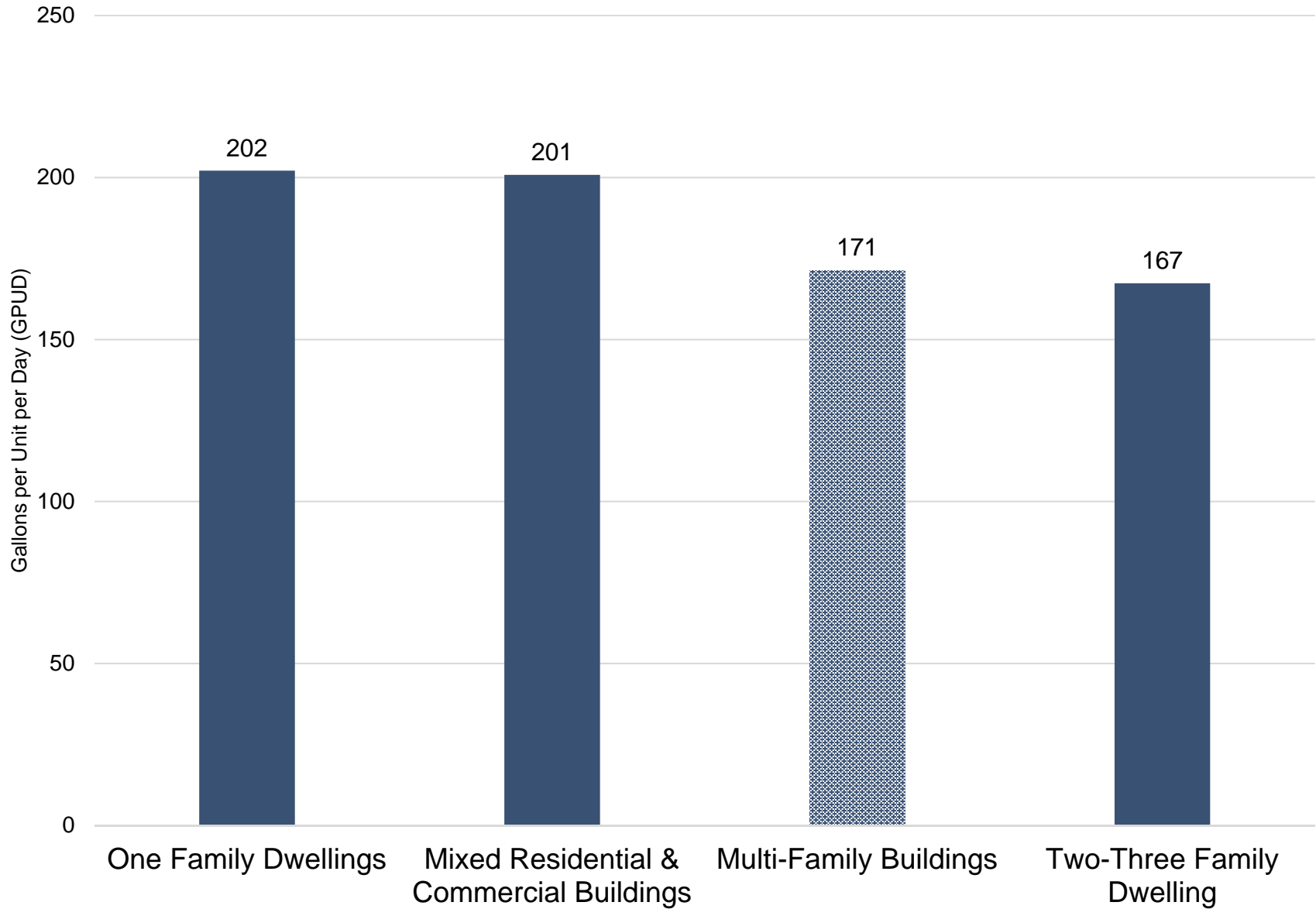
Distributions “skewed to the right”

Comparison of Unit Usage Rates (gallons per unit per day)

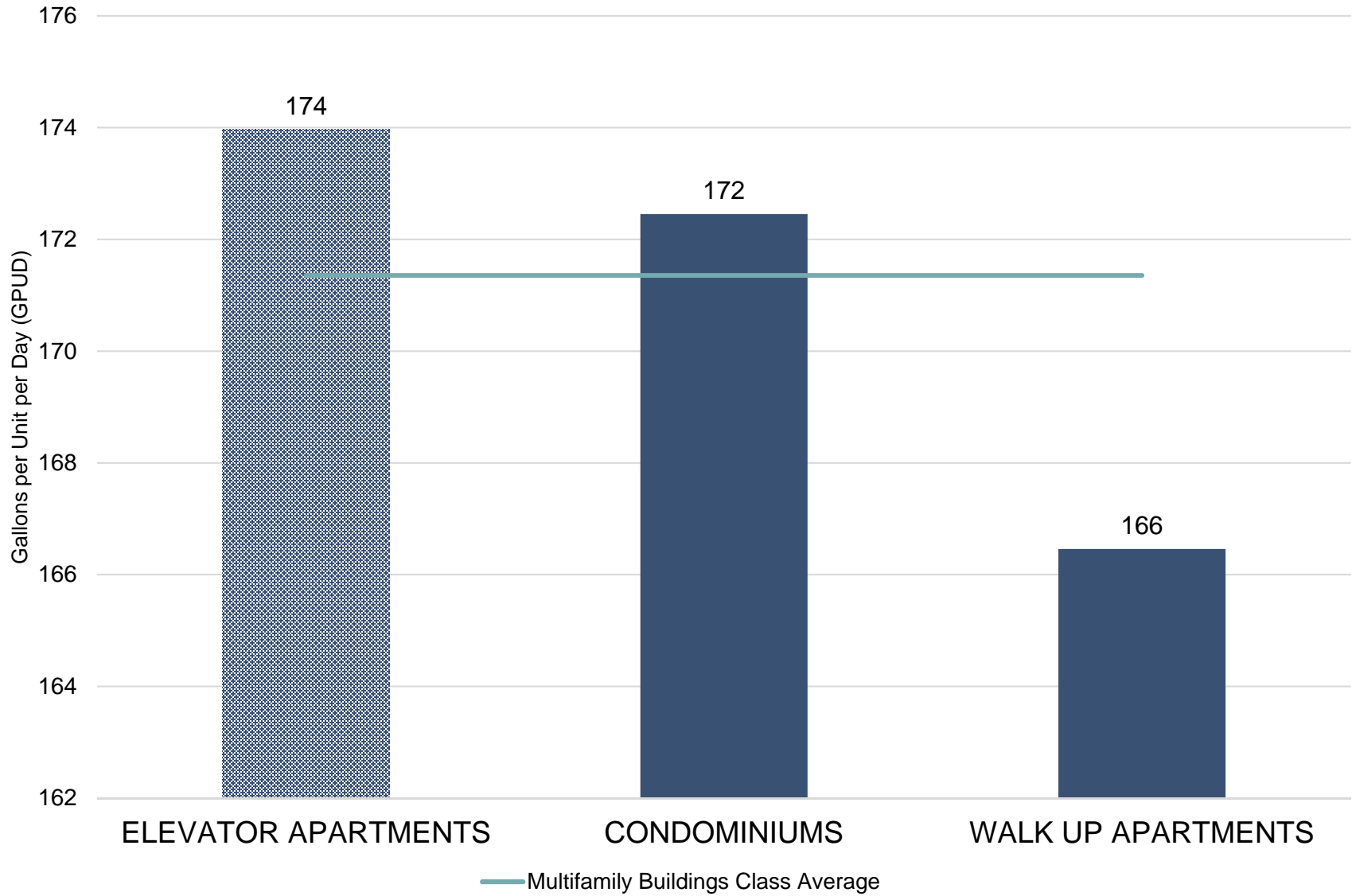
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Phoenix (2014)	MF < SF in all cases		182	158	305,341	331	242
San Diego County (2012)	423,788	164	n/a	670,692	308	n/a	
Tampa Bay Water (2014)	280,865	117	97	404,903	191	150	
*Excludes properties designed for Single-Family or Mixed Residential/Commercial use							

Stronger association with climate in SF sector

New York City Mean 2014 Unit Use by Residential Land Use Tax Classes (GPUUD)

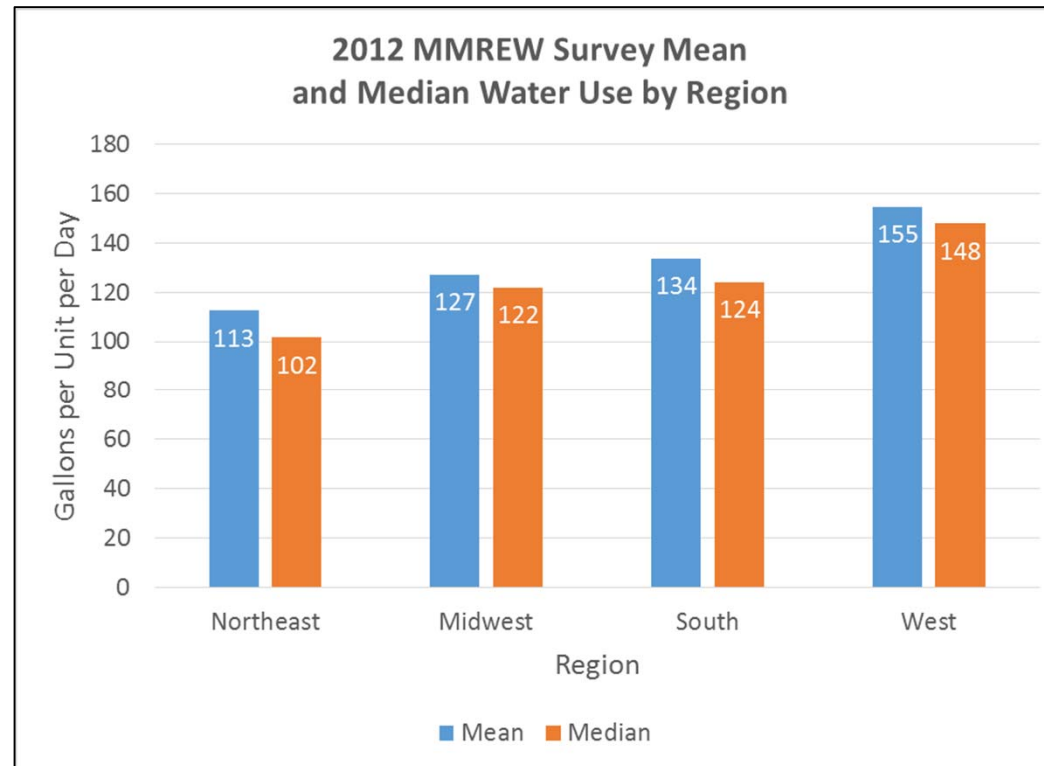


New York City Mean 2014 Unit Use for Building Classes within "Multi-family Buildings" Land Use Tax Class (GPUD)



Property-level Assessments (Fannie Mae Survey)

- Sample of 955 multi-family properties for 2012 categorized by broad region



Plot of Building Age Portion of Regression Equation
 $= \text{Exp}(1.9247 + 0.0789 \cdot \text{AGE} - 0.0021 \cdot \text{AGE}^2 + 1.9756 \cdot 10^{-5} \cdot \text{AGE}^3 - 6.3819 \cdot 10^{-8} \cdot \text{AGE}^4)$

Denver Age profile: +--+

