Saving Water and Saving Energy in Growing Communities

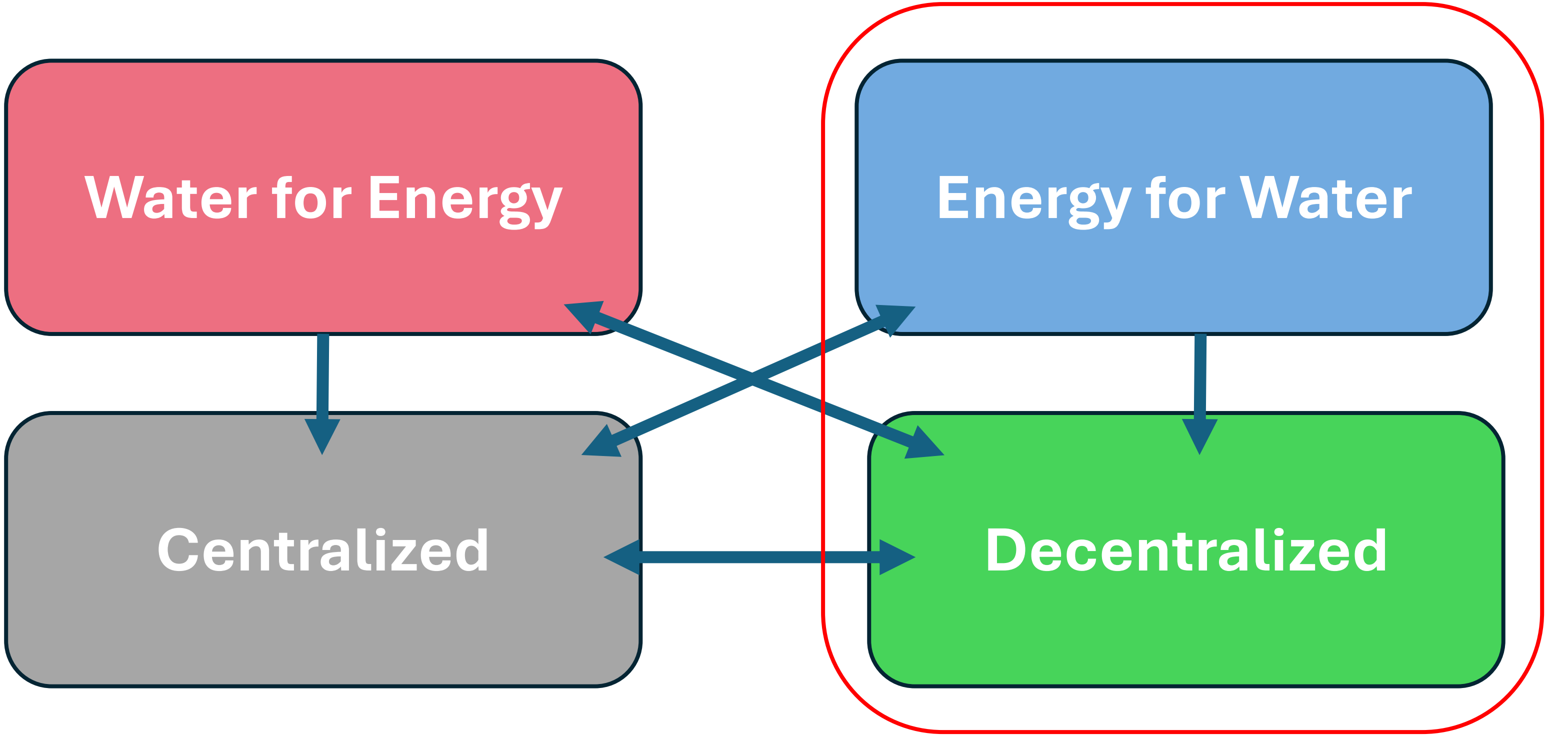
Water

Energy

Dan Cole, Sr. Director of Technical Services and Research The IAPMO Group

2024 EWTS

Water-Energy Interdependence



Water for Energy

Energy for Water

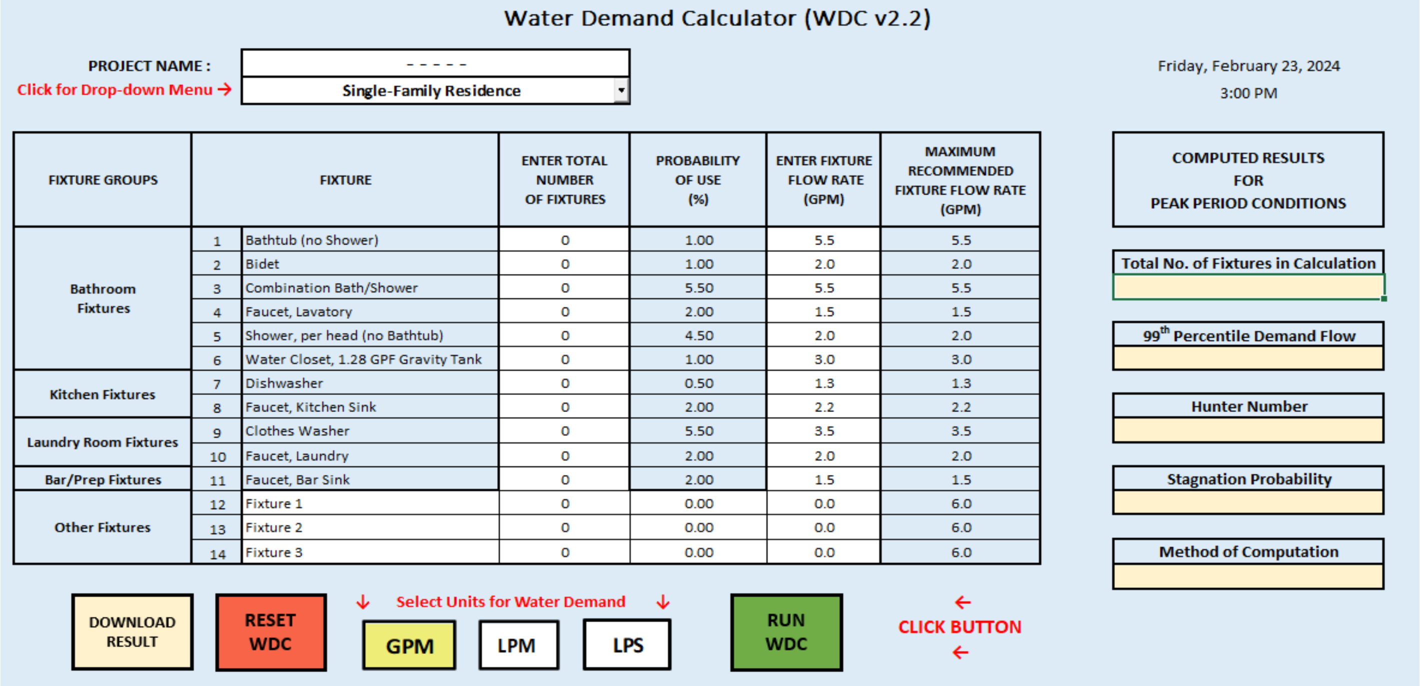
Centralized

Decentralized

Saving Water

Optimize water use with water-conserving fixtures and appliances

Saving Water



Water Demand Calculator (WDC v2.2)

PROJECT NAME : - - - - -
Click for Drop-down Menu → Single-Family Residence

Friday, February 23, 2024
3:00 PM

FIXTURE GROUPS	FIXTURE		ENTER TOTAL NUMBER OF FIXTURES	PROBABILITY OF USE (%)	ENTER FIXTURE FLOW RATE (GPM)	MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
Bathroom Fixtures	1	Bathtub (no Shower)	0	1.00	5.5	5.5
	2	Bidet	0	1.00	2.0	2.0
	3	Combination Bath/Shower	0	5.50	5.5	5.5
	4	Faucet, Lavatory	0	2.00	1.5	1.5
	5	Shower, per head (no Bathtub)	0	4.50	2.0	2.0
	6	Water Closet, 1.28 GPF Gravity Tank	0	1.00	3.0	3.0
Kitchen Fixtures	7	Dishwasher	0	0.50	1.3	1.3
	8	Faucet, Kitchen Sink	0	2.00	2.2	2.2
Laundry Room Fixtures	9	Clothes Washer	0	5.50	3.5	3.5
	10	Faucet, Laundry	0	2.00	2.0	2.0
Bar/Prep Fixtures	11	Faucet, Bar Sink	0	2.00	1.5	1.5
Other Fixtures	12	Fixture 1	0	0.00	0.0	6.0
	13	Fixture 2	0	0.00	0.0	6.0
	14	Fixture 3	0	0.00	0.0	6.0

COMPUTED RESULTS FOR PEAK PERIOD CONDITIONS

Total No. of Fixtures in Calculation

99th Percentile Demand Flow

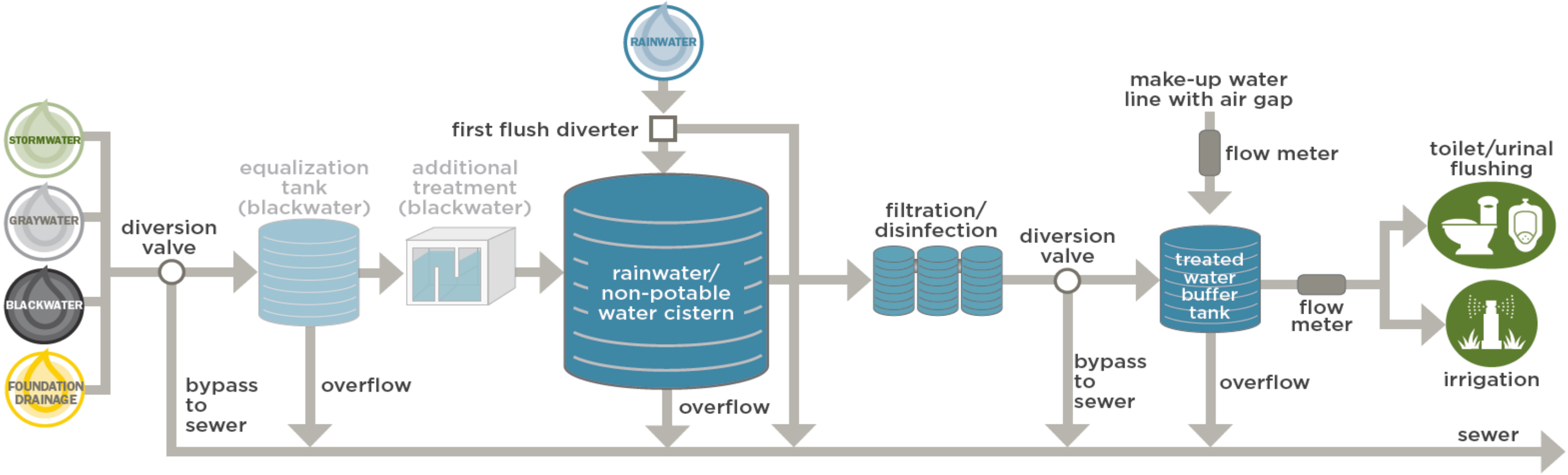
Hunter Number

Stagnation Probability

Method of Computation

Optimize right-sizing the plumbing system

Saving Water



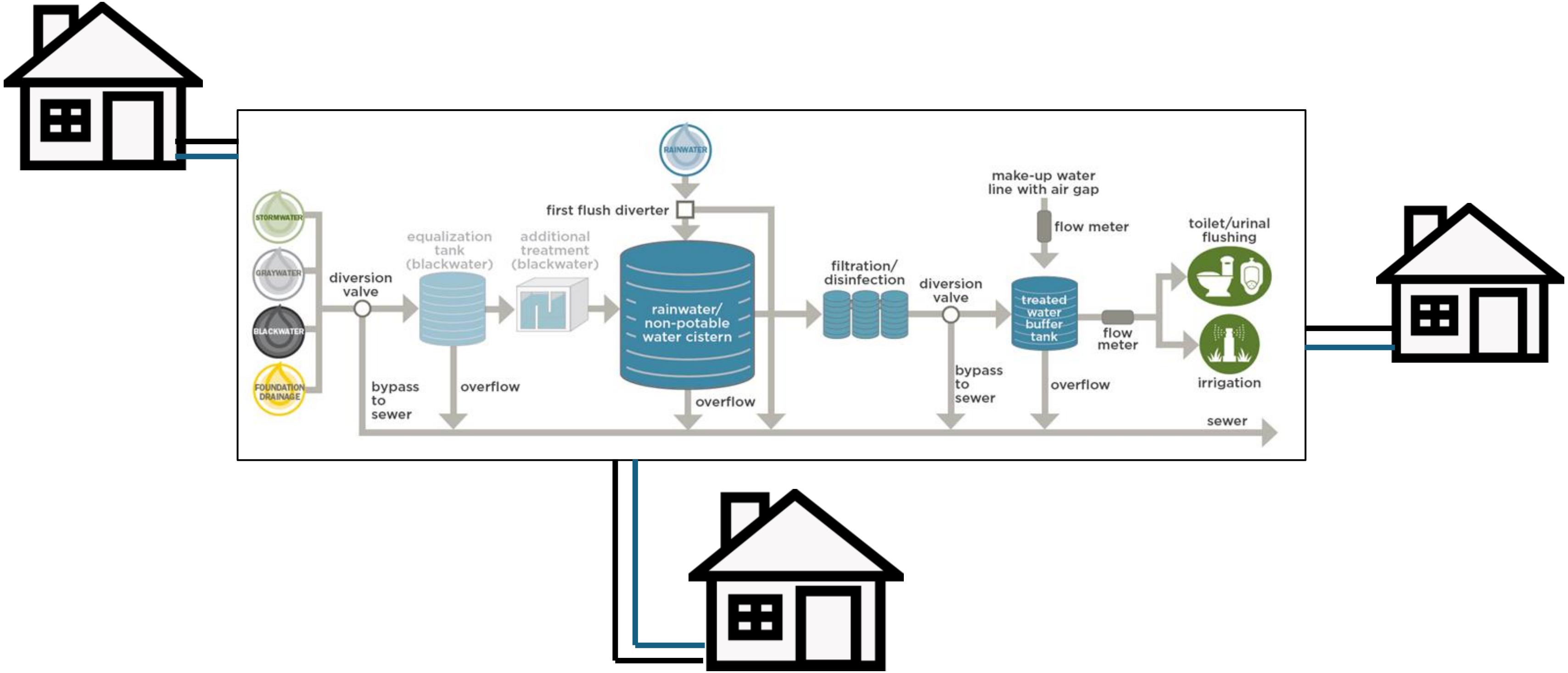
Optimize water reuse options attributed to the built environment

Saving Water

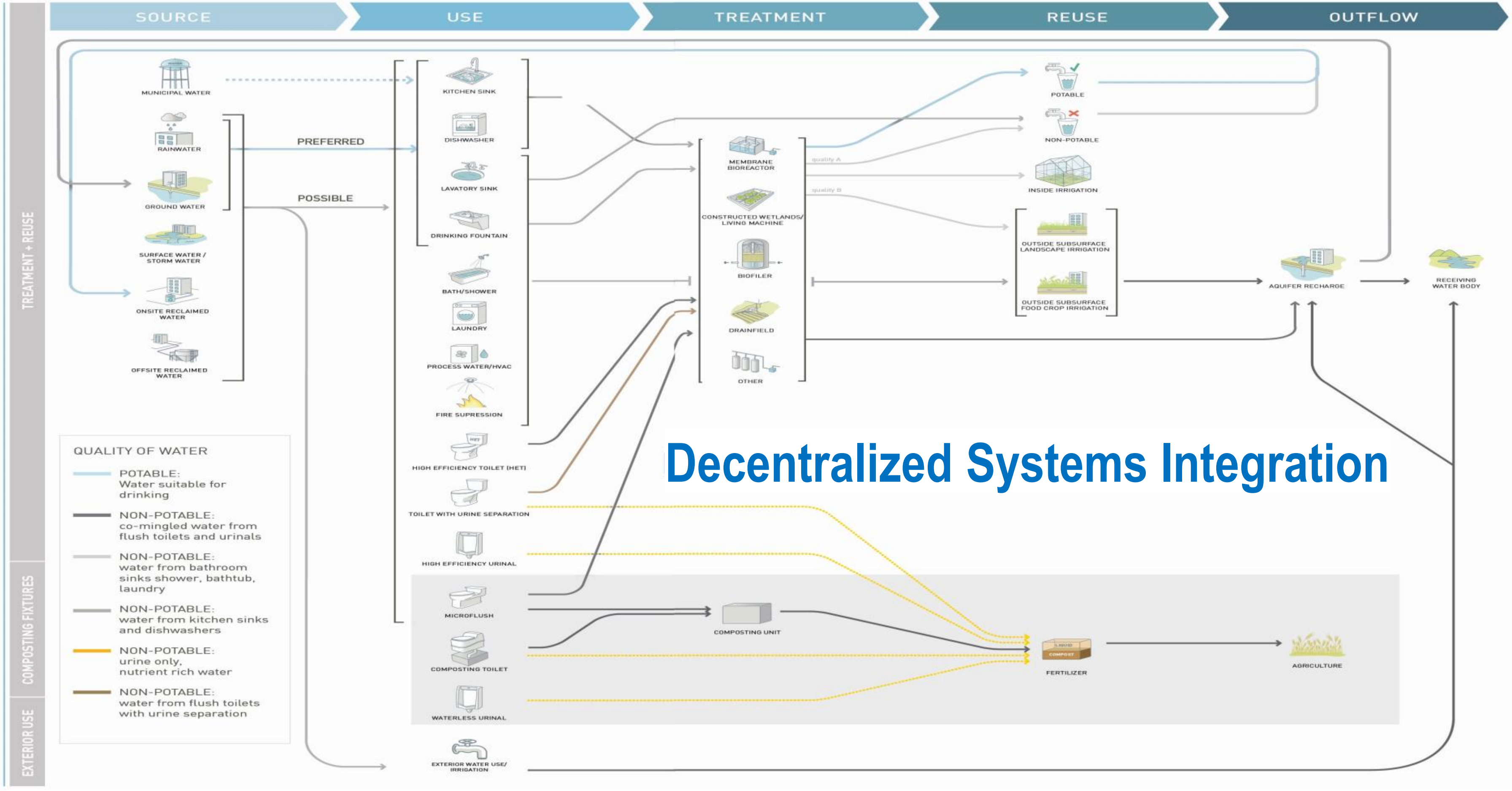
Composting and Urine Diversion

Water Heating Design

Decentralized Treatment for Water Reuse



Decentralized Systems Integration

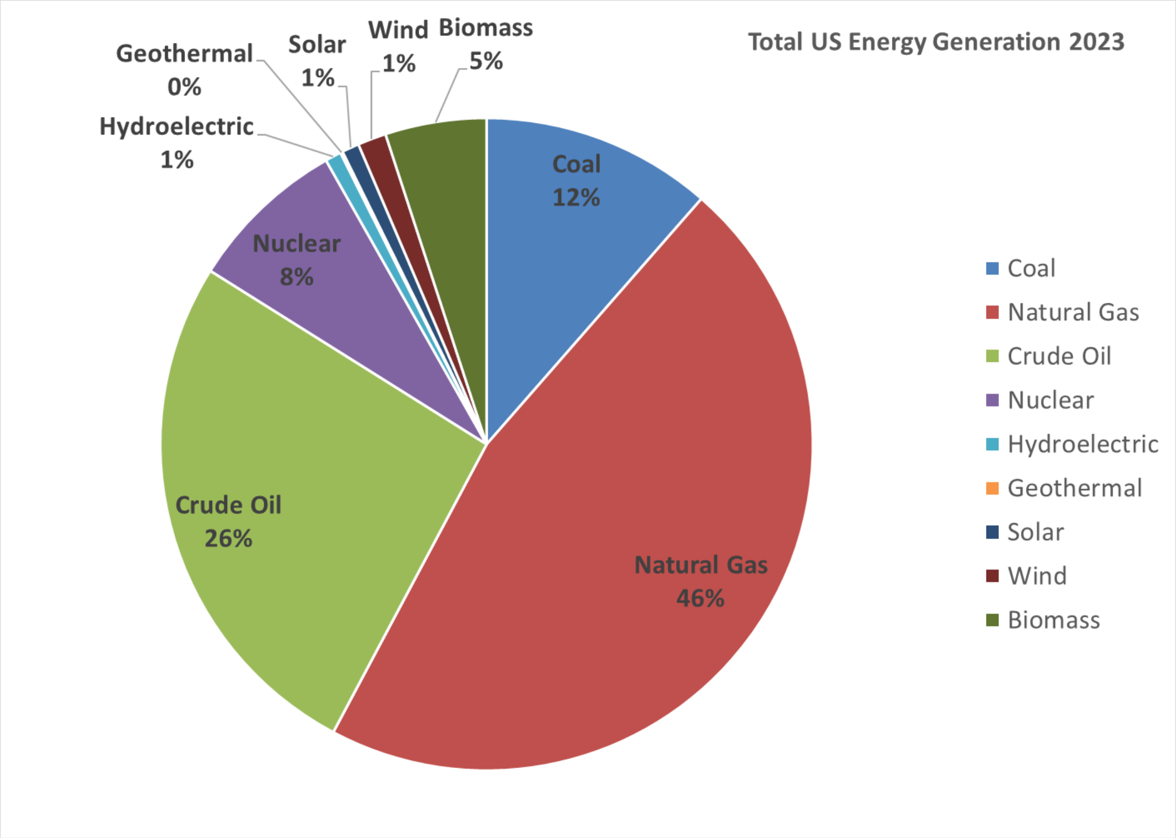


Source: Toward Net Zero Water: Best Management Practices for Decentralized Sourcing and Treatment, 2011

Metrics - Energy for Water

- **Power** - Energy consumption (kWh, MWh, BTU)
- **Mass/Weight** - CO_2 emissions (kg, grams, lbs)
- **Volume** - Water consumption, input/output (cubic meters or gallons)
- **Cost** – economic advantage, capital expenditures, annual operations and maintenance expenditures
- **Infrastructure** and **Human** aspects

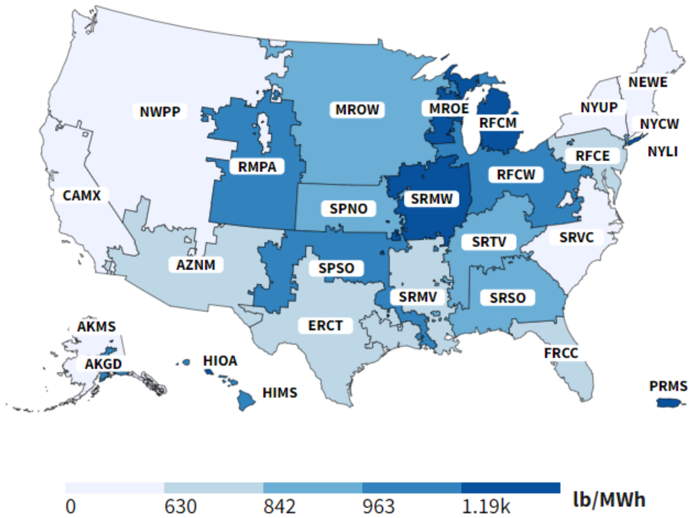
Total US Energy Generation 2023



Source: US Energy Information Administration, March 2024

EPA eGRID

CO_2 total output emission rate (lb/MWh) by eGRID subregion, 2022



Trend, CO_2 total output emission rate (lb/MWh), by eGRID subregion, 2018–2022

Select an eGRID subregion in the map above or the graphs at the right to see its trend here.

State	CO_2 total output emission rate (lb/MWh)	CO_2 total output emission rate (lb/kWh)
US	823.149	0.823149
ALABAMA	787.656	0.787656
ALASKA	912.714	0.912714
ARIZONA	709.12	0.70912
ARKANSAS	1055.801	1.055801
CALIFORNIA	455.94	0.45594
COLORADO	1166.201	1.166201
CONNECTICUT	520.864	0.520864
DELAWARE	899.252	0.899252
DISTRICT OF COLUMBIA	553.976	0.553976
FLORIDA	815.565	0.815565
GEORGIA	737.189	0.737189
HAWAII	1453.179	1.453179
IDAHO	247.852	0.247852
ILLINOIS	588.411	0.588411
INDIANA	1566.914	1.566914
IOWA	617.347	0.617347
KANSAS	820.173	0.820173

Water-Energy Nexus Analysis

Energy Consumption

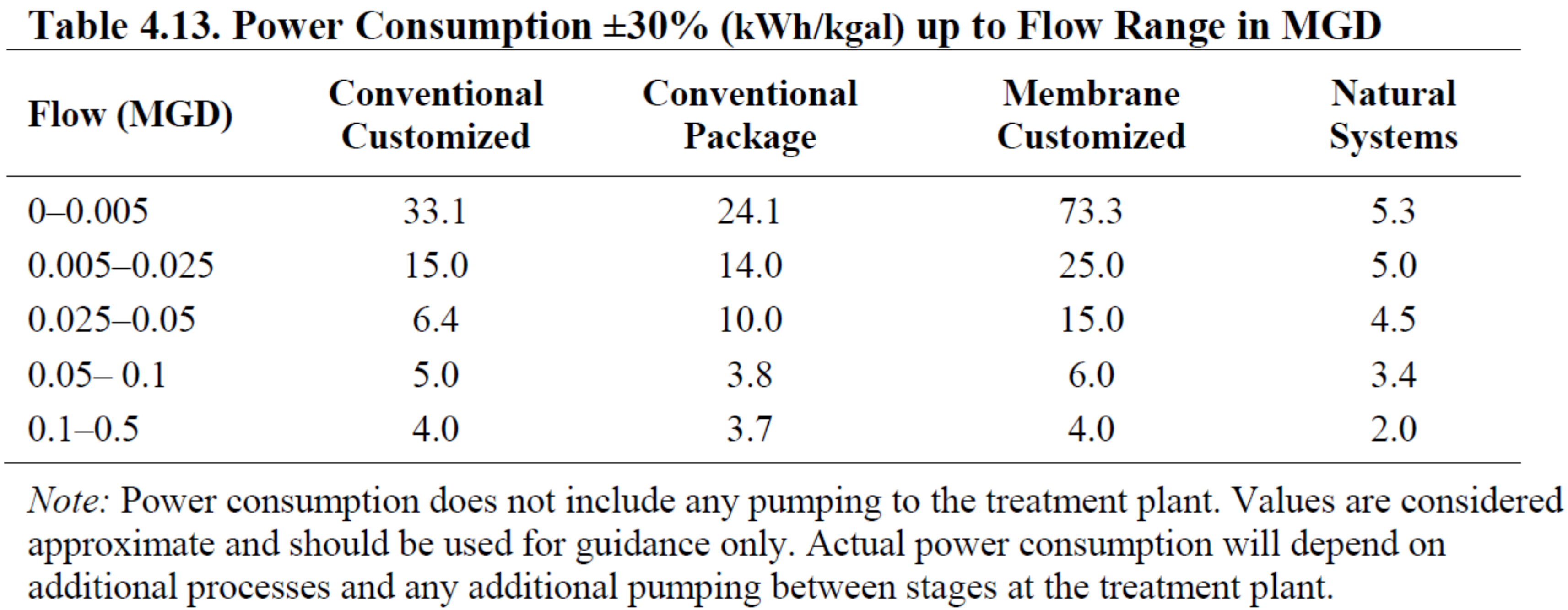


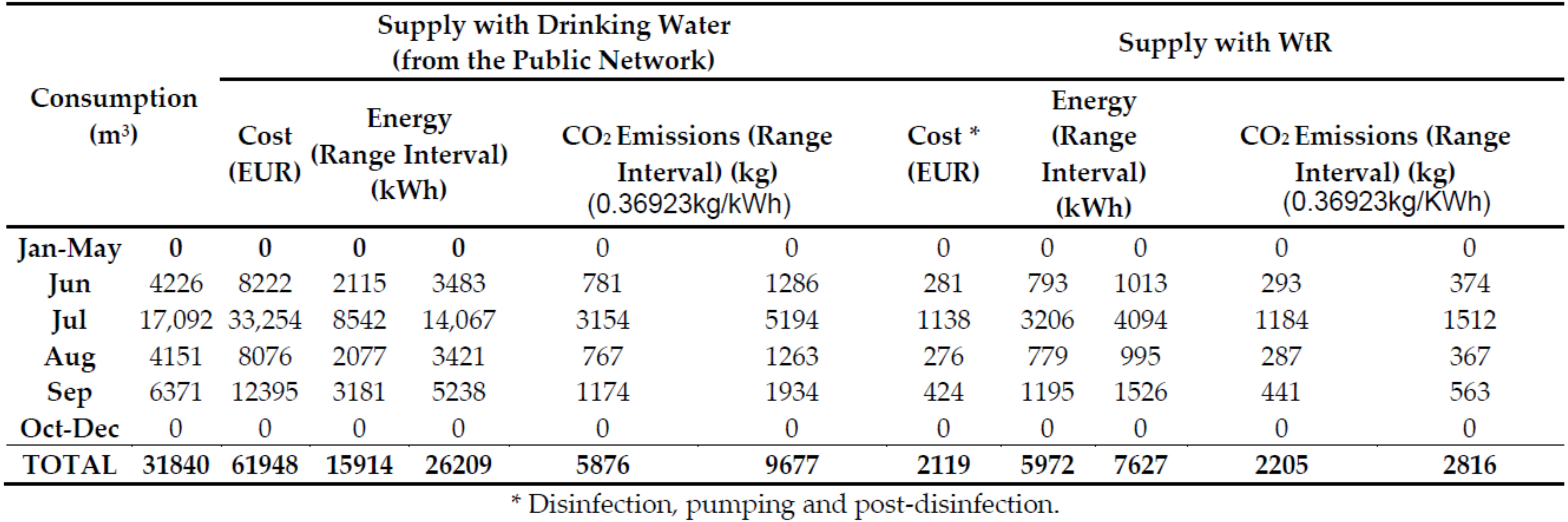
Table 4.13. Power Consumption ±30% (kWh/kgal) up to Flow Range in MGD

Flow (MGD)	Conventional Customized	Conventional Package	Membrane Customized	Natural Systems
0–0.005	33.1	24.1	73.3	5.3
0.005–0.025	15.0	14.0	25.0	5.0
0.025–0.05	6.4	10.0	15.0	4.5
0.05– 0.1	5.0	3.8	6.0	3.4
0.1–0.5	4.0	3.7	4.0	2.0

Note: Power consumption does not include any pumping to the treatment plant. Values are considered approximate and should be used for guidance only. Actual power consumption will depend on additional processes and any additional pumping between stages at the treatment plant.

Source: Guidance for Implementing Reuse in New Buildings and Development to Achieve LEED/Sustainability Goals, 2013

Water-Energy Nexus Analysis

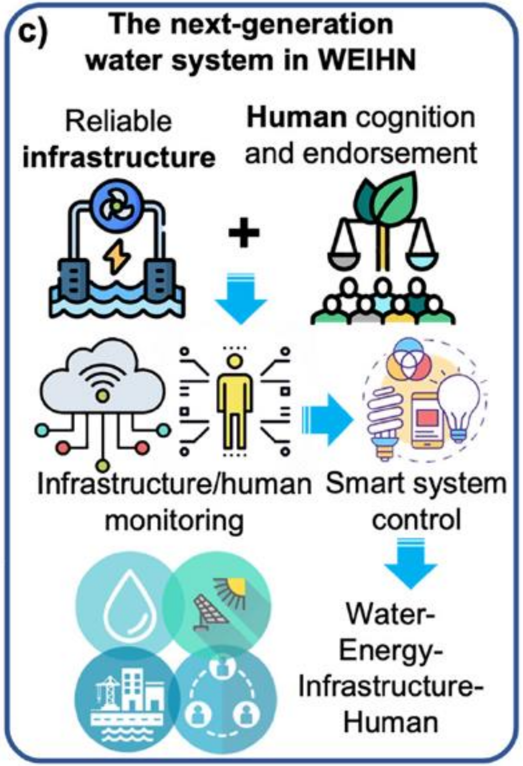


		Supply with Drinking Water (from the Public Network)					Supply with WtR				
Consumption (m^3)		Cost (EUR)	Energy (Range Interval) (kWh)		CO_2 Emissions (Range Interval) (kg) (0.36923kg/kWh)		Cost * (EUR)	Energy (Range Interval) (kWh)		CO_2 Emissions (Range Interval) (kg) (0.36923kg/KWh)	
Jan-May	**0**	**0**	**0**	**0**	0	0	0	0	0	0	0
Jun	4226	8222	2115	3483	781	1286	281	793	1013	293	374
Jul	17,092	33,254	8542	14,067	3154	5194	1138	3206	4094	1184	1512
Aug	4151	8076	2077	3421	767	1263	276	779	995	287	367
Sep	6371	12395	3181	5238	1174	1934	424	1195	1526	441	563
Oct-Dec	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**31840**	**61948**	**15914**	**26209**	**5876**	**9677**	**2119**	**5972**	**7627**	**2205**	**2816**

* Disinfection, pumping and post-disinfection.

Source: Cristina Santos, et. al, 2021. Analysis of the Water–Energy Nexus of Treated Wastewater Reuse at a Municipal Scale, Water.

WEIHN Next Generation Approach



Adding infrastructure-human nexus

Infrastructure Aspect:

- Spatial configuration – small-scale production facilities
- Performance metrics – resource consumption and safety
- Interdependency – interactions between different water and energy infrastructures within a system

Human Aspect:

- Operators – maintaining stability and safety of the water/energy infrastructure
- Decision-makers – policy and marketing strategies to influence how resources are consumed.
- End Users – consumption behavioral patterns

Source: Yuankai Huang, et. al., 2023. Next generation decentralized water systems: a water-energy-infrastructure-human nexus (WEIHN) approach. Environmental Science Water Research & Technology

Water-Energy Savings from Right Sizing Plumbing Systems

Water Savings

Building Type	Unit Water Savings per fixture use* (gallons)	Building Water Savings per unit per day (gallons)	Building Water Savings per building per day (gallons)	Annual Building Water Savings (gallons)
Single Unit	0.62	1.24	1.24	451
6-Unit	0.68	1.36	8.16	2,980
45-Unit	0.54	4.34	195	71,258

* Fixture use was the shower for the single unit and 6-unit, and the kitchen faucet for the 45-unit.

Source: Energy and Carbon Savings Opportunities, Water Demand Calculator. 2023. ARUP.

Water-Energy Savings from Right Sizing Plumbing Systems

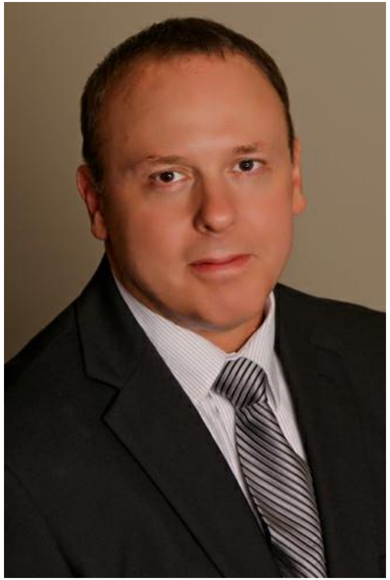
Energy Savings as CO_2 emissions

	2021 Single Family Permits	EPA eGrid emissions factor (lb CO_2/MWh)	Difference in tons CO_2 between WDC & Hunter method
New York	11,099	233.5	248
Arizona	46,561	846.6	3,769
Missouri	13,941	1480.7	1,974

Source: Energy and Carbon Savings Opportunities, Water Demand Calculator. 2023. ARUP.

Select Sources

1. Cristina Santos, Francisco Taveira-Pinto, David Pereira, and Cristina Matos, 2021. Analysis of the Water–Energy Nexus of Treated Wastewater Reuse at a Municipal Scale, Water.
2. Energy and Carbon Savings Opportunities, Water Demand Calculator. 2023. ARUP.
3. Guidance for Implementing Reuse in New Buildings and Development to Achieve LEED/Sustainability Goals, 2013. WateReuse Foundation.
4. Lee, Juneseok and Younos, Tamim, 2018. Sustainability Strategies at the Water–Energy Nexus: Renewable Energy and Decentralized Infrastructure. JOURNAL AWWA.
5. Lutz, J., 2005. Estimating Energy and Water Losses in Residential Hot Water Distribution Systems. Lawrence Berkeley National Lab.(LBNL), Berkeley, CA.
6. Omaghomi, T., Buchberger, S.G., 2018. Residential Water and Energy Savings in Right-Sized Premise Plumbing: WDSA/CCWI Joint Conference Proceedings.
7. Salveson, Andrew, et al., 2010. Low-cost Treatment Technologies for Small-scale Water Reclamation Plants. WateReuse Research Foundation.
8. Silva-Afonso, A.; Rodrigues, F.; Pimentel-Rodrigues, C., 2011. Water efficiency in buildings: Assessment of its impact on energy efficiency and reducing GHG emissions. In Proceedings of the 6th IASME/WSEAS International Conference on Energy and Environment EE’11; WSEAS Press: Cambridge, UK.
9. Yuankai, Huang, Jintao Zhang, Zheng Ren, Wenjun Xiang, Iram Sifat, Wei Zhang, Jin Zhu and Baikun Li., 2023. Next generation decentralized water systems: a water-energy-infrastructure-human nexus (WEIHN) approach. Environmental Science Water Research & Technology.



Dan Cole
Sr. Director of Technical Services and Research

Email:

dan.cole@iapmo.org

Chicago Regional Office
18927 Hickory Creek Drive, Suite 220
Mokena, IL 60448
p: 708-995-3009

Saving Water and Saving Energy in Growing Communities

Emerging Water Technology symposium
Scottsdale, AZ May 13-14, 2024

Gary Klein
gary@garykleinassociates.com
916-549-7080

Key Principles

- Reduce the waste
- Improve the use
- Increase the efficiency

What Reduces Hot Water Use?

- End uses closer to water heater(s)
- Insulating hot water supply piping
- Truly “Instantaneous” water heaters
- Warmer incoming cold water

- Lower flow rate plumbing fixtures
- Lower volume plumbing appliances
- Using waste heat running down the drain to preheat cold water

- Anything else?

What Increases Hot Water Use?

- End uses further from water heater(s)
  - More volume to clear
- Uninsulated hot water supply piping
  - More uses start out with colder water
- Lower flow rate plumbing fixtures
  - Increases waste while waiting for hot water to arrive
- “Instantaneous” water heaters
  - Cold water runs through while ramping up to temp
- Colder incoming cold water
  - Increases the percent of hot water in the mix
- Anything else?

The most valuable water to
conserve is hot water
at the top of the tallest building,
with the highest elevation,
in the area with the greatest
pressure drop.

Customers

1. What do they expect?
2. What do they want?
3. How do we increase customer satisfaction?

What Are We Aiming For?

1. People want:
   - The water flowing from their showers and faucets to “feel” right.
   - Their toilets to flush first time, every time.
   - Clean clothes, dishes and bodies
   - The service of hot water, as efficiently as possible.
2. It does not make sense to discuss efficiency until the desired service has been provided.

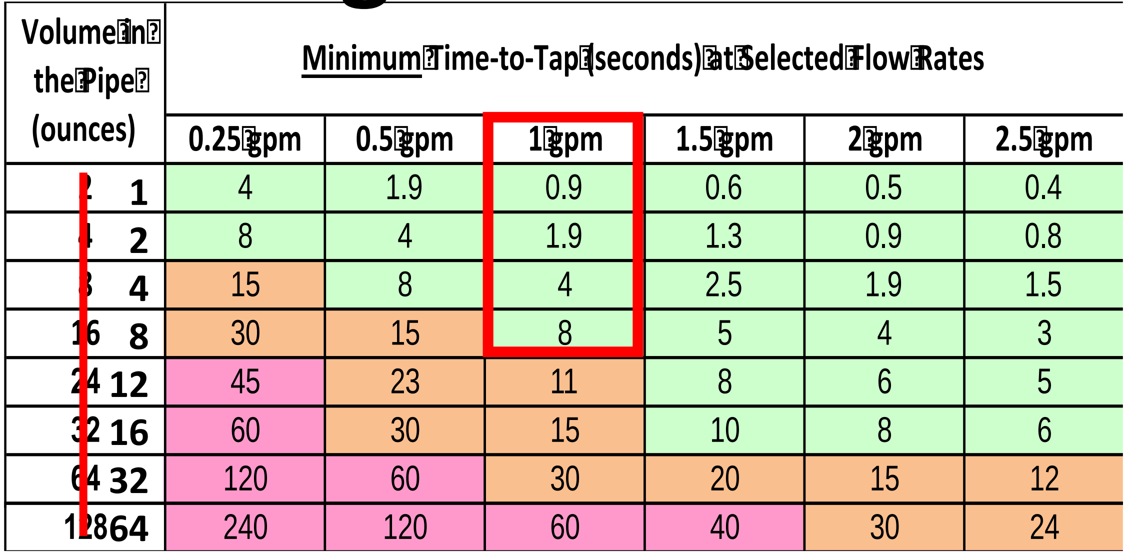
How Do We Increase Customer Satisfaction?

1. Reduce the Time-to-Tap
    a) Reduce the Distance from the Source to the Use
    b) Right-Size the Piping based on Modern Flow Rates and Realistic Simultaneity
2. Reduce the Pressure Drop
    a) In the Pipe and Fittings
        1) Minimize the length
        2) Minimize the number of pressure-consuming fittings
    b) In the Faucets and Shower Valves
3. Install Pressure-Independent Faucet Aerators and Showerheads

The Ideal
Hot Water Distribution System

- Has the smallest volume (length and smallest “possible” diameter) of pipe from the source of hot water to the hot water outlet.
- Sometimes the source of hot water is the water heater, sometimes a trunk line.
- For a given layout (floor plan) of hot water locations the system will have:
  - The shortest buildable trunk line
  - Few or no branches
  - The shortest buildable twigs
  - The fewest plumbing restrictions
  - Insulation on all hot water pipes, minimum R-4

How Long Should We **Wait?**



Volume in the Pipe (ounces)	Minimum Time-to-Tap (seconds) at Selected Flow Rates					
	0.25 gpm	**0.5 gpm**	**1 gpm**	**1.5 gpm**	**2 gpm**	**2.5 gpm**
~~2~~ **1**	4	1.9	0.9	0.6	0.5	0.4
~~4~~ **2**	8	4	1.9	1.3	0.9	0.8
~~8~~ **4**	15	8	4	2.5	1.9	1.5
~~16~~ **8**	30	15	8	5	4	3
~~24~~ **12**	45	23	11	8	6	5
~~32~~ **16**	60	30	15	10	8	6
~~64~~ **32**	120	60	30	20	15	12
~~128~~ **64**	240	120	60	40	30	24

Cut the pipe volume in half to get these times

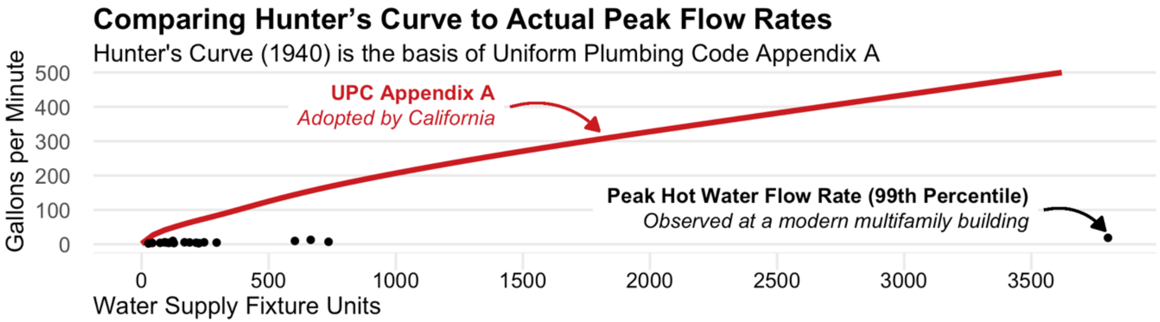
ASPE Time-to-Tap Performance Criteria

🟩	**Acceptable Performance**	1 – 10 seconds
🟧	**Marginal Performance**	11 – 30 seconds
🟥	**Unacceptable Performance**	31+ seconds

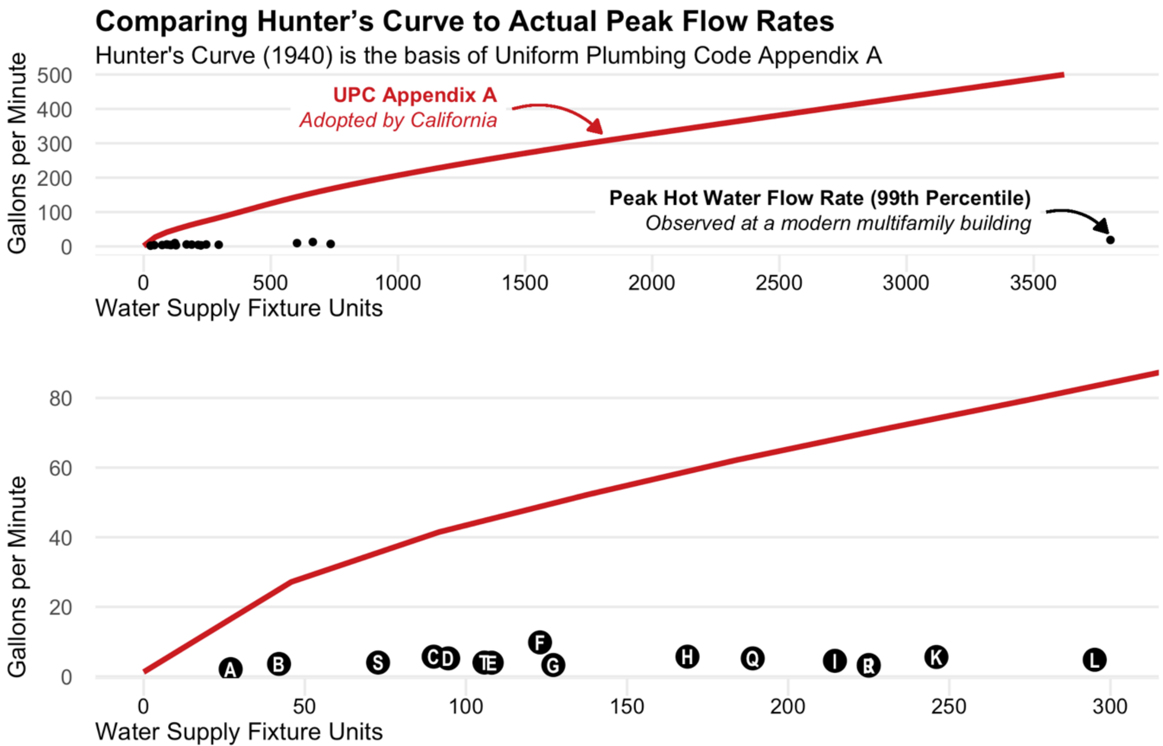
Source: Domestic Water Heating Design Manual – 2nd Edition, ASPE, 2003, page 234

For volume per foot see 2018 UPC Table L 502.7 or 2018 IPC Table E 202.1

Peak Flow Rates-Measured vs Predicted



Peak Flow Rates-Measured vs Predicted

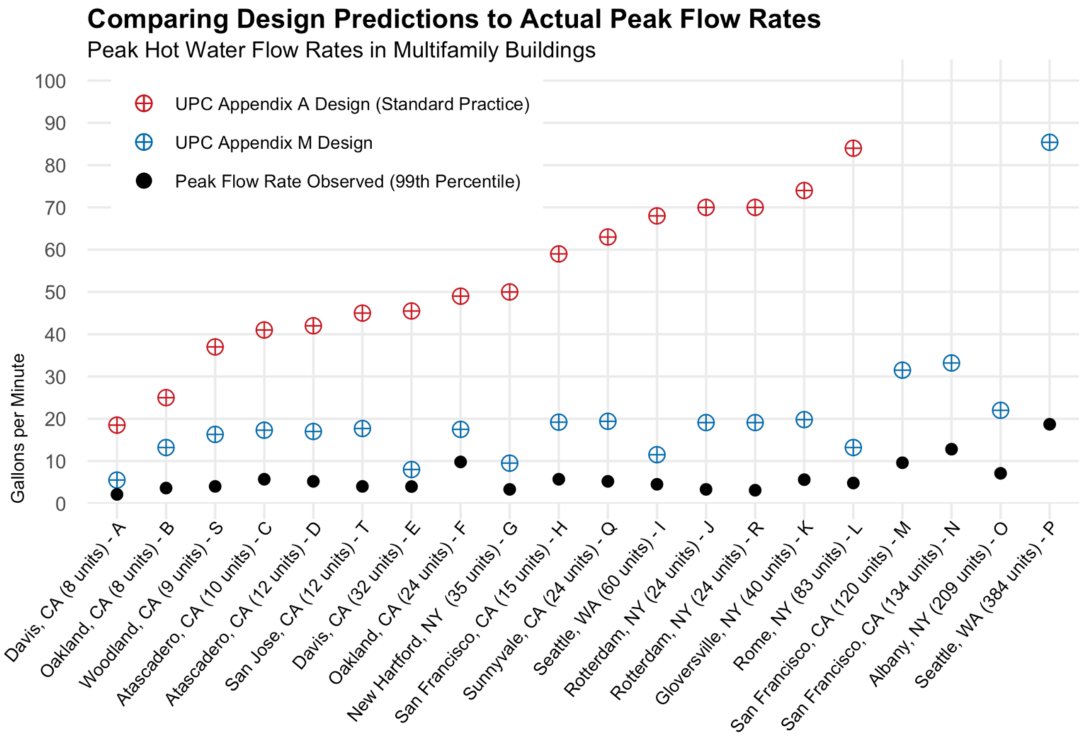


Comparing Hunter's Curve to Actual Peak Flow Rates

Hunter's Curve (1940) is the basis of Uniform Plumbing Code Appendix A

Many thanks to the Association for Energy Affordability, Ecotope, Frontier Energy, Peter Skinner, and the UC Davis Western Cooling Efficiency Center for providing data.

Peak Flow Rates-Measured vs Predicted



Comparing Design Predictions to Actual Peak Flow Rates

Peak Hot Water Flow Rates in Multifamily Buildings

Many thanks to the Association for Energy Affordability, Ecotope, Frontier Energy, Peter Skinner, and the UC Davis Western Cooling Efficiency Center for providing data.

Why Your Shower Feels Wimpy

Let’s Look at a 2nd Floor Shower

	PSI	PSI
Street Pressure	60	80
Go up 20 feet	- 9	- 9
Tub/Shower Valve	- 11	- 11
Losses in the piping	- 20	- 20
Total of the Pressure Losses	- 40	- 40
Residual Pressure at the shower head	20	40

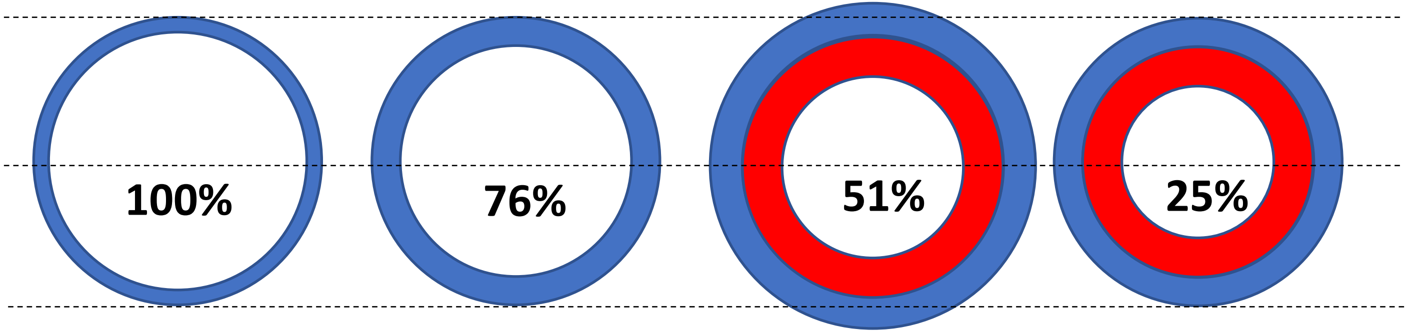
Showerhead flow rates are determined at 80 psi.
For fixed orifice showerheads, the flow rate will be much less
Flow rate at 40 psi = 0.7 * Flow Rated at 80 psi
Flow rate at 20 psi = 0.49 * Flow Rated at 80 psi

Similar reductions for faucets with flow rated at 60 psi

Downey, CA

Arcata, CA

Relative Size of the Waterway for Selected 0.5inch Pipe and Fittings



Copper Type-L

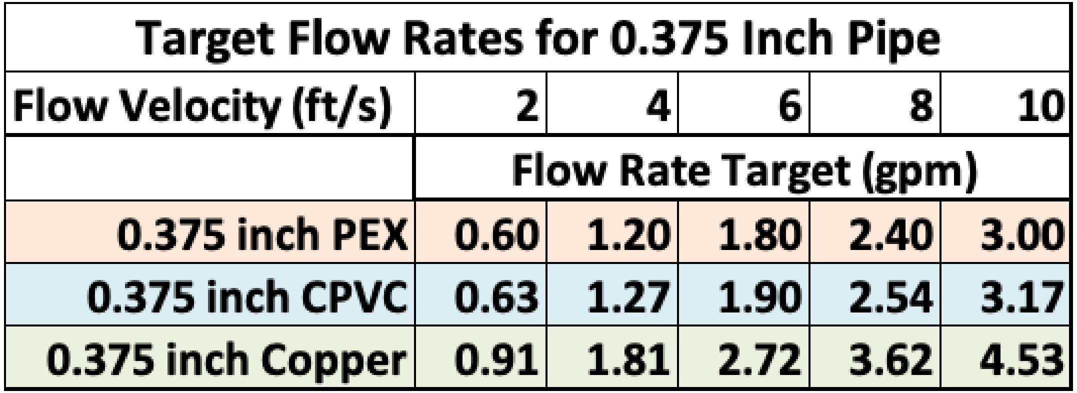
PEX or CPVC

PEX Cold-Expansion

PEX Crimp or Press

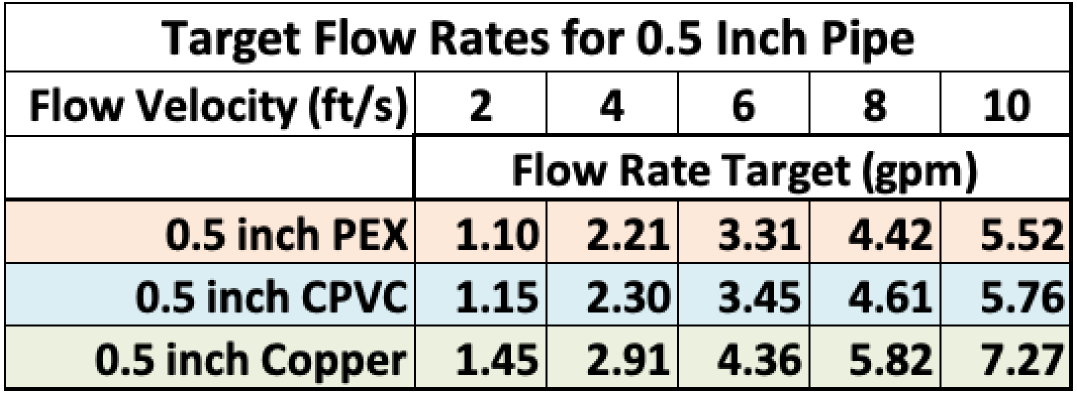
0.5 inch Nominal Pipe (inches)				
Size	**Nom OD**	**Wall Ave**	**Tol+/-**	**Nom ID**
1/2 PEX ASTM F876	0.625	0.070	0.010	0.475
1/2 CPVC, ASTM D2846	0.625	0.07	0.01	0.475
1/2 inch Copper Type-L ASTM B88	0.625	0.040	0.004	0.545

Target Flow Rates



Target Flow Rates for 0.375 Inch Pipe

Flow Velocity (ft/s)	2	4	6	8	10
	Flow Rate Target (gpm)				
0.375 inch PEX	0.60	1.20	1.80	2.40	3.00
0.375 inch CPVC	0.63	1.27	1.90	2.54	3.17
0.375 inch Copper	0.91	1.81	2.72	3.62	4.53

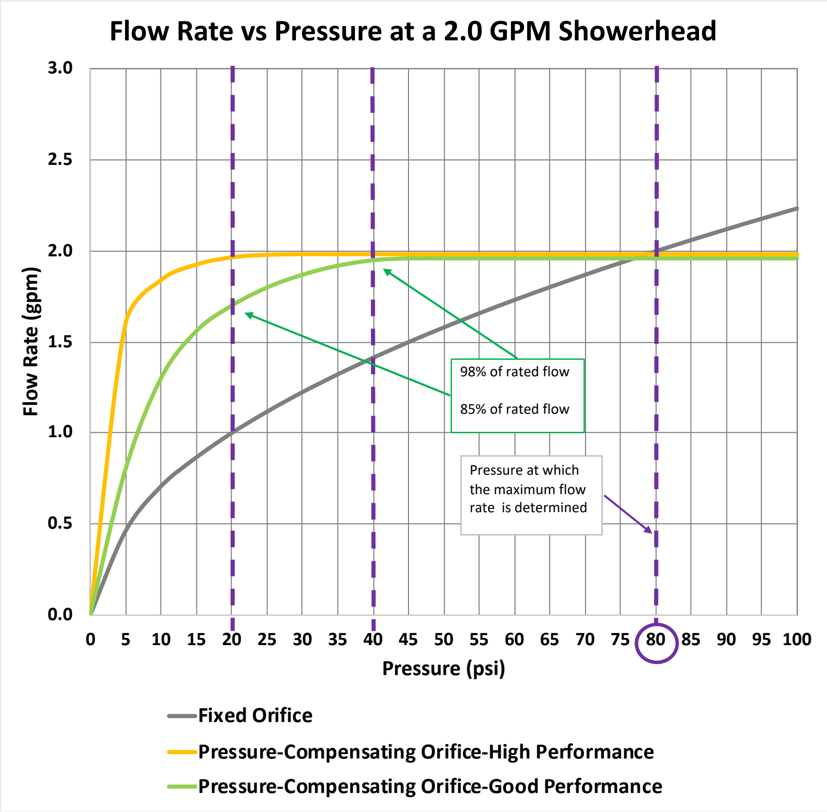


Target Flow Rates for 0.5 Inch Pipe

Flow Velocity (ft/s)	2	4	6	8	10
	Flow Rate Target (gpm)				
0.5 inch PEX	1.10	2.21	3.31	4.42	5.52
0.5 inch CPVC	1.15	2.30	3.45	4.61	5.76
0.5 inch Copper	1.45	2.91	4.36	5.82	7.27

Pressure Independent Showerheads

Which one do you want?


Flow Rate vs Pressure at a 2.0 GPM Showerhead

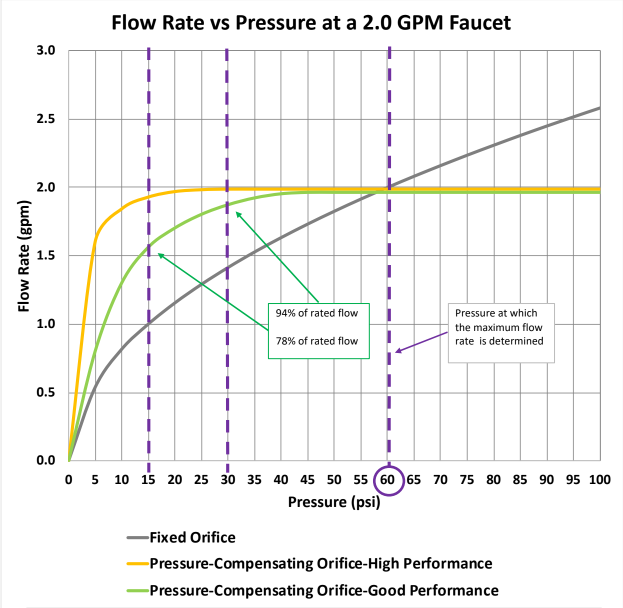
98% of rated flow

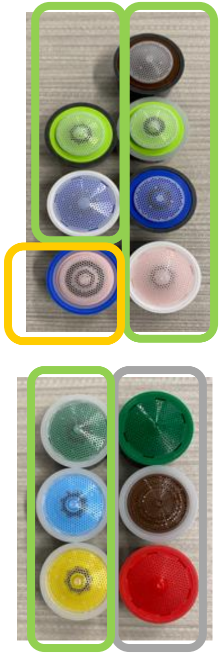
85% of rated flow

Pressure at which the maximum flow rate is determined

Pressure Independent Faucets

Which one do you want?





Select Good or High-Performance Faucet Aerators to Increase Customer Satisfaction.

Will more stringent codes and standards get us to a more resilient lower carbon future?

Given human nature,
it is out job
to provide infrastructure
that supports efficient behaviors.

Questions?