# Maximizing Water Efficiency in Single Family Homes:

## Lessons from 20 Years of Study

Based on Empirical Data from Five Key End Use Studies

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# Introduction: the Water/Power Nexus

- The two essential items for making a house a home are water and power. With adequate supplies of these one can live comfortably almost anywhere on planet Earth.
- Of the two, water is the more critical: you can find substitutes for electricity and gas, but there are no substitutes for water.
- It takes ~ 25 kwh/day of electricity for a home, but up to 150+ kwh/day if you use AC, electric heat, or charge an electric car.
- The typical SF home currently uses ~140 gphd of water, but this could drop to as low as 70 gphd with special measures.

# Key Findings

- Single family water use is decreasing on both a household and a per-capita basis
- Major reductions seen in toilets and clothes washer use
- Significant reductions seen in off-the-shelf new homes.
- The best reductions seen in high efficiency homes (retrofit homes and high efficiency new homes)
- This trend should continue into the future and should be used for future planning studies.
- Outdoor Use was Lower
- We are seeing the limits of conservation.

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# Five Studies, Six Groups

- REUWS (1997) provides the baseline for existing homes (year 0)
- California SF Study (2007) provides a reference for existing homes (10 years after REUWS)
- EPA New Home Study provides two groups
  - Standard new homes, built in 2001, sampled in 2007
  - High efficiency new homes, built around 2006, designed for maximum water use efficiency
- EPA Retrofit Study provides sample of existing homes brought up to high efficiency standards through retrofits
- REUWS2 (2014) Follow-up to REUWS1 17 years later to see how baseline has changed

# Common Methodology:
## Looking beyond billing data

- Selection of random samples from population
- Collection of highly detailed information
  - Surveys to identify key variables
  - Data logging to disaggregate water use
  - GIS analysis of landscapes
- Analysis of indoor and outdoor water use
  - Determination of household and per-capita use
  - Analysis of efficiency of fixtures and appliances
  - Determination of actual irrigation vs. requirements
- Results show conservation potential in homes.

# Indoor End-uses Identified by event

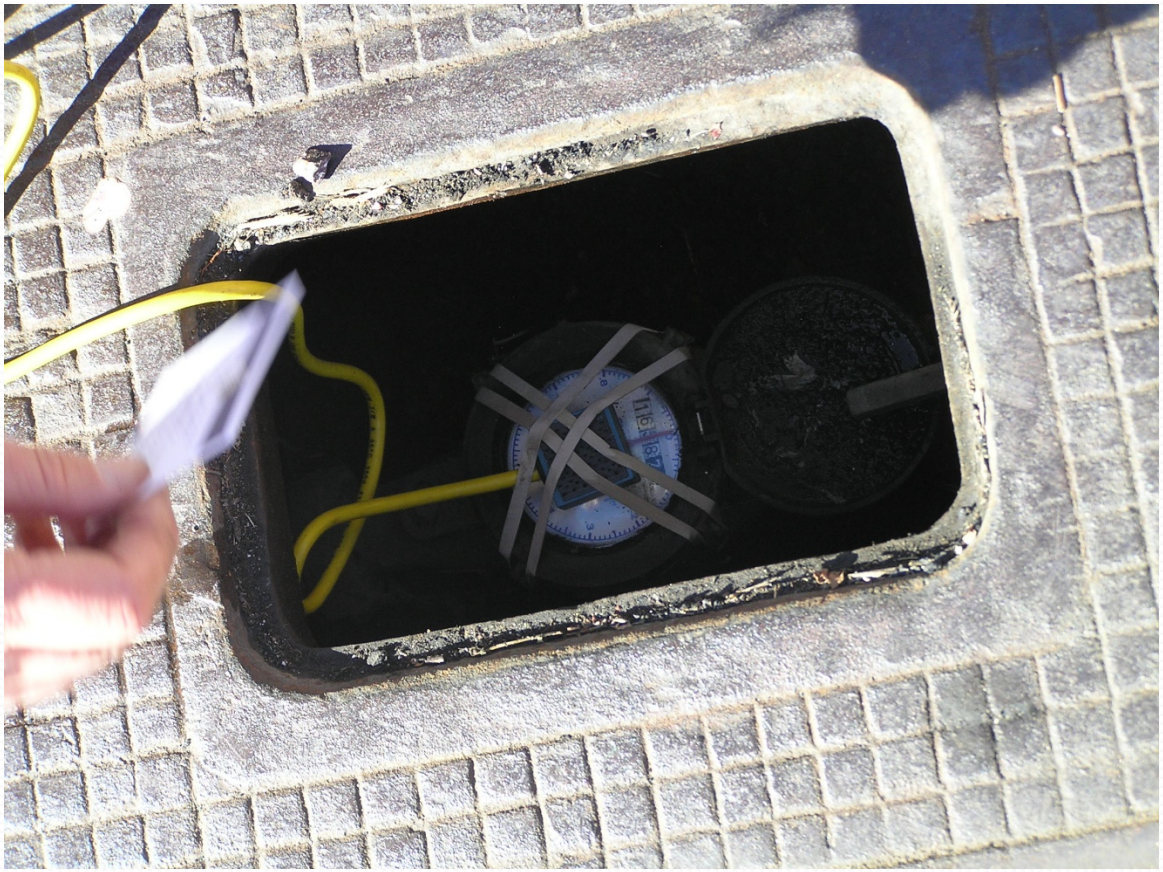
- Toilets
- Showers
- Clothes Washers
- Dish washers
- Baths
- Leaks
- Faucets
- Other

# Simply strap the magnetic sensor to the side of the water meter

# Data loggers provide high resolution flow trace from meter.

- Brainard Meter Master 100 EL

# The sensor picks up the motion of the internal magnets in the meters



# The secret is in the flow profiles and Trace Wizard analysis tool.

This is a toilet flush:

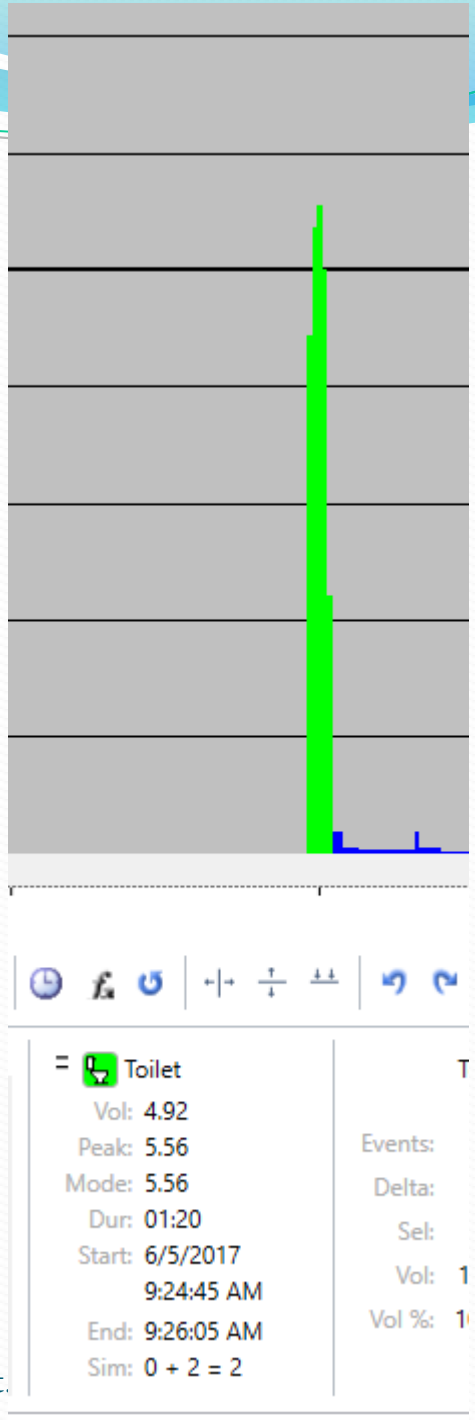
Note the parameters used by Trace Wizard to identify this and all similar events during the logging period.

Volume: 4.92 gallons per flush

Peak Flow: 5.56 gpm

Duration: 1 minute 20 seconds

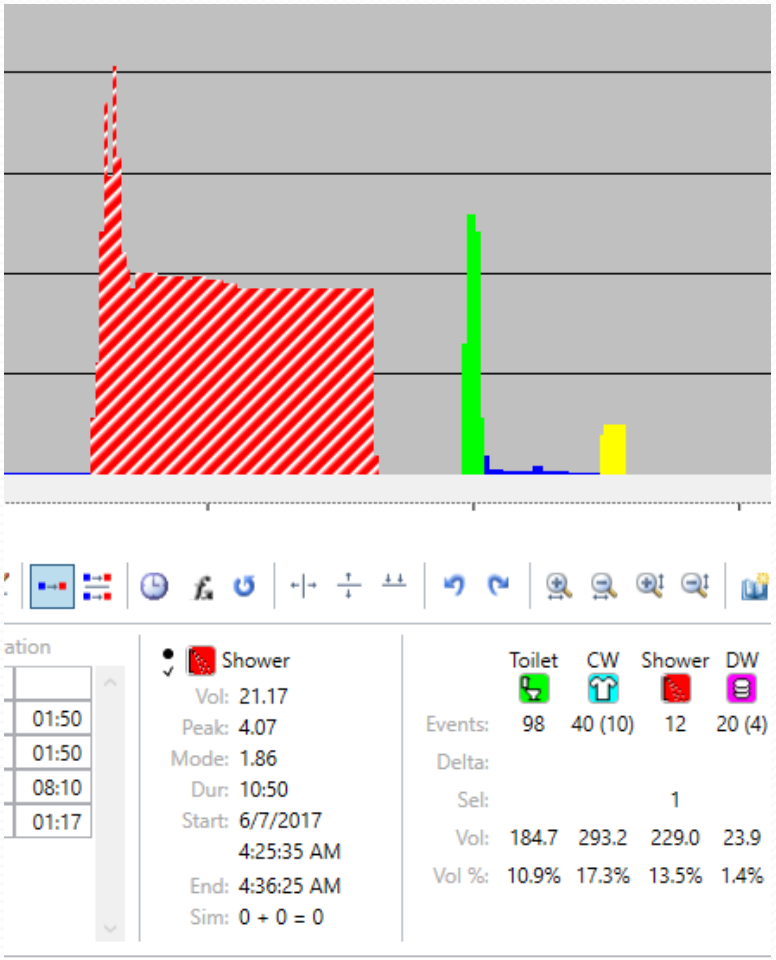
Mode flow, start time, end time and other similar events are also listed.



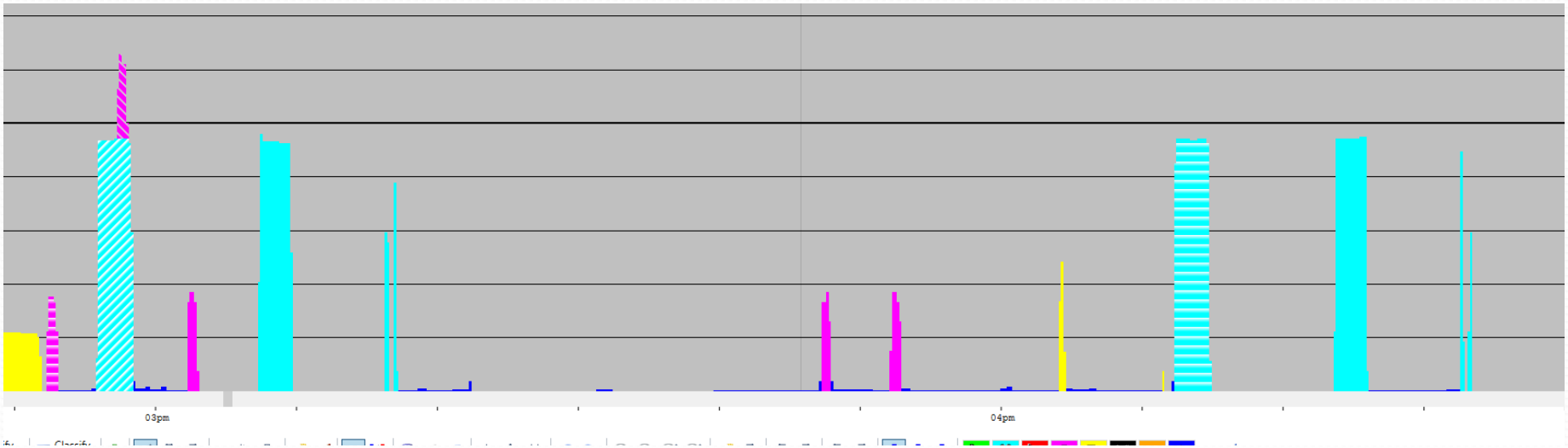
# Typical bathroom sequence: shower, toilet, faucet

A shower is followed by a toilet flush (with a bit of leakage) and a faucet use.

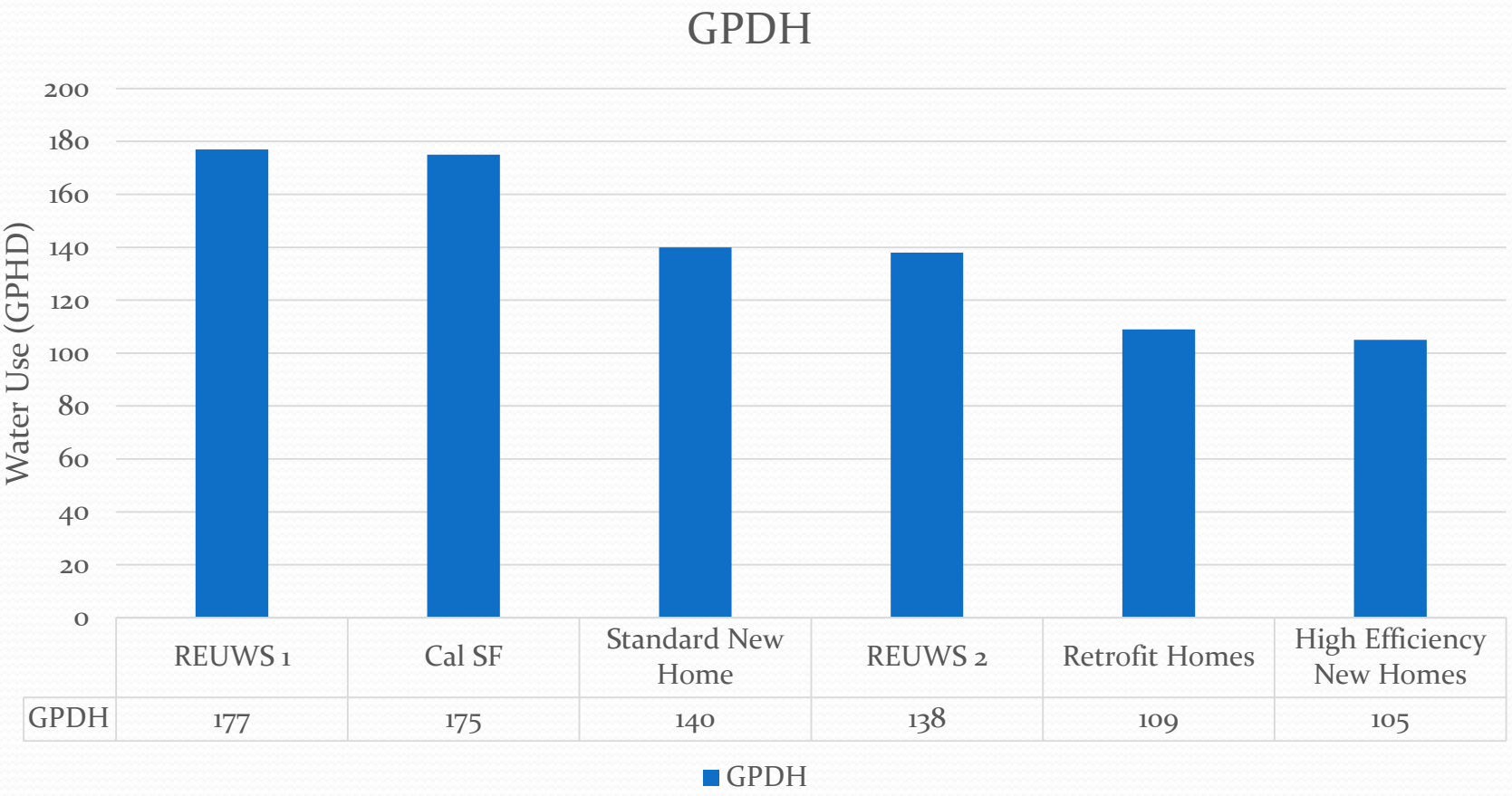
This is a very  typical combination



# Two clothes washers and a dishwasher with some miscellaneous faucets and leak



# Declining Indoor Water Use

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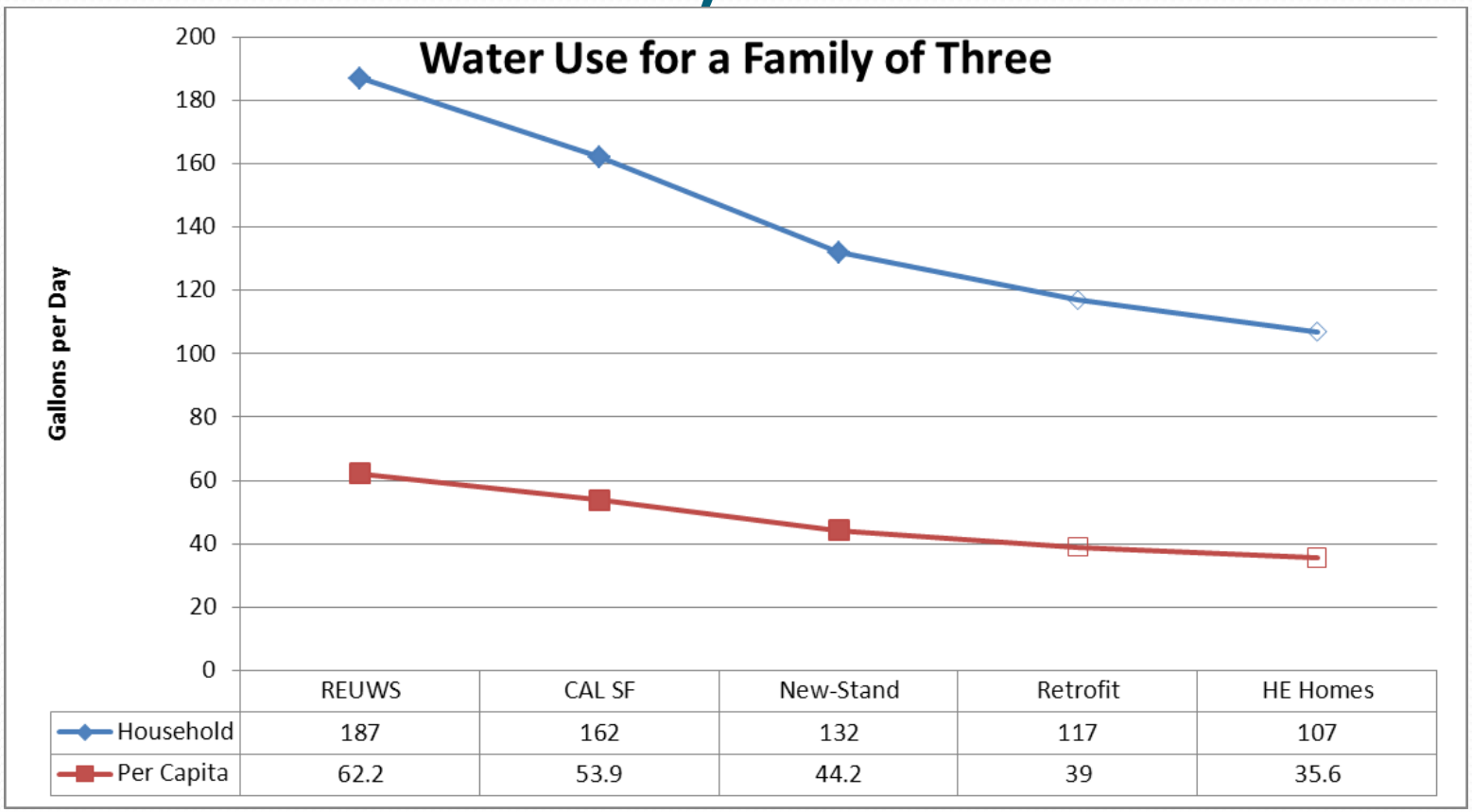
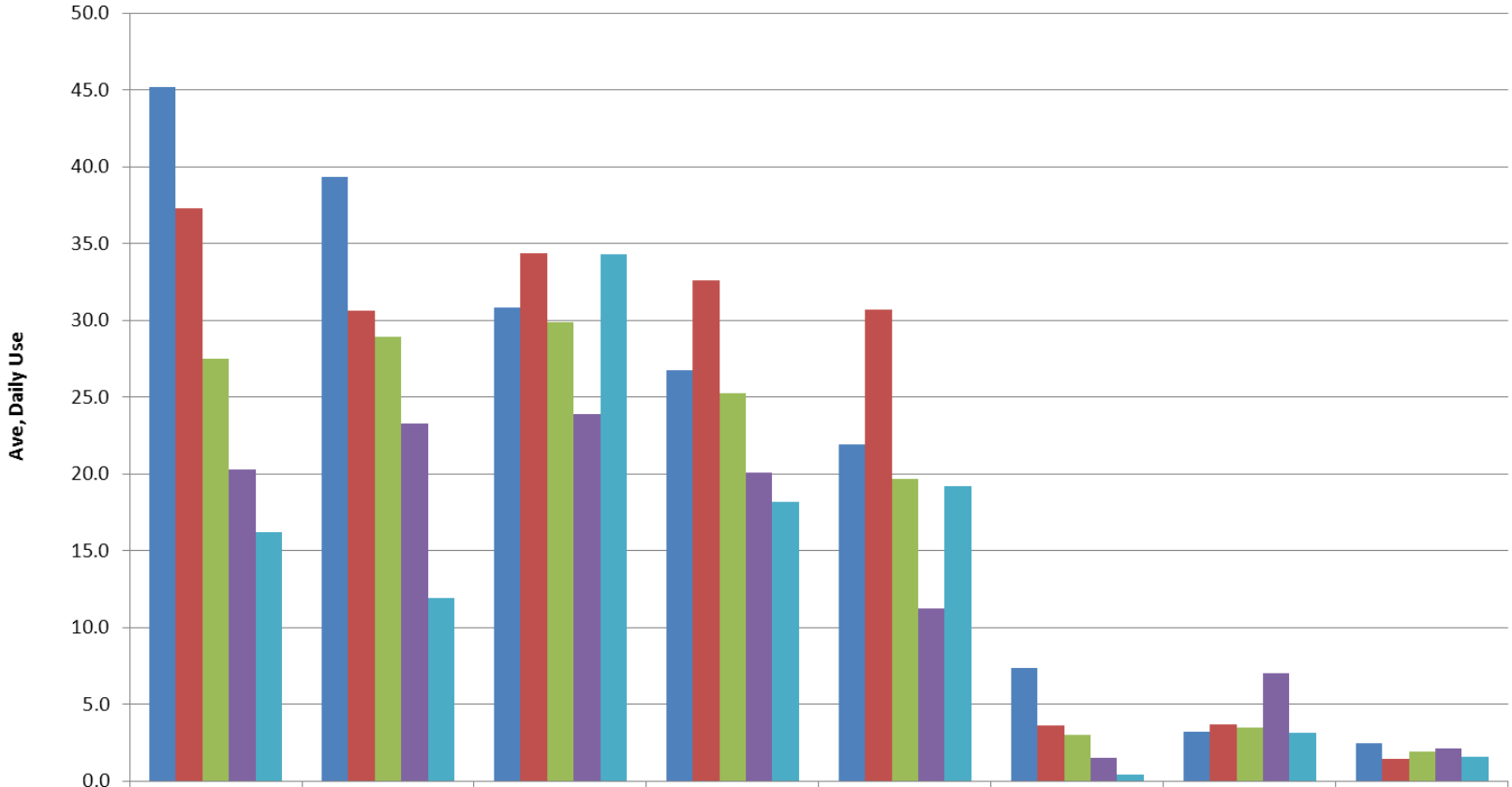
# Per Capita Use is Declining (normalized data)




| | REUWS | CAL SF | New-Stand | Retrofit | HE Homes |
|---|---|---|---|---|---|
| Household | 187 | 162 | 132 | 117 | 107 |
| Per Capita | 62.2 | 53.9 | 44.2 | 39 | 35.6 |

# Biggest Declines in Toilets & CW's



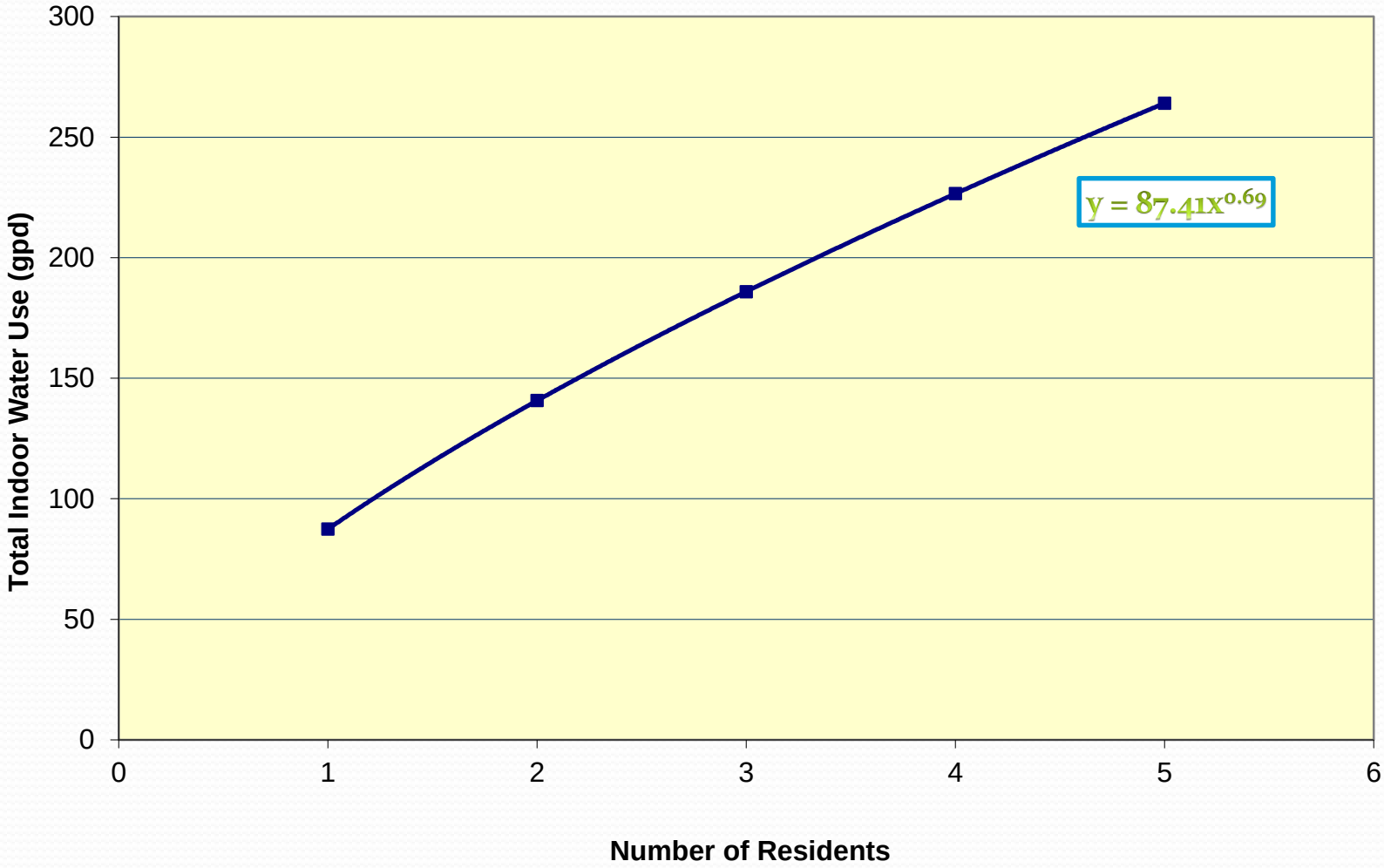

| | Toilet gpd | Clotheswasher gpd | Shower gpd | Faucet gpd | Leak gpd | Other gpd | Bathtub gpd | Dishwasher gpd |
|---|---|---|---|---|---|---|---|---|
| REUWS | 45.2 | 39.3 | 30.8 | 26.7 | 21.9 | 7.4 | 3.2 | 2.4 |
| Cal SF | 37.3 | 30.6 | 34.3 | 32.6 | 30.7 | 3.6 | 3.7 | 1.5 |
| New-Stnd | 27.5 | 28.9 | 29.9 | 25.2 | 19.7 | 3.0 | 3.5 | 1.9 |
| Retrofit | 20.3 | 23.3 | 23.9 | 20.1 | 11.2 | 1.5 | 7.0 | 2.1 |
| New-HE | 16.2 | 11.9 | 34.3 | 18.1 | 19.2 | 0.4 | 3.1 | 1.6 |

# Non-linear nature of demand

- Water demands increase with residents following a power curve relationship:

$$Y = c\,R^{x<1}$$

# Per-capita Use is Non-Linear

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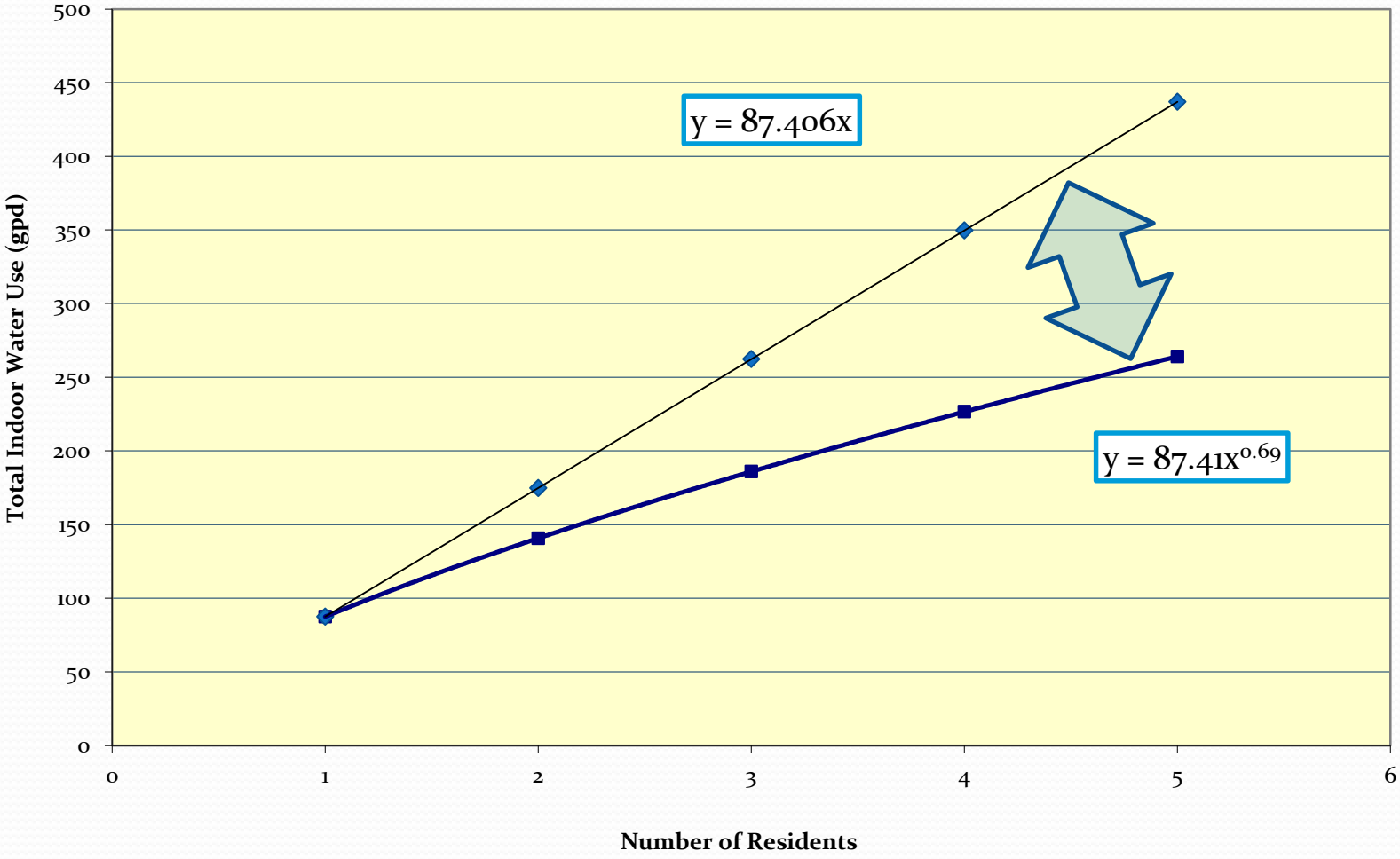
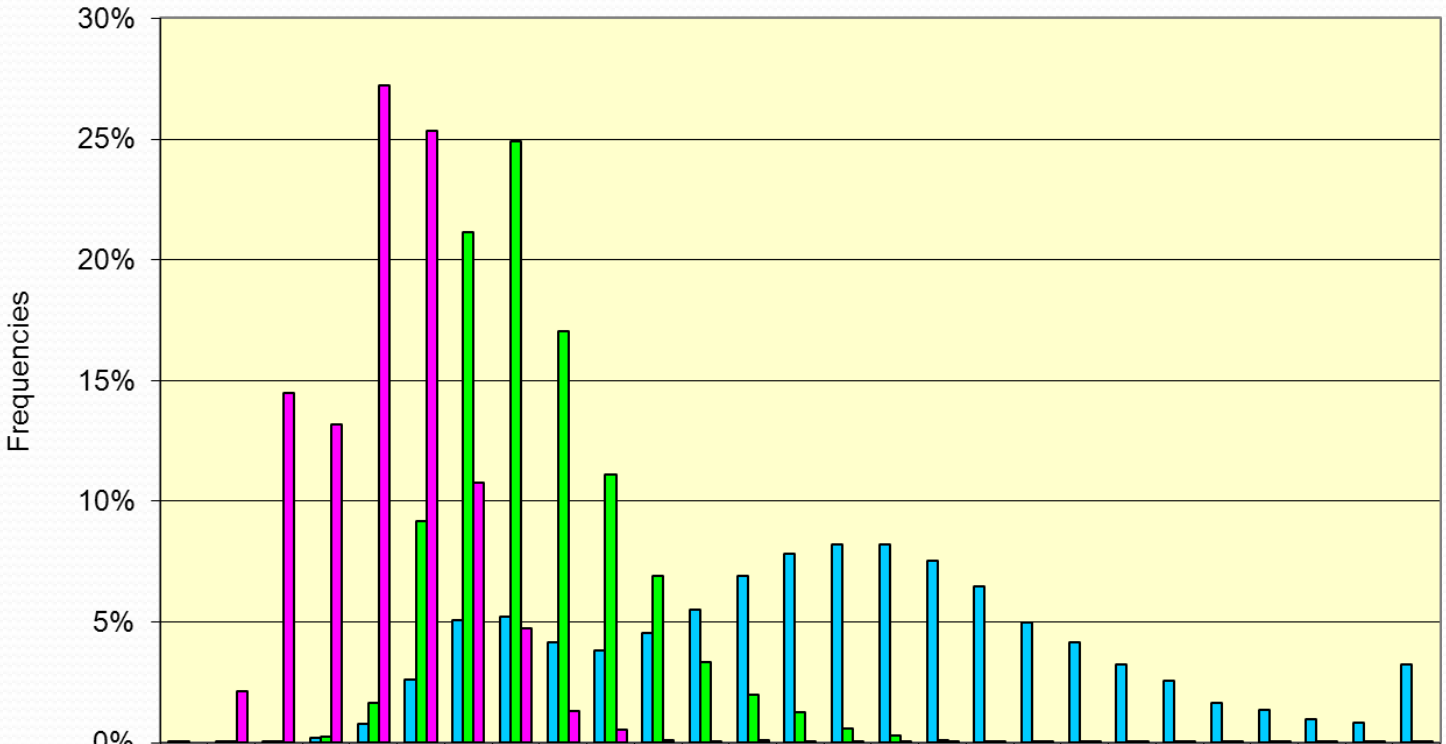
# Linear approach can lead to big errors



# Declining Flush Volumes




| | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 | 4.50 | 4.75 | 5.00 | 5.25 | 5.50 | 5.75 | 6.00 | 6.25 | 6.50 | 6.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REUWS | 0% | 0% | 0% | 0% | 1% | 3% | 5% | 5% | 4% | 4% | 5% | 6% | 7% | 8% | 8% | 8% | 8% | 6% | 5% | 4% | 3% | 3% | 2% | 1% | 1% | 1% | 3% |
| Std NEW | 0% | 0% | 0% | 0% | 2% | 9% | 21% | 25% | 17% | 11% | 7% | 3% | 2% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HE New | 0 | 2% | 14% | 13% | 27% | 25% | 11% | 5% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

Gallons per Flush

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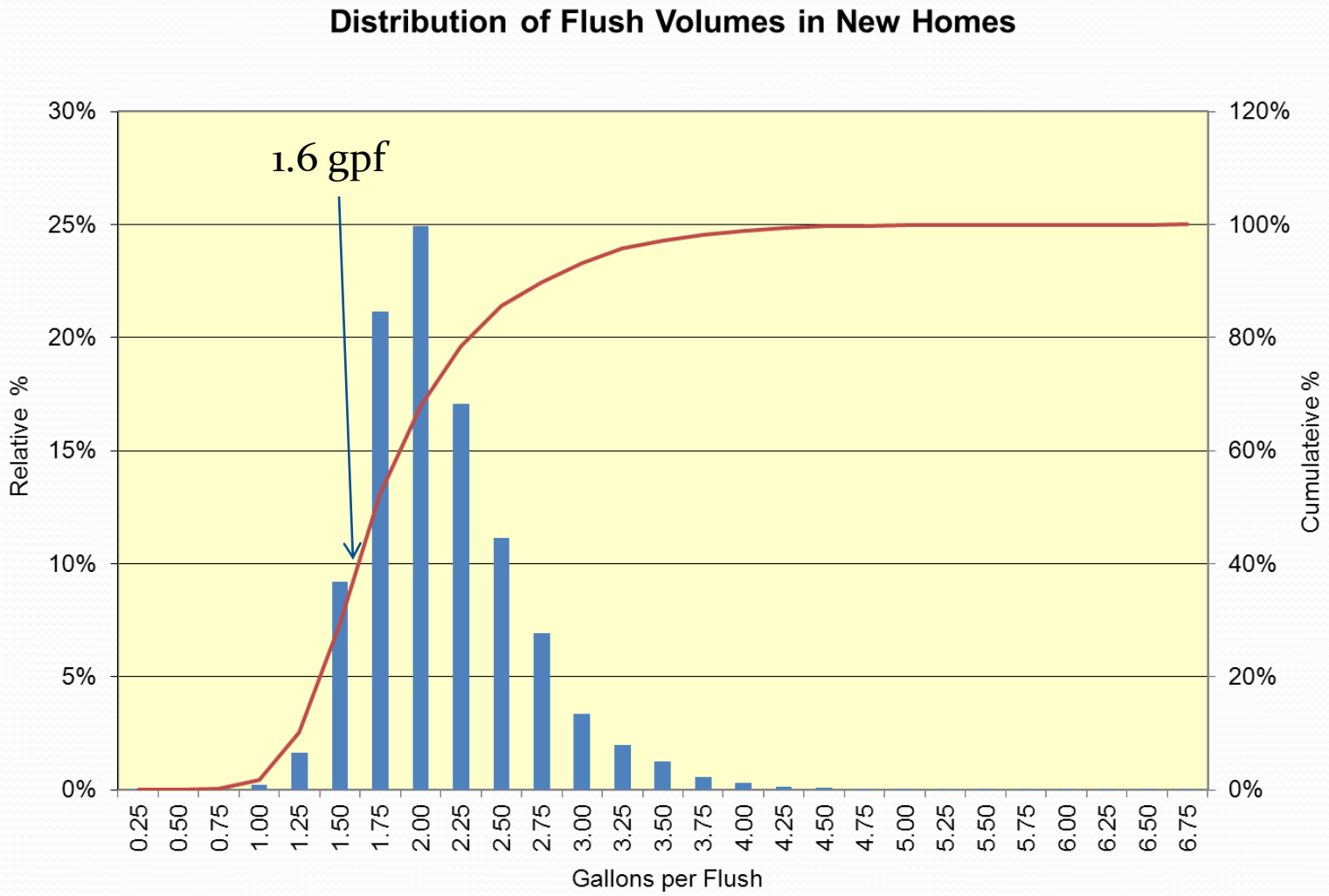
# Unexpected Toilet Volume Distribution

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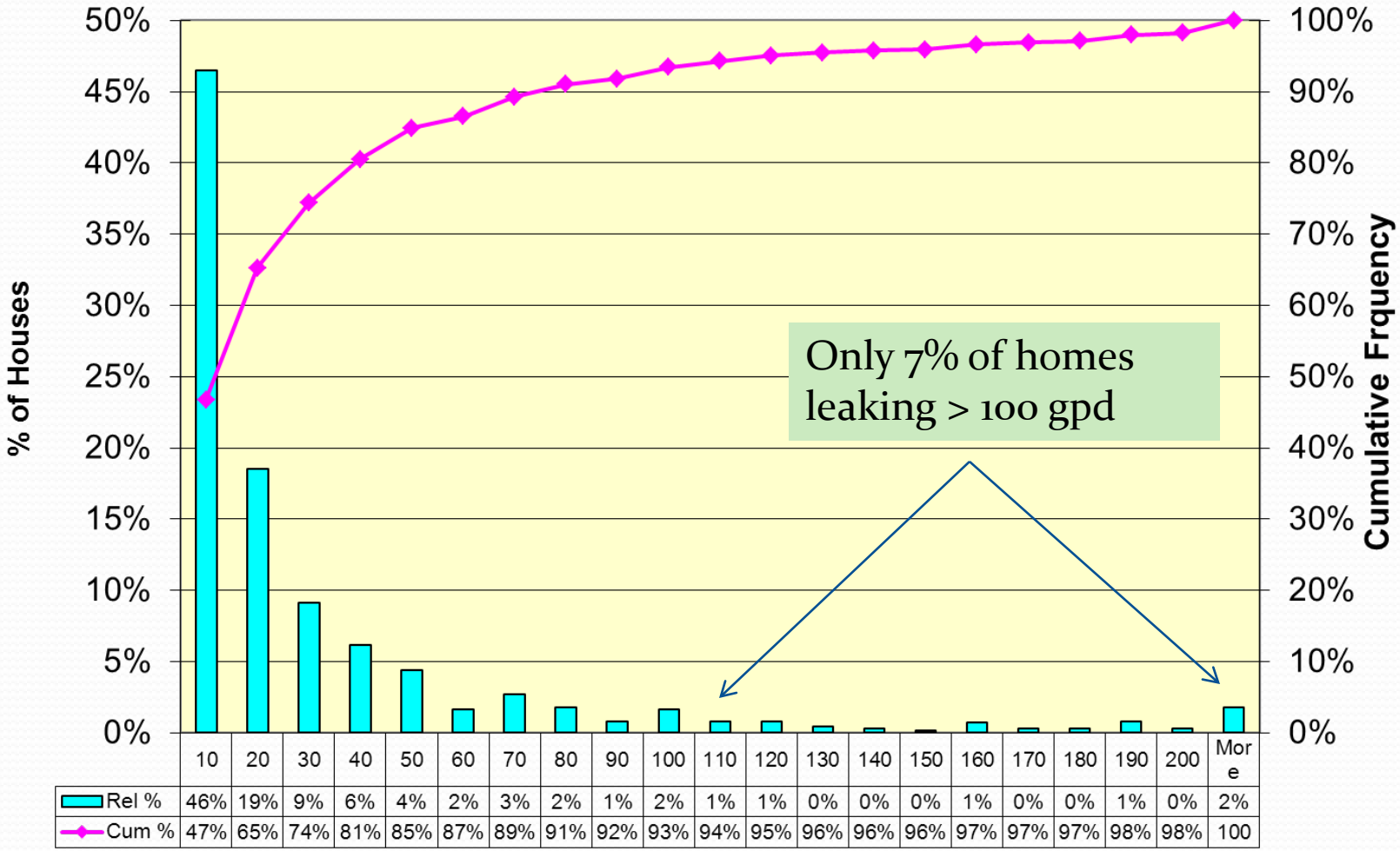
# Leaks are Skewed




| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | More |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rel % | 46% | 19% | 9% | 6% | 4% | 2% | 3% | 2% | 1% | 2% | 1% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | 2% |
| Cum % | 47% | 65% | 74% | 81% | 85% | 87% | 89% | 91% | 92% | 93% | 94% | 95% | 96% | 96% | 96% | 97% | 97% | 97% | 98% | 98% | 100 |

**Leakage Rate (gphd)**

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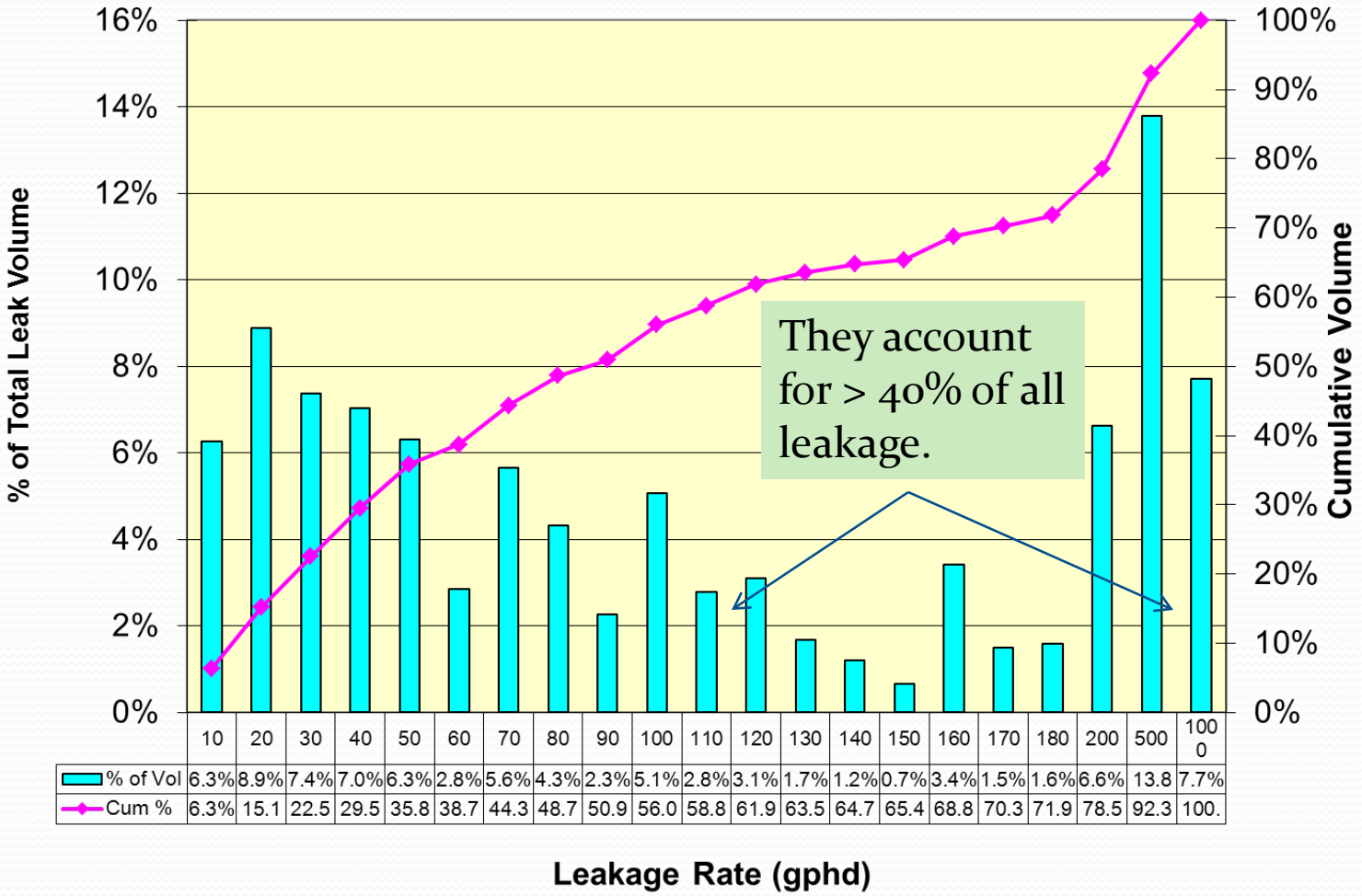
# Leakage by % of Volume




| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 200 | 500 | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % of Vol | 6.3% | 8.9% | 7.4% | 7.0% | 6.3% | 2.8% | 5.6% | 4.3% | 2.3% | 5.1% | 2.8% | 3.1% | 1.7% | 1.2% | 0.7% | 3.4% | 1.5% | 1.6% | 6.6% | 13.8 | 7.7% |
| Cum % | 6.3% | 15.1 | 22.5 | 29.5 | 35.8 | 38.7 | 44.3 | 48.7 | 50.9 | 56.0 | 58.8 | 61.9 | 63.5 | 64.7 | 65.4 | 68.8 | 70.3 | 71.9 | 78.5 | 92.3 | 100. |

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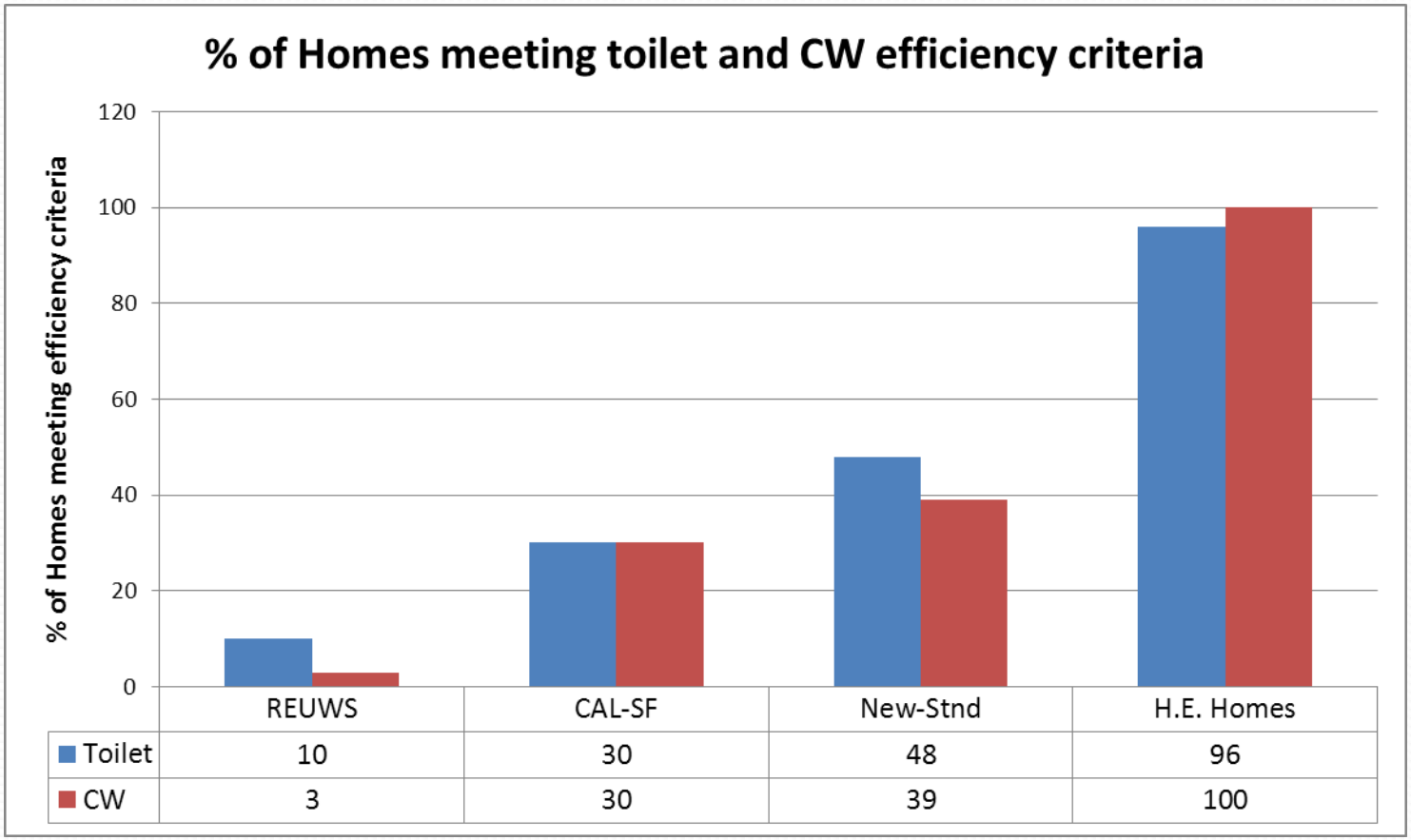
# Increasing Percentage of Efficient Homes




| | REUWS | CAL-SF | New-Stnd | H.E. Homes |
|---|---|---|---|---|
| Toilet | 10 | 30 | 48 | 96 |
| CW | 3 | 30 | 39 | 100 |

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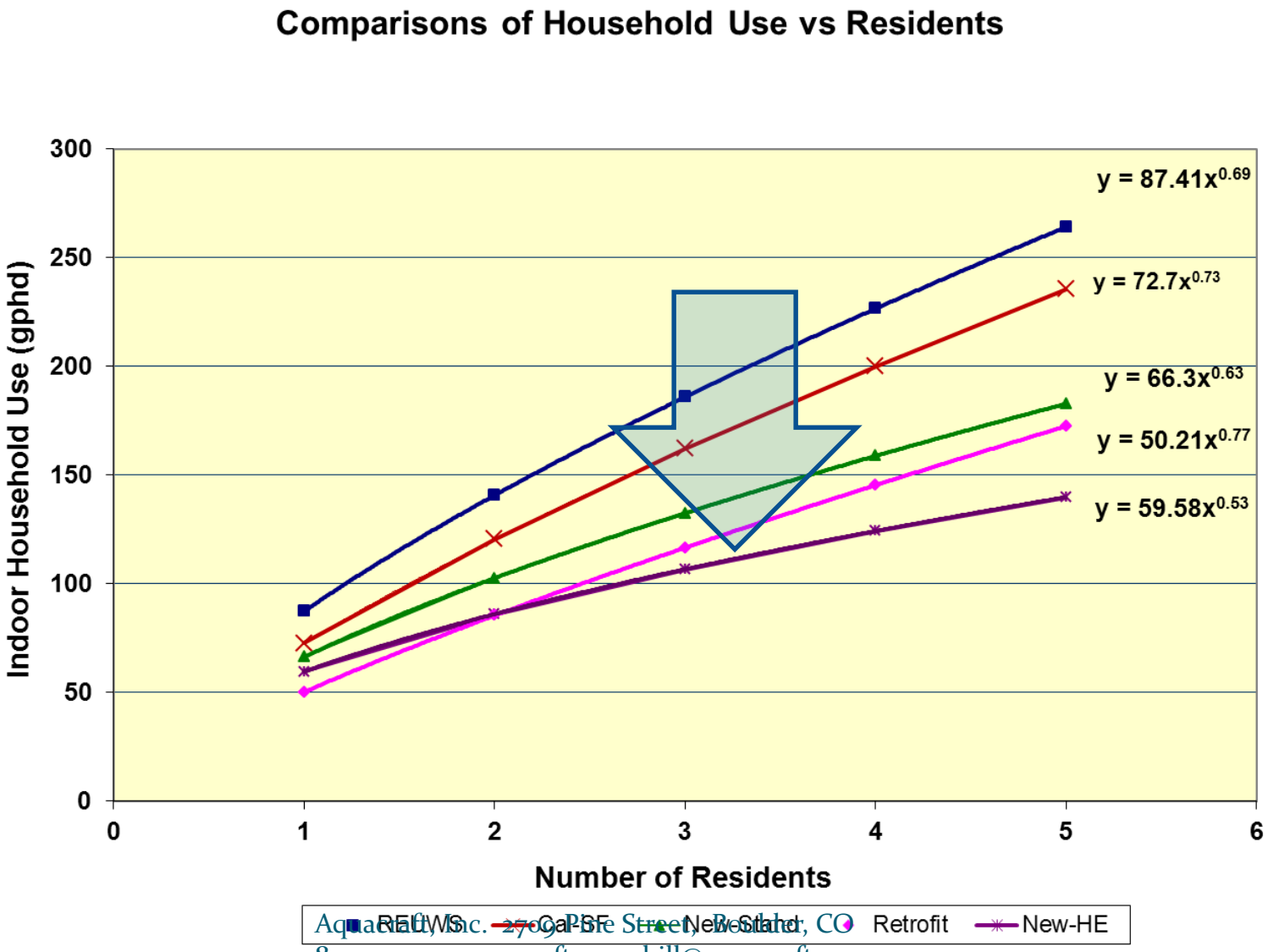
# Determining Per Capita Usage

| Parameter | REUWS (built before 1995) | California Single Family | Standard New Homes (built since 2001) | EPA post-retrofit group | High-efficiency New Homes |
|---|---|---|---|---|---|
| **Mean (gphd)** | 177 | 186 | 140 | 107 | 105 |
| **Per capita relationship (gphd=)** | $87.41x^{0.69}$ | $72.67x^{0.73}$ | $66.30x^{0.63}$ | $50.21x^{0.77}$ | $59.58x^{0.53}$ |
| **Household use for family of 3 (gphd)** | 187 | 162 | 132 | 117 | 107 |
| **Projected per capita use for family of 3 (gpcd)** | 62 | 54 | 44 | 39 | 36 |

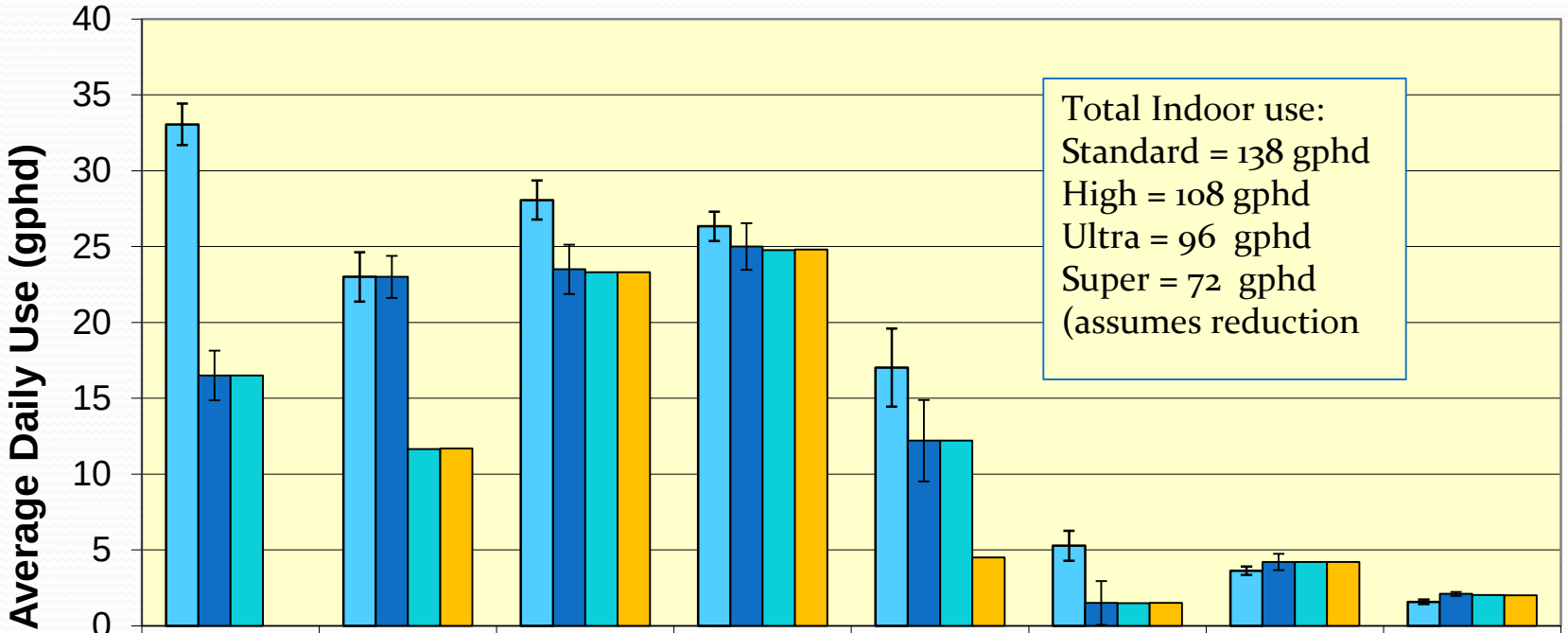
# Grouping Houses by Efficiency



# Factors that Affect Indoor Use

- Number of residents (+)
- Presence of Leaks (100 gpd) (+)
- Presence of High efficiency toilets and clothes washers (-)
- Presence of child or youth (-)
- Presence of garbage disposals and dishwashers (-)

# The super conserving home




| | Toilet gpd | Washer gpd | Shower gpd | Faucet gpd | Leak gpd | Other gpd | Bathtub gpd | Dishwasher gpd |
|---|---|---|---|---|---|---|---|---|
| Standard | 33.1 | 23.0 | 28.1 | 26.3 | 17.0 | 5.3 | 3.6 | 1.6 |
| High | 16.5 | 23.0 | 23.5 | 25.0 | 12.2 | 1.5 | 4.2 | 2.1 |
| Ultra | 16.5 | 11.7 | 23.3 | 24.8 | 12.2 | 1.5 | 4.2 | 2.0 |
| Super | 0.0 | 11.7 | 23.3 | 24.8 | 4.5 | 1.5 | 4.2 | 2.0 |

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# Outdoor Parameters (Look Similar)

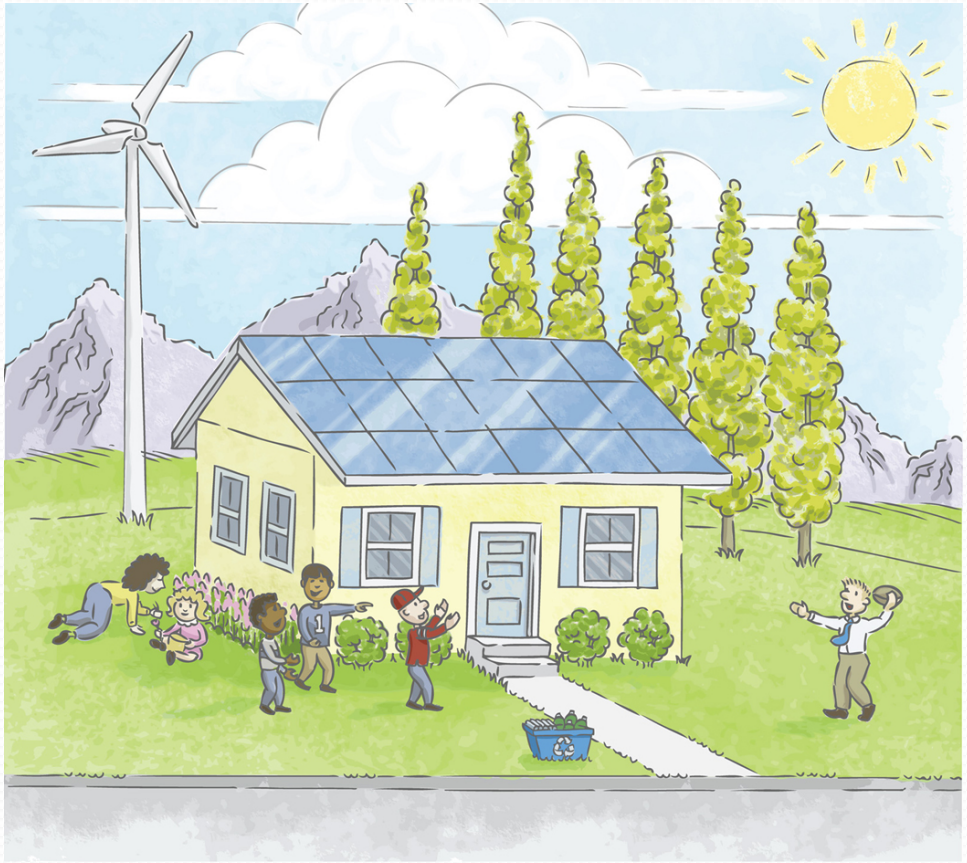
- Existing Homes (Cal SF)
  - Lot Size ~9200 sf
  - Irrigated Area ~3400 sf
  - Outdoor Use ~93 kgal
  - Application ~57 in
  - ETo ~ 42 in
  - App Ratio ~1.36
  - Ave Excess ~ 29.4 kgal
  - Var from ET ~6.5 kgal
- New Homes (EPA)
  - 10,100 sf
  - 3700 sf
  - 78 kgal
  - 56 in
  - 43 in
  - 1.30
  - 30 kgal
  - 7.3 kgal

# Factors that Affect Outdoor Use

- Net ET (in)
- Irrigated Area (SF)
- Income ($)
- Landscape Ratio (TIR/Ref Requirement)
- Pool (?)
- **Excess Irrigation** (?)
- Sprinkler (?)

# Something you can plan on.

- Planners have to include new demands in water supply models.
- Capitalize on benefits of conservation efforts.
- Avoid costly over-building.



# Recommendations

- Look beyond your billing data
- Create better tracking tools
- Get to know your customers better
- Do some sampling and measurements
- Develop demand models from local data
- Use this information for demand projections
- Follow-up with periodic updates for evaluation