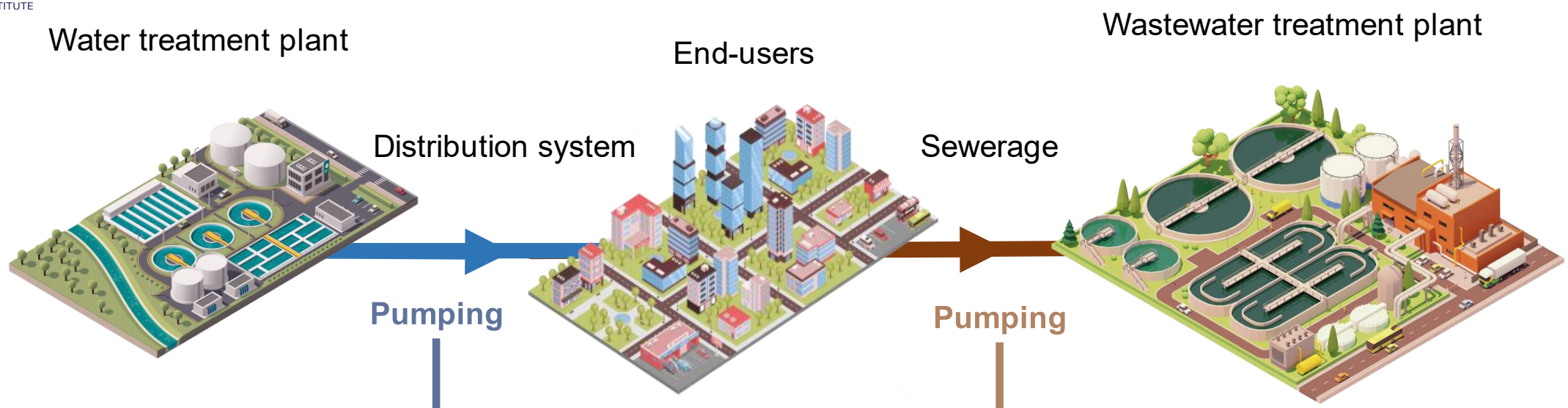
Evaluating water-related energy savings within buildings: insights from research studies

Hugo Jacque – streamSAVE+ Dialogue Meeting #02 – 14th November 2024

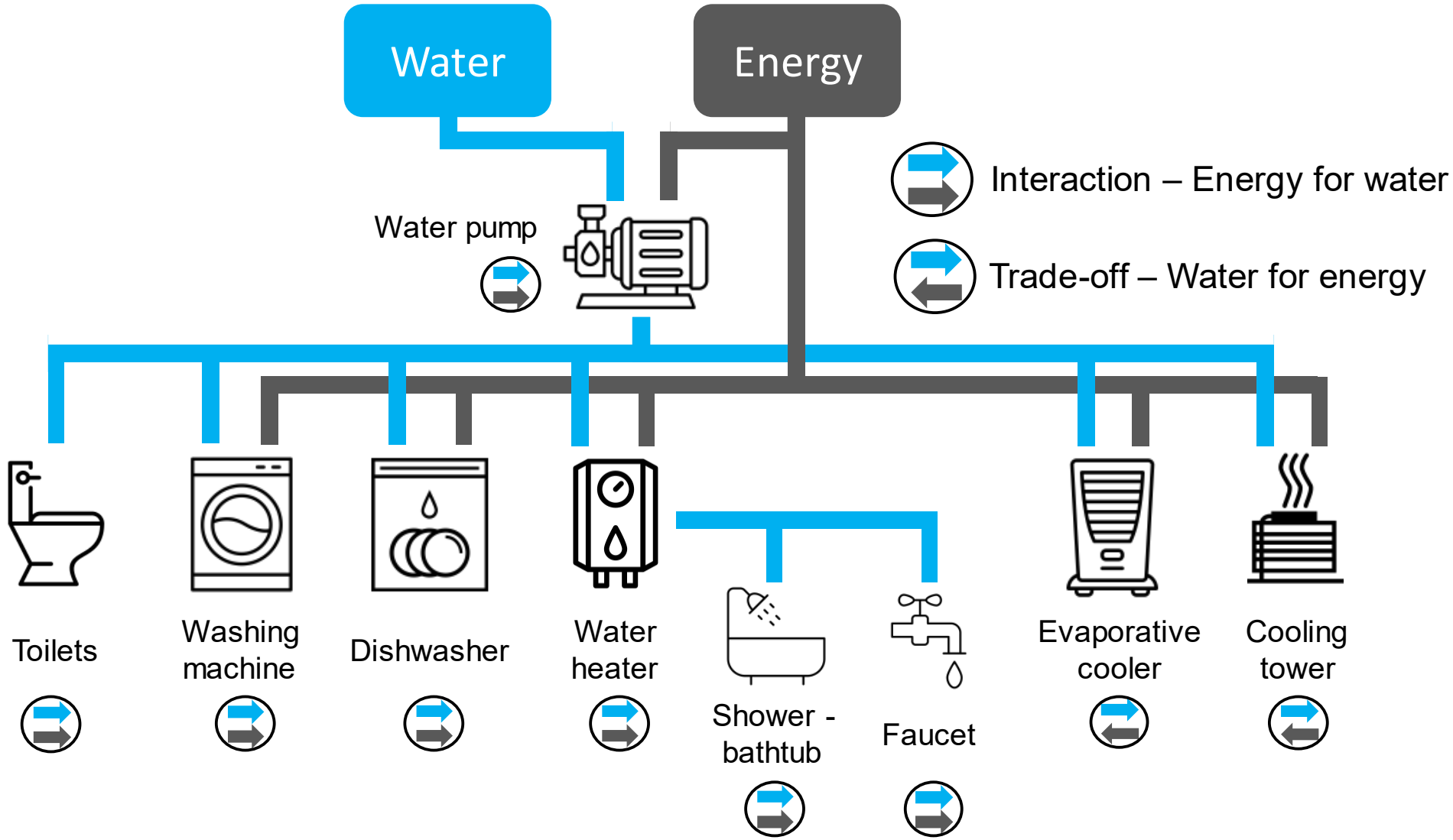
Energy in the urban water cycle



~ 9,4%(1)	~ 4,7%(1)	~ 80%(2)	~ 5,9%(1)	World
~ 5,8%(1)	~ 4,1%(1)	~ 80%(2)	~ 10,1%(1)	European Union/USA
~ 16,3%(1)	~ 3,2%(1)	~ 80%(2)	~ 0,5%(1)	India

(1) Kęsicki et al., 2016
(2) Plappally & Lienhard, 2012; Escriva-Bou et al., 2018

Water-related energy use in buildings



Water conservation in buildings

Water quality

Water losses

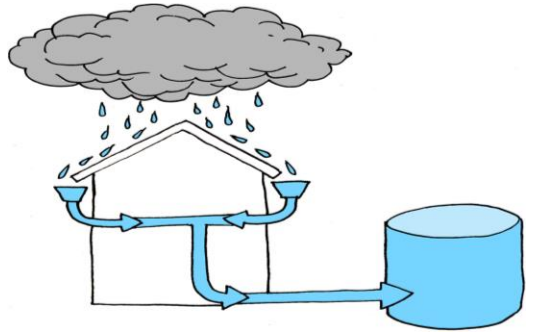
Demand curtailment

Drought resistance

Technical measures

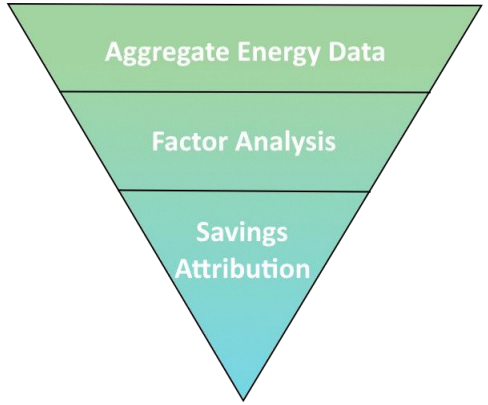
Non-technical measures

Alternative water sources

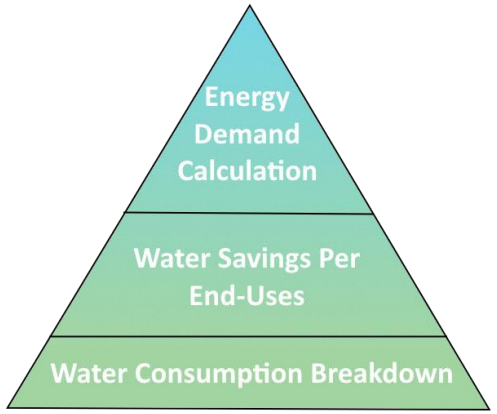


Estimating water-related energy savings

- **Top-down approach:**
  - Analysis of energy bills (annual, bimonthly, or monthly)
    - Ex-post approach
    - Building level
    - Sensitive data
    - Source: energy utilities/providers or building owners
    - Uncertainties due to influence of other factors: weather, occupancy, fittings replacement, etc. (Cabrera et al., 2024)



- **Bottom-up approach:**
  - Evaluate energy savings per end-use
    1. Estimate the volume of water saved
    2. Determine the related energy savings

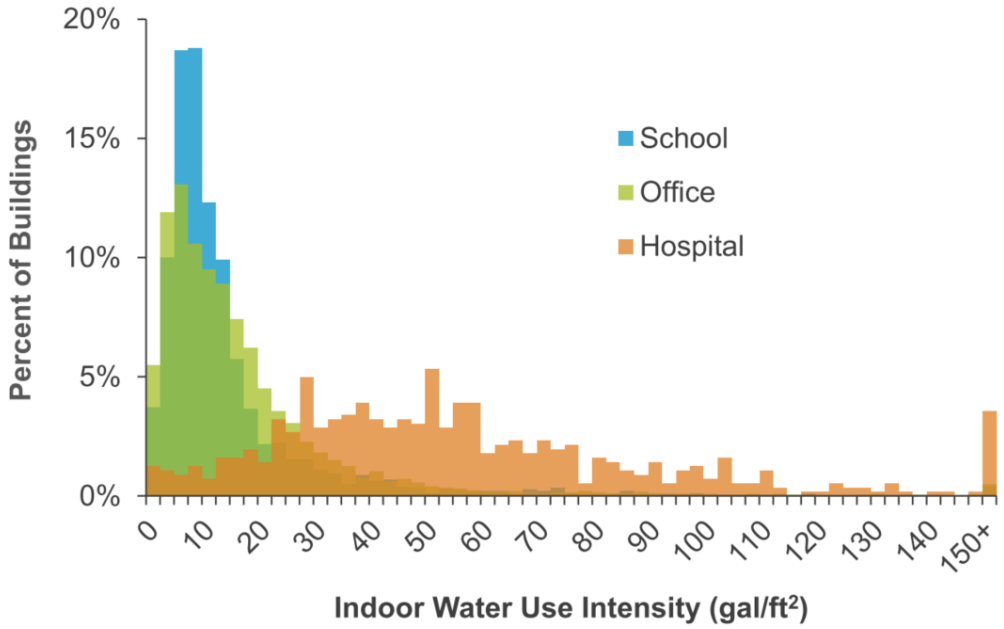


Estimating water-related energy savings

- **Ex-ante water savings calculation methods:**
  - Disaggregation approach:
    - Building/regional level

Billing/meter data (Water utilities/building owners)
Benchmark values (e.g. litre/capita)
Population data
Survey

→ Total water use



Range of water use intensity for some non-residential buildings (ENERGY STAR, 2012)

Estimating water-related energy savings

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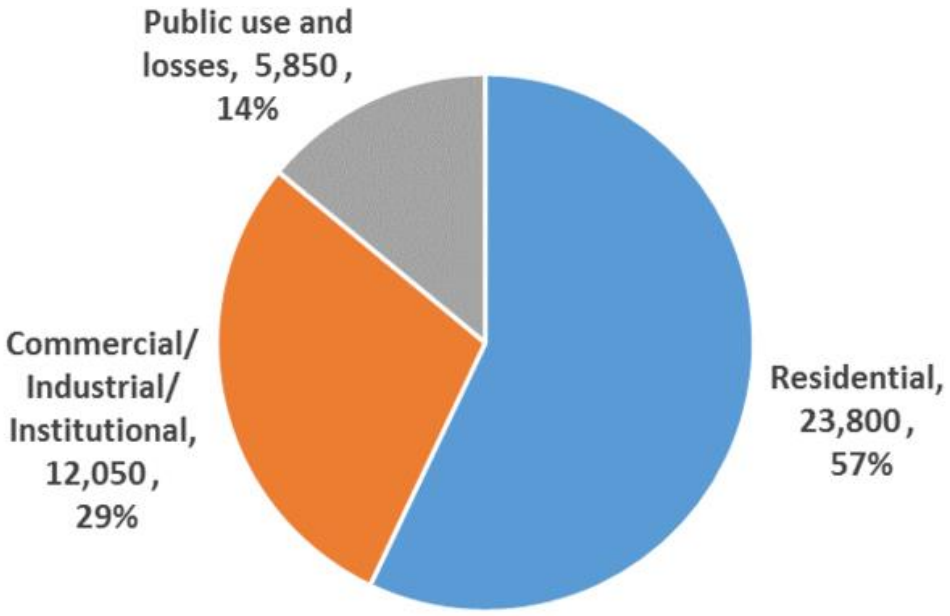
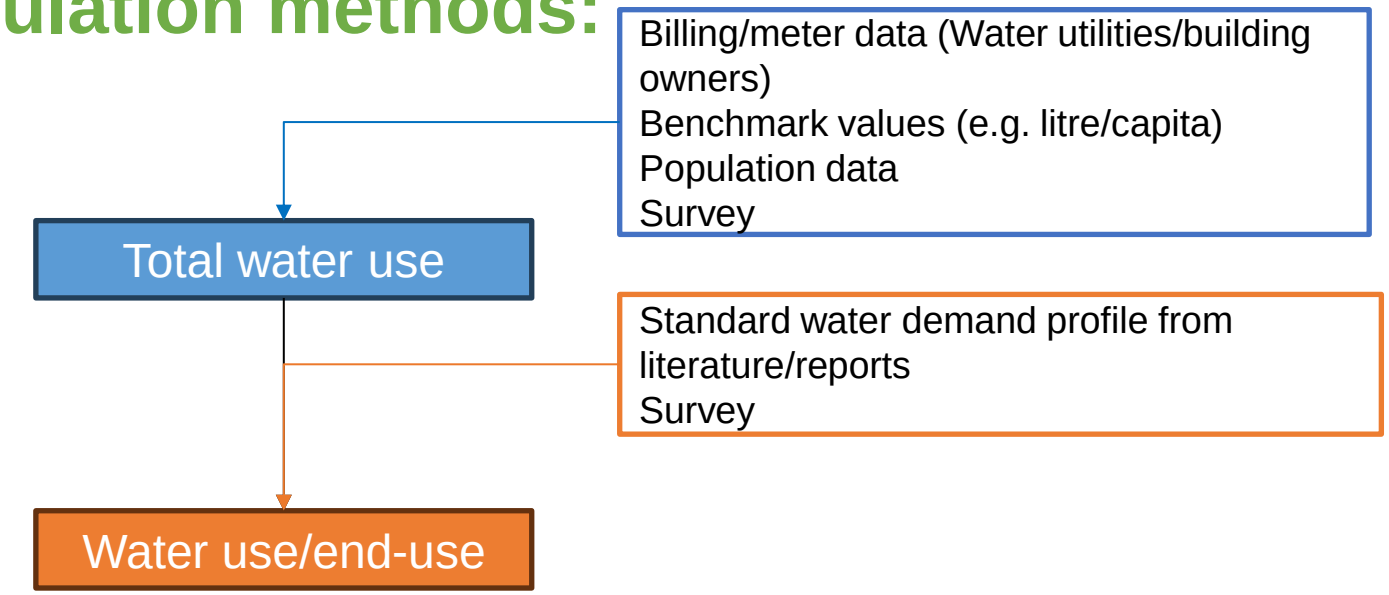


Public water supply deliveries in the United States (Water Resources Mission Area, 2019)



Estimating water-related energy savings

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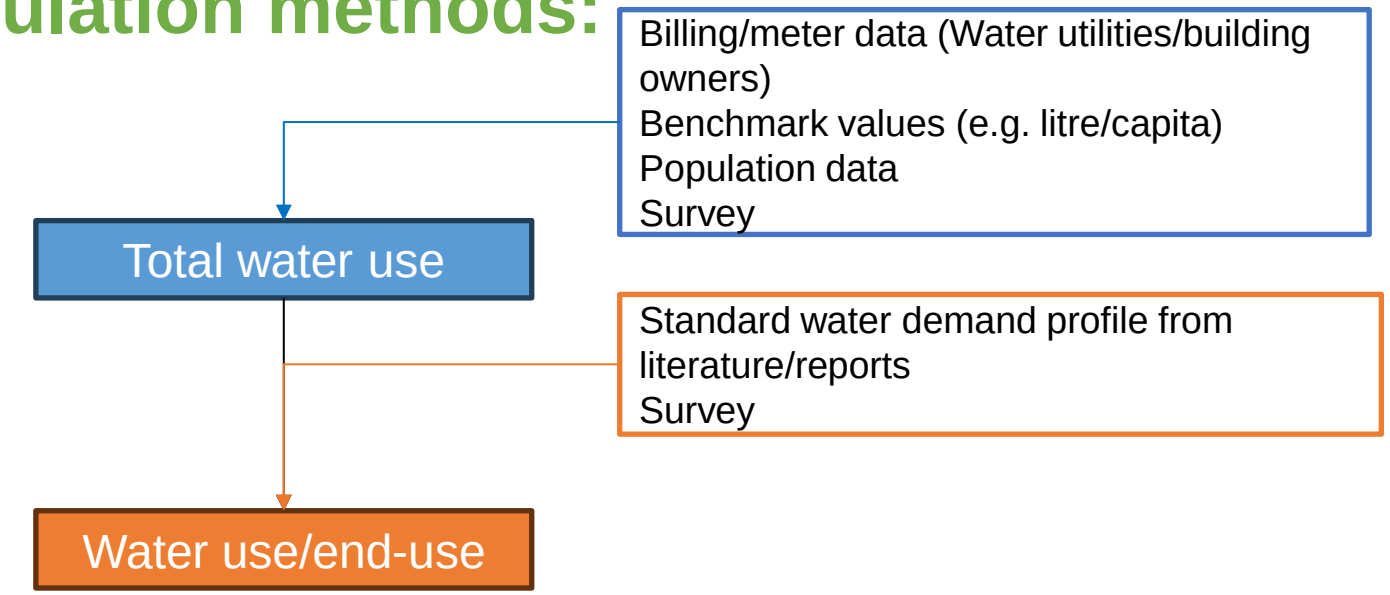
Water use breakdown in US residential buildings (US EPA, n.d.)



Estimating water-related energy savings

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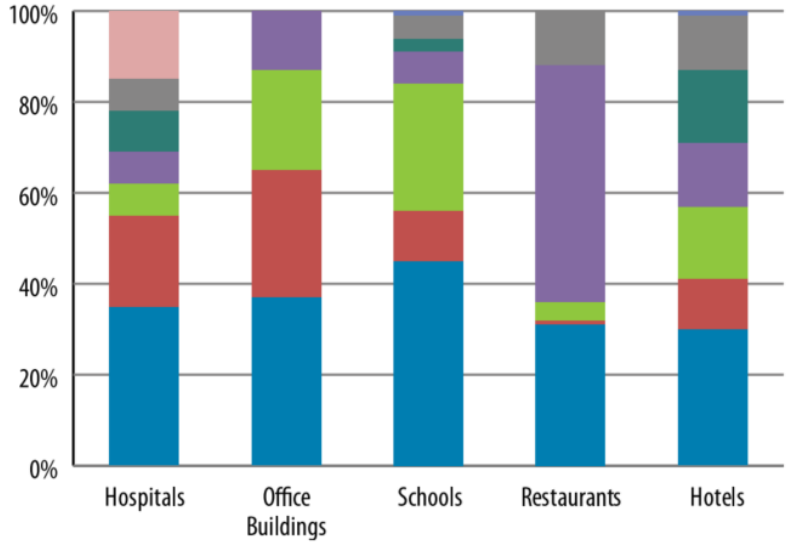
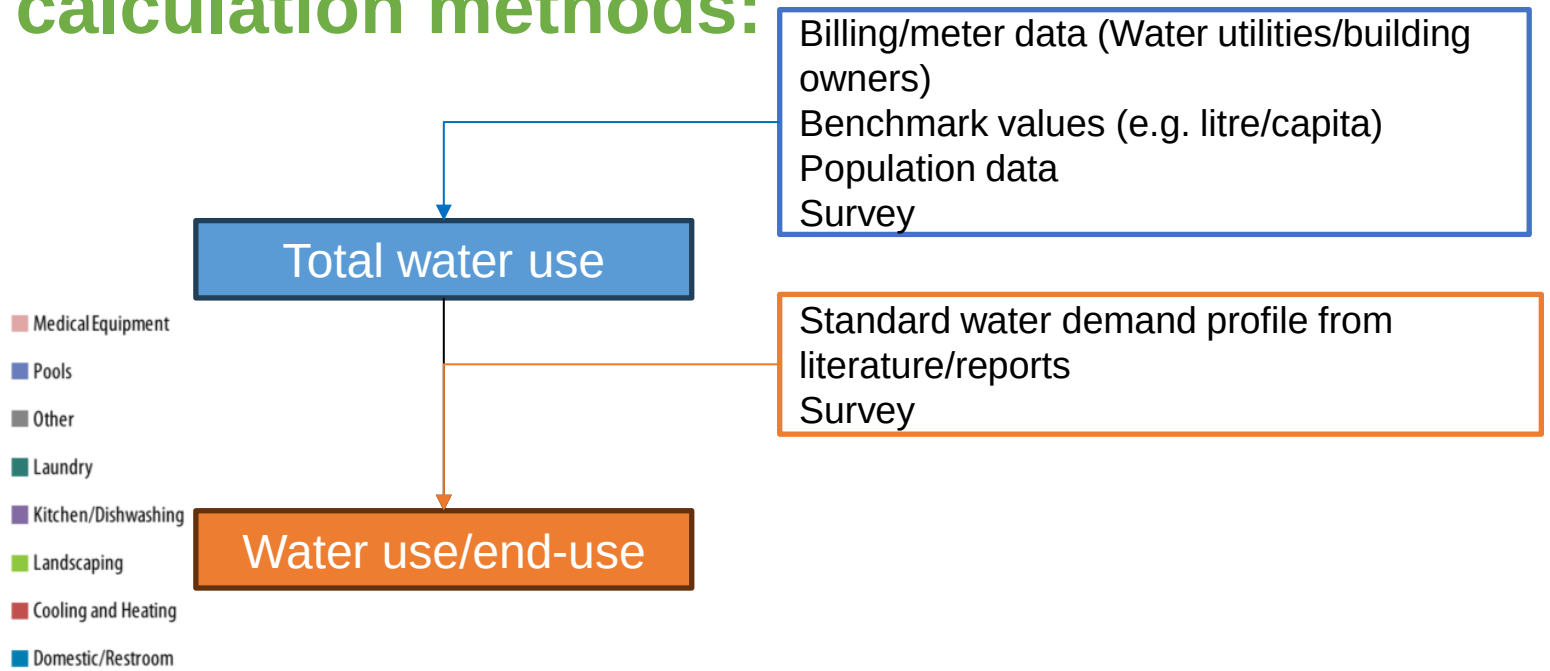


Water use breakdown in US non-residential buildings (WaterSense, 2012)



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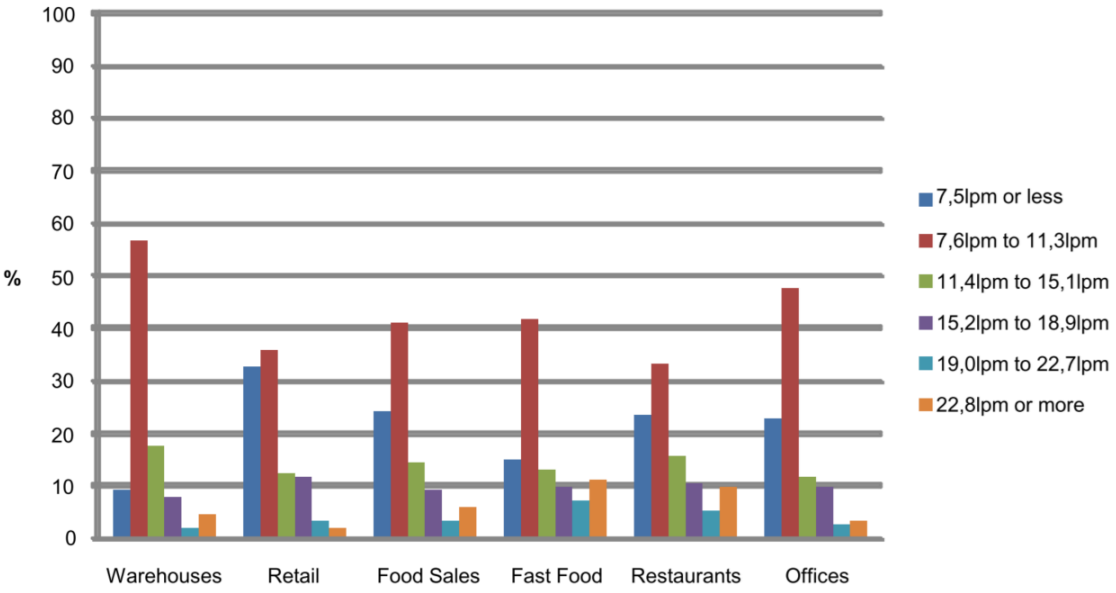
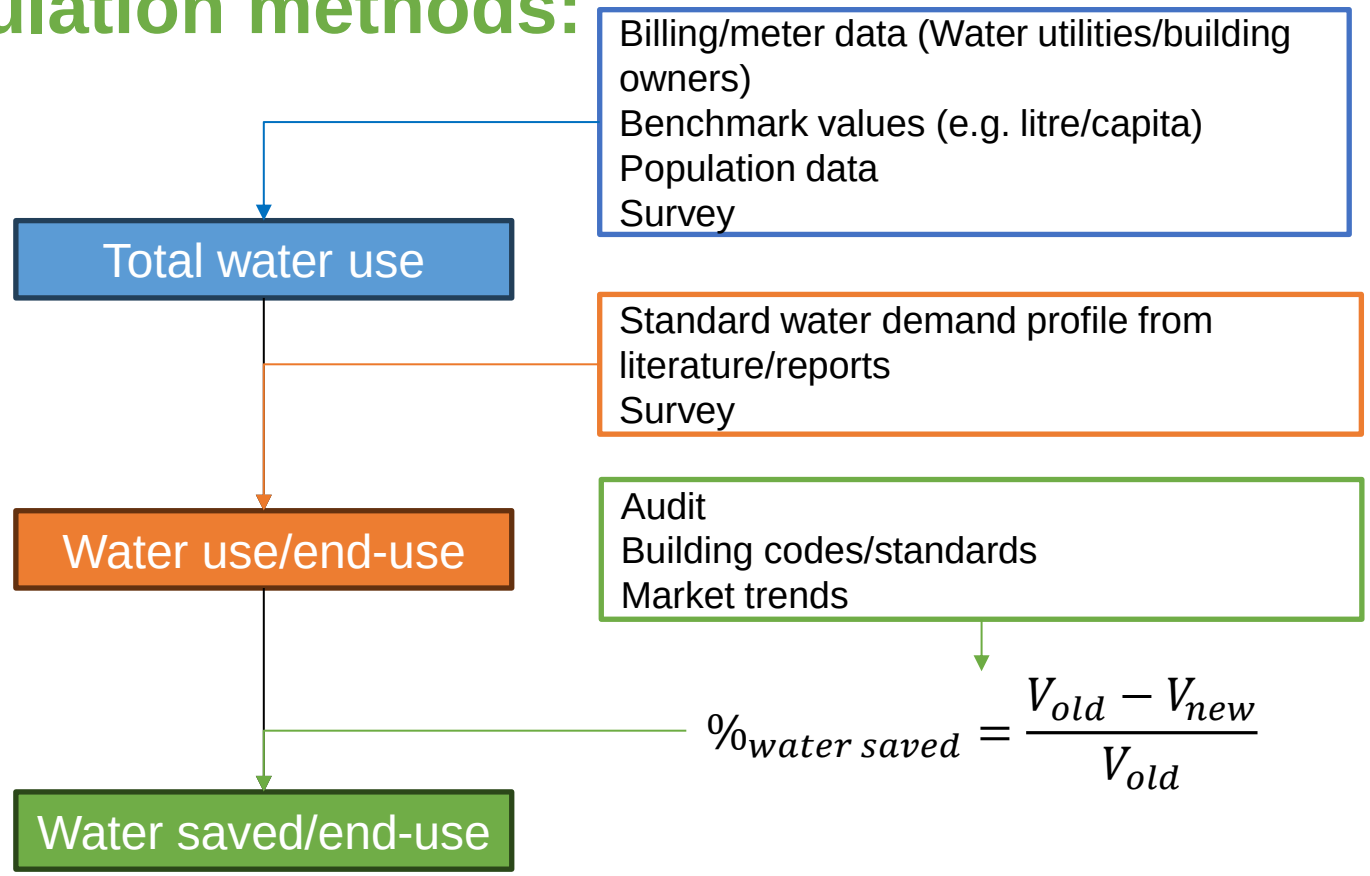
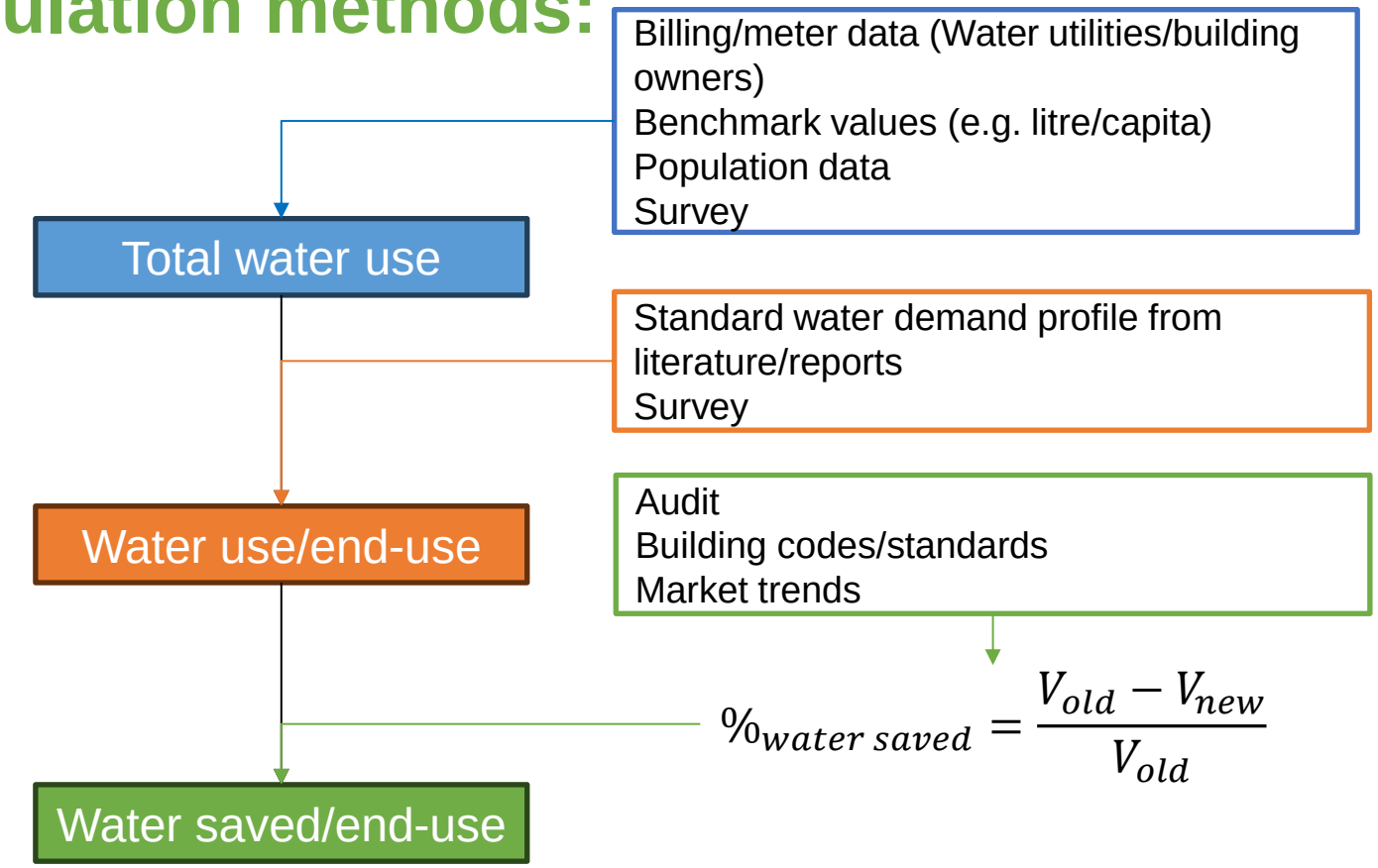


Distribution of non-residential taps by flow rate (Mudgal et al., 2009)



Estimating water-related energy savings

- **Ex-ante water savings calculation methods:**
  - Disaggregation approach:
    - Building/regional level
    - Uncertainties:
      - Lack of local data
      - Water-saving device performance
      - Rebound effect



Estimating water-related energy savings

- **Ex-post water savings calculation methods:**
  - Historical data water use analysis
    - Building/regional level
    - Use of ‘per capita’ or detrended data for proper analysis
    - Source: water utilities/buildings owners
    - Assumption: reduction only due to implemented conservation measures
    - No information on water savings per end-use
  - Market penetration analysis
    - National level
    - Investigate stock and sales of water-using products
    - Adopted to report progress of WaterSense (USA) and WELS (Australia) programmes
    - Source: manufacturers, market/programme/association reports, research article, population data

BAU Scenario:
Stock and sales estimated from market trends prior programme

Programme Scenario:
Stock and sales estimated from manufacturers data

$$Water\ consumption\ (WC) = behaviour\ *\ stock\ *\ flow$$

$$Water\ saved = WC_{BAU} - WC_{Programme}$$

Estimating water-related energy savings

- **Energy savings calculation methods:**
  - Water heating energy use:
    1. Estimate volume of hot water use per end-use
    2. Estimate energy use to heat this volume of water:
       - Building level: use of the WHAM model (Lutz et al., 1998)

Water heater

Assumption based on local context and data from literature

Derived from sales and stock data for hot water systems

$$\text{E (Btu/day)} = \frac{V * \rho * C_p (T_{tank} - T_{in})}{\eta_{re}} * \left(1 - \frac{UA * (T_{tank} - T_{amb})}{P_{on}}\right) + 24 * UA * (T_{tank} - T_{amb})$$

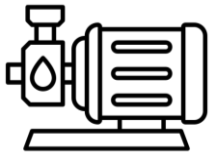
       - National level: simplified model, e.g. Institute for Sustainable Future (2018):

$$gas\ use\ (GJ) = water\ demand\ (ML) \times hot\ water\ fraction \times energy\ required\ to\ heat\ hot\ water\ \left(\frac{GJ}{ML}\right) \times average\ gas\ hot\ water\ efficiency\ \left(\frac{GJ}{GJ}\right) \times gas\ fraction\ of\ hot\ water\ stock$$

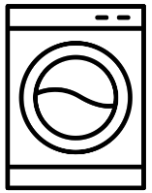
       - Uncertainties: data might not be nationally representative, regional and seasonal variation, variability in hot water piping, cannot account for heat losses

Estimating water-related energy savings

- **Energy savings calculation methods:**
  - Pumping energy use:
    - Generally not calculated due to negligible impact
    - Highly site dependent (pumping requirement, efficiency, system configuration and size, etc.)
  - Energy use for white goods:
    - Fraction of white goods having hot water connection determined from stock and sales data
    - Energy use data available from manufacturers' catalogues



Water pump

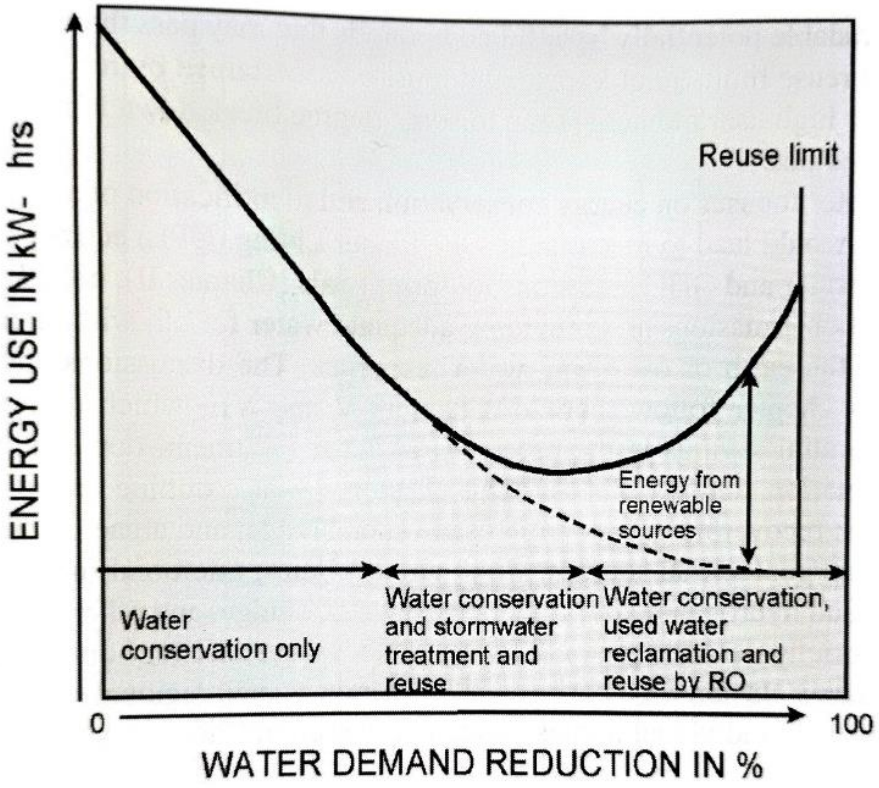


Washing machine

Dishwasher

Estimating water-related energy savings

- **The case of alternative water sources:**
  - Difficult to quantify current or potential water saving at regional scale
  - Energy savings achieved at urban water cycle scale, usually not building scale:
    - Energy inputs are required in buildings to treat and pump rainwater/greywater
    - End-uses considered are more commonly cold water uses (e.g. toilet flushing)



The relation of water demand reduction to energy use at the building scale (Novotny et al., 2010)

Estimating water-related energy savings

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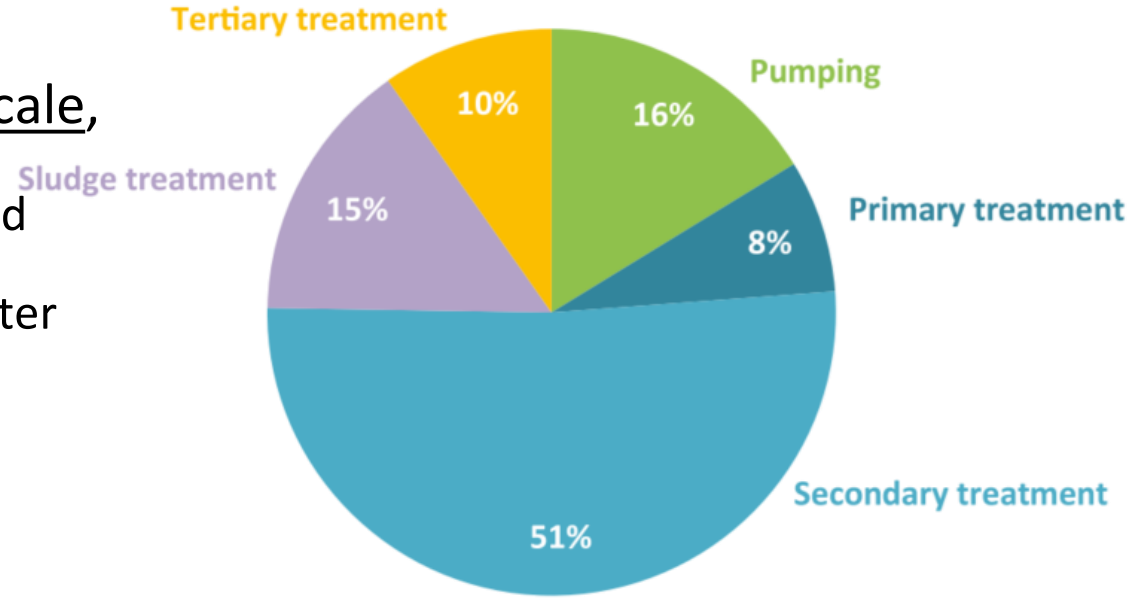
  - Energy savings achieved at urban water cycle scale, usually not building scale:
    - Energy inputs are required in buildings to treat and pump rainwater/greywater
    - End-uses considered are more commonly cold water uses (e.g. toilet flushing)
  - Energy savings calculations methods for water supply and wastewater treatment:
    - Calculate energy intensity of local water systems (kWh/m^3)
    - Data sources: water and energy utilities' data or reports
    - Uncertainty: seasonal variation of energy intensity, efficiency of water systems can be impacted by water conservation, volume of water/wastewater is not the only determining factor energy use



Typical energy consumption in a wastewater treatment facility (Kęsicki et al., 2016)

Indicative value of energy savings

- Energy savings metric:

$$E_{savings}(kWh/m^3) = \frac{Total\ energy\ saved\ (kWh)}{Total\ water\ saved\ (m^3)}$$

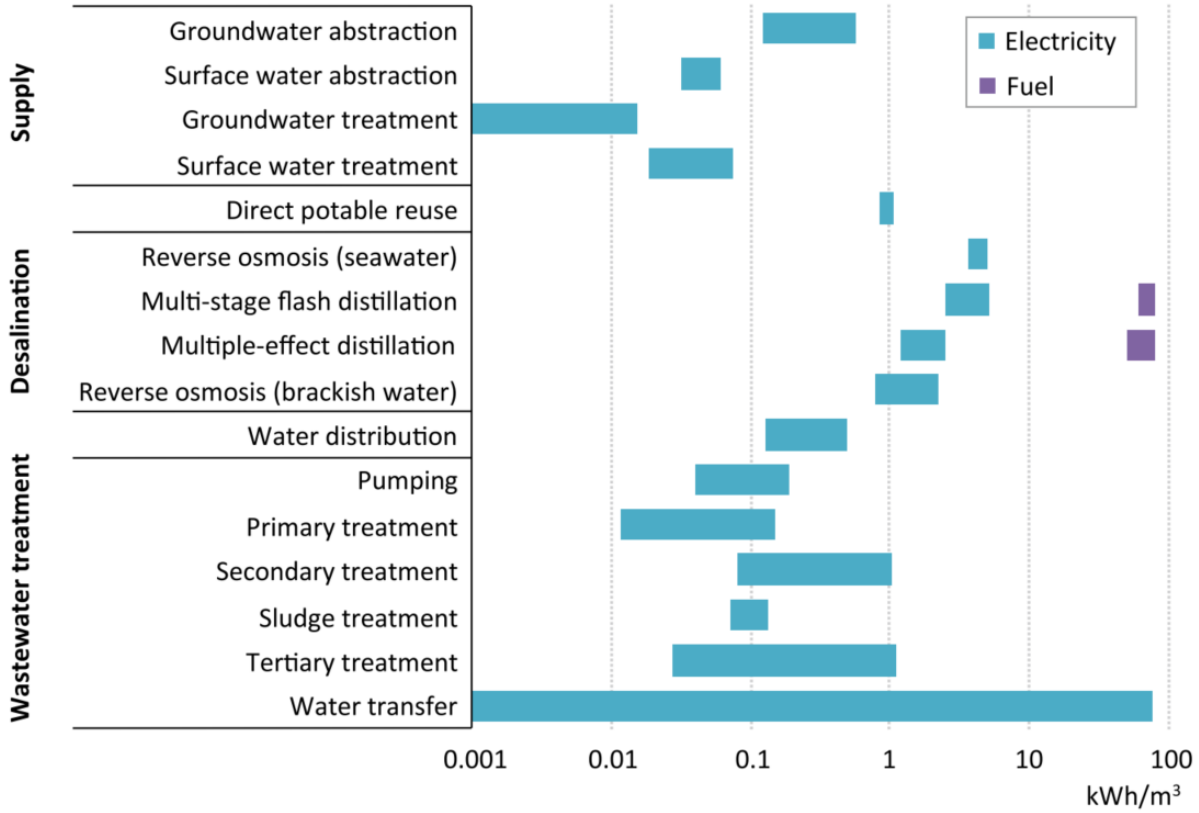
- Considering savings in the whole urban water cycle: $E_{savings}$ ~ 30 kWh/m^3
- End-use considered: **hot** or **cold** water?
- Energy use considered: water supply, building, wastewater treatment?

Indicative value of energy savings

- Energy savings metric:

$$E_{savings}(kWh/m^3) =$$

- Considering savings in the whole url
- End-use considered: **hot** or **cold** wa
- Energy use considered: water suppl
- Factors influencing $E_{savings}$:
  - Water heating efficiency standards
  - Energy calculation method
  - Building insulation standards
  - Water supply source
  - City/region topography
  - Wastewater treatment process and efficiency



Energy use for various processes in the water sector (Kęsicki et al., 2016)

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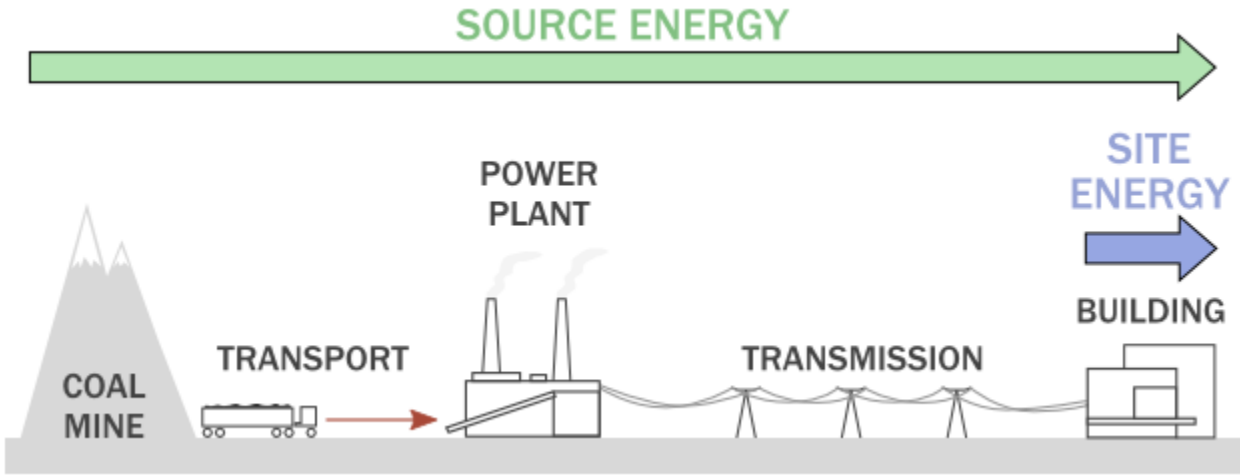
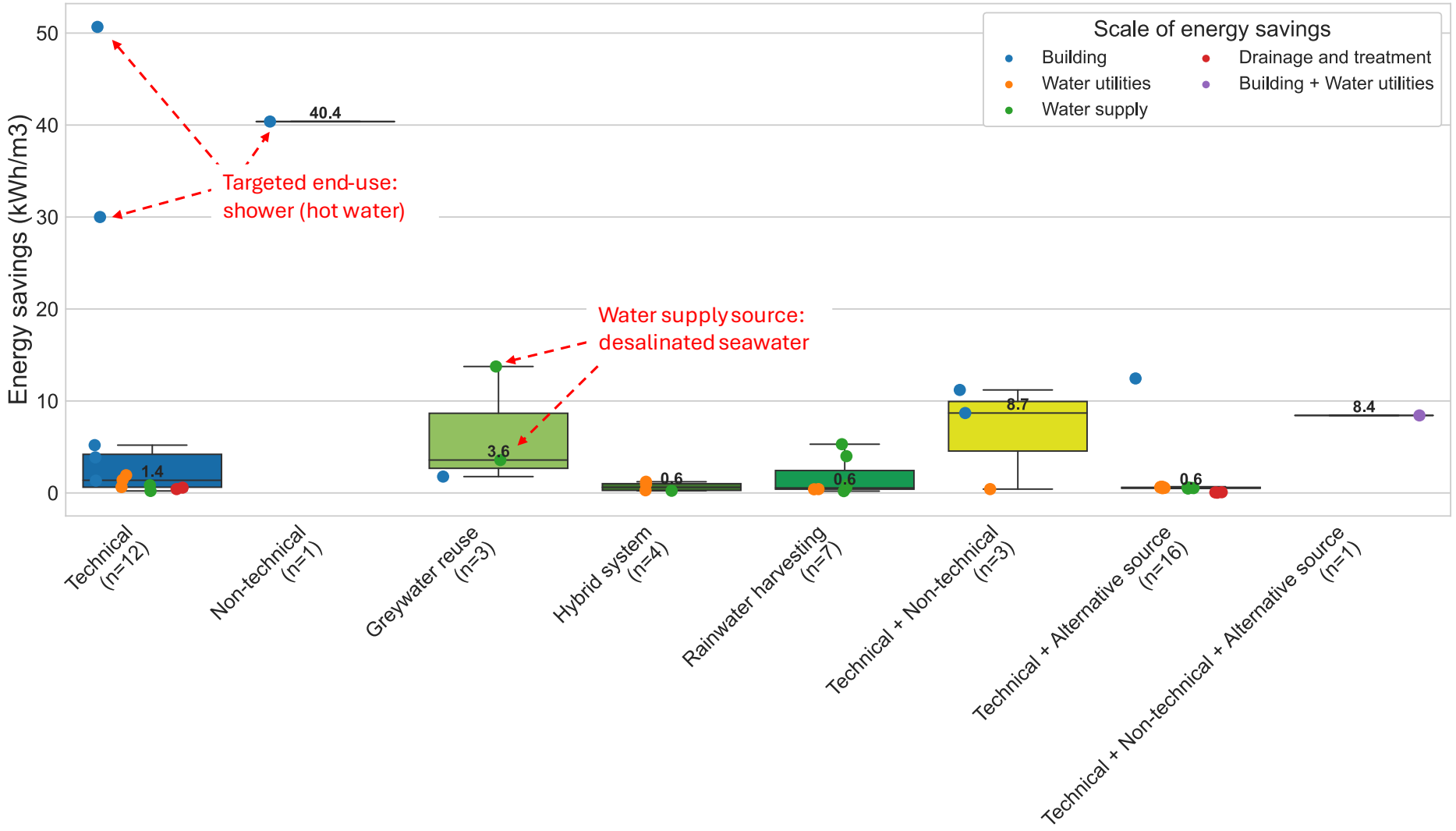
  - If using source energy instead of site energy:
    - Energy source
    - Grid efficiency



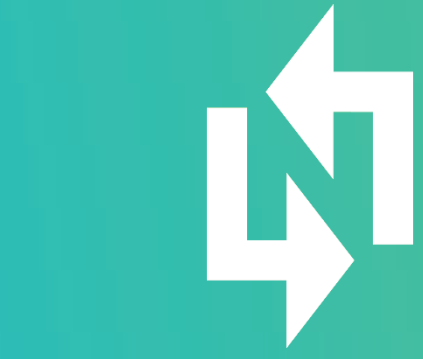
Energy savings from research studies



Energy savings per cubic metre of water saved for different types of conservation measures and at different scales

Conclusions

- Most of the energy in the urban water cycle is used in buildings for water heating
- Conservation actions targeting hot water end-use have highest energy savings
- Savings in the range of 30 kWh/m^3 observed for comprehensive conservation programmes
- Energy saving ratio should be used with caution
- Major source of data for water-related energy savings:
  - Market data/report (trend, stock, sales, penetration) and standards/codes for:
    - Water-using products
    - Water heating systems
  - Water consumption data, e.g. benchmark values (litre/capita, litre/use, etc.), demand profile, etc., from water authorities and research



NEXSYS

Thank you

Maynooth University National University of Ireland Maynooth
UCD DUBLIN
DCU
ESRI
UCD ENERGY INSTITUTE
NUI Galway OÉ Gaillimh
Trinity College Dublin The University of Dublin
UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh
Ulster University
QUEEN'S UNIVERSITY BELFAST

Further reading

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