Insights from Smart Water Meters

Implications for Targeted Management Strategies

Assoc. Professor Mark Thyer , Nicole Arbon

GOYDER INSTITUTE FOR WATER RESEARCH
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SA Water

Who We Are

- Assoc. Professor Mark Thyer
  (email Researcher profile LinkedIn)

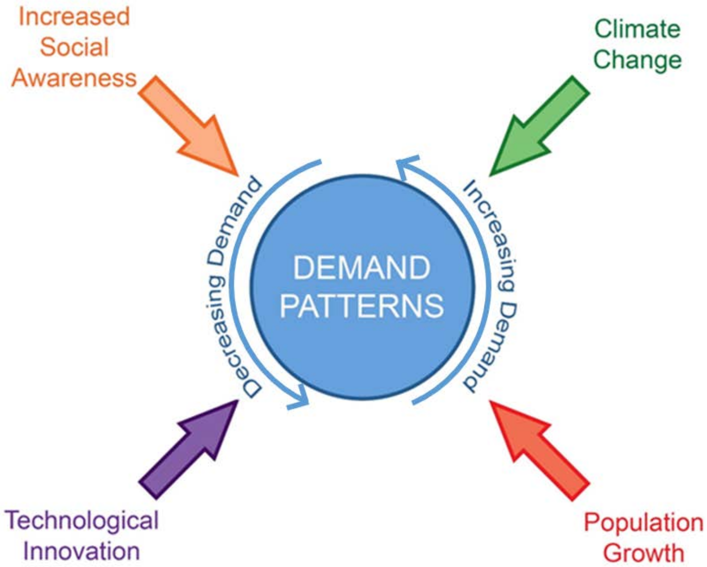
Mark is an Associate Professor in Civil and Environmental Engineering at the University of Adelaide. He has over 17 years research experience in delivering high quality industry relevant research that enhances predictions for hydrological, environmental and water resource models. Mark has over $5 million of research grants and many award winning journal papers. He has led several projects that have developed robust tools for water use prediction that incorporate the wide range of drivers of household water use. Mark has strong industry uptake of his research outputs, including SA Water, Hunter Water Corporation, CSIRO, eWater CRC, SA Dept of Water, Environment and Natural Resources and Australian Bureau of Meteorology.

- Nicole Arbon
  (email)

Nicole is a research associate in the Intelligent Water Decisions group in the School of Civil Environmental and Mining Engineering, University of Adelaide. Nicole has expertise in household water use analysis and pipeline condition assessment. Nicole has experience in working with the water industry through research and commercial projects. Nicole has undertaken consultancy projects for water supply authorities on behalf of the University of Adelaide including United Utilities, SA Water, Queensland Urban Utilities, BHP Billiton and East Gippsland Water.

Motivation

- Water demand is a key factor that drives water network design, operations and management
- Future water demand patterns are becoming more complex to predict

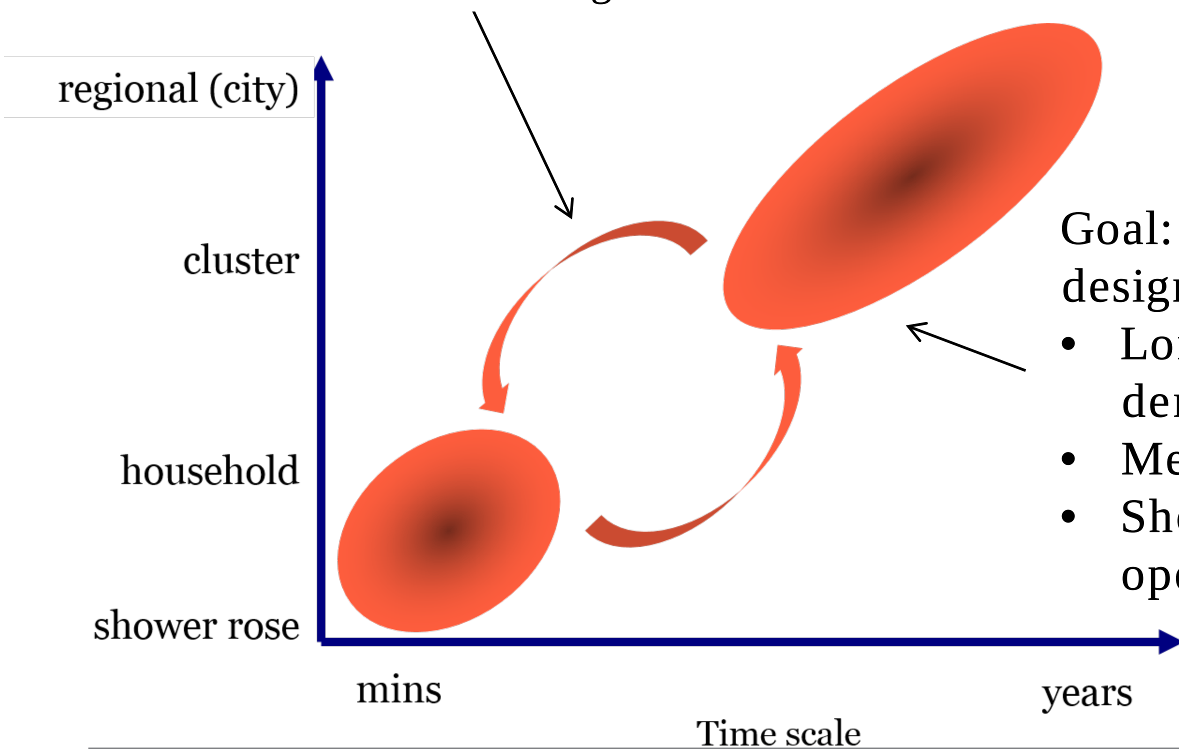


- Smart water meters provide unprecedented detailed information on water demand
  - E.g. Household scale, at 10 secs resolution
- How do you turn this information into practical insights?

Understanding water use is key to identifying opportunities to improve water supply system design and operation

Changes are implemented at large scale, but impact is at small scale

- Restriction policy
- Demand management strategies
- Integrated urban water management (rainwater tanks etc.)
- Urban in-fill, changing demographics
- Peak reduction strategies



Goal: Optimise impact to improve design and operation at larger scales

- Long-term: Annual demand, peak demand for design
- Medium-term: Summer demand
- Short-term: Demand prediction for operations to minimise costs

Identifying key drivers of household water use

Multi-institutional, inter-disciplinary collaborative project

- Mark Thyer, Nicole Arbon, Martin Lambert, Kym Beverley, Lab Staff
- 14 Research Assistants,
- 3 Honours projects, 1 Master project

- Darla Hatton MacDonald
  - behavioural economist

- Cash contribution for 150 Aquiba meters
- In-kind contribution and support
  - Steve Kotz and Nick Thomas (Water Supply & Security team)
  - Thomas Ryan and Laurie McGing (Asset Management and Metering team)

- Michael Stevens (smart Aquiba meter supply and maintenance)

Partner Investment

	Cash	In-kind	Total
All Partners	$510,000	$498,000	$1,008,000

SA Water investment leverage:
(total/individual partner)
Cash ~ 9
Total ~ 6

Outline

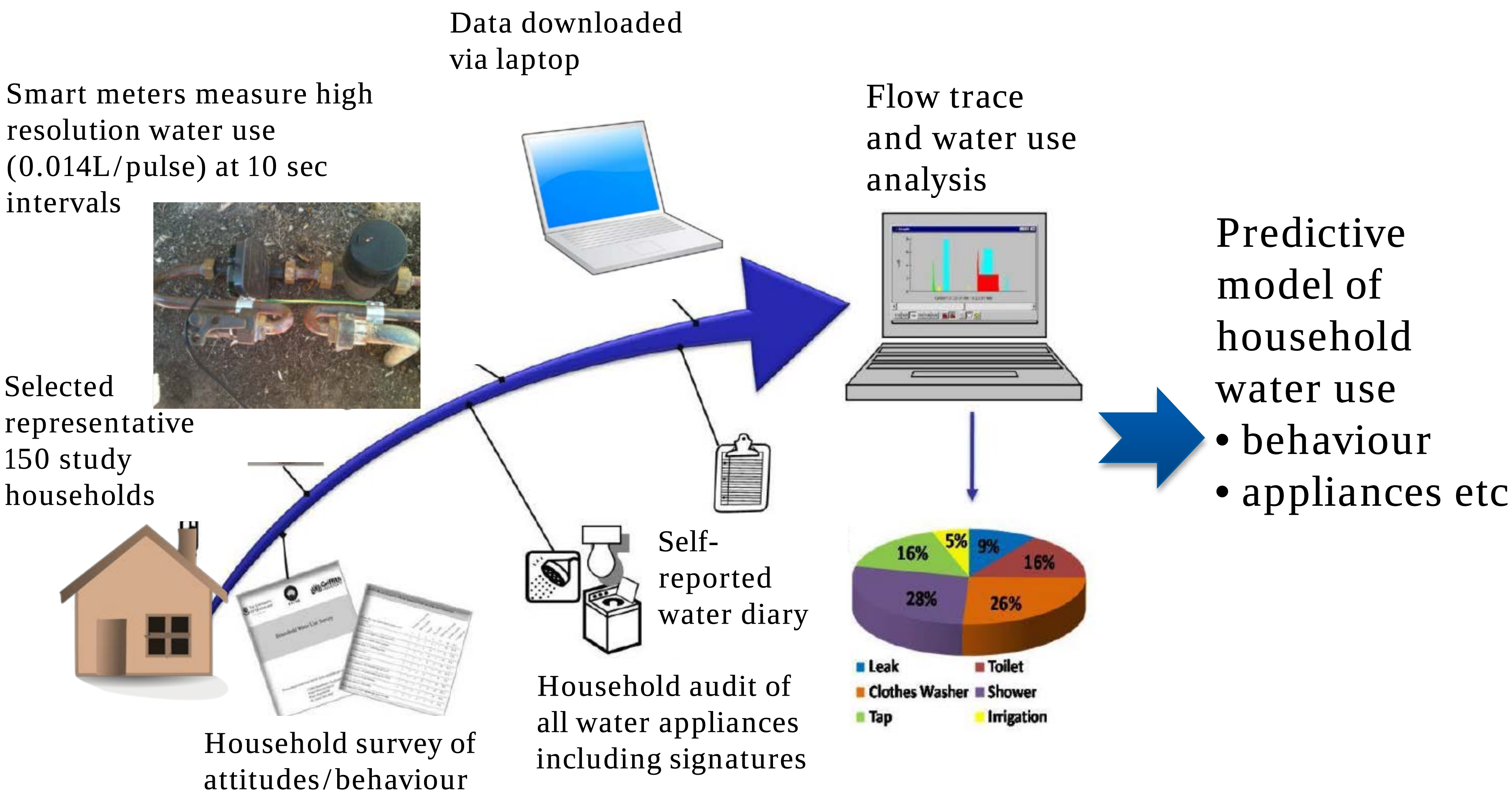
- Key insights and practical implications from 3 years of smart water meter measurements
- Drivers of Indoor Use
  - "Identifying the Key Drivers of Household Water Use" component of the Goyder Institute for Water Research Optimal Water Resource Mix (OWRM) for Greater Adelaide
- End Use Prediction
  - The Behavioural End Use Stochastic Simulator (BESS)
- Drivers of Peak Demands and Outdoor Water Use
  - Additional 2 years of monitoring of households funded by the University of Adelaide
  - Preliminary analysis based on research from Honours and Masters projects

Drivers of indoor water use

- "Identifying the Key Drivers of Household Water Use"
  - Component of the Goyder Institute for Water Research Optimal Water Resource Mix (OWRM) for Greater Adelaide
- Objectives
  - Determine statistical characteristics (frequency/ duration/flow rates) for each household indoor end-use (shower, washing machine, toilet etc)
  - Evaluate the impact of appliance efficiency and socio-demographics on indoor water usage and behaviour
  - Evaluate differences between perceived and actual indoor water use and attitudes to conservation
  - Provide reliable predictions of end-uses at the individual household
- Further Details see Arbon et al (2014)

Arbon, N., M. A. Thyer, M. Darla Hatton, K. Beverley, and M. Lambert (2014), Understanding and predicting household water use for Adelaide.*Rep 1839-2725*, 149 pp, Goyder Institute for Water Research.
http://www.goyderinstitute.org/uploads/OWRM_Household_Water_Use_Final.pdf

High resolution measurement with surveys provides understanding of behaviour



Study households are Representative of Metro. Adelaide households

- 150 Owner occupied separate houses
- High Response Rate (10%-15%) 3-5 times higher than interstate

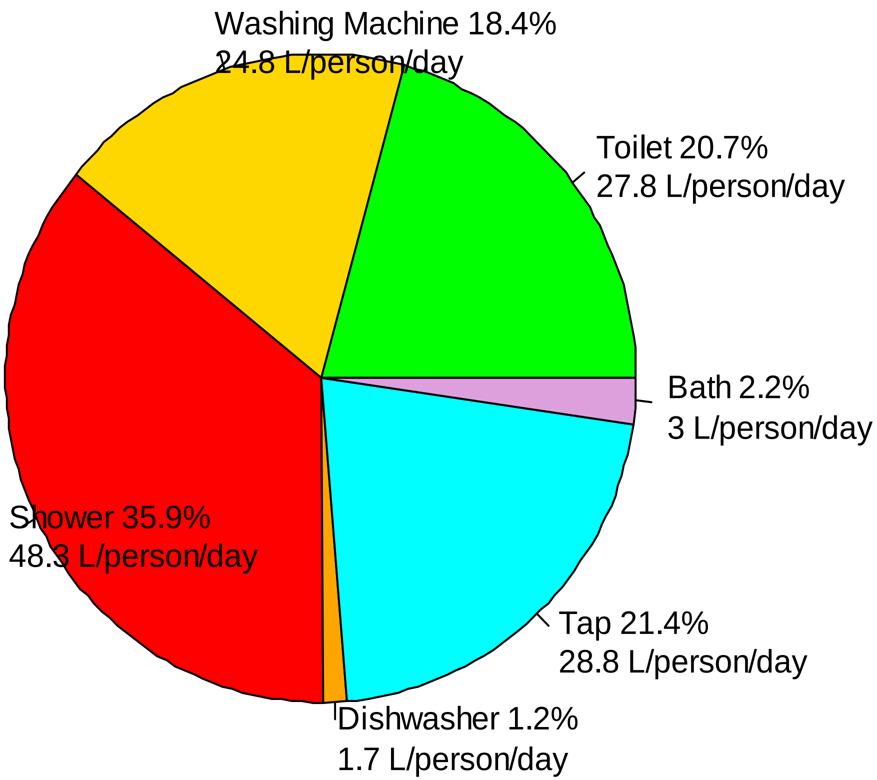
65% of Housing stock based on:

- Income
- Family Composition
- Appliance proportion
- Occupancy
- Dwelling Structure

Under-represented:

- Single parents/renters.
- Units/Newer housing stock

Local high resolution water use values representative of Adelaide



135 L/ person/day

327 L/household/day

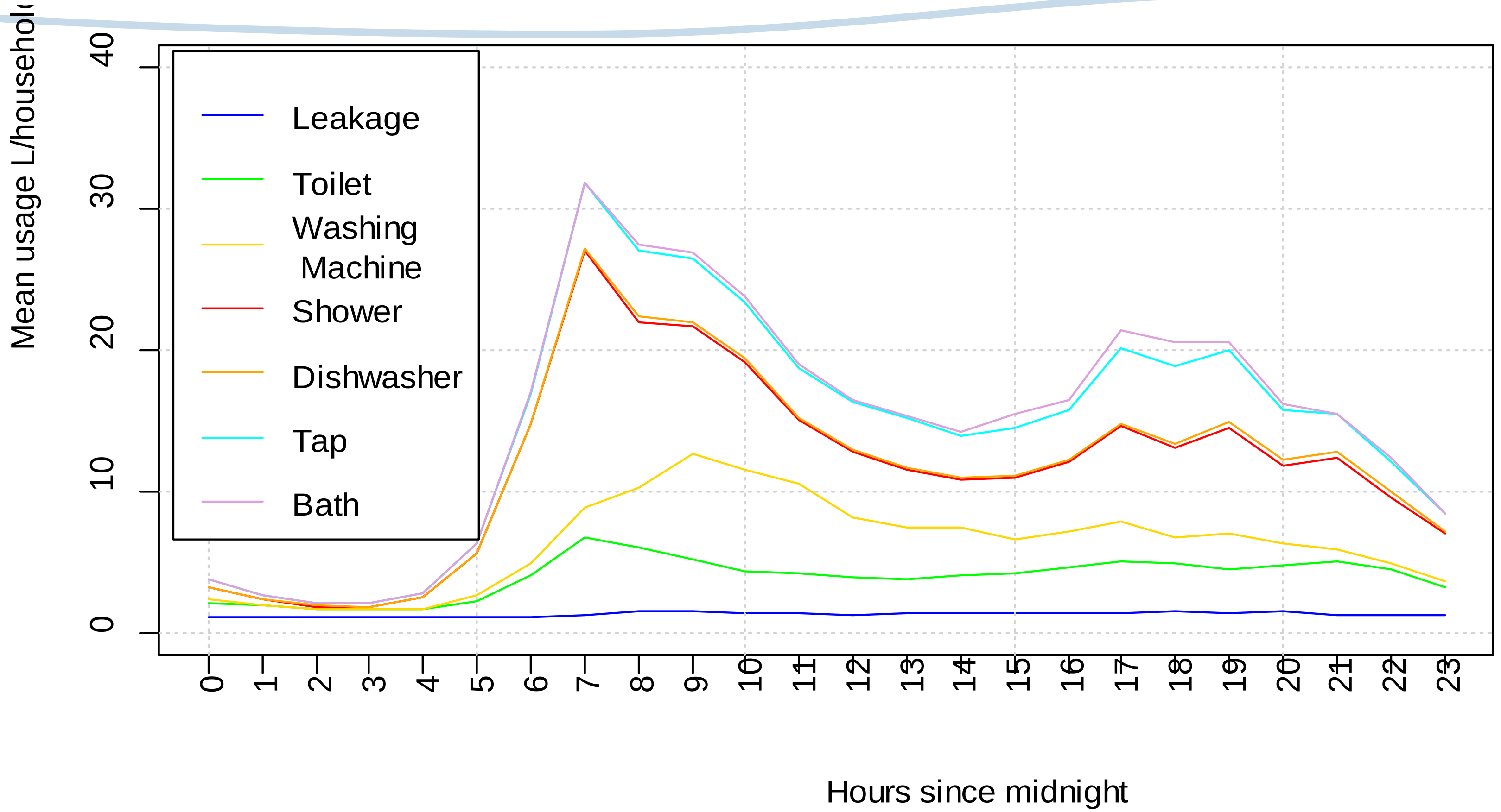
Comparison to other states:

- Lower Washing Machine volume (efficiency)
- Higher shower use (duration)

Practical Opportunity:

- Accurate local end-use values available for demand management, alternate source planning and wastewater volumes

End-uses have different usage patterns

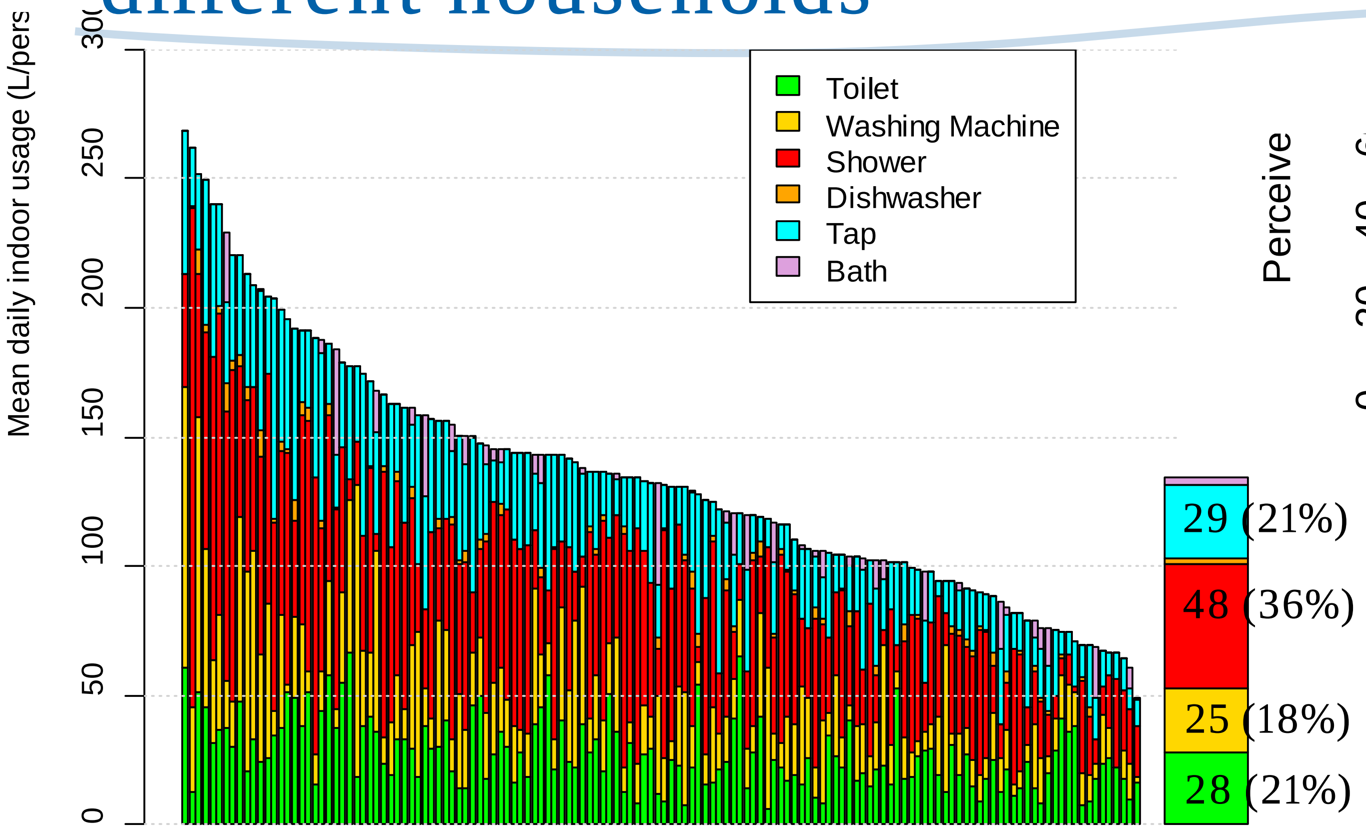


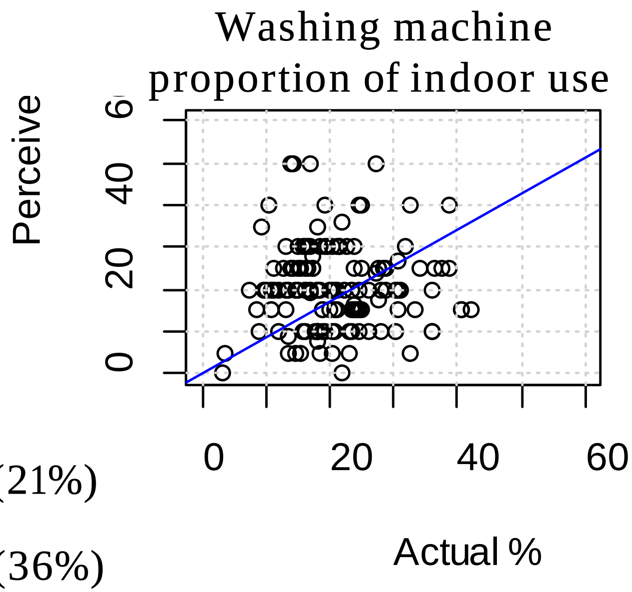
- Detailed knowledge of usage patterns and behaviour

Practical Opportunities:

- Information for operations and planning
- Demand forecasting based on reliable local data at the household level

Significant variability in end-use between different households





- Households have a wide range of end-use that is unknown, but there are patterns or groups

Practical Opportunities:

- Smart meters give households greater information to identify their use within the house
- Comparisons of households to other consumers (i.e. based on ranking like households)

Changes in appliances have a bigger impact then changes in behaviour

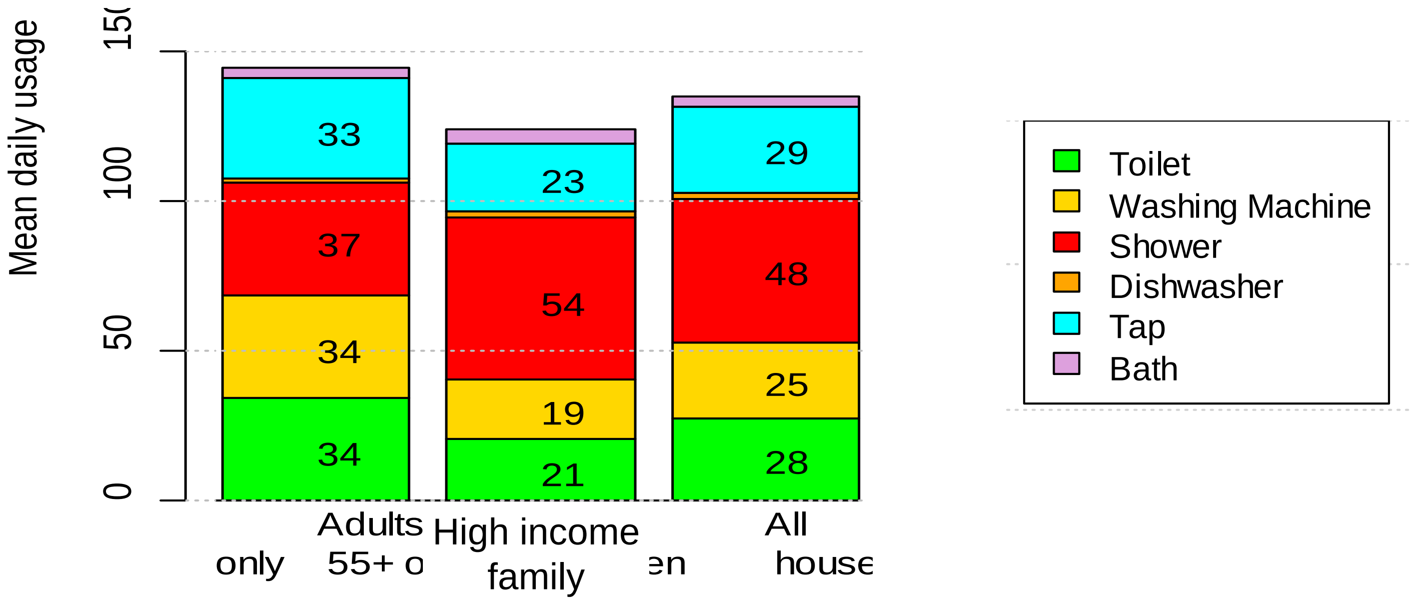
	Shower	Toilet	Washing Machine	Total
Efficient refers to	< 9L/min flow rate	Max 6/3L Dual flush	Front Loader	-
% of households with efficient appliance	43%	35%	55%	-
Potential Savings(L/person/day)	5.5	5.1	8.7	19.3 (15% of total indoor)

- Some changes in behaviours
  - Efficient showers led to longer duration
  - Ratio of full to half flushes increased for high efficiency toilets

Practical Opportunities:

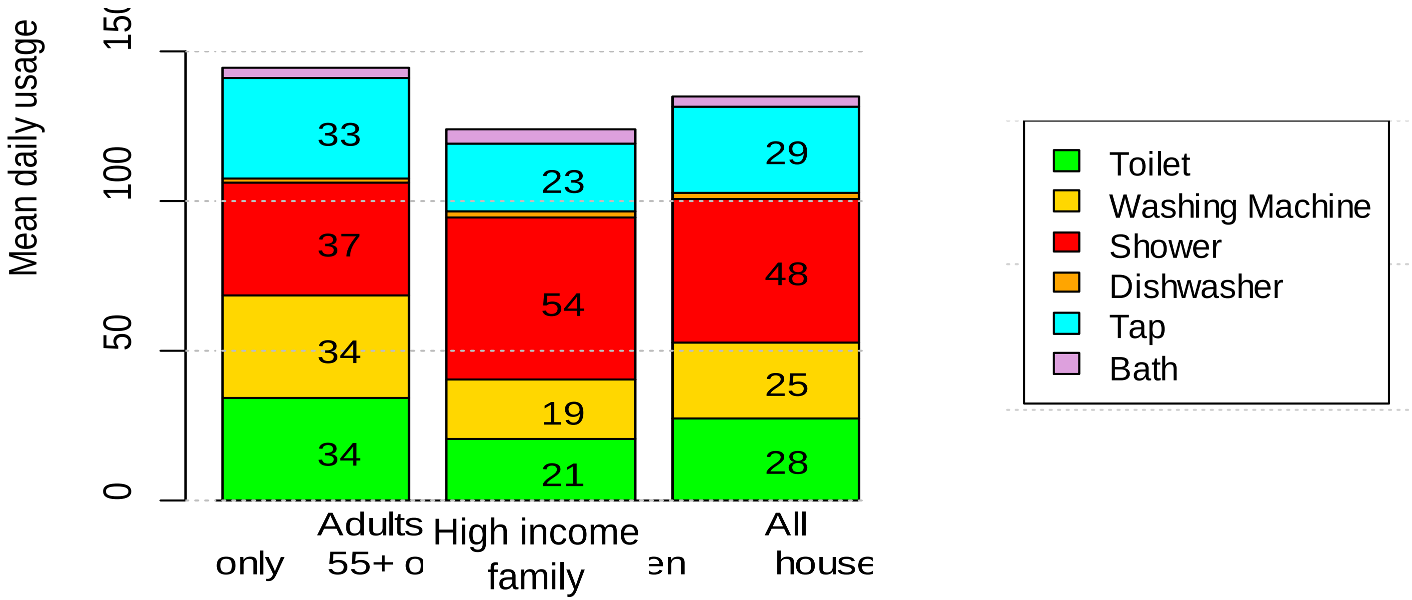
- Increasing uptake of efficient appliances will reduce use
- Appliances are easier to change then behaviour
- Washing machines offer biggest water saving potential

Distinct household usage types require target demand management strategies



- High income family households
  - Indoor use low, due to efficient washing machines (70% uptake) and lower toilet frequency
  - Less likely to think they are water conservers (longer showers)
  - Water saving potential should target shower behaviour (e.g. shower timers)

Distinct household usage types require targeted demand management



- Adults 55+ only households
  - Likely to think they are water conservers (shorter showers)
  - Indoor use high, due to inefficient washing machines (<30% uptake) and higher toilet use frequency
  - Water saving is from efficient washing machines
  - Likely to be growing household usage type as population ages

Practical Opportunity:

- Targeted approaches needed for demand management and planning

The need for predictive tool for water use

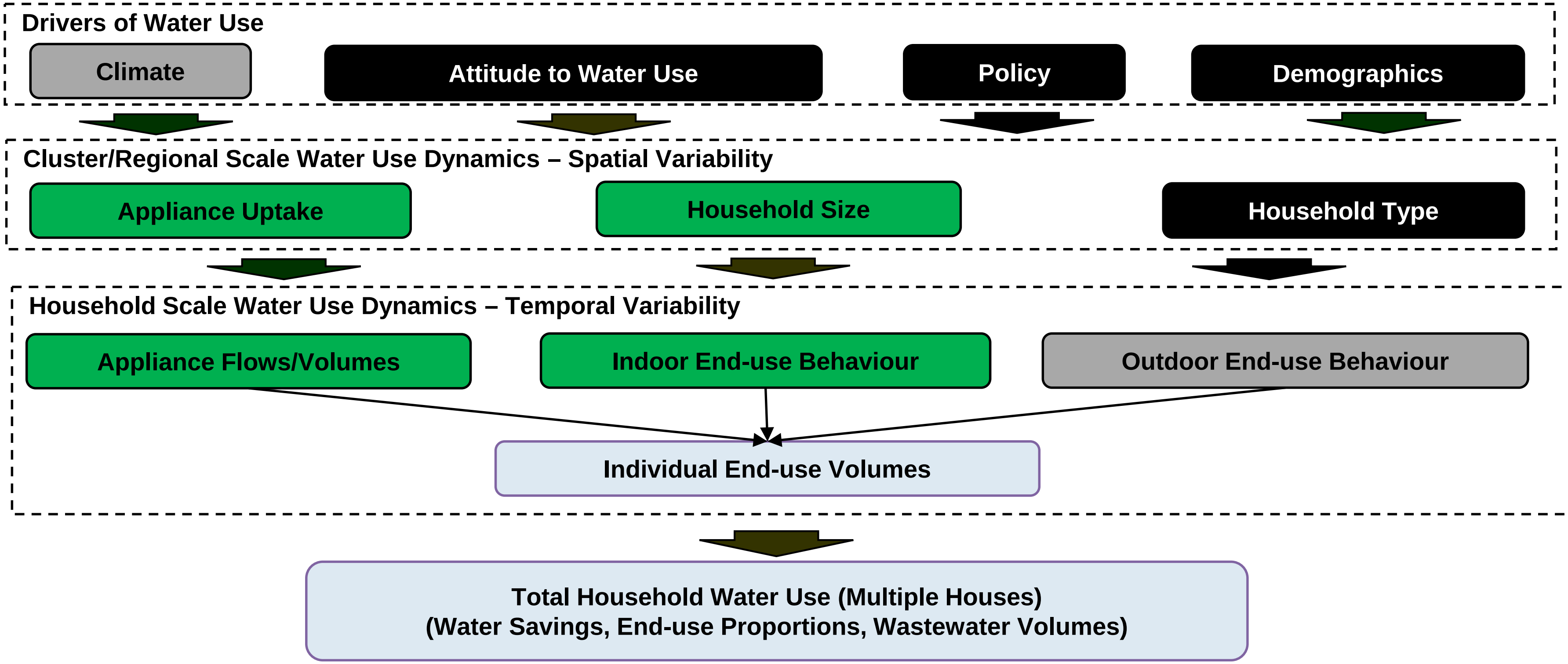
- Water use has changed in the past and will continue to change into future
  - Population and demographics
  - Appliance stock and efficiencies
  - Growth and infill

- Transferability
  - Suburb/operation areas will differ in household types due to differences in socio-economics

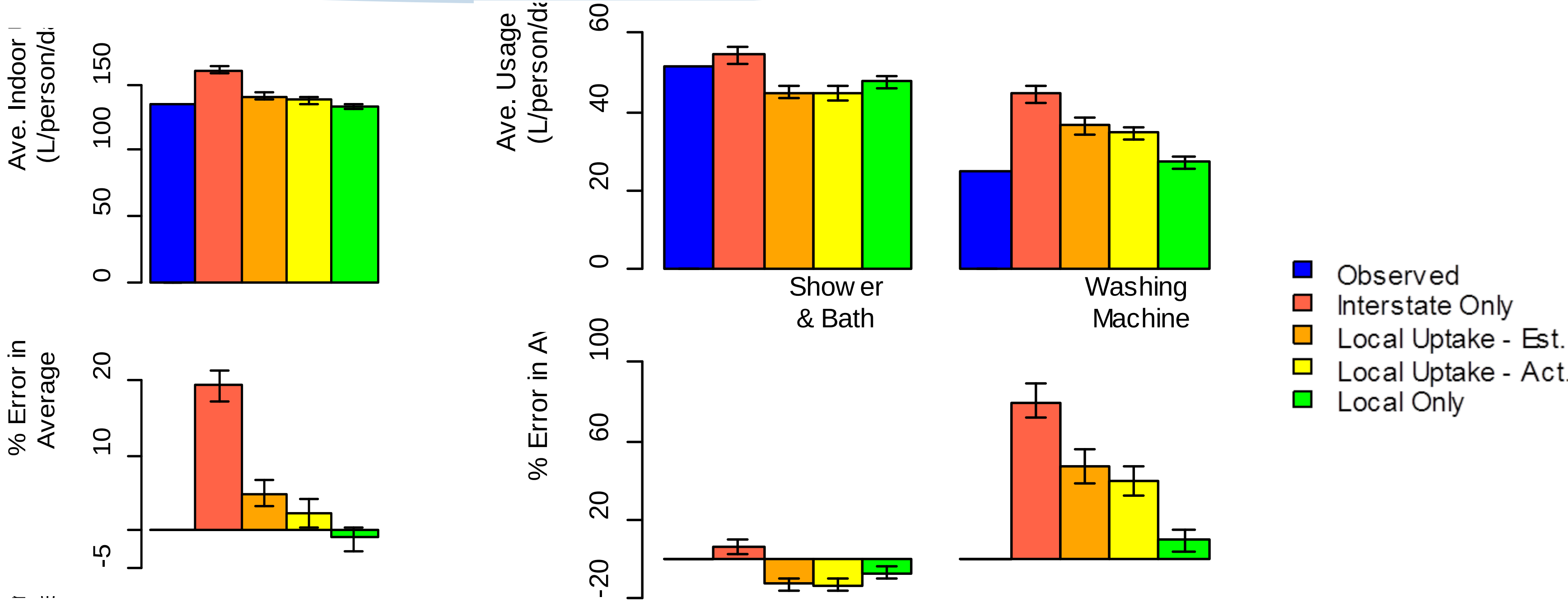
- If you going to predict water use, you need a tool that utilises information on:
  - Household size
  - Appliances
  - Behaviour for different end uses

BESS: Behavioural End-Use Stochastic Simulator

- Predicts volumes for range of individual end-uses
- At a range of time scales (hourly, daily, annual)
- By incorporating volumes based on efficiency and behaviour (durations/frequency)



BESS provided reliable end-use predictions with local data

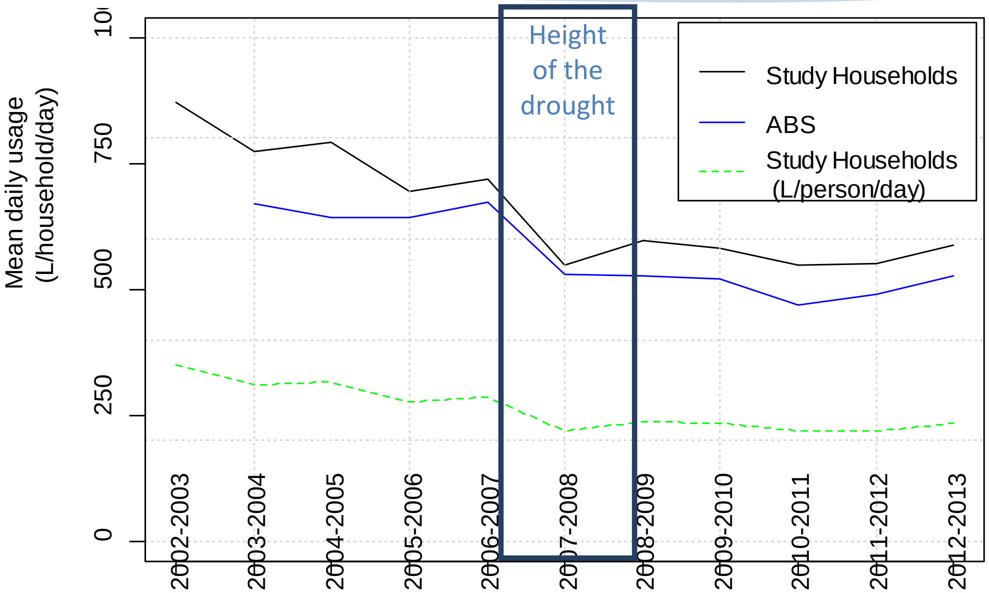


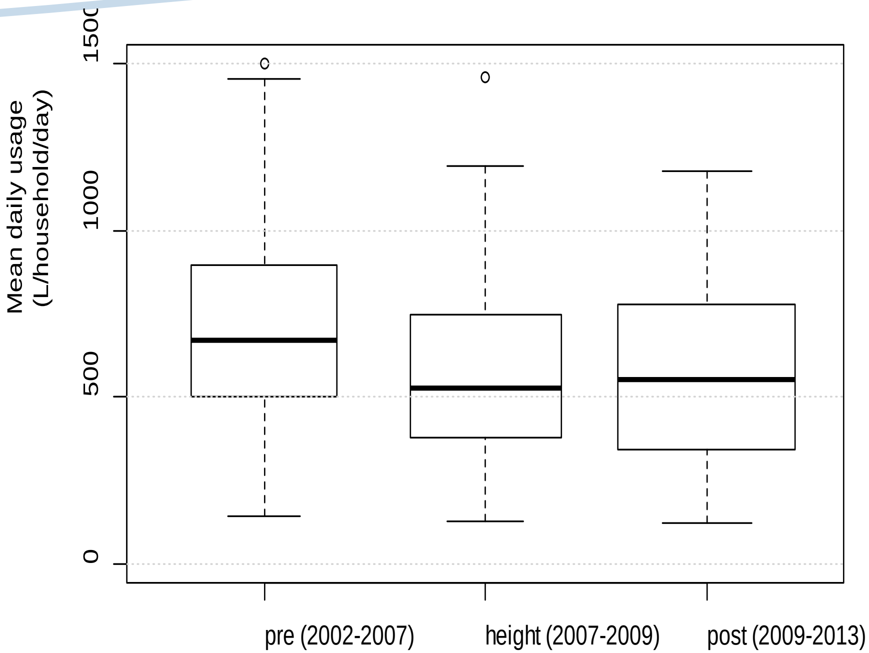
- BESS provides reliable (~5-10% errors) end-use predictions for households with similar characteristics

Practical Opportunity:

- – BESS can be used to reliably predict use and changes in use in the system

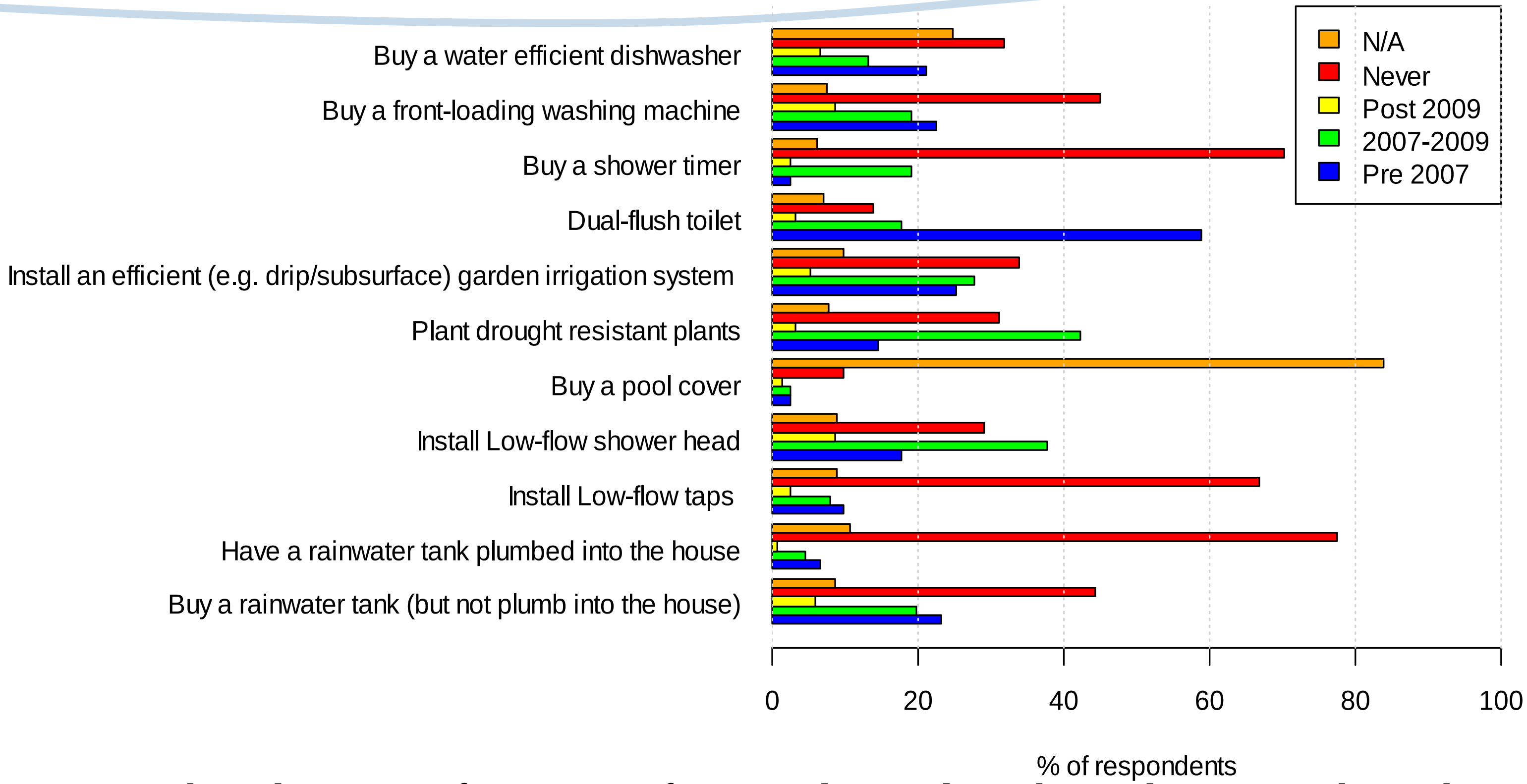
Minimal "bounce back" after drought seen





- During 2007-2009 drought, 15% decrease in water use
- **Are these changes in water use temporary or permanent?**

BESS predicted 50% of past water use decrease is permanent due to uptake of efficient appliances



- BESS combined survey information of pre- and post-drought appliance uptake with water use statistics
- Remaining 50% of past water use decrease attributed to reductions in outdoor or behavioural changes

Practical Opportunities

- BESS can be used to predict impact of past changes in the system
- Household changes during drought/restrictions can have lasting effects on the system

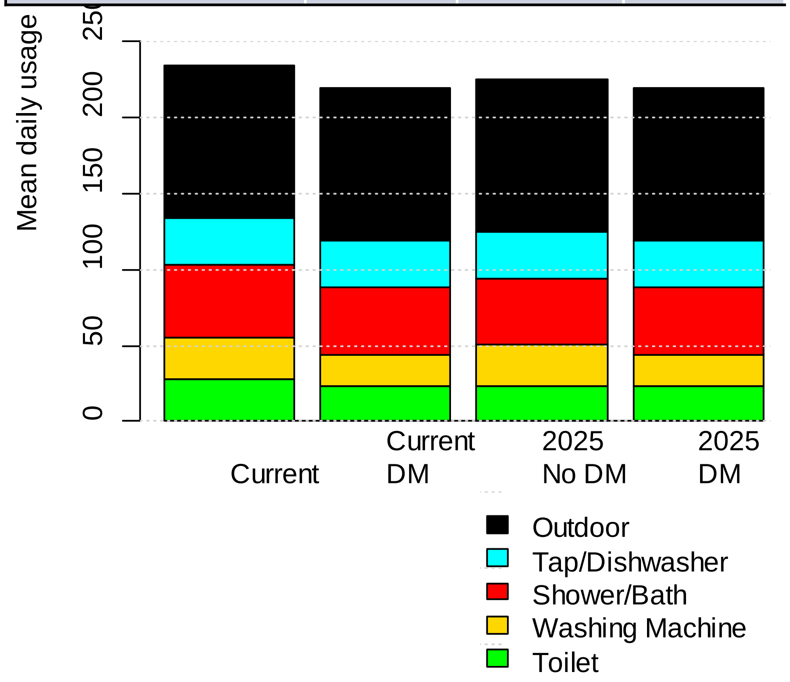
BESS provided predictions of future use and impact of demand management

- Demand Management
  - Uptake of water efficient appliances alone
  - Does not include behavioural change – lower limit
  - Residential only
  - Assumes outdoor does not change
  - 2025 includes expected uptake and population growth

Practical Opportunity:

- Changes in behaviour (indoor and outdoor) will be required to reduce water use, as efficient appliances are reaching saturation (already at 50%)

Water Use Volumes	7%	4%	4%
Wastewater Volumes	11%	5%	6%



Summary of indoor drivers

- Identified key drivers of household water use in Adelaide
  - Smart metering , analysis and surveys
  - First time for South Australia we have accurate local end-use values at the household level
  - Distinct household types based on demographics
- Developed reliable water use prediction tool (BESS)
  - Predicted current end-uses (5-10% error)
  - Past changes in the millennium drought
  - Future scenarios including demand management impacts
- Practical Opportunities: Need for targeted approaches to
  - Demand management strategies
  - Water use prediction for planning and operations to reduce costs

Insights from Smart Water Meters: Drivers of Peak Demands and Outdoor Use

Assoc. Professor Mark Thyer

Outline

- Future changes in peak demands
- Drivers of peak demands
- Drivers of outdoor water use
- Future: Realising the Potential from Smart Water Meters

Background

- Goyder OWRM Project: Oct 2012- April 2014
  - Only a single summer of data (2013/14)
  - Limited scope for analysis
- Additional University of Adelaide investment to extend measurement and analysis to multiple years
  - Over 3 years of subdaily smart meter data for 120 households
  - Three summers: 2013/14, 2014/15, 2015/16
  - Measurement: Modem Purchase + Installation: $65k cash
  - Analysis: Honours and Masters Project: $60k in-kind
- Preliminary Results
  - To be peer-reviewed

Outline

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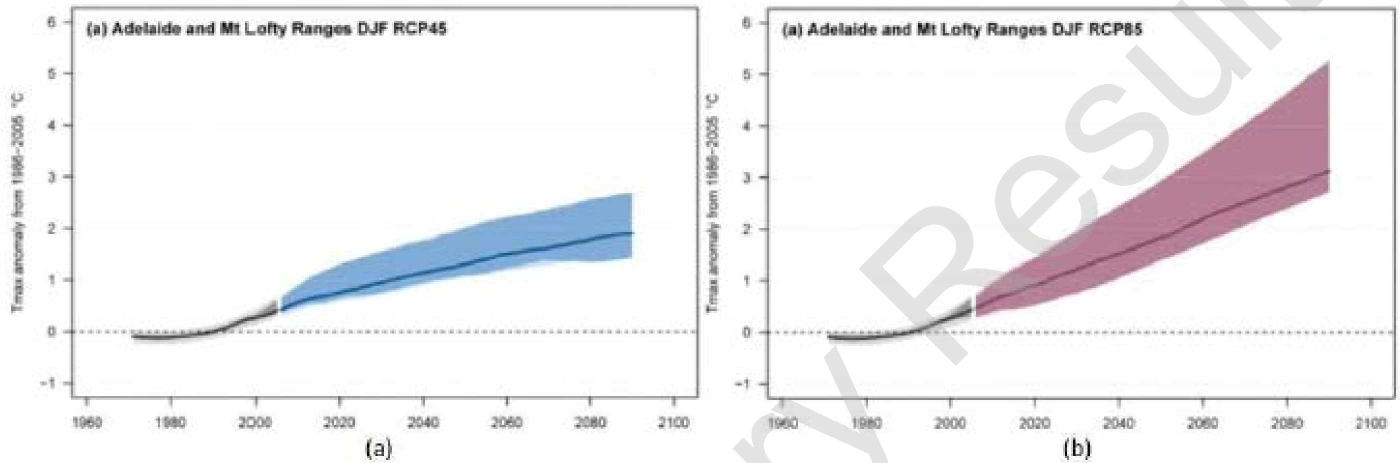
Motivation: Impacts of climate change



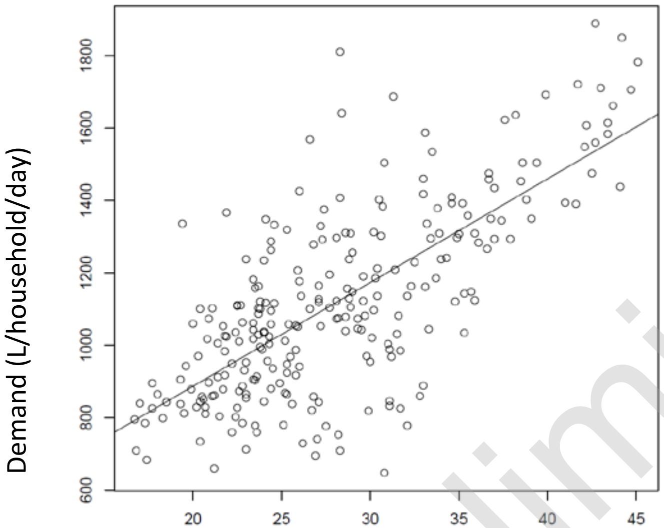
Expected changes in summer max. temp for Adelaide (Charles and Fu, 2015)

- Future climate change will increase temperatures
- What will be impact on peak demands?
- Motivated and supported by Patrick Hayde, Manager Water, Treatment and Network Planning, Strategy and Planning

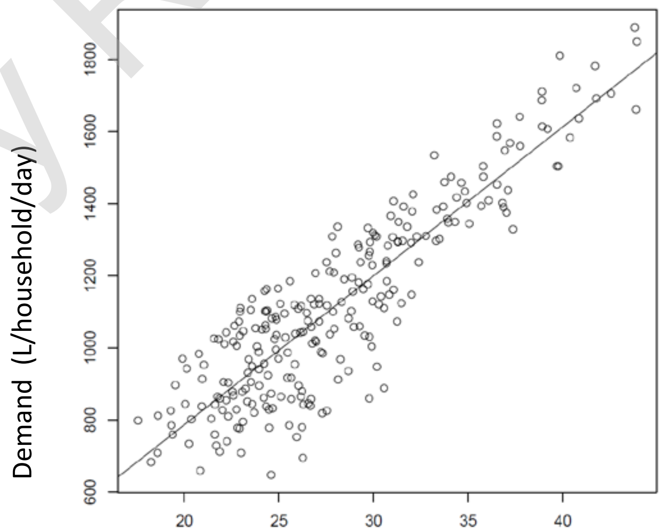
Charles, S. P. and Fu, G. (2015) *Statistically Downscaled Climate Change Projections for South Australia*, Adelaide, South Australia: CSIRO.

Heatwaves are a major driver of peak demand

- Demand (production flows) at representative location within Adelaide Metro area downscaled to a household level (L/household/day)
- Months of December to February on a daily time-step



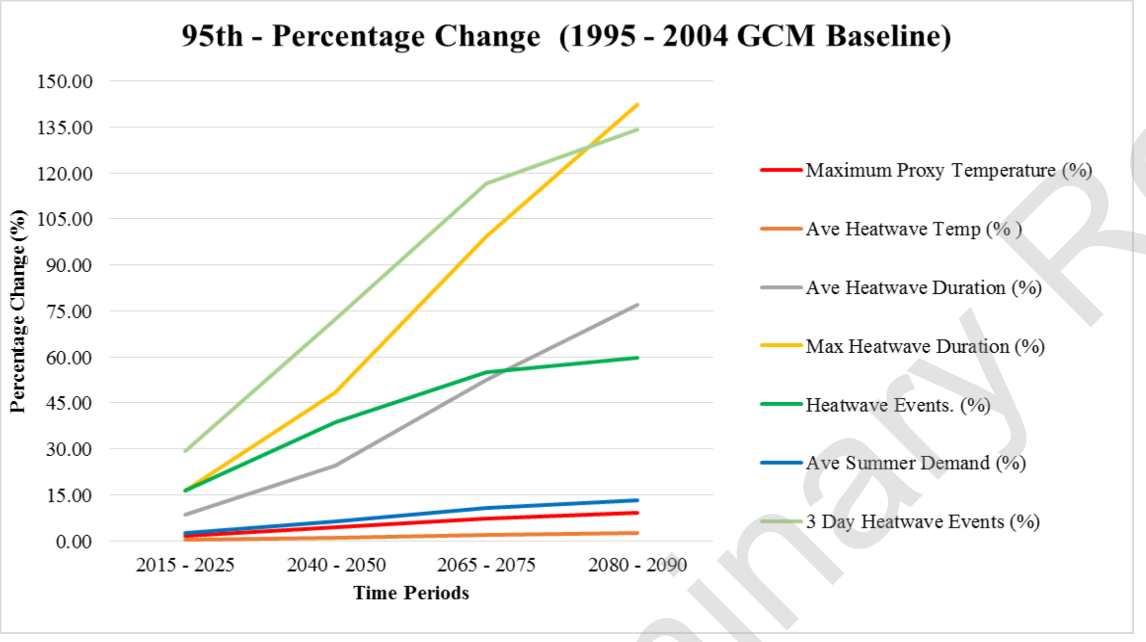
Daily Maximum Temperature (°C) - R^2=0.52



6 day weighted average of daily max temperature (°C) - R^2=0.79

Multi-day heatwaves explain between 50-80% of the variability in peak demand

Peak demands likely to increase because climate change will increase heatwave duration



2040 Projections:

- 25% increase in average heatwave duration
- 49% increase in max heatwave duration
- 39% increase in heatwave frequency
- 10% increase in avg. summer demand

Future Climate projections from *Goyder Institute for Water Research, Climate Change Project*

Practical Challenges:

- Distributed balancing storage tanks may not cope with future peak demands
- Extra pumping may be required, increasing costs and GHG emissions

Practical Opportunities:

- Operations: Develop better forecasting and optimisation tools to better manage peak demands
- Planning: Design a better water distribution system that reduces peak demands?

Outline

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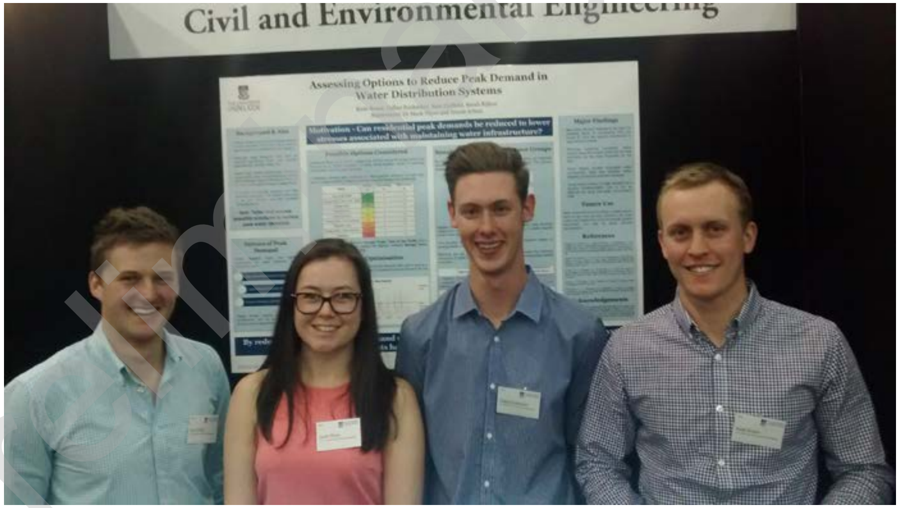
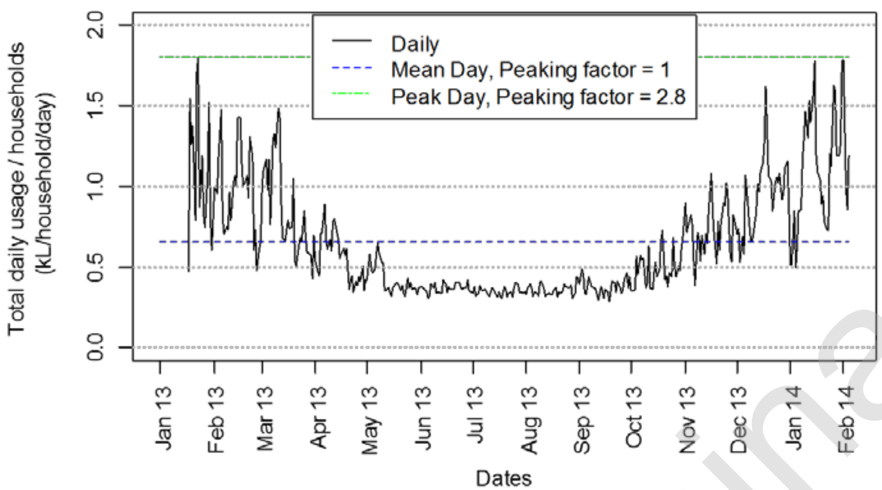
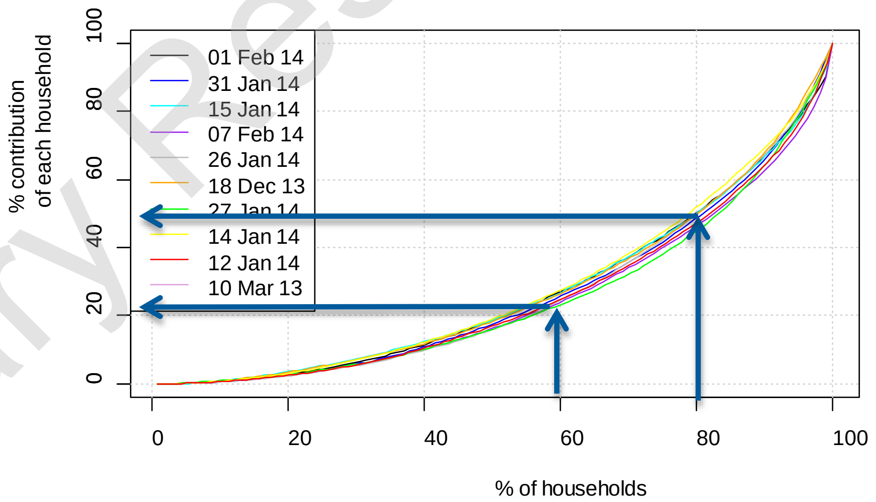


Small proportion of households contribute to system peak demand

- System peak demand: All study households



- Contribution of each household to system peak demand



- 20% of households contribute to 40-50% of system peak demands
- 40% of households contribute to 70-80% of system peak demands
- Insight only possible with household level data

Practical Opportunity:

- Reduce system peak demands (and operational costs) by targeting "high peak usage" households

Profile of "high peak usage" households

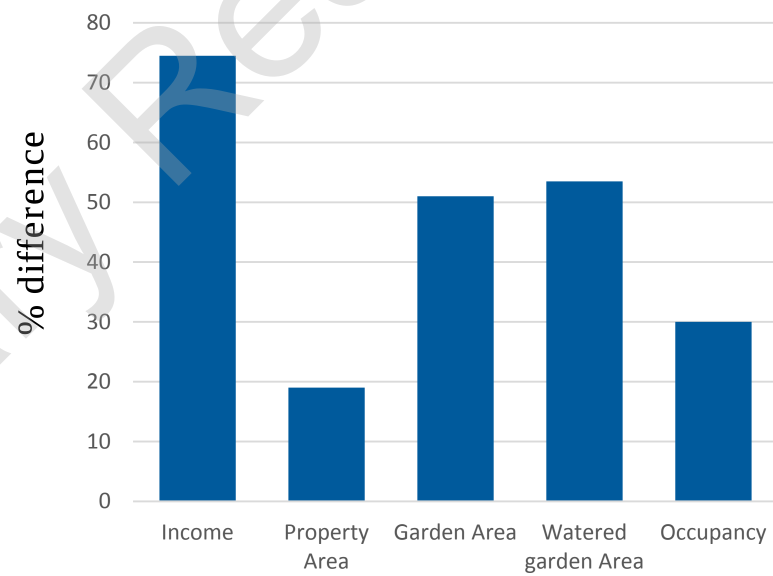
- High Peak Usage Households

(20% of households contribute to 50% of system peak)

Significantly different
- 75% higher income
- 50% higher watered garden area
- 30% more occupants
- More irrigation methods (drip/sprinkler)

Not significantly different
- Property area

Percentage difference between high peak usage households and other households



Practical Opportunities:

- Operations and Planning: Peak demands will vary significantly in different areas due to these socio-economic groupings
- Peak demand reduction management and monitoring strategies can focus on households with these characteristics

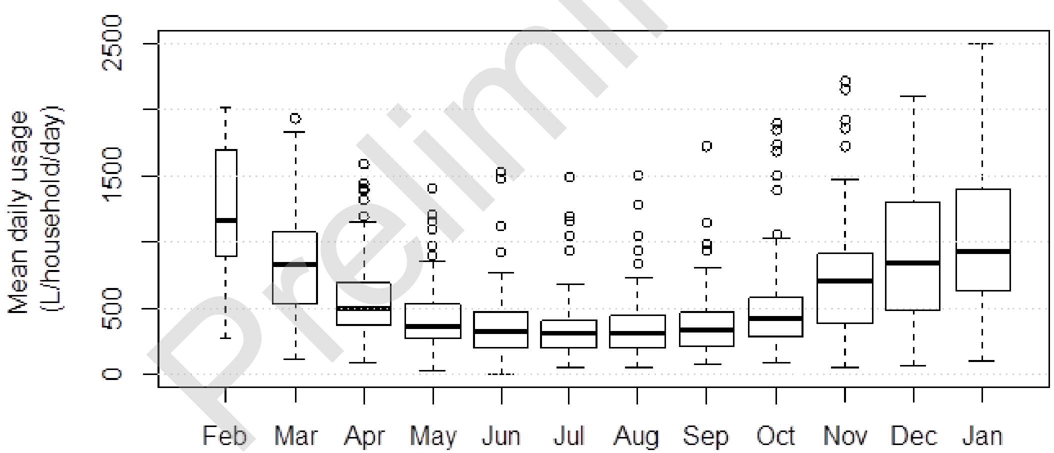
Outline

- Future changes in peak demands
- Drivers of peak demands
- Drivers of outdoor water use
- Future: Realising the Potential from Smart Water Meters

Drivers 0f outdoor water use: Motivation

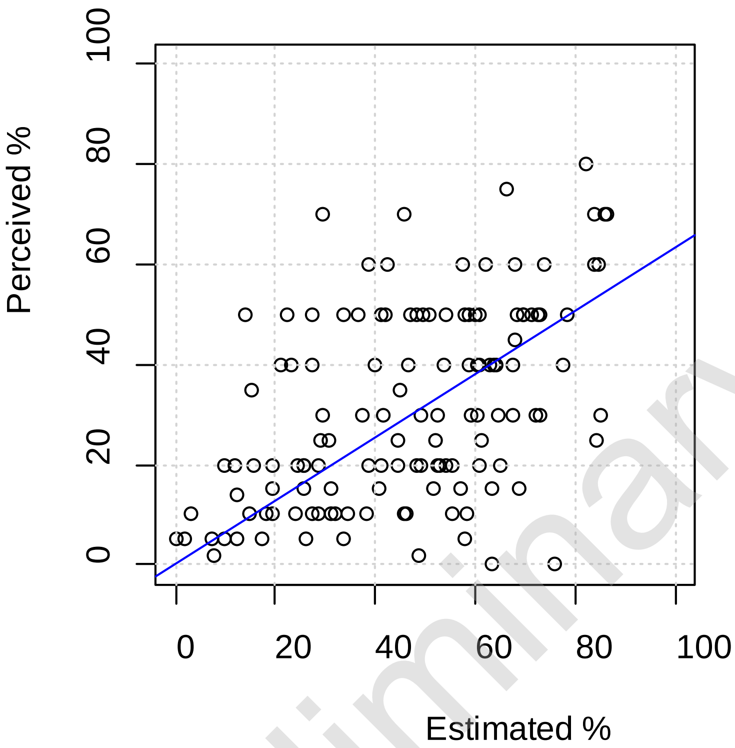
- Key driver of operational and planning decisions (e.g. pumping from Murray during summer)
- During restrictions often first end-use reduced
- Outdoor water use is highly seasonal and varies between households
- Can be viewed as "discretionary" but has inherent value to some households

Winter total ~380 L/hh/day,
Summer total ~ 950 L/hh/day
Outdoor end use ~ 570 L/hh/day (~40% of annual)



Outdoor end use ≡ summer seasonal end use (outdoor, evap air conditioners etc.)

Households cannot predict their own seasonal outdoor end use

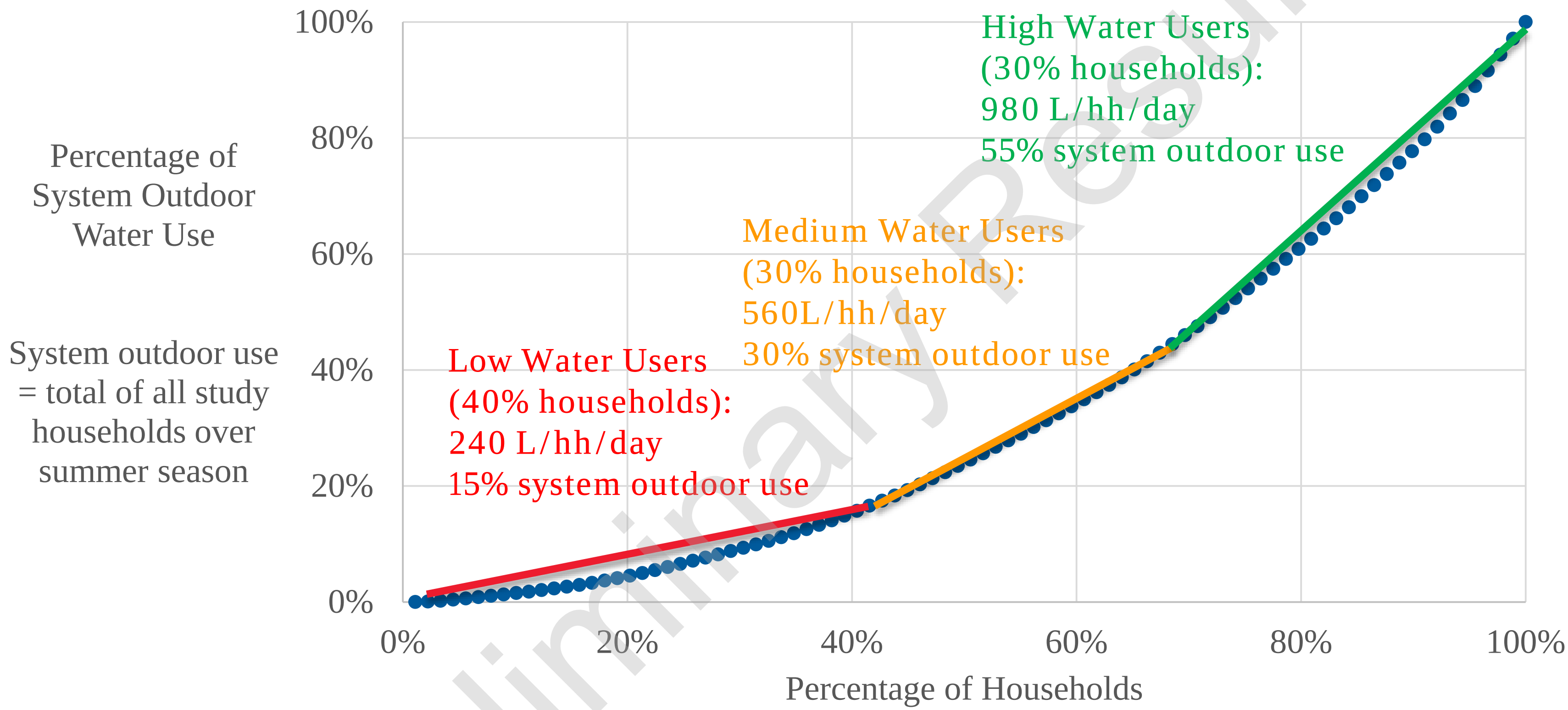


- Perceived is based on household surveys
- Estimated outdoor end use

Practical Opportunity

- Community Engagement: Households need greater information to identify cost-effective water saving opportunities

Small proportion of high outdoor water use households contribute to system outdoor water use

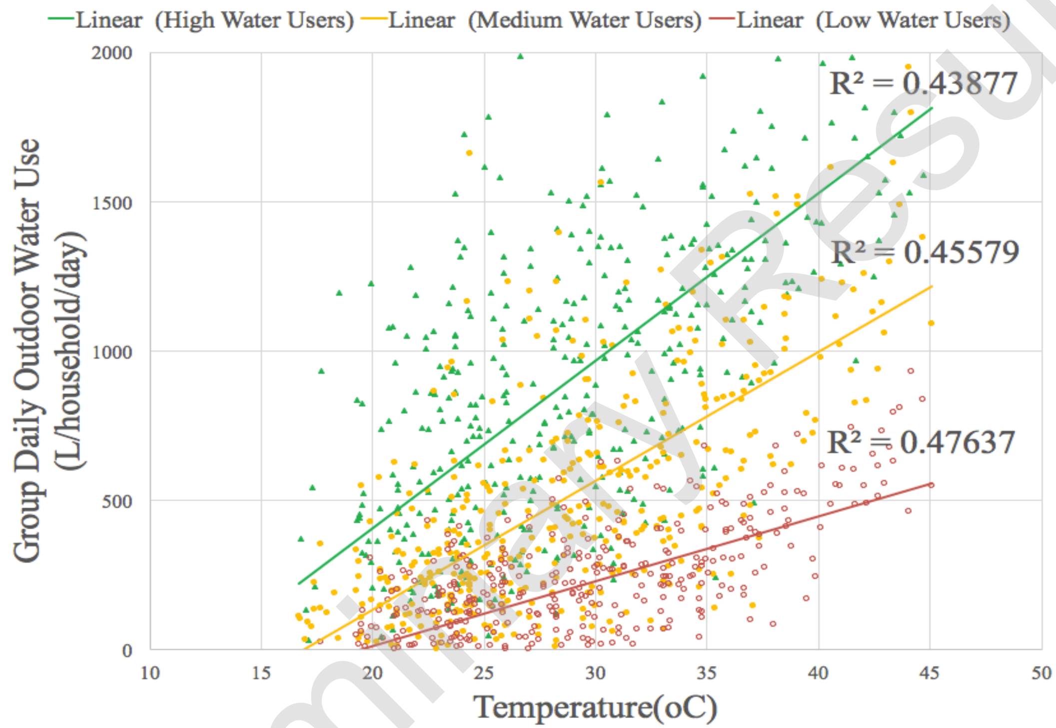


Summer season avg. outdoor water use (over three summers, 2013/14 - 2015/16): 570 L/hh/day

Practical Opportunity

- During drought target "High outdoor water users" instead of restricting all users

High outdoor water users react faster to temperature increases

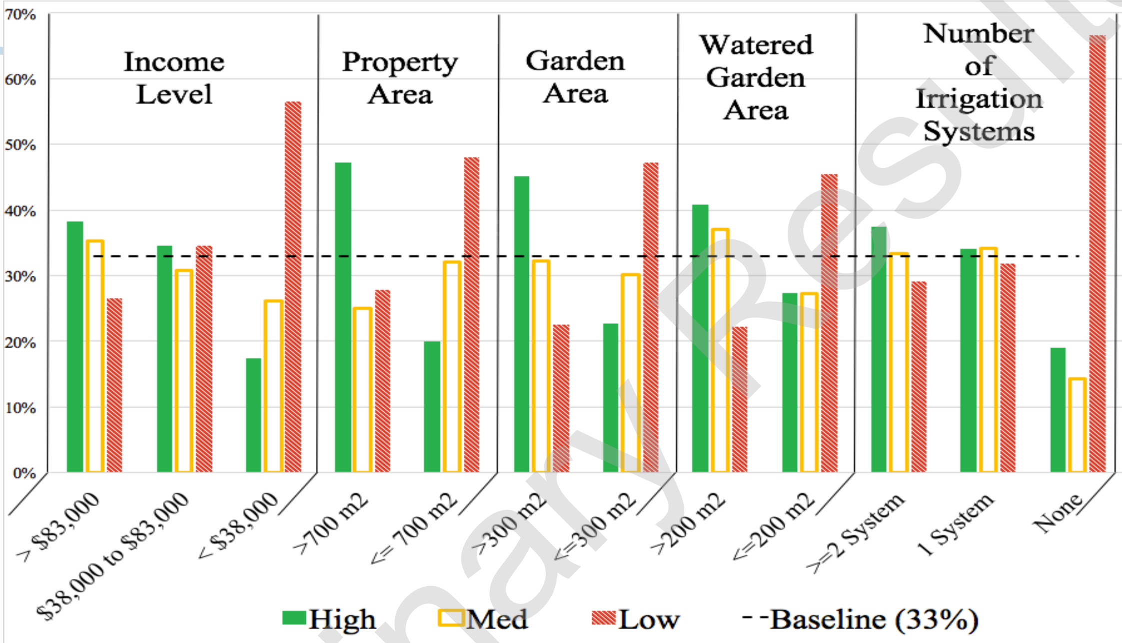


- Increase in outdoor water use day per 1°C temperature increase
- High: 56L/hh/day   Medium: 43L/hh/day   Low: 22L/hh/day

Practical Opportunity

- High outdoor water users react differently which has demand forecasting implications in different areas

Profile of high outdoor use households



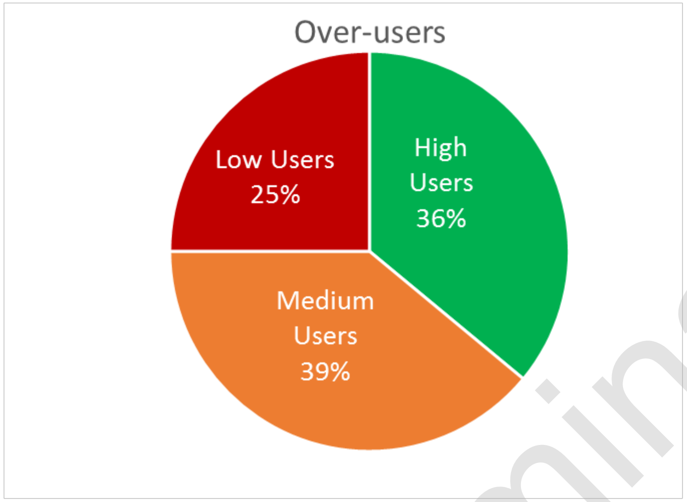
- Average outdoor water use of ~980 L/hh/day (almost double average ~570 L/hh/day)
- Medium to High Income (>$38,000 pa)
- Large property area (>700 m^2), garden area (>300 m^2), watered garden areas (>200 m^2)
- Have at least one or more irrigation systems (drip and/or sprinkler)

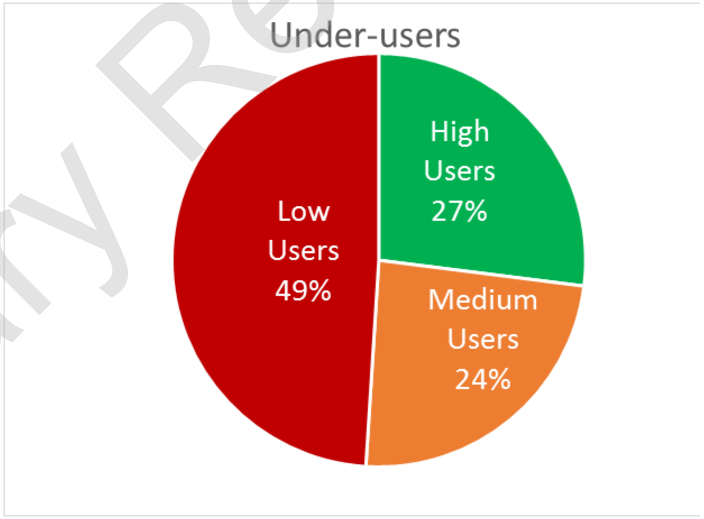
Practical Opportunity:

- High water users may be identified and targeted through household characteristics

Only some "High outdoor water users" are "Over-users"

- Compared Outdoor Water Use vs Estimated Water budget
  - Water Budget = F(Potential Evapotranspiration, Garden Area, Landscape Type)
- Classified Households:
  - Over-users: Water Use > Water Budget
  - Under-users: Water Use < Water Budget



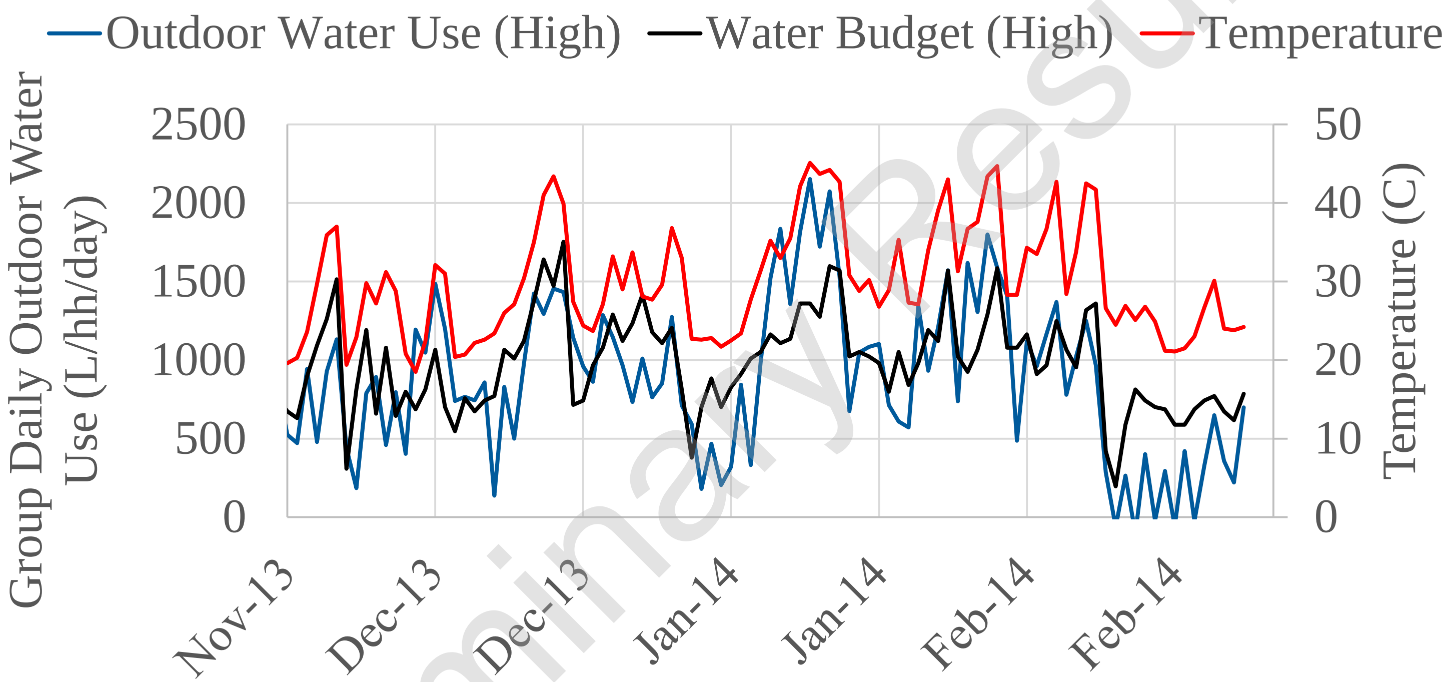


- Many high water users have large garden area, and hence are not necessarily "over-users"

Practical Opportunities:

- Targeting "Over-users" rather than "high outdoor water use" households may reduce outdoor/peak water use and operational costs

Over-users tend to over-water during heat-waves



Practical Opportunity:

- Target "over-users" based on water budget to reduce "unnecessary" peak demands

Summary of drivers of peak demand and outdoor use

- Future changes in peak demands
  - Likely increase as heatwaves duration is increasing due to climate change
- Small proportion of households contribute to system peak and system outdoor water use
  - Peak: 20% of households contribute to 40-50% of system peak
  - Outdoor: 30% of households contribute to 55% of system outdoor use
- Identified profile of high peak and high outdoor usage households
  - Smart metering combined with household characteristics
  - Strategic targeting of "over-users" rather then simply "high users"
- Practical opportunities to develop targeted strategies for operations, design and community engagement
  - "One-size fits" all approach needs re-think
  - Predictive modelling of outdoor and peak use for different spatial locations
  - Community engagement, demand management, restriction policies can focus on targeted areas
  - Potentially reduce peak demand and/or outdoor water use
  - Reduce operational and infrastructure costs

Outline

- Future changes in peak demands
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- Future: Realising the Potential from Smart Water Meters

Future: Realising the potential of Smart Meters

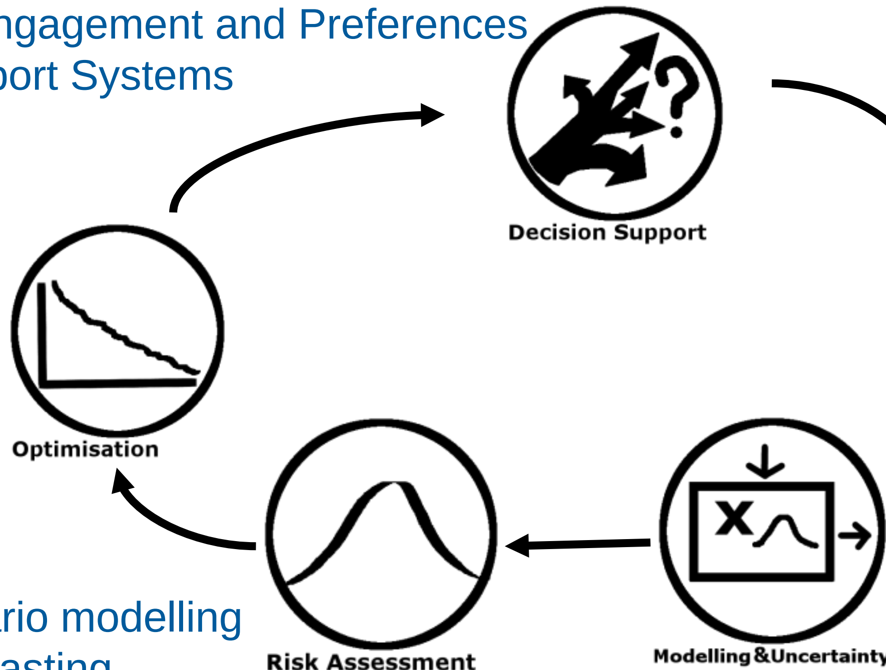
- If you want to
  - Reduce Infrastructure and Operational Costs,
  - Maintain and increase the reliability of water distributions
  - Improve the Customer Experience
- Insights from Smart Meters are potentially useful
- However, only one piece of puzzle....

Intelligent Water Decisions Research Group

- Key Capabilities

www.waterdecisions.org

- Options Analysis
- Community Engagement and Preferences
- Decision Support Systems



- Smart sensors
- Pipe network monitoring
- Citizen Science
- Data analytics

- Multi-objective optimisation

- Climate scenario modelling
- Weather forecasting
- System risks (e.g. droughts)
- Pipe condition assessment

- Water systems modelling
- Hydraulic network modelling
- Statistical modelling for uncertainty/risk

- Water supplies optimised for cost, resilience, reliability, environmental impacts and community benefits

Faculty of Engineering, Mathematics and Computer Sciences: University of Adelaide

- Opportunity to explore research collaboration to address SA Water's key research challenges
  - Attract leverage opportunities (ARC linkage, Water Research Australia, etc)
- Key Capabilities
  - Machine Learning (Computer Science) – develop data analytic methods for extracting insights from large datasets
  - Optimisation techniques (Computer Science and Civil Eng)
  - Integrating domain knowledge into optimisation and machine learning techniques (Civil Eng)
  - Statistical Modelling for Risk Assessment (Maths and Civil Eng)
- Smart Cities Initiative:

  "Cities are safer, more enjoyable, responsive and liveable places, benefiting from the adoption of digital platforms and harnessing data-driven insights"
  - ECMS + expertise from social scientists and legal experts on community engagement and cyber-security