1. **Modeling household water use behavior**

Significant reduction in household water consumption can be achieved by understanding its influencing factors and subsequent modeling. A good model can be used to predict future water demand and recommend behavioral and technological interventions such as end user nudges and water efficient device retrofits. Numerous factors like property characteristics (size, location), housing characteristics (household composition, income), personal characteristics (conservation intention, knowledge, behavioral norms), pricing and socio-economic factors (age, education) influence household water consumption. Recent studies are now able to present more accurate models from a water end use perspective which have been made possible by detailed and disaggregated water consumption data. Blokker et al. (Blokker, Vreeburg, and Dijk 2010) built a stochastic model based on statistic information such as census data and frequency, occurrence and duration of water usage. The simulation results showed good correspondence to water demand in a region of Netherlands. Bennet et al. (Bennett, Stewart, and Beal 2013) used Artificial Neural Networks (ANNs) due to its advantage over stochastic modeling in dealing with variable data types, to forecast future water use demand from appliance, socio-economic, demographic and disaggregated water end use data for a region in Australia. Cahill et al. (Cahill et al. 2013) presented a water use and conservation model using Monte Carlo techniques to include variability in household physical and behavior characteristics. Unlike Blokker et al.’s and Bennet et al.’s methods, they considered outdoor water usage in addition to indoor usage and developed their model for a region in the United States. A copula-based multivariate analysis is presented by Fontanazza et al. (Fontanazza et al. 2016) for water consumption data collected in a region of Italy which produced consistent demand patterns. Froelich and Magiera (Froelich and Magiera 2016) proposed a Bayesian model for forecasting household water time series consumption data. Unlike previous studies, this method does not rely on detailed surveys and questionnaires, but mostly water consumption time series. In conclusion, there exists many modeling methods with pros and cons, and have to be modified for particular use cases.

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1. **ANN-based residential water end-use demand forecasting model**

(Bennett, Stewart, and Beal 2013)

Bennet et al. presents a household water demand model for individual water end use such as toilet, showers, etc. to better understand its relationship to household characteristics and simulate savings from various water management solutions. This study was enabled by the South East Queensland Residential End Use Study (SEQREUS) which provided disaggregated water end use, socio-economic, demographic and appliance specific efficiency data for around 200 households in the greater SEQ region. Artificial Neural Network (ANN) approach was used over others such as multivariable regression, stochastic modeling and Bayesian networks because of its ability to learn, adapt and generalize relationships within input data. Key influencing factors of water demand are first determined, that included household income, occupancy, number of children, teenagers and adults, and appliance efficiency. ANN based models then provided acceptable results when run on the validation data set, amongst which the Hidden Layer Sigmoid Activation Linearly Activation Output (HLSALOA) type had the highest coefficient of determination (R2) and least error values. The developed model is also run to simulate potential savings from water appliance retrofit programs such as efficient toilets, shower heads and clothes washers, amongst which the toilet retrofit program had the highest simulated savings. Bennet et al. concludes by recommending to test complex ANN algorithms, collect data with lesser noise and identify more relevant influencing factors.

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