End Use Energy Demand (EUED)

HotHouse: Hot water Provision in homes

consumption, storage and lifestyle

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hothouse
Hot water provision in homes: consumption, storage and lifestyle

Loughborough University

HotHouse Project Overview

- Grant and Time Scale:
  - Founder – EPSRC
  - Time Period – 2 Years (Dec. 2014 - Dec. 2016)

- Partners and Collaborators:
  - Bentley systems
  - PS Sustainability
  - Energy Saving Trust (EST)
  - Building Research Establishment (BRE)
  - Energy Research Institute (ERI)
  - E.On
  - ISTUTE
  - DEMAND

- Research Team:
  - Principal Investigator - 1
  - Co-Investigators - 3
  - Research Associates – 3

Measured Data Available for Analysis

- **In 20 homes for a period 12-18 months:**
  - Hot water flow rate (secondly)
  - Boiler flow temperatures supply/return (secondly)
  - Tank flow temperatures supply/return (secondly)
  - Gas consumption (secondly)
  - Power (minutely) (mains, showers, washing machines, dishwashers)
  - Rooms and outdoor temperatures (minutely)
  - Occupancy (two minutes timestep)

Objectives and Methodologies

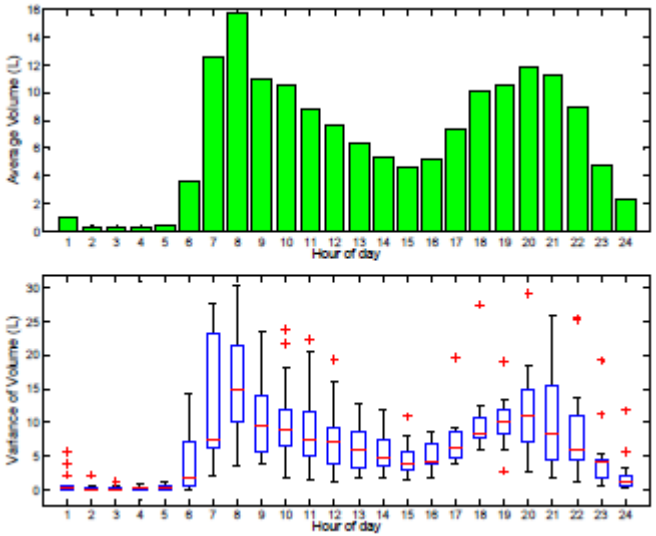
- **Main objectives**
  - Develop future scenarios with key stakeholders that describe hot water provision in family homes in the context of heat generation and storage technology.
  - Use numerical modelling to evaluate hot water provision “stresses” by examining the tensions around: space need for heat generation, storage equipment, costs and capacity.
  - Understand what are family routines (as we move in the future) and new technologies that may affect hot water service efficiency.

- **Data Analysis and Modelling Methodologies**
  - Use Markov Chain-based models (based on meta-data) to develop statistical pattern of the time use data (occupant behaviour – hot water use).
  - Implement Monte-Carlo approach to establish the analysis metrics and a range of the input variables that yield the analysis of hot water consumption.
  - Combine the Markov-Monte-Carlo modelling work to develop a set of ‘stress metrics’ that link the sensitivity and probability analysis.

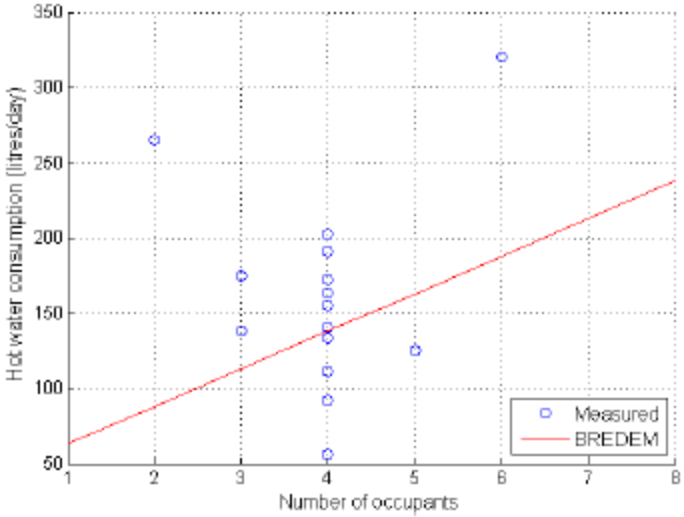
Where we are so far…

- Literature review including: models and simulation studies, policy & standards, user behaviour (social sciences) studies.
- Carried out statistic analysis and estimated consumption values (hot water/energy) across homes measured data.
- Modelled and simulated hot water system with static/dynamic tools and validated with measured data.
- Developed an analytic model to estimate heat losses from distribution system.

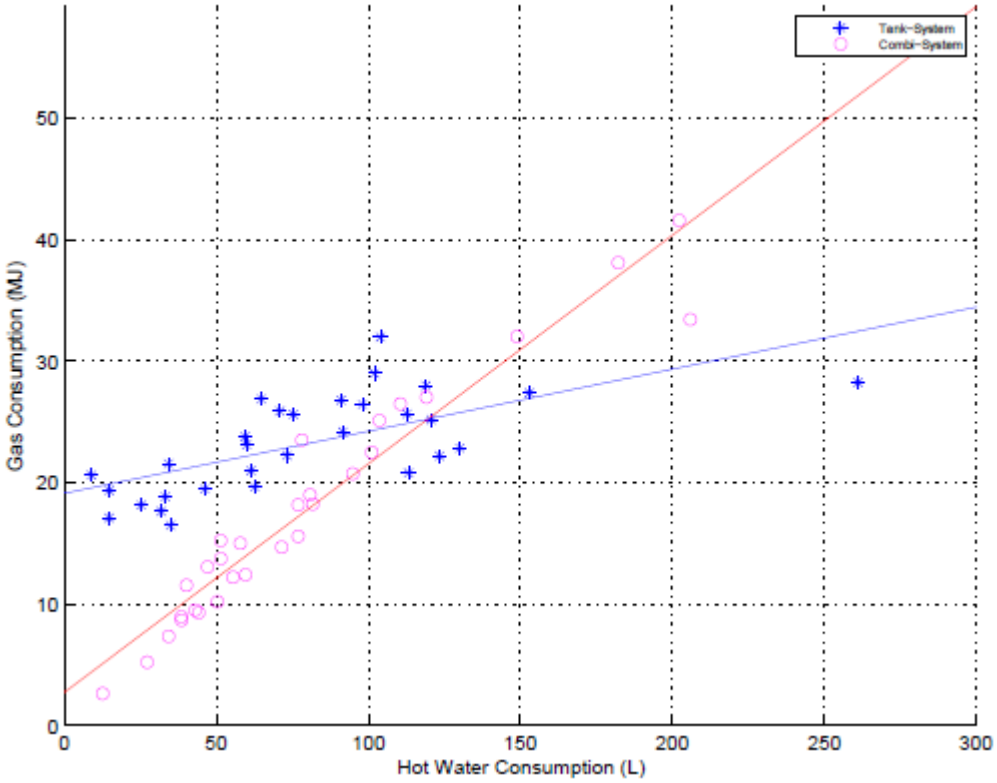
Some results from statistic analysis



Hot water demand profile average (top) variance (bottom)

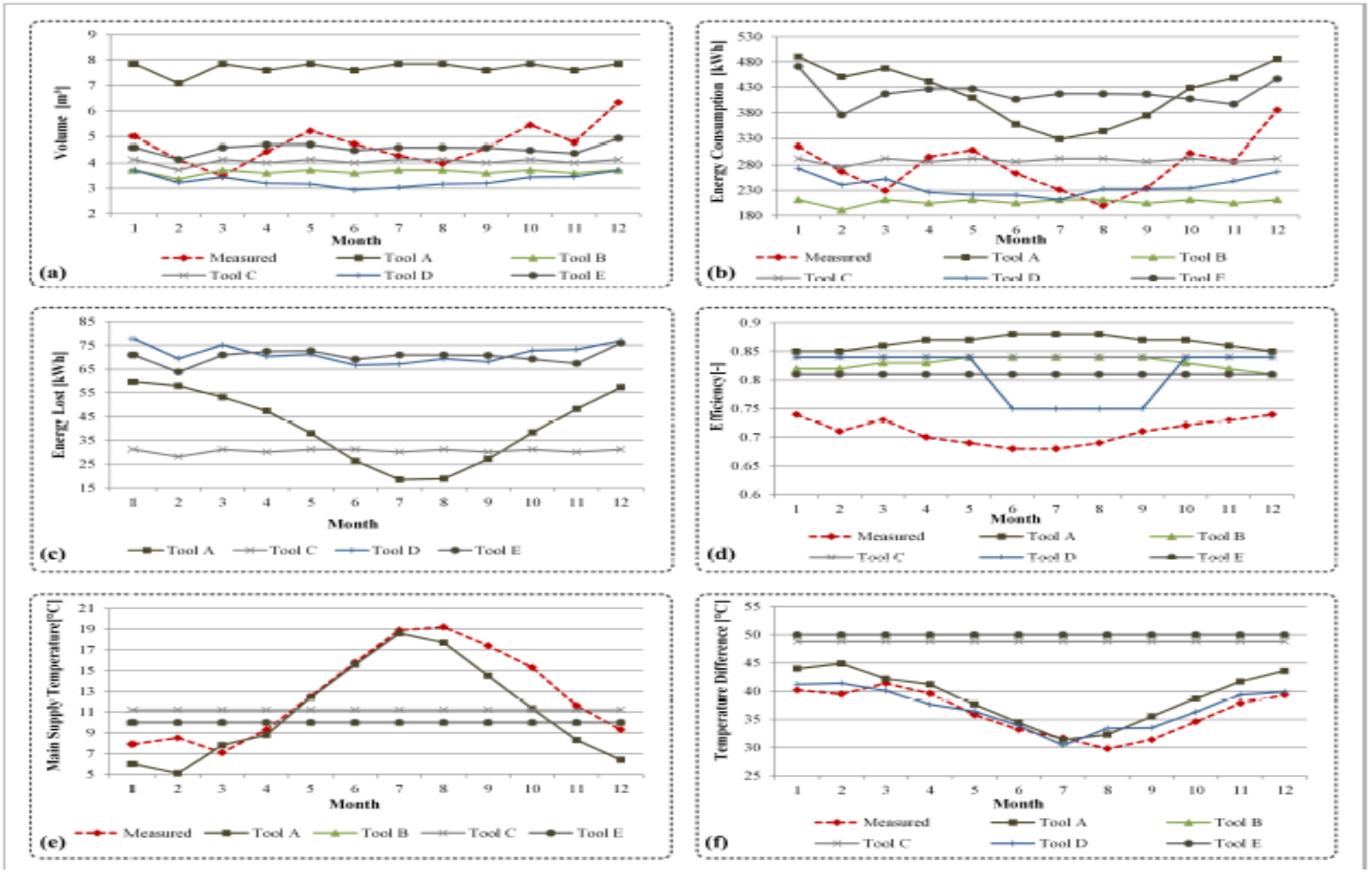


Volume of hot water use as function of occupancy level



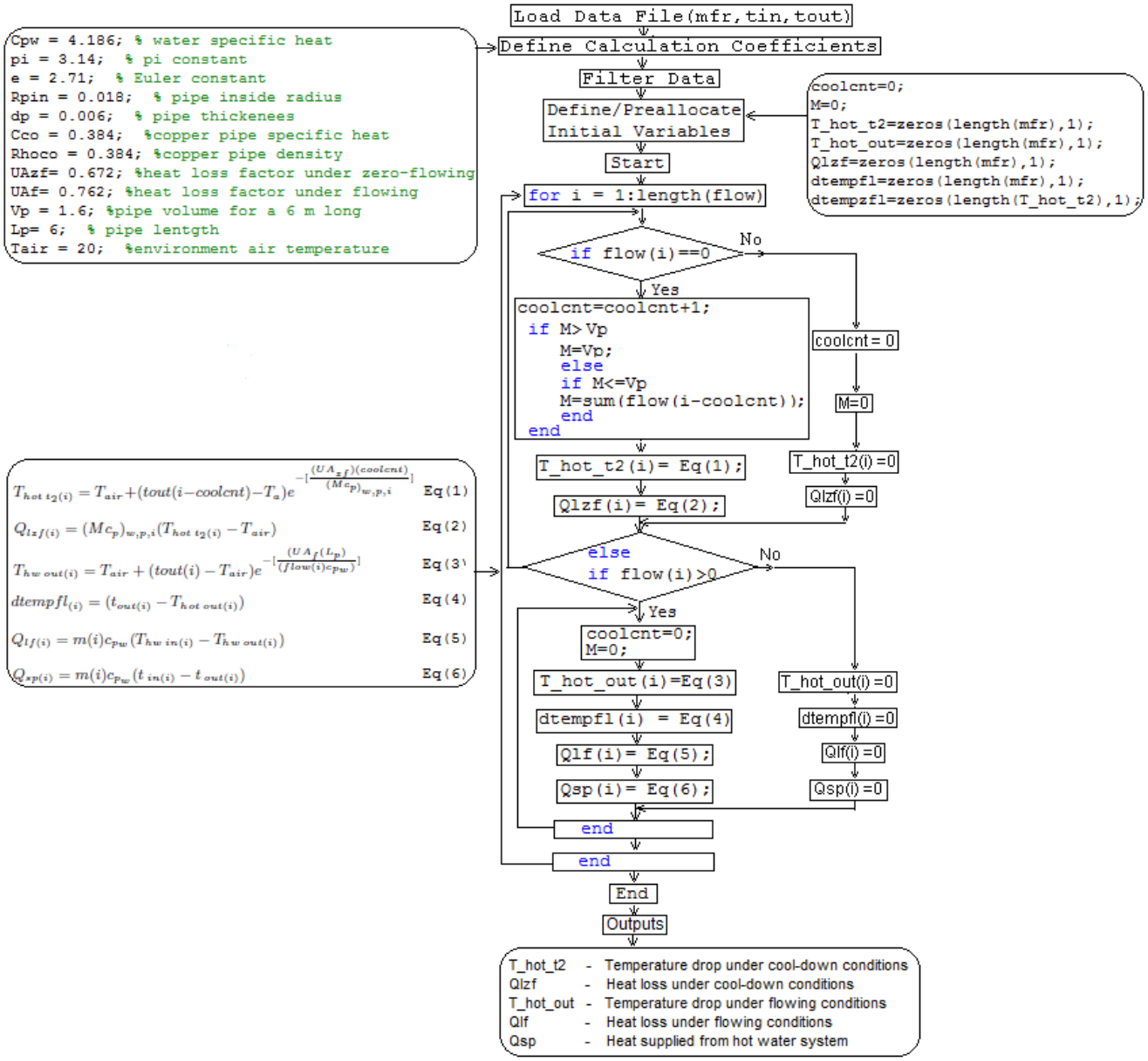
Gas consumption as function of hot water volume produced (combi (condensing) boiler vs. conventional (storage) boiler.

Models vs. measured – case study example results



Estimated results comparing the measured data with the output of the five simulation tools; showing the results for (a) Volume [m³], (b) Energy Consumption [kWh/m²yr], (c) Energy Lost [kWh], (d) Efficiency [-], (e) Main Supply Temperature [°C], (f) Temperature Difference [°C].

Diagram of Algorithm for distribution system Heat loss calculation



$$T_{hot\ t2(i)} = T_{air} + (tout(i-coolcnt) - T_a)e^{-[\frac{(UA_{zf})(coolcnt)}{(Mc_p)_{w,p,i}}]} \quad \text{Eq(1)}$$

$$Q_{lzf(i)} = (Mc_p)_{w,p,i}(T_{hot\ t2(i)} - T_{air}) \quad \text{Eq(2)}$$

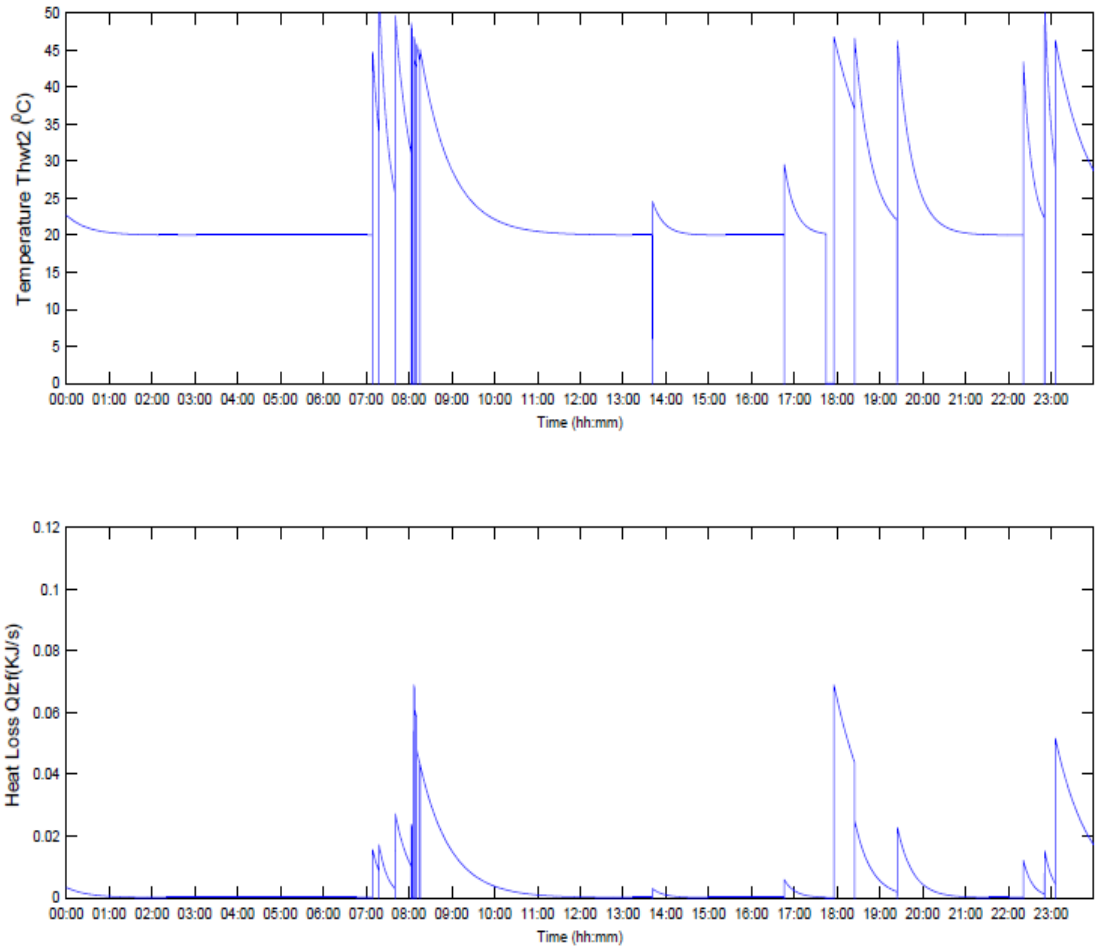
$$T_{hw\ out(i)} = T_{air} + (tout(i) - T_{air})e^{-[\frac{(UA_f)(L_p)}{(flow(i)c_{pw})}]} \quad \text{Eq(3)}$$

$$dtempfl_{(i)} = (t_{out(i)} - T_{hot\ out(i)}) \quad \text{Eq(4)}$$

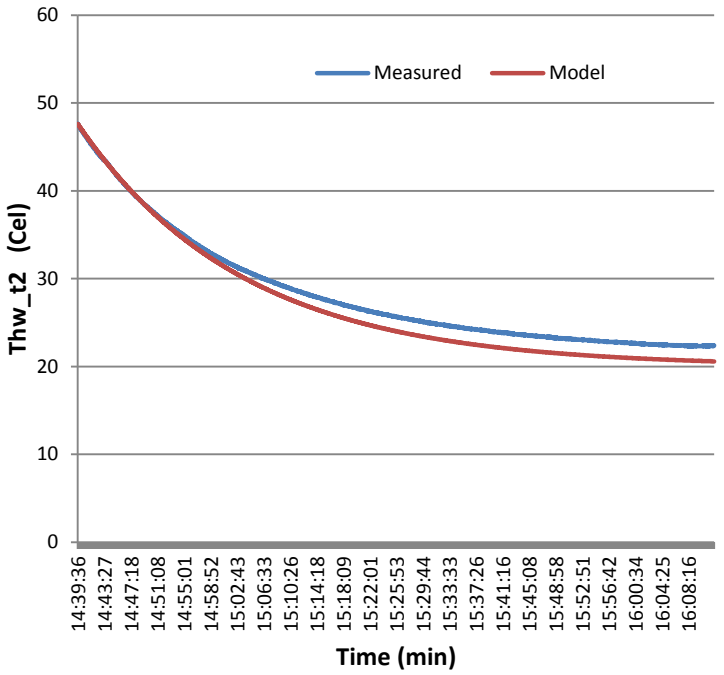
$$Q_{lf(i)} = m(i)c_{pw}(T_{hw\ in(i)} - T_{hw\ out(i)}) \quad \text{Eq(5)}$$

$$Q_{sp(i)} = m(i)c_{p_w}(t_{in(i)} - t_{out(i)}) \quad \text{Eq(6)}$$

Simulated and Validated Results for Heat Loss Model



Simulated results from model (Thwt2 -Temperature drop & Qlzf - heat loss under cool down conditions.



Model vs. measured validation of Temperature drop (Thwt2) under cool down conditions.

Following work plan…

▪Continue data analysis across homes measured data and estimate consumption values (hot water/energy).

▪Use analytic model to investigate distribution heat losses and system efficiency under different draw-off duration profiles.

▪Conclude and submit the working paper (work in the progress including results from data analysis and model).

•Use/develop Markov Chain & Monte-Carlo models/approaches for hot water modelling and meta-data analysis.

Thank you!

Questions ?

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