Improving Domestic Hot Water System Performance through Load Shifting and Optimal Sizing

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

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Research Gaps and Objectives

- ➢ Domestic Hot Water (DHW) production account for about 25% of total energy consumption in UK dwellings[1].
- ❑ There is not a clear evidence how tank size and load shifting methods influence production of hot water and operation cost.

Objectives:

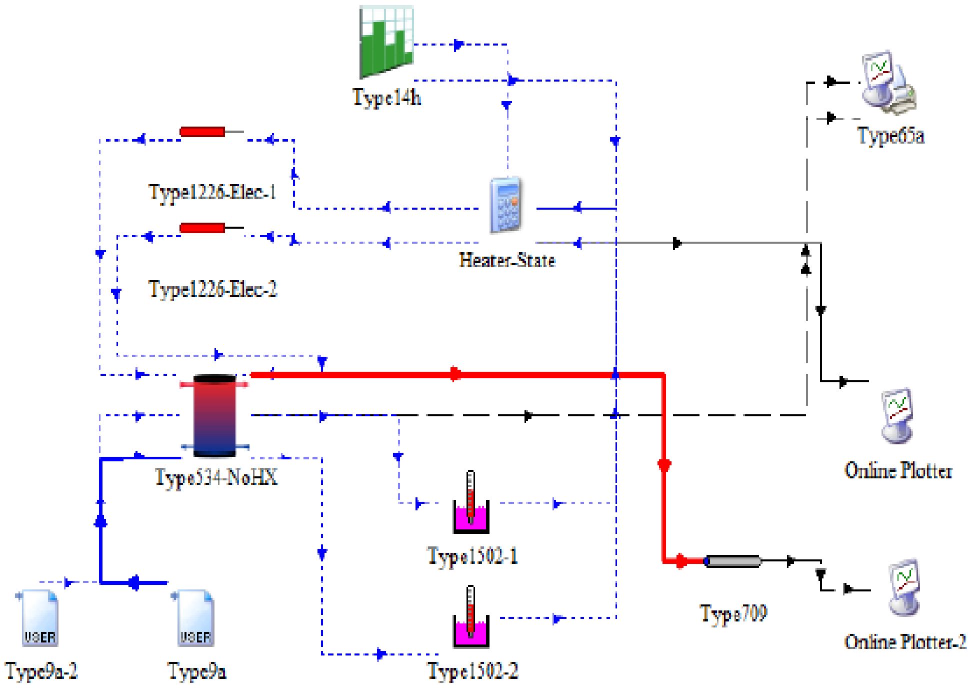
- Develop a model of domestic water heater system driven by high resolution (1sec) hot water measured data.
- Investigate how tank size and load shifting strategies influence: delivery temperature, power consumption heat loss and operation cost
- Introduce a notion of “service” that can be evaluated and used to compare the performance of different systems along side more traditional metrics such as cost, power and tank size.

Example of DHW system Modelled with TRNSYS

Design input parameters for simulated storage tank unit

Design Parameter	Unit	Range Value	Increment Value*
Tank capacity	l	100 - 500	100
Tank height	m	0.9 - 1.7	0.2
Tank insulation thickness	mm	40	0
Tank heat loss coefficient	W/m² K	0.77	0
Number of heater elements	qty	2	0
Upper heater capacity	W	2000 - 4000	500
Lower heater capacity	W	2000 - 4000	500
Height of lower heater	m	0.15 - 0.35	0.05
Height of upper heater	m	0.7 - 1.12	0.1
Height of lower thermostat	m	0.2 - 0.4	0.05
Height of upper thermostat	m	0.75 - 1.17	0.05
Temperature setpoint for lower thermostat	°C	50	0
Temperature setpoint for upper thermostat	°C	55	0
Upper thermostat temperature dead band	°C	2	0
Lower thermostat temperature dead band	°C	2	0

* *The increment values refers the increment of input parameters as increasing them by one step*



Modelled DHW system with TRNSYS

Load Shifting Methods and Power Rate Charges

Load Shifting Methods (operation time periods for heater elements)

Load Shifting Method	Time period	Heaters Operation
No Load Shifting	00:00 - 24:00	ON
Peak Load Shifting	00:00 - 16:00	ON
	16:00 - 20:00	OFF
	20:00 - 24:00	ON
Economy10	23:00 - 06:00	ON
	06:00 - 12:00	OFF
	12:00 - 15:00	ON
	15:00 - 23:00	OFF
Economy7	23:00 - 06:00	ON
	06:00 - 23:00	OFF

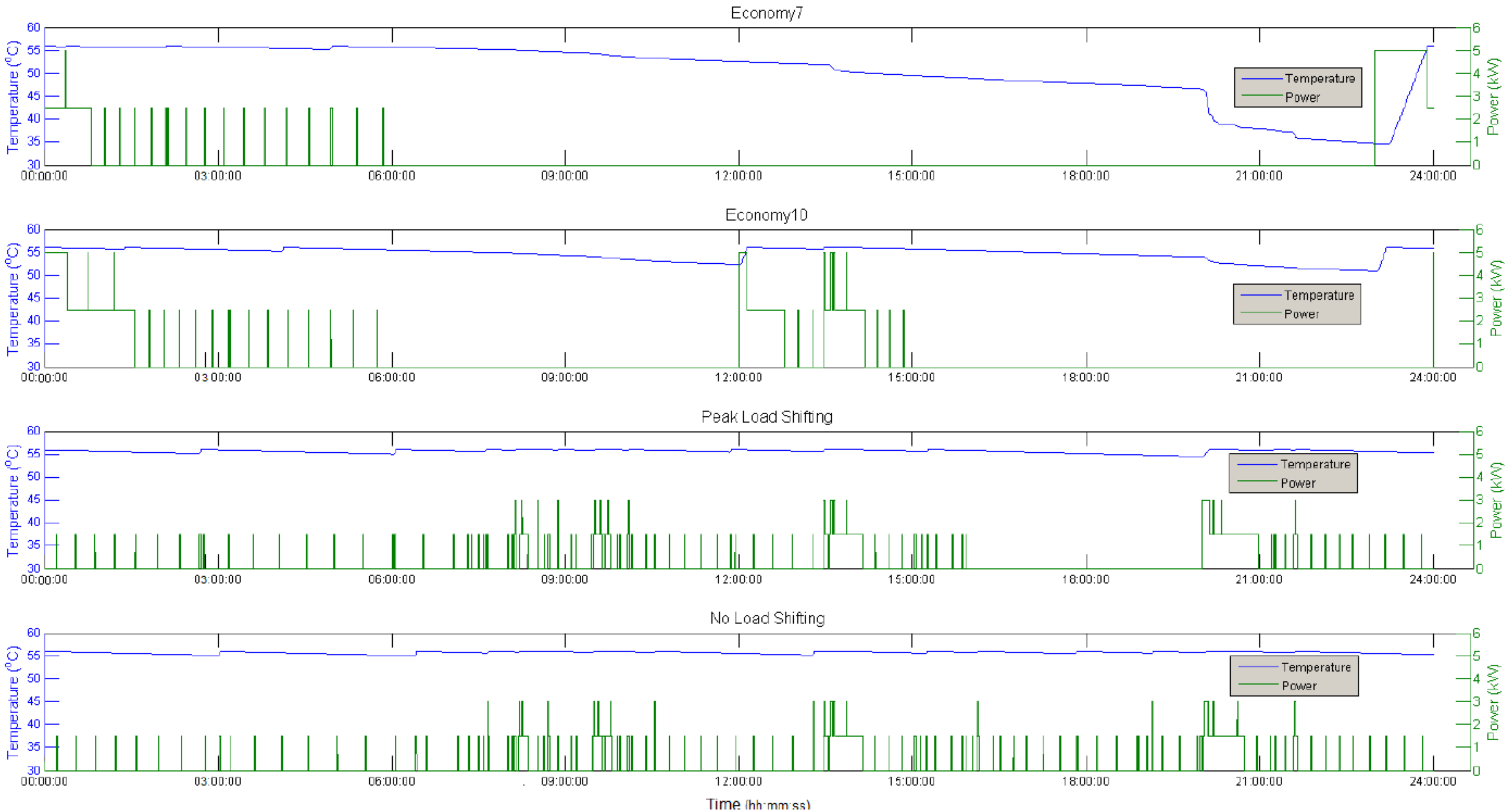
Domestic power rate charges*

Tariff Method	Time period	Price (£/kWh)
Single rate	00:00 - 24:00	0.122
Two rates tariffs	08:00 - 22:00	0.174
	22:00 - 08:00	0.06
Off peak tariffs	16:00 - 20:00	0.172
	20:00 - 16:00	0.106

* *British Gas supplier with effect from March, 2016*

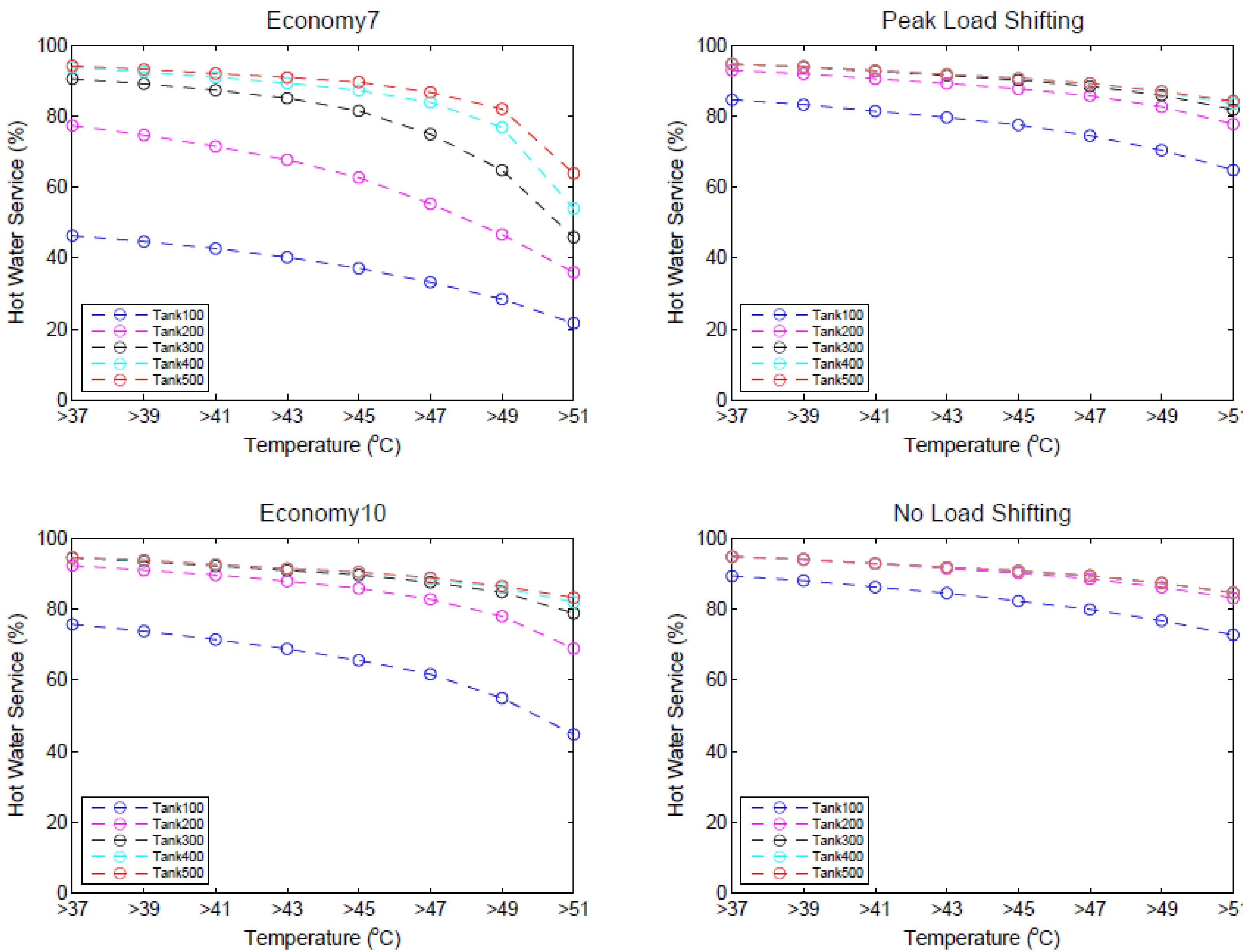
- *No Load Shifting* - heater elements can operate continuously when there is a need for heat over the 24 hr period (business as usual).
- *Peak Load Shifting* - heater elements are forced to switch OFF (despite that there is need for heat) during evening peak hours demand (16:00-20:00) and allowed to switch ON for the rest of the hours.
- *Economy10* - heater elements are allowed to switch ON only seven hours during the night period (23:00-06:00) and only three hours during the day time period (12:00-15:00) and forced to switch OFF for the rest of the hours.
- *Economy7* - heater elements are allowed to switch ON only seven hours during night period (23:00-06:00) and forced to switch OFF for the rest hours.

Temperature and Power Loads



Temperature oscillations and power loads considering a tank storage 200(l) and four load shifting methods

Influence of Tank size and Load Shifting on HW service



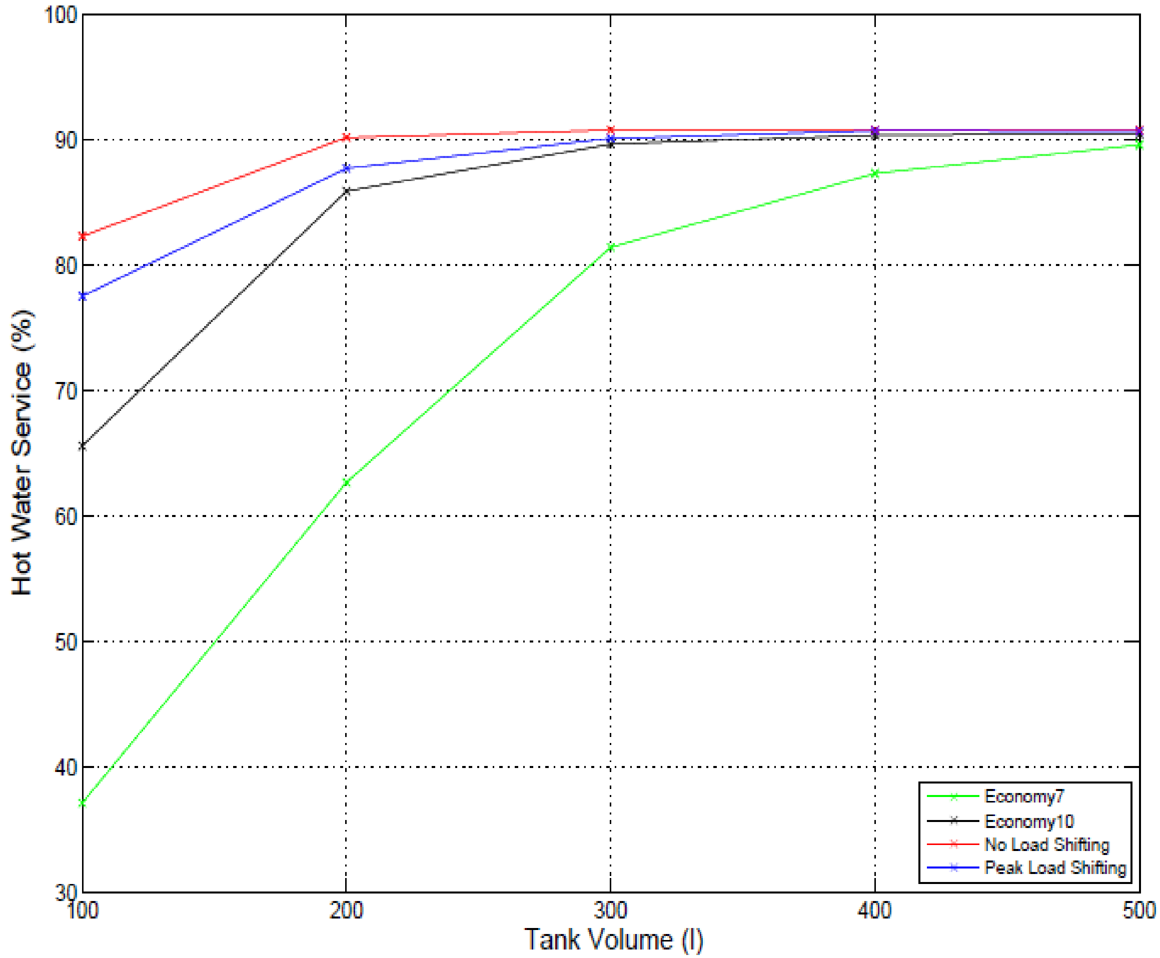
Hot water supply Temperature/service as function of tank size and load shifting methods

Hot Water Service for Different Tank Size and Load Shifting

In order to estimate the level of “service” that hot water system provides, a measurable metric is applied Φ given as:

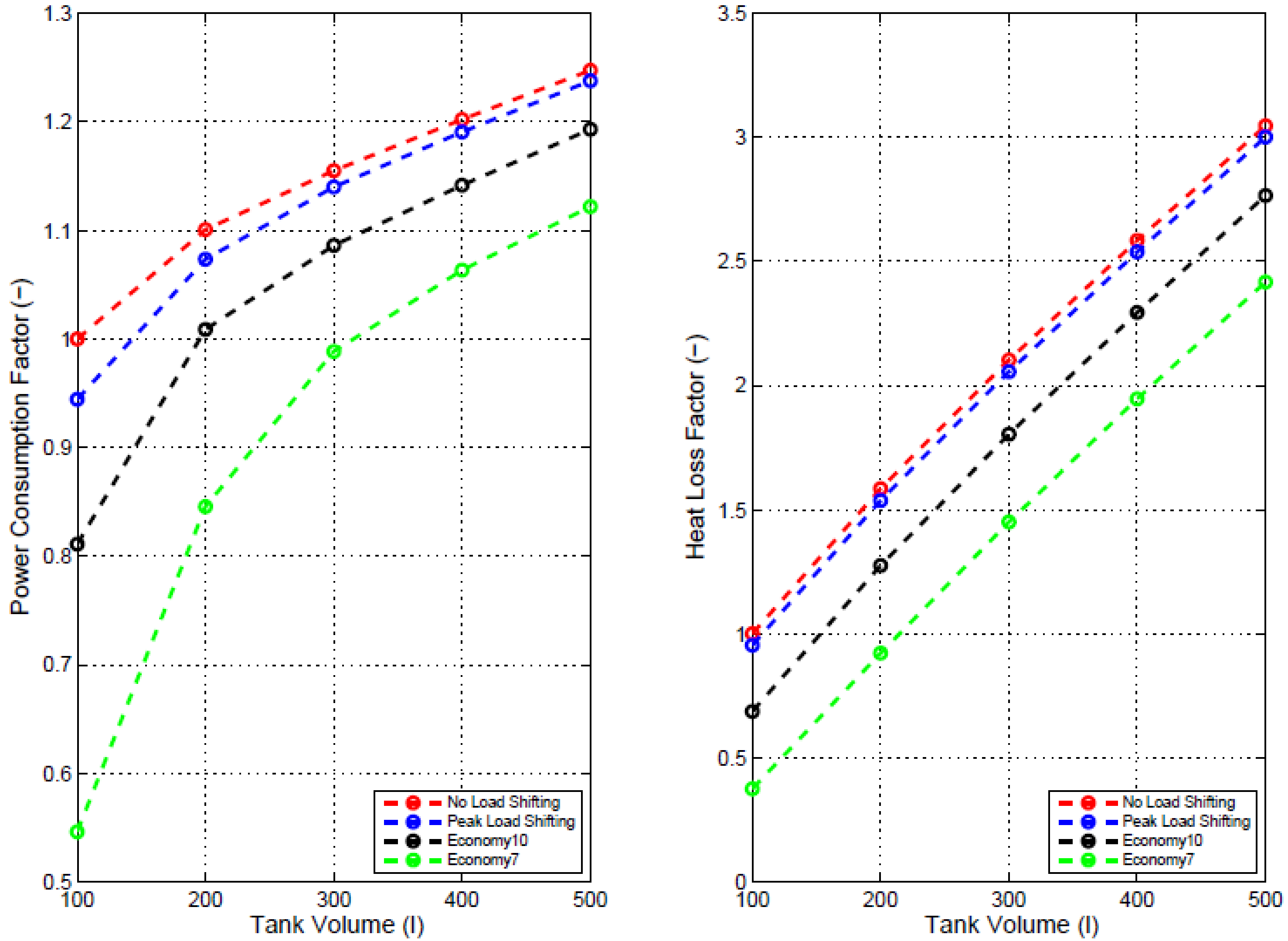
$$\phi = \frac{d^{\theta}}{d^{total}},$$

Where: d^{θ} is the total volume of hot water drawn where the temperature at the outlet is at or above the temperature threshold Φ and the d^{total}, is the total water draw-off volume.



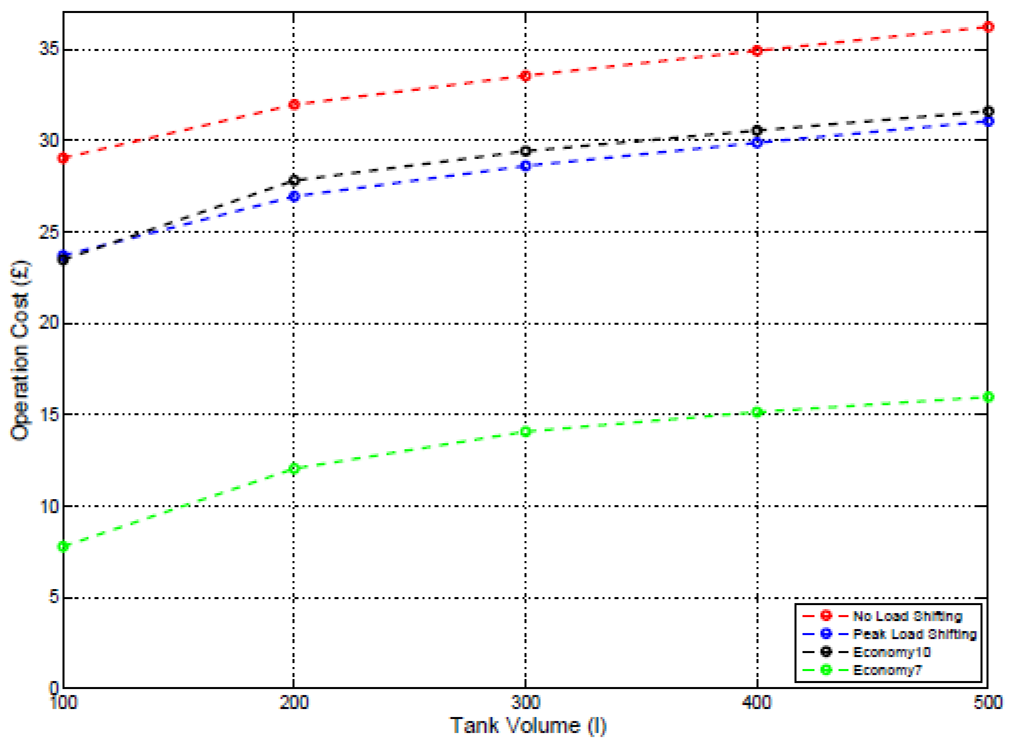
Comparison of hot water service considering a minimum supply temperature T>45°C

Impact of tank size and load shifting on power and heat loss



Estimated Costs and Potential Reduction

- Estimated operation cost for each load shifting method and tank size calculated as based on defined power price rates.



Tank Size (l)	Load Shifting Method		
	Peak LSh*	Economy10	Economy7
100	-18.9	-19.2	-73.2
200	-15.7	-13.0	-62.3
300	-14.0	-12.3	-58.0
400	-14.4	-12.5	-56.6
500	-14.2	-12.7	-55.9

* *Peak Load Shifting*

- Potential cost reductions (%) when implementing: Peak Load Shifting; Economy10 and Economy7 vs. No Load shifting (business as usual).

Summary of Findings

Hot Water Service

- A dwelling that use about 140 l/day, with a tank volume of 300(l) and the Economy7 load shifting method, can provided hot water service (T>45°C) over 80% whilst the operational cost reduces about 58% as compared with No Load Shifting.
- Increasing the tank size from 200(l) to 300(l) the hot water service increase from 63% t0 91% depending on load shifting.

Power consumption

- The reductions of power consumption range from 5% (Peak Load Shifting) up to 45% (Economy7) compared to No Load Shifting method, however that is associated with service of hot water provided.

Heat Loss

- Increasing tank size from 100(l) to 500(l) the heat loss range from 5% to 17% depending from tank size and load shifting.

Costs

- Depending on tank size and load shifting methods, the potential reductions of operation costs range from 13% to 73%.

Conclusions

- The tank size and load shifting methods have a significant impact on: the hot water service, power consumption, heat loss and operation cost.

- A good hot water service can be provided whilst at the same time reducing the operation costs by considering different load shifting and tank sizes.

- Further research might be necessary to investigate how:
  - different hot water demand profiles influence this findings and
  - power consumed from other devices (and heating system) might influence the overall dwelling power costs

- It is demonstrated that optimal tank size and the service the system can provide are very sensitive to load shifting strategy applied

Thankyou for attention!

Questions ?