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Household toolkit for Water Efficiency in Existing Domestic Buildings

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Abstract
The balance between water supply and demand is increasingly difficult to maintain, as a result, water shortage is a challenge now faced in many regions around the world. The effects of climate change and global warming have significant impacts on how resources are managed globally and locally; underground water is taking longer to replenish due to increased surface water run-off especially in urban areas, and water contamination from flooding and prolonged periods of droughts.
In the UK, changes were made to the building regulations in 2010 to highlight the importance of conserving water in buildings. However, the quality and performance of the building assets does not guarantee efficient water consumption during its use. A joined up approach through proactive policy measures, behavioural change and technological interventions is required. Evidence suggests that change in behaviour alone may not promptly achieve the substantial levels of reduction which is required in buildings to mitigate ongoing and future projected water stress. Therefore, technological interventions are required. However, for dwellings in particular, socio-technological factors cannot be ignored for the deployment of technological solutions to yield long term, sustainable savings.
This paper introduces co-creation as the rationale for a proposed toolkit and discusses the proposed approach to engaging water customers in the debate for sustained change. The objective of the toolkit is to facilitate feedback and improve the adaptive capacity of the household to adopt new technologies and change behaviour all of which are necessary to improve water efficiency in the long term.

Keywords
Co creation, Domestic buildings, Water Efficiency, Water consumption toolkit

1. Introduction

About half the water put into supply is produced in order to meet household demand and the quantity of water used by households in the UK increased by 55% in the last 25 years (Defra 2008). Some of this increase is attributed to population growth, while the rest is mainly due to the prevalence of domestic technologies such as washing machines, power showers and water waste during use. To mitigate the increasing trend, it is important to engage with water customers and influence consumption behaviour; either through policy measures, public information bulletins or encouraging increased self-awareness through experience or media reports of risk events such as flood or prolonged droughts. The evidence to support the transforming effect of the latter is however inconclusive. For example, the highest rates of consumption are in the 'water stress' areas such as the South East of England where household water use for unmetered properties is more than 170 litres per person per day (EA 2008). Yet another study of public perception in the same area found that members of the public had a good level of awareness of the water shortages in 2006 (after a period of drought) concluding that consumers are willing to change their behaviour if a threat is obvious or to protect the environment (Dessai and Simms 2010).

Water efficiency, as opposed to water conservation, is the optimised use of water commensurate to need. Water efficiency is different from water conservation, in that it acknowledges essential water use and does not advocate the reduction of water consumption to the extent detrimental to consumer health or welfare. Therefore, water efficiency cannot be measured with objective indicators only; consideration must be given to subjective need. In the anticipation that an understanding of customer behaviour, and interactions with technology, solutions can be collaboratively developed to improve and reduce waste in water processes.

This premise was the starting point for this research project and this paper presents one its main outputs, a toolkit which demonstrates a systemic approach, based on principles of co-creation, for engaging water customers on socio-technological issues and fostering interactions and dialogue between them and other stakeholders, especially policy makers. The paper focuses on the description of the application and use of the toolkit; this makes it accessible to non-technical audiences. With the toolkit, a sequential method for engaging with water customers is proposed in order to improve their capacity to make positive choice and adopt available technologies. The prototype utilises data from user studies: to provide information and recommendations for adaptive change and positive choice to water users, and collates information contributed by water users for evidence and targeted decision making by policy makers and strategic stakeholders such as water companies and developers. In this format, it will be possible to track trends over time and assess what initiatives are working or how attitudes are changing over time (Fuller 2010).

The objectives for developing the toolkit were:

- To enable customer engagement and awareness useful for co-creating personal experiences and adaptation of technologies to water efficiency benefits (a variation of principle of personalisation)
- To facilitate customer knowledge and customer knowledge management as a process of learning - to "know what their customers know – their condition and experience" for both customer and public benefit.
- In the long term, produce virtual communities for water customers, where:
  "Open innovation is used for purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough 2006)

1.1 Co-creating value with water customers

Co-creation is simply the creation of value by customers. Zwass (2010) refers to this as the creation of marketable value which is not necessarily confined to the market. Four essential components must be in place for co-creation to occur: dialogue, access, transparency and risk - the DART of co-creation (Prahalad and Ramaswamy 2004). Building upon mass customisation strategies, co-creation takes a step forward to engage the customer in a more interactive way in the process of creation prior to start of the process of production. It aims to satisfy, in a more cost effective manner, the needs and wants of a specific *individual or entity* by giving them the opportunity to participate in defining their needs and co-creates their preferred solutions to those needs in form of products or services offered by services and manufacturing indusctires. In this sense, Consumers are *empowered* to exert influence on organisations or processes. The level of this influence, however, is subject to further scrutiny and widely differs from industry to industry depending on the nature, dimensions and specific attributions of the products or services provided.

In the co-creation environment, consumers naturally play multiple roles and by this their self-perceptions can *sometimes be* changed (Zwass 2010). Change of perception requires customer-knowledge competence. This is a process where knowledge about specific customers is generated (Gibbert *et al.* 2002). Gibbbert *et al.* Also describes customer knowledge management as a strategic process where customers are emancipated from being passive recipients of products and services, to empowerment as knowledge partners. The objective being to gain, share and expand the knowledge residing in customers, for both customer and corporate/public benefit. Cook and Brown (1999) describe this as the "generative

dance between knowledge and knowing" which distinguishes an epistemology of possession (knowledge that can be built, owned, circulated, used for innovation) and an epistemology of action (knowledge that is produced during the process of acting).

Information systems and technologies provide valuable support for customer interaction and engagement in the co-creation process. There are two vital components to achieving these benefits; the availability and transparency of information from policy makers in order to engage customers in the process of co-creation and, a holistic and non-compartmentalised approach to realising water efficiency objectives through co-designing by customers:

> "This two-way improved communication has an important role to play in facilitation of the changes in the behaviours of individuals and other agents, as changes in behaviours are more likely to occur when agents are able to translate the potential impact to their own situation, and to understand how their own well being would be negatively impacted if no change occurs and thus actively acquiesce to change in behaviour" (Larson 2010).

The use of information tools to facilitate co-creation is not new and toolkits are often deployed to allow the transfer of tacit knowledge and enable consumers to innovate (von Hippel 2005). Research evidence support the premise that information systems offers benefit to co-creation process (von Hippel and Katz 2002; Leimeister *et al.* 2009; Zwass 2010 etc). One significant benefit is achieving better participation and empowerment. Research conducted by Fuller *et al* (2010) demonstrated the important role of virtual interaction tools and technologies in consumer empowerment. Perceived empowerment positively influences consumers' trust in the provider of the virtual co-creation task and enhances their intention to participate. Information systems and tools therefore support the delivery of value to customers who participate with the expectation of rewards, satisfaction of need, curiosity or interest (Fuller 2010).

2. Toolkit development: methodology

The research commenced with three hypotheses:

- Technology is socially deterministic. The availability of water saving technologies does not imply adoption and positive use for reducing water waste and increasing efficiency.
- Generic water efficiency measures and initiatives are ineffective for promoting long term change.
- Co-creation; dialogue, explicit knowledge and understanding, adaptive capability combined with positive experience as well as empowerment (responsibility) will improve water customer engagement and customised adoption of technologies to meet their needs.

A user study was required to map water customer attributes, attitudes, awareness, preferences etc. Data presented in an empirical/numeric manner was also considered more beneficial for analyses. Therefore, the quantitative questionnaire method was utilised. The survey was via the internet using the services of a market survey company. This approach increased the potential to reach a wider range and number of respondents across the UK. The survey in general measured perceptions, preferences and attitudes either on a standard Likert scale or in a response matrix. A total of 546 individuals participated in the survey and 393 responses were included in the data analysis. The remainder were discounted due to incomplete responses. Statistical analysis was conducted using the SPSS and Sofa statistical packages. Deductions were derived using general attributes such as age, location, gender, household profile, building profile, attitude to saving water, perception of water saving technologies.

3. The proposed toolkit

Holland (1995) defined the essential characteristics of 'value-driven' information as:

- The presence of motivators necessary to elicit participation and knowledge revelation from participants with relevant knowledge
- Diversity of the participants in aspects relevant to the decision
- Independent decision-making by participants (thus avoiding mutual influence and groupthink); and the presence of an aggregating mechanism (in this instance the value of water and the perception for conserving it).

Holland referred to these three criteria as the fundamentals of the complex adaptive systems in which independent agents compete and cooperate, with complex collective behaviour emerging in the process. The development of the toolkit utilises this concept as the basis of its architecture. As a demonstrator, agents were created to interact with pre-determined behaviour or rules generated from the survey findings. An example of such permutations is shown in Figure 1.

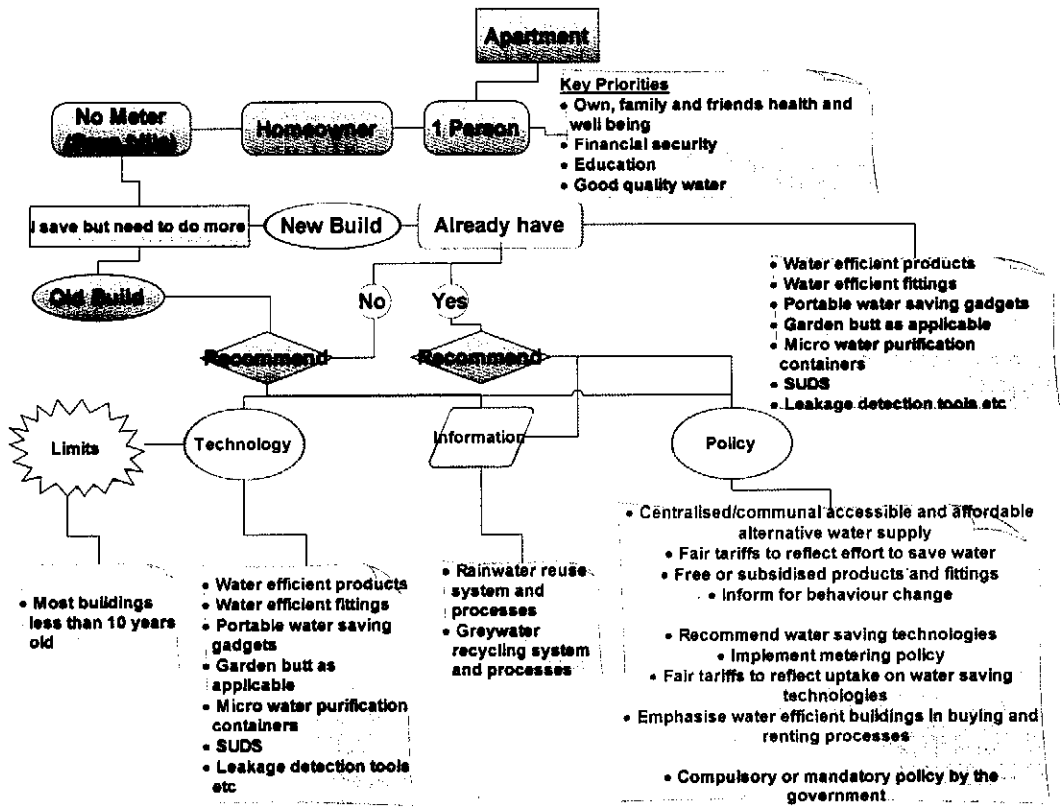

Figure 1: A Sample decision permutation

3.1 The design principles

The toolkit was designed using principles enumerated in (Fuller 2010). These principles were proposed to foster enagement, usefulness and usability. For the toolkit design, it was important to:

- Give water customers/users something to do but not too much.
- Give water customers/users some choice of how much they engage and compensate with outputs irrespective of the level of engagement. The two parts of the toolkit; simple and detailed, facilitates the varing levels of engagement, intensity and content to suite user needs.
- Create some level of personalisation giving water customers/users some level of ownership.
- Link water customers/users with custodians of information and policy.
- Foster relationship among water customers. In this instance, through a moderated message board.

- Give incentives in the form of customised advice on water saving methods and technologies tailored for the specific customer.
- Use an open and accessible platform. The toolkit was developed using Java™ which makes its functions accessible via web and a portable device such as a mobile phone.

3.2 The system

The toolkit's components are a series of relational databases operating the programmed rules, and the input pages and the output functions. The toolkit was developed using Java and JavaScript Programming (JSP) languages in dynamic Java Server and Html pages. It is deployed in a web interface to make it accessible via the internet and through portable devices such as a mobile phone. At the core of the tool were 292 initial 'agents' each governed by rules and attributes generated from existing data and the user study. As expected, these 'agents' do not represent all the possible permutations and combinations that exist in a given population and there are a number of 'agents' whose attributes and decision matrices could not be completed due to gaps in data or non-alignment in data. Therefore, the system was designed to adopt new 'agents' and add them to the repository as new and unprecedented users. Agents in the toolkit are defined as a set of rules that represents and presents the interactions of autonomous individuals or households. It also serves a means to achieve decision goals and to define and compare relationships. If new 'agents' are adopted, the decision matrix is resolved based on this new information to provide decision outputs for the user.

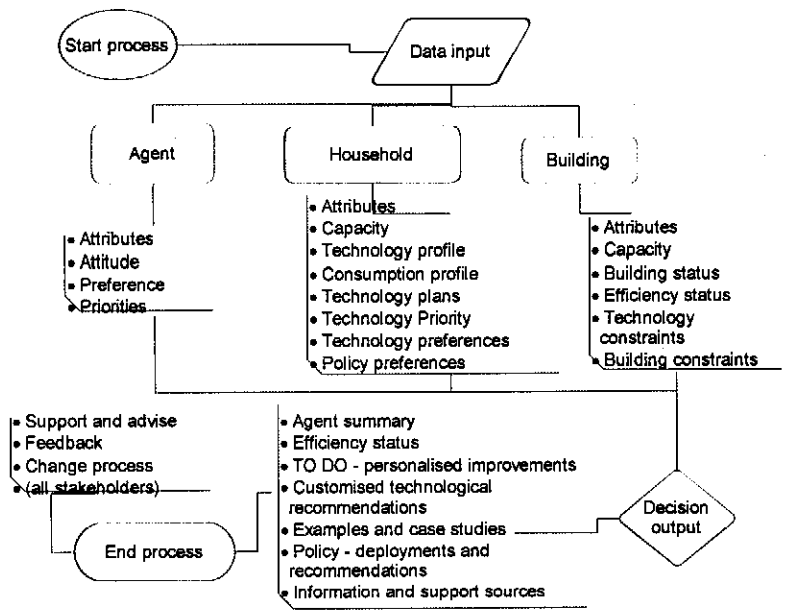

Figure 2: Decision criteria

Figure 2 show the datasets utilised in the decision matrix. At the start of the process, a user logs a unique identifier (an email address) and is given access to the main attribute page. The user enters key attributes such as household size, building type etc which the system checks against what exists in the databases. If a similar 'agent' is found, it automatically populates the remaining input pages. As the user progresses through the input pages, he/she can make changes or alter data entries attributed to their profile. As changes are made, the system either creates a new agent or creates a variation of an existing agent. This variation is tagged to the unique identifier and the user may return to make changes when circumstances change or input new data (e.g. using the activity logs) in order to further customise their results.
After this process, a summary page is displayed which the user reviews before proceeding to the result page. The result page details options and recommendations co-designed with the user and customised for their needs. It makes recommendations about behaviour changes, technologies to adopt and where to

obtain further information, support or advice. It also facilitates a feedback process via a message board which can also be used to foster conversations between interested stakeholders, policy makers and water customers.

3.3 The content

In an ideal scenario, the toolkit will integrate information and solutions for water efficiency from the strategic stakeholders which is accessible from the homepage in a systemic and holistic manner. The homepage also provides log-in access to the back functions of the toolkit. This function allows gate-keeping and some degree of content moderation. From the homepage, various stakeholders can access information/decisions through customised portals which link into the central databases. A message board is provided for communication among all the stakeholders thereby facilitating the sharing of knowledge, experience and expertise. In the customer portal, customers are provided with the choice of using the simple toolkit or the detailed toolkit.

3.3.1 Simple customer toolkit

The simple toolkit is designed for water customers who want quick information on what they need to do to improve water efficiency at home. To use the simple tool, the user enters an identifier. The ideal choice was an email address because majority of users will have an email account and remember it. The user proceeds through the attribute pages as previously described, populating or altering attributes – individual, household and building factors, preferences etc.

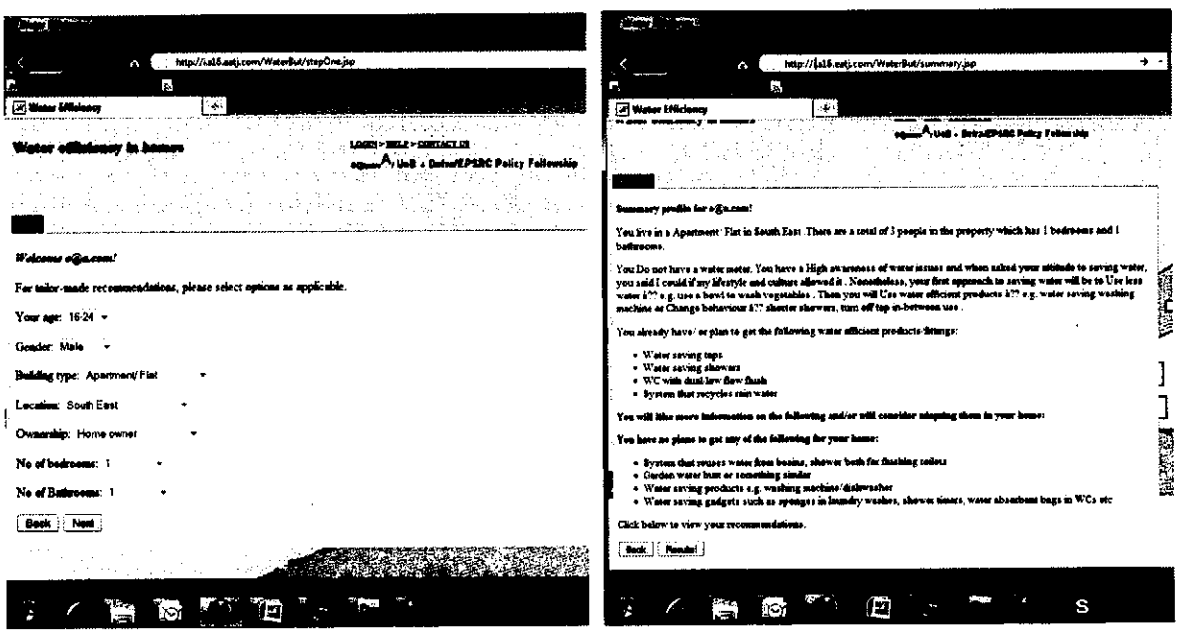

Figure 3: Water customer toolkit (Simple) – Attribute and summary pages

At the end of the input pages, a summary is displayed. From the user's profile, personalised recommendations are displayed based on the user's profile and attributes. If there are decision criteria that are still unresolved, a message is displayed. Pop-up forms are provided for the user to manually input this criterion and further fine-tune their results.

3.3.2 Detailed toolkit

In addition to the functions provided in the simple toolkit, the detailed toolkit provides an opportunity for users to input consumption data and obtain a detailed review of consumption patterns and identify where and how improvements can be made to improve water efficiency in their homes. The user starts by

inputting basic details about their fittings and products. This information is then use to calculate and compare household consumption against the benchmark figures (Table 1).

Table 1: Benchmark data (Source: CSH Calculator, DEFRA's Future Water 2008)

Water Outlet	Benchmark Data	
	Benchmark A (Typical level)	Benchmark A (Best level)
Kitchen Tap	12l/min	8l/min
Washing Machine	49l	35l
Dishwasher	13l	10l
Cloakroom Tap	12l	6l
Cloakroom Toilet	12l	6l
Bathroom Toilet	6/4l per flush	4/2.6l per flush
Bathroom bath	225l	165l
Bathroom bath tap	-	-
Bathroom/ Shower room/En -suite basin tap	12l	6l
Bathroom/ Shower room/ En-suite Shower	14l	6l
Shower room/ En-suite Toilet	6/4l per flush	4/2.6l per flush

After this stage, the user is offered the option to either record their water consumption by creating an activity log or to input weekly or monthly meter readings. The activity log is the preferred approach and a simple web applet was developed to assist with this process (Figure 4). To start, the user accesses the applet via the mobile phone and inputs basic measurements to check the flow/consumption rates of their basic fittings and fixtures. After this is done, activity logging can begin. Buttons are provided to represent the fittings, fixtures and products in the home. The user simply clicks on the button representing the product, fitting or fixture at the start of an activity e.g. using the kitchen tap and click it again at the end of the activity. This needs to be done even if use is intermittent. For example, to conserve water, it is expected that the tap will be turned on and off several times while one is brushing teeth.

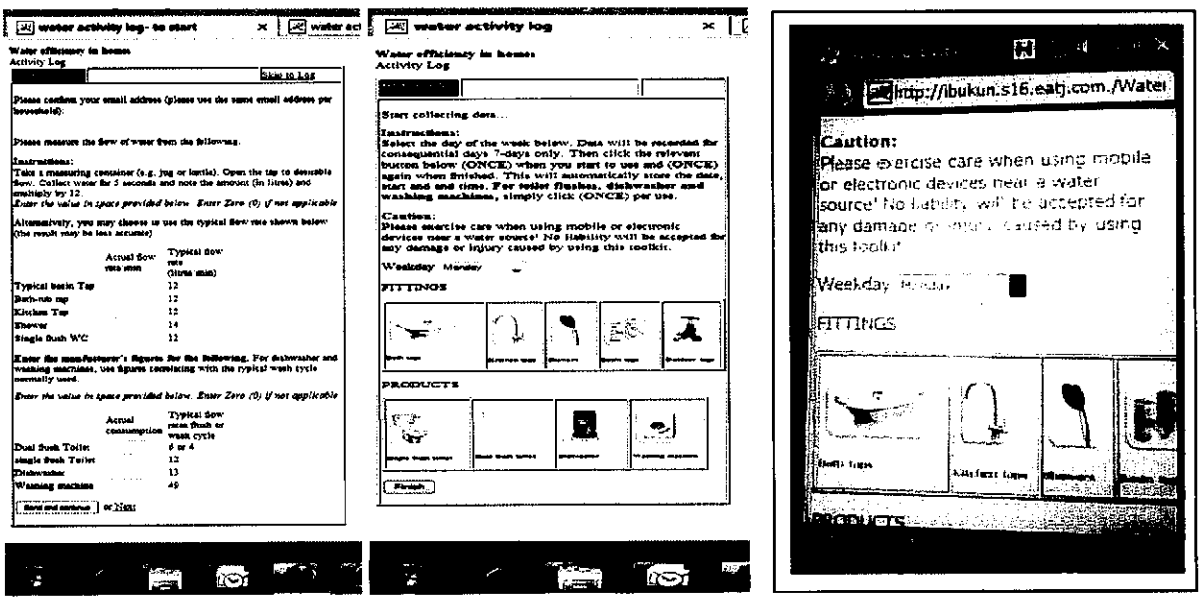

Figure 4: Water customer toolkit (Detailed) – activity log: web and mobile interface

There is an automatically time-out function to each fitting, fixture or product, if no input is received after a preset amount of time, the reading is discounted. All readings are instantly displayed in the live activity log if active connection the internet is detected or at a later time when a connection is made. Users are advised to log activities for a minimum of one week.

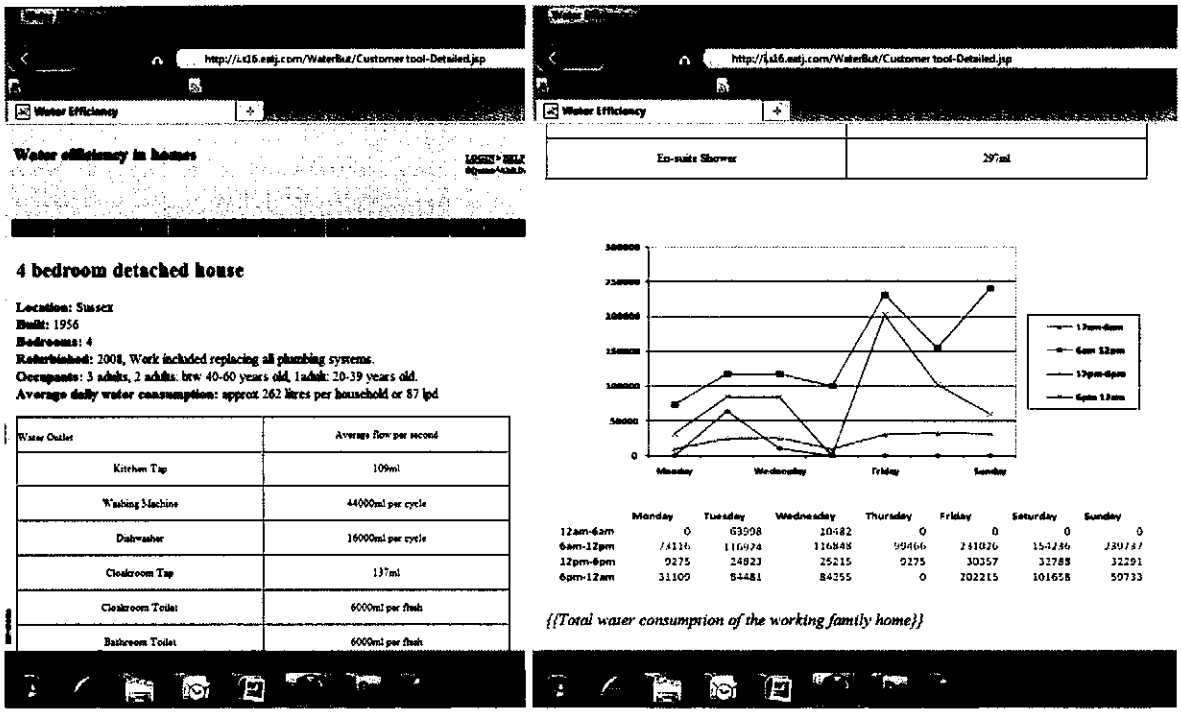

Figure 5: Water customer toolkit (Detailed) – results page

The results page provides detailed user consumption results using tables and charts (Figure 5). It also compares user data with national benchmark data and potentially with other similar households/ building types in that region. Using the activity logs, it is possible to review consumption by fittings or products. Therefore, the customer need only change the fixture or fitting that is inefficient. By pin-pointing the activity, source and time of water waste users can address change of behaviour or implementing technological interventions in a positive and proactive manner.

4. Closing Remarks

The proposed toolkit is still at the early stages of development offering further opportunities to enhance its functionality and ease of use. The next stage is to deploy and test it with water customers. The toolkit in its current form was discussed as a means for direct engagement with water customers, a tool for collecting longitudinal data and a means to inform policy making processes. More importantly, it identifies water customers and their households as a unique entity in an otherwise passive, dissociative process. With this approach, water users are more likely to get involved, make positive choice to embrace the change necessary to improve water efficiency in their homes.

5. Acknowledgement

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