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PROOF OF CONCEPT: LARGE-SCALE MONITOR AND CONTROL OF HOUSEHOLD WATER HEATING IN NEAR REAL-TIME

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ABSTRACT

Two fundamental challenges for efficient energy management are the lack of timely demand and consumption information at the distribution level, and inability to responsively control supply at that level. With recent advances made in wireless communications and machine-to-machine (M2M) networking, a plethora of new solutions have been proposed for smart-grid and home automation. The many approaches, however, focus on the communications and technological domains of these solutions. In this paper we present the design and results of a proof-of-concept project, in which 18 homes were equipped to remotely monitor and control hot water cylinders in real time. The system makes use of the SMART platform to collect and collate telemetry data, and to deliver commands through the use of a cellular network. Users can set the on-off times of their water heating, and also monitor the consumption on a daily basis, in energy or monetary units. The data is centrally processed to provide useful information to the utility, such as the expected total demand for the system in 15 minute intervals, detected leaks, sudden drops in pressure, anode depletion, and to control each cylinder individually. In this paper we look at the system design and highlight some key results.

Keywords: Demand-side management, water heating, hot water cylinder, boiler, geyser, hot water tank, M2M communications, proof of concept, cellular communications, energy management, smart grid.

NONMENCLATURE

Abbreviation

API	Applications Programming Interface
APN	Access Point Name
GPRS	General Packet Radio Service
HWC	Hot Water Cylinder
M2M	Machine-to-machine
SIM	Subscriber Identity Module
TCU	Timer Control Unit

1. INTRODUCTION

Energy management has received attention recently due to the important role that energy plays in modern society, the increasing cost of electricity, and the potentially catastrophic consequences of global warming.

One of the largest contributors to household energy consumption is the heating of water by means of a hot water cylinder (HWC) (also known as a hot water storage tank), which consumes as much as 30% of household electricity [1, 2].

HWC systems, including piping, suffer significant energy losses, mostly through the surface of the HWC or through the plumbing. Some of the solutions proposed to reduce the loss of energy through HWCs, include insulating thermal blankets, reduction in set temperature, and timer control units (TCUs).

TCUs allow users to control HWC's on/off periods to attempt to reduce energy consumed.

The main challenge in the use of TCUs is to ensure that the TCU energizes the HWC only when hot water is needed. This challenge implies that the HWC must be energized for a period immediately preceding hot water use, only long enough to reach the required temperature. This challenge is dependent on user behavior, which follows similar patterns, but is unique for every household.

Since the energy-saving effect of TCUs has been disputed, this paper also presents a theoretical analysis and the related results that demonstrate that energy is in fact saved through the use of TCUs.

A challenge from the electricity supplying utility's perspective is to firstly understand the demand from the consumers, and secondly, to be able to control that demand. The former has been mostly impossible, while some rudimentary solutions have been used for the latter.

In some countries, especially developing countries where electricity is in short supply, power utilities have little choice but to introduce rolling black-outs to manage load demand [5]. Rolling blackouts is a crude way of demand management in which the power to regions are cut to allow the supply to continue to other regions. The effects of these blackouts are dire for the consumers, and typical approaches to avoid them include notification of critical supply to consumers via terrestrial television broadcasts, financial incentives to install energy efficient lighting, financial incentives to install solar heating, installation of remote HWC control systems.

A third player in the HWC market is the insurance companies, which insure against HWC bursts. Since HWCs operate at high temperatures, they are prone to rust, and, given the high water pressure, they are susceptible to bursts, which could result in house flooded. A way to mitigate the rust is to use a sacrificial anode made of magnesium or aluminum, which is more chemically reactive than the inner surface of the HWC. The sacrificial anode degrades over time, herby protecting the HWC, but when it has depleted, the HWC starts to rust from the inside. Since the sacrificial anode is embedded in the HWC, it is difficult to monitor the state of its degradation. The result of this monitoring difficulty, and lack of awareness from consumers, is that sacrificial anodes go unchecked, and this leads to unnecessary burst HWCs and subsequent insurance pay-outs.

The recent resurgence of wireless communications technology has enabled the novel field of machine-to-machine (M2M) communications, in which devices can use cellular wireless networks for autonomous (without human intervention) and large-scale data communications.

M2M communications have been proposed for various application fields, including vehicular communications, home automation, smart-grid, and remote health care [3][6].

The generic architecture of an M2M has the multitude of devices (up to billions) spread out over great distances and controlled by a central agent. The remote devices act as sensors that collect data, but also as actuators that affect commands. Data collected from the devices are aggregated and transmitted to the centralized server through a wireless gateway, and commands are received by the devices from the server through the gateway. The interaction between the devices and the server is autonomous - a characteristic feature of M2M communications – and requires built-in intelligence, which is normally based on simple rules.

The architecture of the M2M network is dependent on the technology employed and the specific application. The network architecture employed for the system described in this paper is shown in Figure 1. HWCs play the role of the

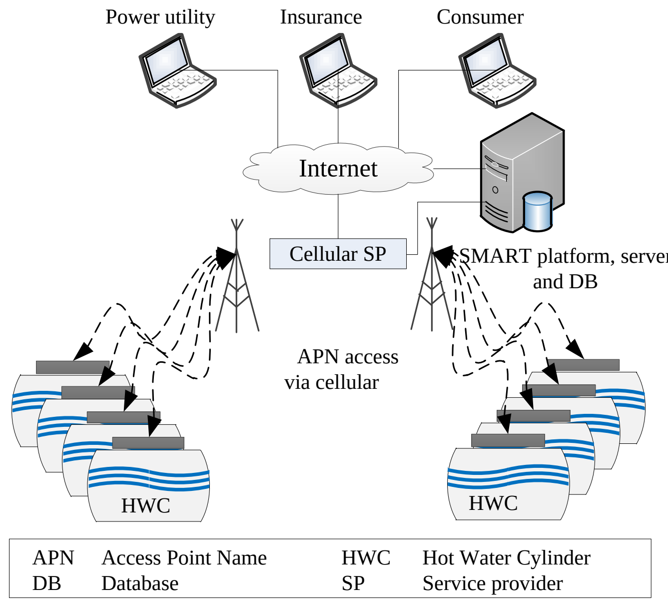

Figure 1 System diagram

machines that exchange data and commands with the remote server in Trinity's SMART platform [4] through a gateway to the cellular network (GPRS or 3G). The system described in this paper is currently deployed in various parts of South Africa.

1.1 Contribution

This paper presents the design of a HWC proof-of-concept system that employs M2M communications to monitor and control HWCs remotely. The system provides functionality to electricity consumers, utilities, and insurance companies to allow for quick and efficient control of HWCs, which is a large contributor to household electricity usage. The system improves control by providing various near real-time measurements through visualizations, remote control, and easy to use online user control interfaces. An analysis is performed to establish the energy savings due to timer control, and the analysis is substantiated with test results.

This paper also presents some of the significant results obtained with the system, including observations on human behavior.

The rest of this paper is organized as follows: Section 2 reports a theoretical analysis that demonstrates that energy can be saved through the use of TCUs. Section 3 describes the system and the design of the system to achieve an M2M network that allows for the near-real-time monitor and control of a multitude of HWCs. Section 4 describes the results observed with the system, and also discusses some of the interesting human behavior witnessed. Section 5 concludes the paper.

2. HEAT DISSAPATION ANALYSIS

This section presents an analysis to illustrate the benefit of using a timer (TCU). The analysis is performed using a lumped parameter model for the thermodynamics of a typical HWC. The energy usage *without* a TCU will be compared with the energy usage *with* a TCU, given the same HWC parameters and the same hot water usage profile. The parameters used in the analysis are listed in Table 1. The 75 liters of hot water per 12 hour cycle is based on the water usage of an average household over 24 hours, taking into account one bath of 75 liters of hot water, and two showers of 35 liters of hot water each [7]. The symbols used in the analysis are illustrated in Figure 2.

Table 1 Parameters used for the heat dissipation analysis

HWC Capacity	150 liter
Volume of hot water used per cycle	75 liters
Cycle period	12 hours
Standing loss (manufacturer specification)	2.59 kWh/day
Thermostat set temperature	60 °C
Ambient temperature	20 °C
Cold water temperature	20 °C

2.1 Energy Usage Without Timer Control Unit

After hot water is consumed, an HWC without a timer control unit will rapidly heat the cold water to the thermostat setting and then maintain the temperature at this setting until the next hot water usage. The total energy usage therefore equals the sum of the energy used to heat the replacing cold water, and the energy used to then maintain the temperature at the thermostat setting by continually replenishing the energy lost to the environment.

The energy used to heat the cold water, E_{heat}, is given by

$$E_{heat} = cm_{cold}(T_{thermostat} - T_{cold}) \qquad \textbf{(1)}$$

where c is the specific heat capacity of water, and m_{cold} and T_{cold} are respectively the mass and temperature of the cold water that enters the HWC, and $T_{\text{thermostat}}$ is the thermostat temperature setting. The cold water temperature must be raised by the difference between $T_{\text{thermostat}}$ and T_{cold}.

The specific heat capacity of water is known to be 1.1615 $\text{W.kg}^{-1}.\text{K}^{-1}$, the mass of the 75 liters of cold water is 75 kg, and the temperature by which the cold water must be raised is 40 °C. Substituting these values into equation (1), the energy required to heat the newly added cold water, E_{heat},, is

$$E_{heat} = 1.16 \times 10^{-3} \times 75 \times 40 = 3.48\,\text{kWh} \qquad \textbf{(2)}$$

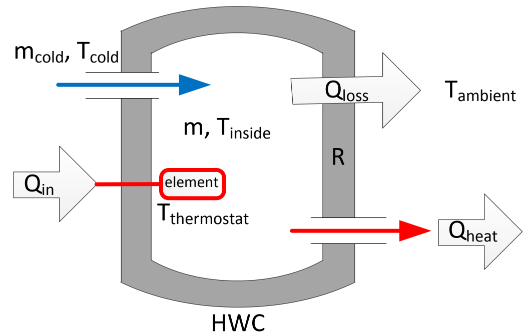

Figure 2 Symbols used in thermal analysis.

The energy lost to the environment E_{loss} while maintaining the temperature at the thermostat setting is given by

$$E_{\text{loss}} = Q_{\text{standingloss}} \times t \qquad \textbf{(3)}$$

where $Q_{\text{standing loss}}$ is the standing loss energy flow out of the HWC, and t is the duration over which the energy loss occurs. The standing loss of the HWC is specified by the manufacturer to be 2.59 kWh/day for a water temperature of 60 °C. For this analysis the temperature is maintained for 12 hours, or 0.5 days. Substituting these values into equation (3), the total energy lost to the environment, which must be continuously replenished to maintain the set temperature, is

$$E_{\text{loss}} = 2.59 \times 0.5 = 1.30\,\text{kWh} \qquad \textbf{(4)}$$

The total energy usage of the HWC *without* the timer control unit for one 12 hour cycle is therefore

$$E_{\text{in}} = E_{\text{heat}} + E_{\text{loss}} = 4.78\,\text{kWh} \qquad \textbf{(5)}$$

2.2 Energy Usage With Timer Control Unit

An HWC with a well-configured timer control unit will not immediately heat the cold water that replaces the used hot water, but will wait until a short time before the next hot water usage to heat the entire volume of water, thereby reducing energy lost to the environment. This analysis therefore assumes that the TCU is configured to only heat the water prior to usage, i.e., the timer will not be energizing the element while the water is consumed. The total energy usage equals the amount of energy required to raise the water from the final temperature, to which it cooled down just before the next usage, back to the thermostat setting temperature.

Subsequent to the hot water usage, the water temperature quickly drops when the cold water replaces the used hot water and mixes with the remaining unused hot water. After the initial drop, the temperature then further cools down with an exponential decay towards the outside temperature of the environment (similar to standing loss, but without maintaining the heat).

The initial water temperature (at t=0) in the HWC, $T_{\text{inside}}(0)$, after the cold water mixes with the unused warm water, is calculated using the energy balance equation

$$m(T_{\text{inside}}(0)-T_{\text{ambient}})=m_{hot}(T_{\text{hot}}-T_{\text{ambient}}) \quad \textbf{(6)}$$

where m is the total mass of the water in the HWC, T_{ambient} is the ambient temperature, and m_{hot} and T_{hot} are, respectively, the mass and temperature of the unused hot water remaining in the HWC. Making $T_{\text{inside}}(0)$ the subject results in

$$T_{\text{inside}}(0)=\frac{m_{hot}}{m_{total}}(T_{\text{hot}}-T_{\text{ambient}})+T_{\text{ambient}} \quad \textbf{(7)}$$

Given that the unused hot water has a mass of 75 kg and a temperature of 60 °C, that the total mass of water in the HWC is 150 kg, and that the outside temperature of the environment is 20 °C, the initial water temperature in the HWC after the cold water mixes with the unused hot water is

$$T_{\text{inside}}(0)=\frac{75}{150}(60-20)+20=40\,°\text{C} \quad \textbf{(8)}$$

The subsequent decay of the water temperature towards the ambient temperature is given by the following thermodynamic differential equation

$$cm\dot{T}_{\text{inside}}=-\frac{1}{R}(T_{\text{inside}}-T_{\text{ambient}}) \quad \textbf{(9)}$$

where R is the lumped thermal resistance from the inside of the HWC to the environment. This thermal resistance represents energy losses through both the HWC wall and the water pipes, by way of conduction, convection and radiation.

Solving equation (9) results in an expression for the water temperature as a function of time

$$T_{\text{inside}}(t)=T_{\text{ambient}}+(T_{\text{inside}}(0)-T_{\text{ambient}})e^{\frac{-t}{cmR}} \quad \textbf{(10)}$$

The water temperature therefore decays exponentially from the initial water temperature to the outside temperature of the environment with a time constant of $\tau = cmR$.

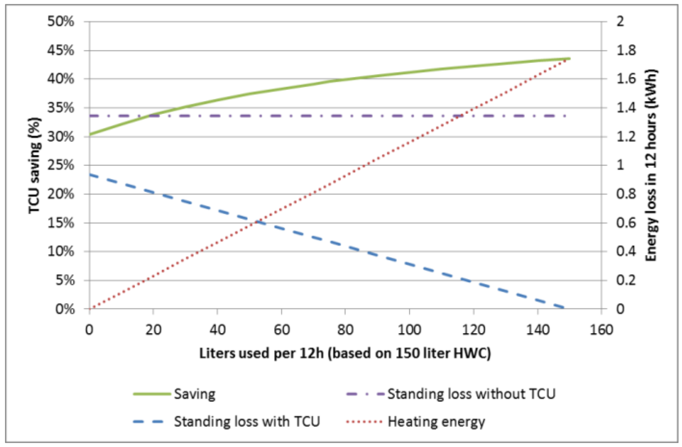

Figure 3 TCU Energy saving for different consumption levels.

All the parameters in equation (10) are known, except for the value of the thermal resistance. However, the thermal resistance can be calculated from the standing loss specified by the HWC manufacturer, using the following equation

$$Q_{\text{standingloss}}=\frac{1}{R}(T_{\text{inside}}-T_{\text{outside}}) \quad \textbf{(11)}$$

The thermal resistance is therefore

$$R=\frac{1}{Q_{\text{standingloss}}}(T_{\text{inside}}-T_{\text{outside}})=15.4\,°\text{C.(kWh)}^{-1}\text{.day} \quad \textbf{(12)}$$

and the time constant of the exponential decay is

$$\tau=cmR=1.1615\times10^{-3}\times150\times15.4=2.68\,\text{days} \quad \textbf{(13)}$$

After the water has cooled down over the 12 hours (0.5 days), until just before the next hot water heating cycle and usage, the water temperature is therefore

$$T_{\text{inside}}(0.5)=20+(40-20)e^{-\frac{0.5}{2.68}}=36.6\,°C \quad \textbf{(14)}$$

The energy required to heat the entire mass of water in the HWC back to 60 °C for the next hot water usage is therefore

$$Q_{\text{in}}=cm(T_{\text{thermostat}}-T_{\text{inside}}(0.5))=4.08\,\text{kWh} \quad \textbf{(15)}$$

2.3 Comparison of Energy Usage

For a typical 150 liter HWC, with a thermostat setting of 60 °C, and a hot water usage of 75 liters every 12 hours, the energy usage *with* a timer control unit is 8.16 kWh per day, while the energy usage *without* a timer control unit is 9.56 kWh per day. The timer control unit therefore results in a 14.7% energy saving for this usage profile. Figure 3 illustrates the equivalent saving for different consumption

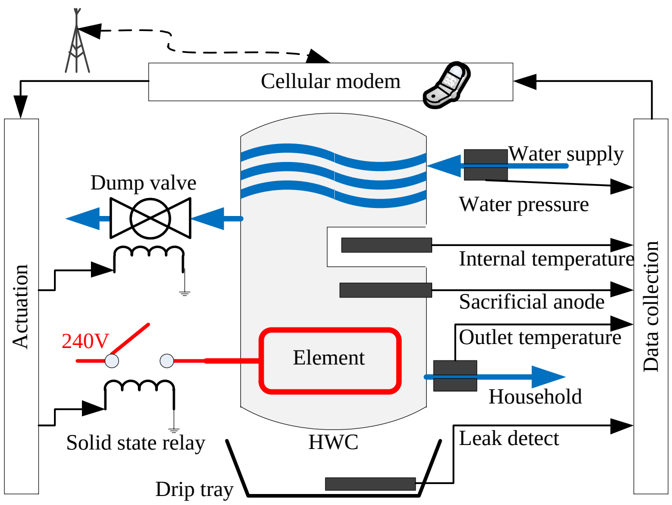

Figure 4 Single hot water cylinders with remote monitor and control system

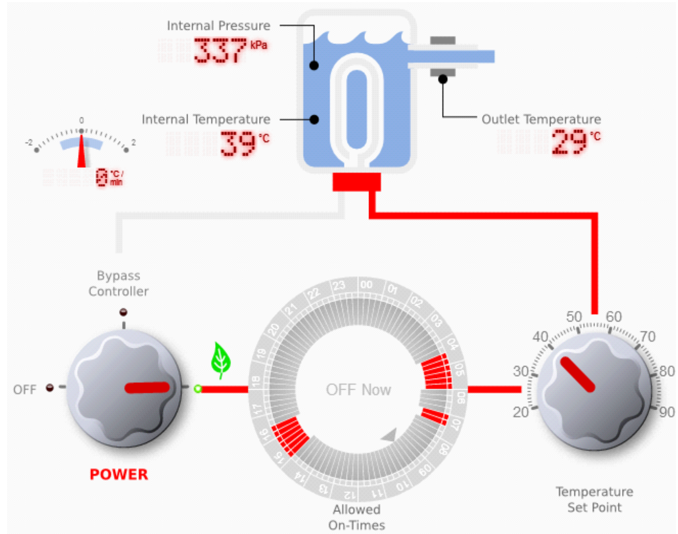

Figure 5 Web-based control interface of a single asset.

levels. The more water used per event, the higher the saving.

If the analysis is repeated for hot water temperature of 45 °C and an empirically determined standing loss at this temperature of 1.88 kWh/day, the saving is 16.6%.

The energy conversion efficiency of the element is assumed to 100%. This assumption affects the absolute values of electrical energy consumed, but will not affect the saving achieved.

3. SYSTEM DESIGN

The overall system illustrated in Figure 1 is composed of three sections: (i) *sensing and actuation*, (ii) *network connectivity*, and (iii) *visualization and control* sections.

The *sensing and actuation* section includes the HWC and related sensors and actuators; the *network connectivity* section includes the cellular modem and the service provider network; the *visualization and control* section includes the remote server and database.

Communications between the HWC devices and the remote server are based on GPRS (General Packet Radio Service) cellular connections, through an Access Point Name (APN), which provides direct access into Trinity's SMART platform [4]. The cellular modem reports measurements to the SMART platform at a configurable rate (normally set to once a minute), and affects pending commands at the same rate.

3.1 Sensing and actuation section

Two actuators, depicted in Figure 4, are used, a solid state relay and a dump valve. The relay is used to control the power to the heating element. The purpose of the element control is mainly to enable a user to turn the HWC on or off remotely, but also to enable the implementation of a simple temperature controller in the local microcontroller's software. The temperature set-point can then be controlled remotely. The second actuator is the dump valve, which can be used to safely empty the HWC in case of a failure (burst HWC), or to empty the HWC for maintenance.

Data collection is performed through the use of various sensors mounted inside, on, or around the HWC.

Water pressure is measured by a transducer installed on the inlet pipes, which will be at the same pressure as the HWC. The pressure is monitored to enable detection of over-pressure conditions, which can lead to bursts, as well as to detect sudden loss of pressure, which implies a burst HWC.

The HWC internal temperature is monitored using a thermocouple that is mounted onto the thermostat's sensor in a cavity of the HWC. This temperature is primarily used as input for software control of the water temperature. It is also provided to the user to control, since it impacts on energy efficiency, as demonstrated in section 2.

The state of the sacrificial anode is measured by replacing the standard sacrificial anode with a transducing sacrificial anode. Finally, a conduction sensor is used to detect the presence of water in the drip tray, which points toward a burst HWC.

Outlet pipe temperature is measured by a thermocouple which is mounted on the outlet pipe. The outlet temperature is measured to enable detection of hot water flow, and also acts as a proxy for ambient temperature in prolonged states of inactivity.

3.2 Network connectivity section

Data and command exchanges between the HWC smart devices and the remote server are supported through a cellular modem installed at the user premises and playing the role of a gateway to the service provider's cellular network.

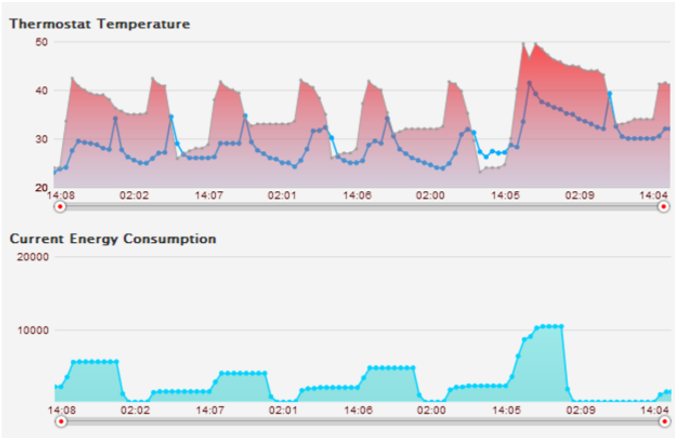

Figure 6 Graphical reporting interface of a single asset.

Network connectivity is simply supported through an APN and Subscriber Identity Module (SIM) card activation in the modem, and by equipping it with an embedded software agent that communicates with the portal.

Trinity has developed an extension to the AT command set of commercial modules that allows quick and effortless integration by connecting the HWC to the modem via the serial port and simply issuing an extended AT command to the modem.

The SMART platform gives the flexibility to manage data exchanges over the GSM/GPRS/EDGE/HSDPA/3G networks. However, GPRS is sufficient for the purpose of the implemented monitoring solution and given the small amount of data to be periodically transmitted (less than 500 bytes per transmission).

3.3 Visualization and Control section

The SMART platform encapsulates a database and an Internet portal with highly visual data models with configurable dials and controls built in.

The software is developed with Google's OpenSocial Applications Programming Interface (API), which can be embedded into a web page to provide ubiquitous access to the devices in the M2M network.

All the sensing and actuation capabilities described in Section 3.1 are supported by the online interface, called SMART Sight, which is illustrated in Figure 5.

One of the two interfaces enables the user to control the HWC from any remote location with Internet access. The user is able to turn the HWC off, on, or to hand control the system. If the HWC is set to be on, the thermostat of the HWC controls the temperature. If the system is in control, the energized state of the element is determined by a "pool timer" interface (see Figure 5), which the user can set to control the HWC to be on or off during certain times of the day. Also, if the system is in control, the temperature of the HWC is controlled by a software algorithm, to a temperature that the user can set using the dial in Figure 5.

The other interface, shown in Figure 6, allows the user to plot temperature and energy graphs, to better understand the recent temperature variations and energy consumption profiles. This second interface shows the temperature profiles (internal and external), the daily cumulative energy usage.

4. RESULTS AND DISCUSSION

This section reports some of the results seen with the proof of concept, and looks at HWC performance, system performance, and observations on human behavior.

4.1 Hot water cylinder and peripheral devices

Figure 6, which is a snapshot from the SMART Sight website, shows the results for a single HWC for a period of four days. The top graph shows the internal HWC temperature (red surface) and the corresponding outlet temperature (blue line). The second graph shows the daily cumulative energy consumed in Watts-hour, and this integrating function is reset at midnight, to provide a daily reflection of energy use. Figure 6 shows that the HWC internal temperature plummets when water flows out and cold water flows in, and at the same times the outlet pipe temperature shoots up as the flowing hot water heats the pipe. The results also show how the injection of energy (second graph) corresponds to increases in temperature in the HWC. The two distinct horizontal levels per day in the second graph relate to the time when the element is turned off by the "pool timer control" (See Figure 5), and the increasing slopes relate to times when the element is energized. It is clear that, due to the "pool timer" control, energy is injected in two stages, and for the HWC shown here, the majority of energy is consumed during the afternoon stage. The high second slope on last day illustrates the effect of forcing the element on (overriding the "pool timer").

To support the analysis from Section 2, an experiment was run in one of the households in the project. The thermostat control was set to maximum, and the temperature control was handed over to the SMART system, which was set to 45 °C. To confirm the standing loss of the system, the HWC was permanently energized, but no water was used. The energy consumed during 48 hours was measured with the controller, and confirmed with a power meter to be 3.76 kWh, resulting in an actual standing loss of 1.88 kWh. Replacing the thermostat setting of 45 °C and the standing loss of 1.88 kWh in the analysis of Section 2, results in a predicted saving of 16.6 %

The timer was used to enable power to the HWC's element. In the first stage the timer was set to enable the element only before consumption hours, and for the second stage was set to always enable the element (essentially overriding the timer control). The results show an average

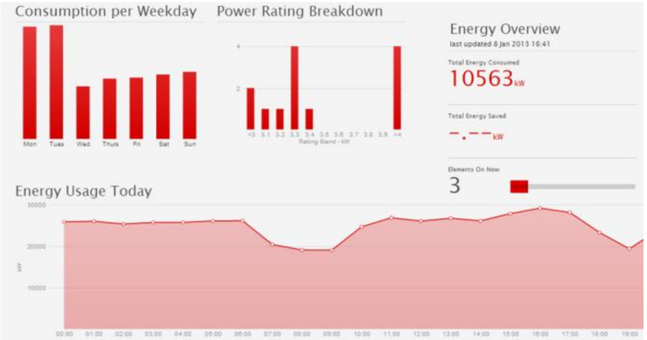

Figure 7 Consumption of all devices.

saving of 16.3% in energy when the TCU is used, closely matching the predicted value.

4.2 System

The system overview provided by the SMART platform collates and displays the energy consumption for all the HWCs in the system. The system views are shown in Figures 7 and 8. Figure 7 shows the energy consumption summary, and Figure 8 gives an overview of the settings of the system. The results in Figure 6 display consumption per weekday, load spread of today, number of elements energized at the moment, and a summary of the power ratings of the elements in the system, which is derived from the power consumptions. Other information (not shown) includes monthly cumulative loading and used Carbon (in tons). The snapshot shown in Figure 7 was taken on a Tuesday, which was the second workday in the year – it can be seen how

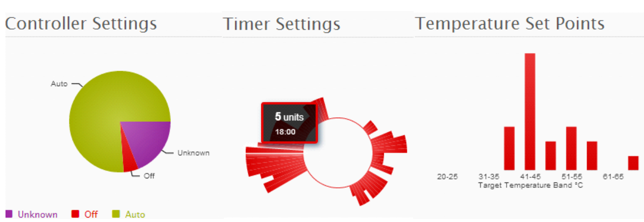

Figure 8 Overview of all devices.

the system's power consumption increases from the Wednesday to the Tuesday, corresponding to consumers' return from holidays.

The system overview also allows total cellular data uploaded and downloaded by all the HWCs to be displayed and analyzed, as illustrated in Figure 9. Although the data usage is dependent on the number of times a user change the settings on the platform, the trend has been for users to modify settings for a few weeks, until an optimum is reached, where after minimal changes are made. When this steady state is reached, the data usage reduces to around 1 Megabyte per device per day, of which roughly 20% is downloaded to the device and 80% is uploaded from the device.

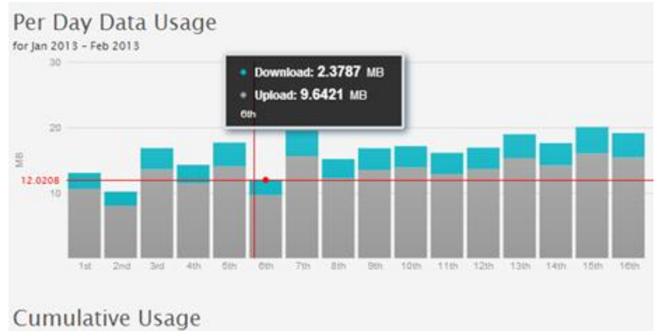

Figure 9 Overview data usage for all devices.

4.3 Human behavior

Apart from the energy savings due to the timer function as described in Section 2, a significant reduction in consumption was visible after the system was introduced. For one household that was monitored, a total reduction of 25%, which is 9% more than what could be attributed to the timer. This additional saving is attributable to *changes in behavioral patterns* – before the system was introduced usage was uninhibited, but after the system was installed, users became aware of and sensitive to the monetary value of the energy in a hot bath or shower. Moreover, the fact that hot water became a limited and scheduled luxury, people tended to group their activities to better make use of the available energy.

A second factor attributing to this additional energy saving, is the *ability to optimize* the system through the easy interface with a quick human-in-the-loop feedback system. When comparing data from one HWC that was on an electronic controller before the system was introduced (i.e. removing the benefit of mere electronic control), a year-on-year energy saving of 5% to 10% was noticed in term of average energy consumed per day.

Interestingly, the majority of people have set their HWCs to be on between 17:00 and 18:00 for the afternoon heating, which is not ideal from the utility's and load spreading perspective, since many people are also preparing food at this time. The morning settings are more diverse, corresponding to diverse household needs in the mornings. The majority of users have settled on a set temperature of 41-45 °C, which, relates to a real temperature of just above 50 °C due to the cavity being used to measure temperature.

5. CONCLUSION

This paper describes the design of a smart grid solution to demand side management of household hot water cylinders. The design employs a machine-to-machine network architecture, which enables deployment of billions of devices. The system allows the electricity utility, the users, and insurance companies to monitor and control any of the hot water cylinders in the system in real time, from any remote location with Internet access. The paper gives the rationale for the design and describes the design of the network, remote peripheral devices, and the overall system. An analysis is performed to evaluate the savings achieved by employing timer control. The results indicate substantial savings due to timer control, user awareness, and ease of use, and also shed light on hereto unknown user behavioral patterns.

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REFERENCES

[1] E. Schmautzer, M. Aigner, M. Sakulin, and M. Anaca, “Load potential for demand side management in the residential sector in austrian smart grids,”
in Clean Electrical Power (ICCEP), 2011 International Conference on, june 2011, pp. 614 –618.
[2] C. Diduch, M. Shaad, R. Errouissi, M. Kaye, J. Meng, and L. Chang,
“Aggregated domestic electric water heater control - building on smart
grid infrastructure,” in Power Electronics and Motion Control Conference
(IPEMC), 2012 7th International, vol. 1, june 2012, pp. 128 –135.
[3] D. Niyato, L. Xiao, and P. Wang, “Machine-to-machine communications
for home energy management system in smart grid,” Communications
Magazine, IEEE, vol. 49, no. 4, pp. 53 –59, april 2011.
[4] Trinity Telecoms SMART interface, online, http://www.trintel.co.za/smart_sight.html, accessed 21 January 2013.
[5] Viljoen, M.; , "Cascade disruption of generation — Using adversity for learning & improvement," EUROCON - International Conference on Computer as a Tool (EUROCON), 2011 IEEE , vol., no., pp.1-4, 27-29 April 2011.
[6] M.J. Booysen, J.S. Gilmore, S. Zeadally, and G.-J. van Rooyen, “Machine-to-machine (M2M) Communications in Vehicular Networks,” KSII Transactions on Internet and Information Systems, vol. 6, no. 2, pp. 529–546, Feb 2012.
[7] Engineering toolbox, online, http://www.engineeringtoolbox.com/hot-water-consumption-person-d_91.html, accessed 21 January 2013.