Appliance for **W**ater consumption management in showering by using **Ar**duino kit, **E**nergy **NE**xus and **S**ensor**S** – AWARENESS kit

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Keywords

Awareness Kit; IoT-based showerhead; Real-time sensing; Water-energy nexus

Highlights

- IoT-based shower appliance provides real-time awareness to end-users during showering.
- Appliance reduces water and energy use in household showering.
- Behavioural economics is applied to turn the measured data into nudges.
- AWARENESS kit is simple but effective impacting end-users in real-time.
- All data is stored in cloud-based data sources to further analysis.

Purpose

Currently, many people experience water scarcity, particularly in semi-arid/arid regions [1]. Even regions that are abundant in freshwater resources are threatened by needs for appropriate wastewater treating and rising energy costs [2]. Showering accounts for 40% and 30% of total household water and energy consumptions, respectively [3]. To reduce shower water consumption, various water-saving gadgets such as smart showerheads, smart shower remote controls, and internet-of-things (IoT) showerhead devices have been introduced [4]. While smart showerheads can accurately display the temperature and volume of water consumed during bathing, they are limited by their expensive purchase and installation costs, vulnerability to adequate maintenance and calibration, and inability to adapt to current outdated bathing systems [5].

IoT showerhead gadgets are gaining popularity in the smart building era as they can quickly link to mobile phones or laptops and send measured data for further analysis [6]. However, their key shortcomings are their complexity, high-cost requirements, and inability to build real-time connections. They are also unable to alert users when they are showering, and the technical information they provide is often too complex for most users to comprehend and follow [7].

The main objective of the AWARENESS kit is to develop an innovative and user-friendly IoT-based shower gadget that can effectively reduce household water usage. The aim of paper is: (1) to create an affordable, easily assembled, easy-to-replace prototype appliance that has a wide range of applications, (2) to provide a real-time user awareness system that continuously monitors water usage volume and temperature, enabling users to be more conscious of their water consumption habits, (3) to leverage the principles of behavioural economics to transform raw data into more user-friendly, tangible, and understandable knowledge. This will help users to make more informed decisions and take action to reduce their water and energy consumption.

Materials and methods

All material and appliances that are used for AWARENESS kit is demonstrated in Figure 1, including: (1) IOT components, (2) showering components, and (3) board instruments.

The AWARENESS kit measures water flow rate and temperature and then transmits to an Arduino board for real-time processing. The raw data is compared to several criteria, as shown in Figure 2.

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To encourage positive reinforcement for reducing water consumption, data are turned into practical and understandable information: (1) economic awareness and (2) environmental awareness. Two sets of LED-bulbs are used to display the cost of water and energy or the number of water bottles or trees' CO_2 absorption. When 50% of the total water allowance is consumed, the first LED-bulb turns on, followed by another when water usage reaches 100% of the allowance. An energy-related LED bulb turns on when the equivalent of 350-trees is cut down (equal to standard energy consumption recommended by British energy providers), and the last LED bulb is activated when a certain amount of money is spent, such as £5. When the board is switched off, the entire operation can be reset.

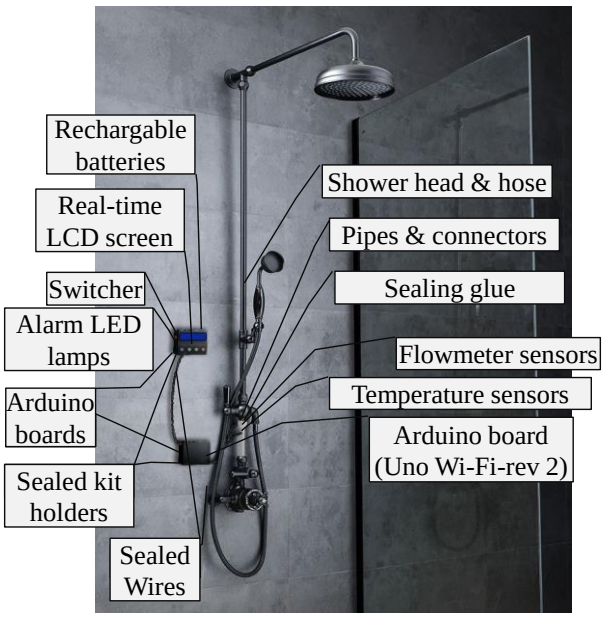
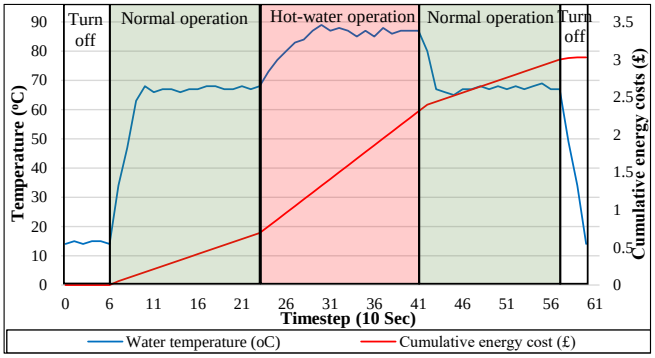


Figure 1. Main components of AWARENESS kit

An LCD screen is used to display both water and energy consumption as separate and total costs in real-time. The screen is positioned in front of the end-user to ensure they are aware of their consumption levels and can make more informed decisions about their water and energy usage. All parameters are also transferred over Wi-Fi to cloud-based platform for further analysis. The board is powered by rechargeable batteries than can stands for 640 times 10-min showering.



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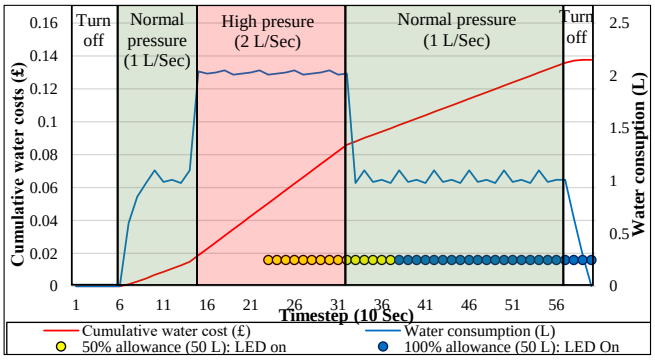
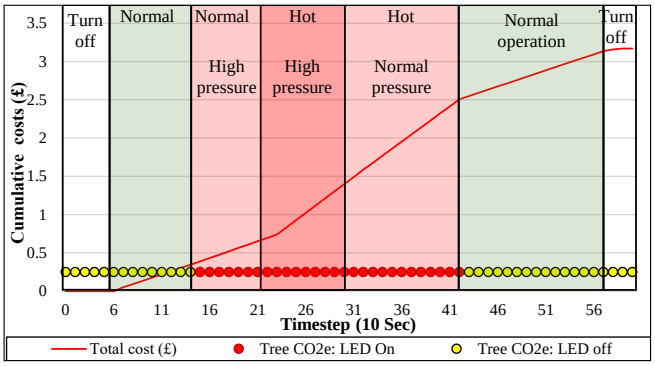


(b)



(c)

Figure 2. Results of simulated 10-min showering operation: (a) energy-related measurements, (b) water-related measurements, (c) total cost

Results and discussion

This prototype appliance creates awareness among individual users about the major impacts of water consumption. When the real-time warning system is enabled, bathroom users will be alerted and encouraged to act quickly or complete their showering. Over time, showering patterns and water use habits are expected to change, leading to potential reductions in water consumption in other areas of home use. By measuring temperature and providing corresponding energy consumption, the nexus effect is used to understand the relationship between water and energy usage. The widespread use of this technology can significantly reduce

freshwater demand as well as the cost of water treatment and distribution. Using a behavioural economic strategy to transfer water usage concerns to users can also enhance public participation at a greater scale.

As a result, it appears that users, water and energy corporations, and decision-makers can readily justify achieving sustainability standards. This concept can also be used in conjunction with other components such as flush tanks, hand washing, and general cleaning. This appliance can be beneficial for various water domestic users such as hospitality, commercial, leisure centres, or office spaces, as these users do not typically pay for consumed water and may have fewer concerns about water consumption management.

Water consumption limits can be set by national law, local regulation, or environmental recommendations from water and energy organizations. This value is modified using an API or a Wi-Fi connection, but for this prototype, it is fixed, and dynamic rates will be saved for when the project grows. The LCD screen installed in front of the end-user displays the water and energy consumption as separate and total costs in real-time to increase user sensitivity. To keep things simple, the prototype can operate offline with LED lighting and a sealed adapter.

Conclusion and perspectives

The presented work introduced simple but effective IoT-based showering appliance to reduce water and energy consumption in household showering sections by applying real-time awareness and economic-behaviour of nudges. The cloud-stored data can be analysed to encourage lowering showering temperatures by a few degrees or stimulating off-peaking usage. Individual reports covering various data combinations can be useful for individuals such as hotels, council properties, and gyms. Furthermore, this is a modular appliance that can easily connect to other water and wastewater sensors such as water hardness for protecting hair and skin, or wastewater turbidity indicating concentration of shampoo, soap or detergents.

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