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Residential water heaters in Brisbane, Australia: Thinking beyond technology selection to enhance energy efficiency and level of service

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ABSTRACT

A holistic approach to residential water heating systems specification is required to provide optimal energy efficiency. The objective of this study is to analyse the performance of residential water heating systems for the city of Brisbane in Australia, for different combinations of heating system technologies (solar, heat pump, electric), storage tank sizes (125 l, 250 l, 325 l), time-distribution of energy in accordance to the tariff selection (all-day, controlled, night off-peak) and washing machine water heating sources (internal and external). Performance assessments considered the influence of 54 different water heating system configurations on the electricity grid (i.e. power peaks, time-distribution of energy according to electricity tariffs, and energy intensity), as well as their level of service (i.e. compliance rates with recommended hot water temperatures). Empirical water end use data from 27 households was utilised to model the performance of water heating systems. The study demonstrated that beyond merely specifying the type of technology (e.g. solar hot water), other key criteria such as hot water demand, hot water tank size and electricity tariff selection should also be considered in order to systematically optimise the energy and service performance of hot water systems in residential buildings.

1. Introduction

Currently, residential buildings are responsible for approximately 30% of the energy consumption in developed countries [1], with the trend forecast to increase over the coming decades [2]. The operational phase corresponds to 80–90% of the total life-cycle energy consumption of the residential sector [3].

In order to reduce the energy consumption in buildings, guidelines and regulatory frameworks were established mainly for building envelopes, heating and cooling air systems, and lighting [4,5], as well as relevant scientific studies in this branch of knowledge [6–9]. Hot water supply is also a standard item of comfort in residential buildings in developed regions worldwide; hence, it is a key component to achieving energy and water efficiency in buildings. From a life-cycle perspective, water heating is the most energy-intensive phase of the urban water cycle, corresponding to 84–97% of the total energy consumption for cold and hot water supplies and sewage collection, treatment and disposal in buildings [10–12].

Pérez-Lombard et al. [2] reported that water heating is equal to 14%, 17%, 22% and 26% of the total energy consumption in residential buildings in the European Union, the United States, the United Kingdom and Spain, respectively. Similarly, Boait et al. [13] and Liu et al. [14] found that water heating corresponds to 18% of the total energy consumption in standard residential buildings in the United Kingdom and the United States, respectively. In contrast, Thiers and Peuportier [15] observed that energy for water heating represents over 40% of the total energy consumption in energy efficient residential buildings in France. In Australia, Aye et al. [16] and Kenway [17] described that water heating is equivalent to 40% and 50% of the total energy consumption of homes, respectively. The more representative energy consumption for water heating reported by Thiers and Peuportier [15], Aye et al. [16] and Kenway [17] may be primarily related to the low energy demand for ambient heating and cooling in the studied building typologies. Therefore, to further enhance the energy performance of buildings, attention must be drawn to the energy performance of water heating systems [13], particularly in energy efficient buildings and regions with warmer climates where ambient heating is not required and natural ventilation is used.

So as to reduce the considerable amount of energy required to heat water, new policies have been implemented to foster the use of renewable energy and energy efficient technologies to

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supply hot water in buildings worldwide [18]. The reduction of hot water consumption patterns has also a considerable potential to reduce the energy consumption associated with water in buildings [19]. Additionally, new electricity supply tariffs have been tested in order to reduce peak energy consumption. For instance, the Queensland Government in Australia committed AUD $63 million towards tariff control and AUD $92 million in rebate programs for residential water heating systems in the south-east Queensland (SEQ) region [20]. Moreover, SEQ electricity utilities have implemented off-peak electricity supply tariffs for water heating systems in order to reduce peak energy demand [20].

As described by Brahme et al. [21], the lifestyles of residents and the local weather conditions will considerably affect the energy performance of buildings. Therefore, notwithstanding the theoretical enhanced performance of energy efficient water heating technologies (i.e. solar and heat pumps), the feasibility of each water heating system type will depend on its energy performance under local weather conditions and hot water consumption patterns [22,23]. Further, the electricity supply tariff selected (i.e. all-day, controlled off-peak, night rate off-peak) may also play an important role in the performance of each system, as the supply of off-peak energy may not suit the demand patterns of a particular household. As a result, depending on the system design and operation patterns, either the capacity to deliver hot water may be constrained, or the performance of energy efficient water heating systems (i.e. solar hot water) may be poor. Therefore, studies addressing the effect of different electricity supply tariffs on the performance of water heating systems are crucial in order to determine the optimal strategy that combines asset and non-asset solutions. Such studies should primarily focus on the reduction of the total and peak energy demands of residential water heating systems without constraints on the required level of service for hot water supply in buildings.

The objective of this study is to analyse the performance of residential water heating systems in the Queensland state capital city of Brisbane in Australia, for different electricity supply tariffs, hot water tank sizes, and washing machine heating sources. The study analyses electric, solar and heat pump water heating technologies, considering their effect on the electricity grid (i.e. power peaks, time-distribution of energy according to electricity tariffs, and energy intensity) and their level of service (e.g. compliance rates with recommended hot water temperatures).

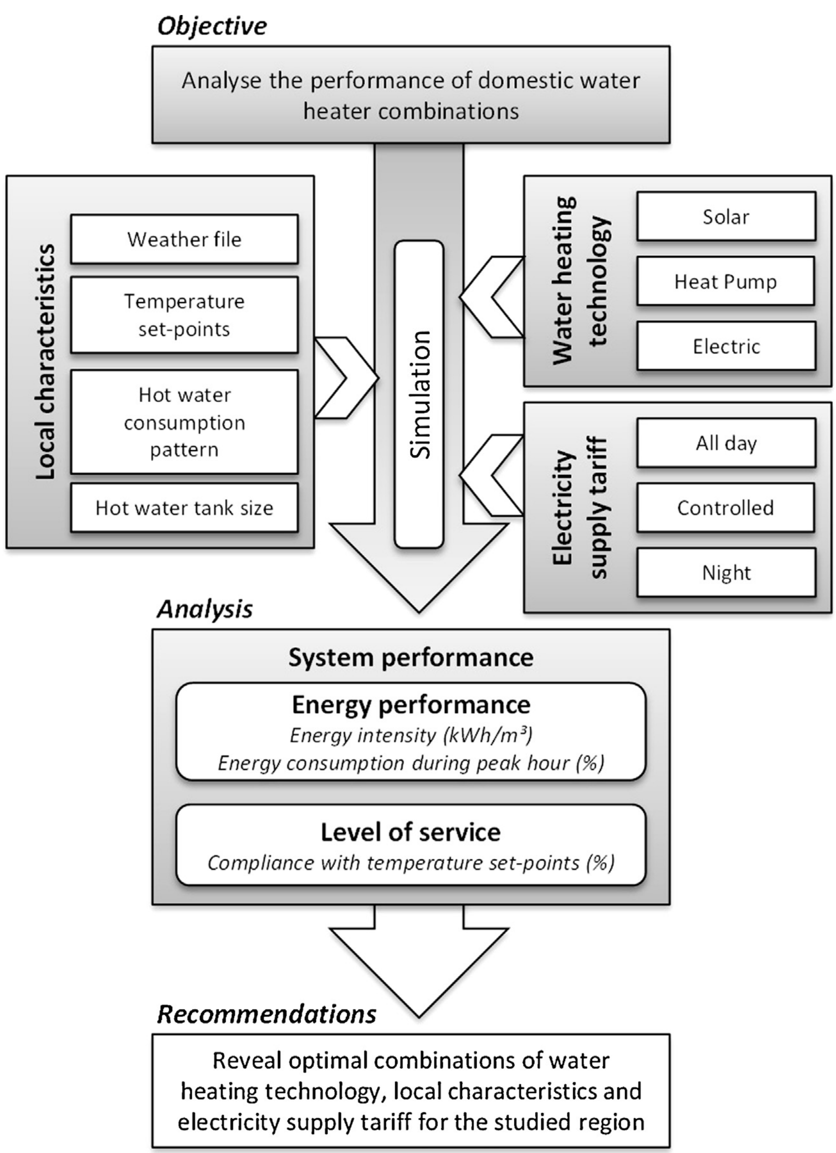

Fig. 1. Flowchart of the study method.