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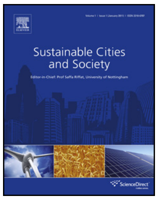

Dissonance in building services guidance: Implications for energy consumption

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ABSTRACT

Building designers rely on a plethora of design guidance beyond compulsory building codes or regulations. However, it has been noted that guidance can be conflicting or contradictory. There is also evidence that design teams opt for 'the safe option', or that which colleagues have used. This is known to have led to the over-engineering of buildings and systems, potentially leading to unnecessary energy use, in direct conflict with the low carbon agenda. To quantify the potential scale of the impact, we investigated the energy use of commercial swimming pool halls, using the full-range of common design standards. Swimming pools were chosen due to their high-energy demand and because there are many guidance documents available from different sources. We found that different standards (which revolve around temperature, humidity and ventilation rate) produce designs with very different energy consumptions. Furthermore, the optimal ventilation rate (derived from a physics-based approach) was found to be far from values presented in guidance documents. Use of this new rate implies a 90% reduction in energy use, compared to the most conservative guidance, confirmed using measured data. This suggests this is a real issue and the existence of such contradictory guidance runs against the low carbon agenda.

1. Introduction

Buildings in use are responsible for approximately 40% of the total energy consumption in Europe (EUROSTAT, 2008). Hence, there is a continuing emphasis in building design on reducing energy consumption and running costs. Unfortunately, there is a growing body of evidence suggesting that the known discrepancies between modelling and reality create a barrier to achieving low carbon buildings (Adeyeye, Osmani, & Brown, 2007; Häkkinen & Belloni, 2011; Kershaw & Simm, 2014; Osmani & O'Reilley, 2009; Zuo, Read, Pullen, & Shi, 2012). This paper examines if further conflicts in building services design guidance create further discrepancies, and if these are large enough to be considered detrimental to building energy performance.

2. Background

Design guidance and regulations can be seen as both drivers and barriers to low carbon design (Adeyeye et al., 2007; Häkkinen & Belloni, 2011; Kershaw & Simm, 2014; Osmani & O'Reilley, 2009; Zuo et al., 2012). Williams and Dair (2007) showed that it is common for stakeholders' sustainability objectives to be restricted by regulation, and this could be attributed to policy and regulation lagging behind best practice. Despite this, Morton et al. (2011) showed that the majority of activity related to low carbon design was to adhere to industry standards and guidance. The benefits stated by those surveyed by Morton were that guidelines provided clear standards, were effective, and made addressing environmental issues more routine (cheaper).

Williams and Dair (2007) also reported a lack of awareness of sustainability in general and a lack of experience in building sustainable developments amongst building professionals. This is echoed by Häkkinen and Belloni (2011) who found a gap in the knowledge of developers/clients regarding sustainable building and a lack of communication between building professionals. This lack of communication has been identified as a major barrier to achieving sustainable/low carbon design and prevents a design team from working effectively (Kershaw & Simm, 2014). Williams and Dair (2007) state "*Without such information, those involved in development either as professional advisors or developers themselves are unlikely to take what they see as risks to achieve more sustainable outcomes.*" Morton et al. (2011) suggests that while many individuals within an organisation may be open to changing practices and taking more risks, the power to do so rests with the more senior

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members of staff. In a survey of building professionals within a large international engineering firm it was found that the more senior an individual within an organisation the more resistant to change they were, and the more they believe that current practices were adequate. Other surveys of building professionals have reported similar findings (Adeyeye et al., 2007; Osmani & O'Reilley, 2009; Zuo et al., 2012). Exacerbating the resistance of building professionals to stray from traditional practices is a known overall lack of a stated sustainability requirement by clients (Osmani & O'Reilley, 2009). This is supported by the findings of Adeyeye et al. (2007) who found that clients often do not even specify energy conservation requirements in design briefs.

A lack of communication between design team members and any gaps in knowledge will likely lead to individual design team members relying more heavily upon guidance documents. Therefore there is the need for guidance, policy and regulatory documents to be practical, accessible and up to date and not be in conflict. Adeyeye et al. (2007) states "*User-specific documents such as a practical guide for clients, architects and engineers could also be useful.* . . .[as] *architects are more likely to consult simple, accessible and easy to use documents that offer practical information which can immediately be applied to design without the need for further interpretation or consultation.*"

In the typical architect-led design team, input from specialists can often occur late in the design process resulting in standard responses and typical off-the-shelf solutions (Kershaw & Simm, 2014). Such highly standardised responses can fuel conflict with the architect, who will resist solutions that they view as an incomplete response to a bespoke project (Fischer & Guy, 2009). If the architect does not understand the relevant principles, and the design team does not communicate effectively, then the building design process can become one of trial and error. It seems obvious then, that a clear set of guiding principles are required to influence industry to progress towards sustainable design principles (Adeyeye et al., 2007; Kershaw & Simm, 2014; Morton, Bretschneider, Coley, & Kershaw, 2011; Zuo et al., 2012).

3. Swimming pools

Swimming pool halls consume more energy per m^2 than almost any other building and often five times more per unit area than office blocks (Carbon Trust, 2008). For swimming facilities a large part of the energy is used to maintain the temperature of the pool water and the temperature and humidity of the pool hall, changing rooms and other areas (Carbon Trust, 2006, 2008; Passivpedia, 2015). This is to overcome the cooling effect of water evaporation and maintain comfortable conditions for occupants. The processes of heating/cooling and humidifying/dehumidifying are typically energy intensive and hence care must be taken when sizing and commissioning these systems to avoid wastage. A study of a low energy German swimming pool [Passivpedia] showed that nearly half (47%) the heating energy used by swimming pool complexes is to ventilate and heat the pool hall (33%) and replace heat lost from the pool water due to transmission and evaporation (14%). The next largest values are heating replacement water for the swimming pool for sanitary reasons (33%) and heating of hot water for showers and basins (12%), heating of the changing rooms and other areas is minimal by comparison. The German study [Passsivpedia] indicated that typical swimming pools use on average ∼3600 kWh/m^2 of pool area for space and water heating. This indicates that swimming pools are ideal candidates for the implementation of energy saving features and generation of renewable heat and energy.

The heating, ventilation and air-conditioning (HVAC) system are normally the primary (or only) means of controlling the pool hall air quality, temperature and humidity (Carbon Trust, 2006, 2008). The need for controlling temperature and humidity is two-fold. The presence of a large body of water within the pool hall leads to a high moisture content in the air above. This can lead to condensation on cold surfaces (such as windows and cold bridges) or in low airflow areas. Without the correct conditions this condensation can give rise to corrosion damage. The HVAC system also plays a key role in removing contaminants such as Chlorine from the air and producing comfortable environmental conditions for bathers, who would otherwise experience thermal discomfort due to reduced clothing levels and evaporative cooling from their skin.

Ventilating and heating pool halls can be rather complex and it is essential to manage these services correctly. The control of evaporation from the water surface is a function not normally encountered in standard HVAC systems, and therefore can be misunderstood by designers and engineers. While airflow is required to prevent condensation there is a direct link between the energy consumption of ventilation systems and evaporation of water from the pool, due to the increased air velocity over the water surface (Carrier, 1918). The amount of heat in the pool lost to evaporation depends on the air conditions immediately above the pool (air temperature, humidity and velocity). This energy, together with a small amount of heat loss through conduction and radiation, represents a major part of the energy exchange from the pool water to the pool hall air. Controlling this is therefore the key to saving energy.

Given this complexity it is not surprising that guidance documents play a central role in swimming pool design. There are various industry guidelines in the UK relating to the environmental conditions and fresh air circulation within a pool hall. The guidance documents are generally in good agreement about the internal air temperature (∼30 °C, a minimum of 1 °C above pool temperature) and relative humidity (60% ± 10%) (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) guide suggests 50–60%) but are contradictory about ventilation rates. They hence point toward different ventilation solutions and the energy required to drive the system. This in turn has implications for the sizing of integrated renewable energy systems or the need for energy savings elsewhere in the building if the design is targeting a specific total energy demand (as is the case for example in Passivhaus, 2016). The Sport England 'Swimming Pool Design Guidance Note' (Sport England, 2011) suggests an air change rate of 8–10 fresh air changes per hour (ac/h). This guidance seems misleading, as the actual fresh air exchange in litres per second needed to deal with condensation and other issues are not dependant on the volume of the pool hall, but rather the size of the pool surface and wet surround which are the source of evaporation. This will lead to increased energy usage for pool halls with higher ceilings, even if the water surface is the same size and hence has the same evaporation. In addition, since external air is typically cooler and drier than the internal air, if the fresh air change rate is too high this will lead to increased evaporation from the pool and increased heating and ventilation load and potentially humidification of the air to maintain occupant comfort.

By comparison, Good Practice Guide 219, 'Energy efficiency in swimming pools' (DETR, 1997) gives the following ventilation guidance at various points:

- 10 l/s per m^2 of total pool hall area
- 4–6 ac/h for standard use (8–10 for extensive water features i.e. flumes)
- Minimum 12 l/s per person
- 100% fresh (external) air operation should be available.

This guidance is also somewhat confusing since it implies several different ventilation rates and the final statement indicates that this might not be 100% fresh air and that some can be re-circulated, however, this is not stated explicitly. The general guideline of