ENERGY EFFICIENCY THROUGH WATER-USE EFFICIENCY IN LEISURE CENTRES

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ABSTRACT

Climate change poses significant challenges, and the global community is not on track to meet sustainable development goals or the Paris Agreement to mitigate climate change. The COVID-19 pandemic and necessary government measures to curb the spread of the virus has put climate action on hold and shut down economies. The need for improved ventilation as an important mitigating factor against the risk of COVID-19 transmission has additional implications for costs and emissions for businesses. Leisure centres, as large users of water and energy, account for significant emissions and operational costs. However, there is scope for significant reductions in water and water-related energy demands and associated emissions and costs without impacting service quality and delivery. These reductions can be a promising response to the current challenges of climate change and post-COVID-19 economic recovery, particularly given current UK energy crises and inflation trends. We have been working with leisure centres to support them in improving energy efficiency through water-use efficiency as part of the cross-border, interdisciplinary Interreg Dŵr Uisce research project on improving the energy performance and long-term sustainability of the water sectors in Ireland and Wales. In this paper, we discuss the potential of energy efficiency gains based on the framework on water management hierarchy which prioritises management actions in order of preference of implementation, where the next hierarchy should only be considered once all potential savings from the hierarchy above have been exhausted. We also discuss how these interventions are not one-size-fits-all – although leisure centres typically have the same water-use types, they differ significantly in age, size, location, building types and materials, functionality, and efficiency; and why therefore, interventions must be considered on a site-specific and case-by-case basis.

Keywords: climate action, energy efficiency, water efficiency, water–energy nexus, heat recovery, sustainability.

1 INTRODUCTION

The water industry is highly energy intensive and on average between 2% and 3% of the world's energy use is used to treat water to potable quality, deliver it to consumers, and to process and dispose of wastewater. In the UK, for example, up to 3% of total energy consumption is by water companies [1]. However, this represents only around 11% of actual water-related energy consumption, with most of the water-related energy use attributed to water demand [2]. Given this obvious link between water and energy use, reducing the water for demand, especially in hot water use, can significantly reduce water-related energy demand and associated GHG emissions and costs.

Better management of water demand is promising as both a climate change mitigation and adaptation strategy, and can reduce water consumption to conserve the resource, thus reducing the energy need and associated GHG emissions, operational costs, and to reduce negative environmental impacts without impacting service quality and delivery. This also makes business sense as even the simplest interventions can provide significant savings in operational costs and environmental taxes. In the UK for example, some local authorities or business may even be able to claim capital allowances for investing in low-carbon technology through schemes like Non-Domestic Renewable Heat Incentive and water efficient enhanced capital allowances. It is good practice to also consider water and energy management as a single, integrated management task rather than two separate tasks as is currently typically the

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case because one typically affects the other. This is in line with both the UK and Welsh governments' ambitious targets to reduce GHG emissions to net zero by 2050 and other initiatives such as the Welsh governments' Well-being of Future Generations (Wales) Act 2015, the UN Sustainable Development Goals, and the European Green Deal, therefore water management should be considered as a core component of energy management policy and carbon reduction ambitions and targets.

Leisure centres are large users of water and energy and account for significant emissions and operational costs. Progress is being made in reducing energy use in leisure centres, particularly in Local Authority (LA) owned centres. All the LA-owned leisure centres we worked with have made considerable investments and improvements in energy management, however, not much has been done in terms of water management except from ongoing and phased refurbishment of water using fittings and appliances even with the considerable scope for very significant reductions in water and water-related energy demands and associated emissions and costs without impacting service quality and delivery. These reductions can be a promising response to the current challenges of climate change, post-COVID-19 economic recovery, and the current UK energy prices.

It is important to also consider the whole building in leisure centres and not just their Mechanical, Electrical, and Plumbing (MEP) systems as a more cost-effective way to improve energy efficiency, and adoption of new standards like Passive House [3] and Part L of the Building Regulations [4] and technical guidance from industry groups such as Pool Water Treatment Advisory Group (PWTAG) [5] will also lead to much better energy efficiencies. Policy is a very important starting point to help drive change and reasonably moving in the right direction in terms of new-builds as it is much easier to do this with new-builds that must go through the regulatory and compliance process than it is with retrofitting existing leisure centres that form most of the leisure centres in the UK, even with the quiet reasonable impact it can have on cost and carbon savings. One way leisure centres can take initiative and positive climate action and have a critical mass emissions reduction as a sector is to work very closely with industry (e.g., through PWTAG) to embed the idea of reducing carbon footprint into operation guidelines.

2 WATER AND WATER-RELATED ENERGY USE IN LEISURE CENTRES

To identify areas with potential water–energy savings in leisure centres, it is important to understand how water is used in the centres and how this relates to energy use. It is estimated that water, energy, and waste costs can account for over 30% of the running costs in leisure centres with swimming pools [6], [7].

Research indicates that in general swimming pool and pool hall; Heating, Ventilation, and A/C (HVAC) systems; and domestic hot water heating represent the highest consumption of water and energy in leisure centres [7]. The Carbon Trust also identifies pool hall, ventilation and A/C systems, and space heating to be the common areas where energy is typically wasted [6]. This provided a baseline indication of the areas of focus at the leisure centres we audited in Wales. In general, the audit process was used to assess:

- the types of wet leisure centres;
- how water is used in the different leisure centres;
- the areas where water and water-related energy savings and emissions can be made;
- how this can be achieved;
- what this can mean in terms of emissions and costs savings; and
- how this can be used to improve the carbon footprint and wider environmental performance of the leisure centres.

The audits allowed for the benchmarking of water and water-related energy use the centres and a better understanding of where water-related energy and emissions savings can be made. The managers and operators of the centres interviewed during the audit process recognised the need for adopting a water management policy and strategy and had some knowledge and understanding of how this can be achieved in practice. The audits found the leisure centres to be generally water efficient – in all but a few centres which had issues with leaking WCs, dripping taps, and push taps no longer performing effectively, particularly, but not exclusively with the oldest fittings.

Some of our recommendations on the ways leisure centres can reduce their energy use through water-use efficiency, include metering and regular monitoring of water consumption, regular site walk-arounds and continuous record keeping of water use and water fittings and appliances, implementing a programme of interventions focussed on behavioural change in water use, and if possible increasing the stock of low-carbon and/or renewable technology installations at the leisure centres like Wastewater Heat Recovery (WWHR), solar PV, biomass boilers, and heat pumps to further reduce carbon footprint and improve environmental performance.

The recommendations are based on the framework of water management hierarchy (Fig. 1) which prioritises water management actions in order of preference of implementation, where the next hierarchy should only be considered once all potential savings from the hierarchy above have been exhausted. This is based on the principles of waste management hierarchy of the EU Waste Framework Directive [8] which ranks interventions according to their environmental performance with respect to climate change, air and water quality, and resource depletion.

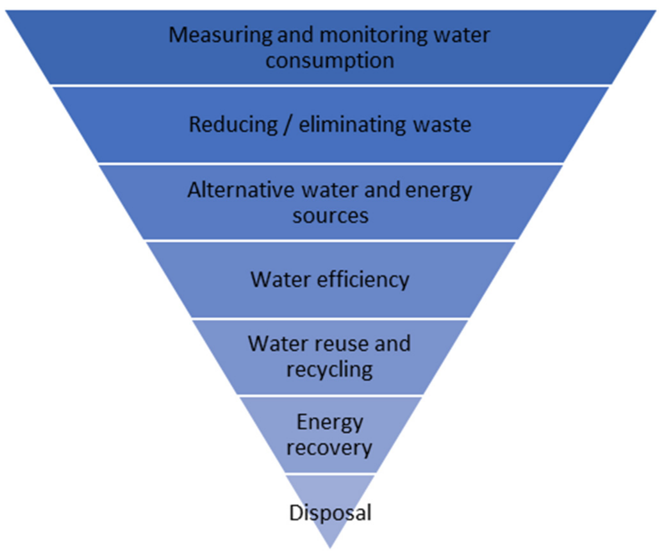

Figure 1: Water–energy management hierarchy (after water management hierarchy).

However, it is important to note that not all interventions will result in reduction in both water and energy use, and some interventions can increase water or energy use. In general, if water or energy demand is to be reduced, then some other factor must change to accommodate this reduction, and where a reduction of water or energy results in an increase of the other, it may not necessarily be clear which is the more sustainable outcome, and this should be decided on project- or site-specific basis [2]. There are also some health and safety implications in water and energy efficiency that must be considered and addressed. Another important note is that these interventions are not one-size-fits-all because although leisure centres typically have the same water-use types, they differ significantly in age, size, location, building types and materials, functionality, and efficiency, and therefore interventions must be considered on a site-specific and case-by-case basis.

It is estimated that leisure centres can save up to a third of heating costs through simple energy efficiency interventions, such as using energy efficient lighting; maintaining appropriate temperatures; ensuring HVAC systems match building occupancy; and maintaining boilers and pipe work [9]. The amount of water and water-related energy demands that can be saved depends on several factors, including building type and age, building materials, specific centre functions, footfall, etc., and these savings are also influenced by the installed water using fittings and appliances, number of people using water on site, the efficiency of the HVAC system, energy source, and system loses [10].

Leisure centres must also meet certain minimum water and energy performance standards for customer comfort, hygiene, and health and safety. Even so, many centres use more water than they need to, leading to higher than necessary water use, sewerage discharge, energy use, emissions, and costs. The leisure centres we audited differed significantly, but they all had typical water-related energy use in these areas:

- plant room (boilers and hot water heaters);
- swimming pool and pool hall (pool heating and HVAC systems);
- domestic hot water use for showers, WCs, urinals, taps in both dry and wet areas, kitchen and cafeteria areas, staff areas, laundry, and for facilities cleaning.

Some of the centres also had shared premises and/or facilities with schools and/or other tenants and some had some low-carbon and/or renewable energy technology such as biomass boilers, heat pumps, Mechanical Ventilation with Heat Recovery (MVHR), and Building Management System (BMS). Some of the leisure centres also replaced all lighting to LEDs and have switched to renewable energy supply.

Of course, with COVID-19 there is an additional need for ventilation and therefore energy use and costs. There is legislation and guidance [11], [12] in relation to minimum requirements for ventilation and efficiencies for heat recovery systems to allow centres to reopen and keep the pool environment as safe as possible. However, the requirement to increase the fresh air and flush out as much of the contaminated air as possible without putting it through the recycling system back into the space is not energy efficient. There is therefore a trade-off between the efficiency gains in carbon savings and the need for additional ventilation to ensure safety.

3 WATER–ENERGY SAVINGS OPPORTUNITIES IN LEISURE CENTRES

By far, swimming pools and pool halls were the largest users of both water and water-related energy use in all the centres, which is in line with estimates that pool heating and ventilation alone can account for up to 65% of energy use – mainly from pumping, filter backwashing, and heating pools and pool halls [7]. Pool temperatures vary depending on activity or use but are typically heated from average mains temperatures which changes seasonally to about 30°C on average. The pool halls were also kept at 1°C above pool temperature to limit evaporation from pool surface.

Pool halls also need to be ventilated to maintain pool hall temperatures both for comfort and to prevent condensation from humidity and damage to building and equipment [9], and HVAC and MVHR systems are highly energy intensive. Energy and money are wasted when air is mechanically removed and replaced by cold air from the outside which needs to be heated or cooled to match inside temperatures [7].

After accounting for swimming pools and pool halls, the largest single factor determining water use in leisure centres is occupancy, which includes both staff numbers and customer footfall. This is because water use is a function of both installed water using fittings and appliances and of water-use behaviours. In general, three variables determine the amount of domestic water use [13]:

- flow rate;
- water-use event duration; and
- frequency of use of water fitting or appliance.

Of these variables, event duration and frequency of use are dependent on user behaviour. Flow rates vary widely and are largely governed by several physical factors, including water pressure and the design of installed fittings or appliances. The frequency of use of use of fittings and appliances is related to occupancy, and in general, the more footfall a centre has, the more water it will use.

3.1 Water-related energy efficiency

One way of reducing water and water-related energy demands in leisure centres is through water-use efficiency, which is often a simple, zero or low-cost intervention with immediate results and short payback periods that can have an important role to play in reducing energy use as well as help reduce operational and maintenance costs whilst still maintaining minimum standards of hygiene and comfort.

Water efficiency can also be used to improve energy performance of leisure centres and their carbon footprint, and improve environmental ratings (e.g., LEED and BREEAM) and therefore overall sustainability and wider environmental performance. It can also be used to reduce the amount and flow pattern of wastewater to drainage systems, resulting in reduction in total volume of wastewater discharge and sewerage costs [13].

Water efficiency can therefore have an important role to play in helping leisure centres meet their carbon targets and responsibilities, as well as help reduce operational and maintenance costs – reducing consumption helps reduce supply costs, increase useful life of water using fittings and devices, which at the very least can result in deferment of investment in upgrades and replacement by reducing the risk of damage to buildings from condensation due to overheating and evaporation. This can be accompanied by fixing, retrofitting, and/or replacing older inefficient or broken water using fittings and appliances, implementing process and operational improvements, and/or social interventions such as behavioural change initiatives or education and awareness raising campaigns for both staff and customers.

In managing behavioural change, it is necessary to understand what the drivers for change are. This can be for example, linking water and energy efficiency to help meet carbon targets and sustainability goals. The drivers for behavioural change in this case can include savings in water, energy, emissions, and costs; improving sustainability and environmental performance; and improving global or corporate social responsibilities. Behavioural change should also ideally be considered as a continuous cycle of improvement.

A key step in water-use efficiency is to measure and monitor consumption over time. The aim of this is to help understand exactly how much water is used, where, and why. This can be done using water consumption data, which is available from water billing (available in m^3) and/or by regular meter readings. The consumption data can be used to produce a water demand profile to help assess consumption over time and to benchmark water use against industry standard or other KPIs.

Benchmarking water use is straightforward for leisure centres that occupy whole buildings or premises [10]. Information needed for accurate benchmarking of these types of centres include at least a full year consumption data (m^3) and the use of actual, rather than estimated consumption data to ensure billing is based on meter readings and not an estimate of consumption. Where more data is available, for each year can be calculated to help understand consumption over time or to identify wastage or inform of necessary refurbishment.

Where a full year consumption data is not available, it is possible to use quarterly data to benchmark per day [10]. However, it is important to note that this may not be an accurate representation of water use given the likely seasonal fluctuation in footfall but can still be very useful for assessing and understanding how much water is being use, identify problem areas, and inform necessary interventions. Where footfall is transient and can significantly vary over the course of the year, it will be better to benchmark per floor area (m^2). For leisure centres that share premises or facilities, the best way to accurately assess water use will be to sub-meter the different areas of water use and water-use types.

A simple way to understand leisure centre water consumption and sewerage discharge is to develop a water balance model (Fig. 2). This is a numerical accounting of how water enters a site, how it is used, and how it is disposed of; and is done by mapping water flows through a site using information on water billing, sewerage and trade effluent discharge, meter readings, and site walk-around to ensure all water fittings and appliances are accounted.

A water demand profile is also a useful way of modelling consumption over time and can highlight changes in water use that may not be otherwise obvious. At least a whole year of data, and ideally a minimum of three years data, is needed and should be done quarterly, given the seasonal variation in footfall and water consumption in some leisure centres [12]. Average daily consumption can be calculated by dividing the number of opening days in the period by the annual consumption.

3.2 Wastewater heat recovery potential in leisure centres

Increasing the stock of low-carbon and/or renewable technology installations at the leisure centres like solar PV, biomass boilers, heat pumps, and WWHR will further reduce energy use and emissions and improve the carbon footprint and environmental performance of leisure centres with reasonable paybacks.

Although there is the potential for leisure centres to adopt heat recovery as a means of emissions and cost reductions, much remains to be done for the leisure sector to mobilise a critical mass for this to make meaningful impact for the sector. Even with the significant potential for energy savings through WWHR the capital cost for can be quiet substantial because most leisure centres operate year-round. Costs also vary widely because of the typically significant variation in types, sizes, ages, building fabric, etc., of leisure centres.

An example of the potential of WWHR in leisure centres was in the showers on the pool (wet) side of a community owned and operated leisure centre in rural Wales which has around 300 showers a week using four thermostatic mixed showers set at 40°C at an average flow rate of 12 litres per minute and average duration of 6 minutes. The water for the showers is heated by a pressurised boiler system set at 40°C which runs on oil gas. The plant where the

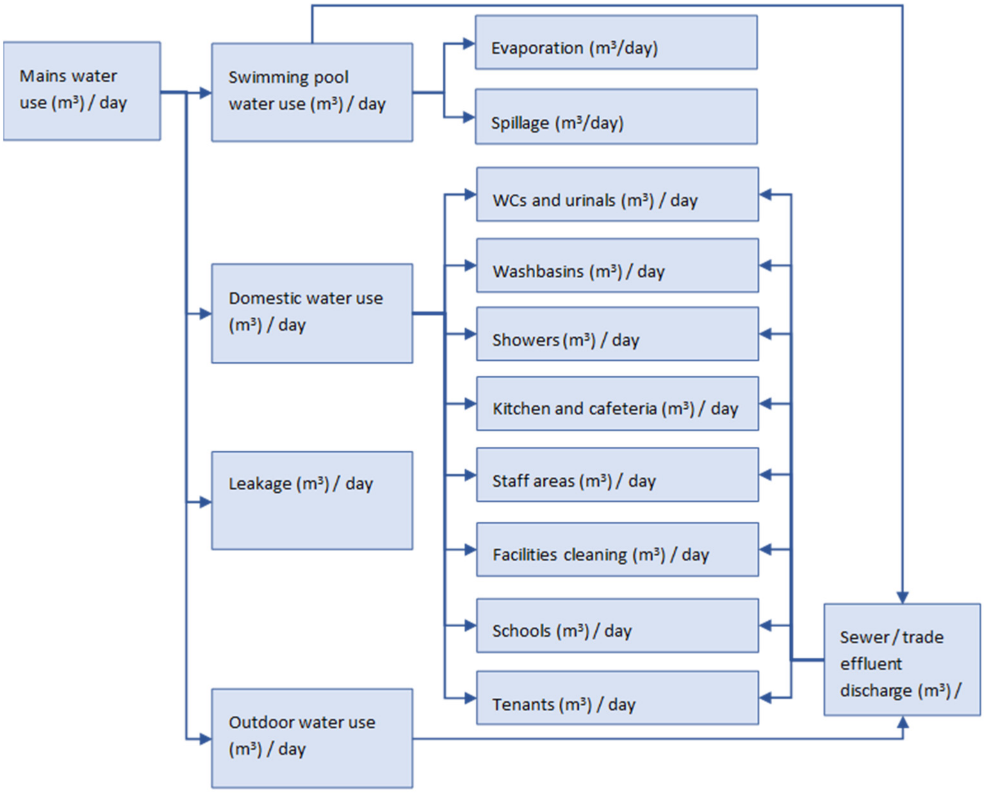

Figure 2: A water-balance model of a small rural leisure centre in Wales.

boiler is located is around 15 metres from the main plant room which is located on the dry side. Assuming total wastewater of 3,024 litres per day at 40°C and a flowrate of 45.6 litres per minute, a commercial wastewater heat recovery system can save 14,586 kWh energy, displace 4,000 kgCO_2eq per year, save £1,245 per year with a payback of around 4 years with oil gas prices of £0.83 per m^3 and the price of electricity for pumping unit of £01.2 per kWh.

There is also the potential for other significant savings through other simpler, lower-cost interventions such as upgrading older fans and impellers to newer systems or the use of heat pumps. Opportunities for heat recovery are a lot larger when there is a pump type system than when it is only burning gas.

An ambitious intervention would involve the use of waste heat from chillers or condensers that would be otherwise dissipated for small and ambient heat networks within leisure centres. There is also the opportunity for localised networks to recover heat from different users though out the leisure centres, e.g., from gyms and other sport facilities to preheat pools, and vice versa in existing leisure centres, which is already becoming standard in a lot of new builds.

3.3 Improving systems control and optimisation

There are energy and cost savings potential from optimising of pool water circulation, air circulation, and even through water chemistry as the effectiveness of water treatment can have an impact on energy use and costs. The rate of removal of particulate material from pools can be greatly increased and the energy use much reduced by improving water circulation, thereby improving water quality and energy efficiency, and reducing costs.

Both circulation and air distribution in the pool hall are important mitigating factors in COVID-19 transmission, given the dramatic change in the quality of the air close to the water surface when moving for example, from a high-level extract to a low-level extract system. It is therefore important to get unidirectional airflow to reduce as many contaminants as possible, which is coincidentally the more energy efficient way of improving ventilation.

In terms of water circulation, we are developing guidelines on how much flow is needed and the minimum number of air turnovers in pool halls or water turnovers in the pool tank required to maintain hygiene and health and safety standards. More attention is also needed on water mixing characteristics and where water flows rather than just the outflow rate.

It is important to reliably estimate evaporation from swimming pools as incorrect calculations may lead to incorrect sizing of Air Handling Units (AHU) which could result in excessive humidity that can cause discomfort in the pool hall or even damage to building and equipment [15]. There is a potential in energy and cost savings from reliable estimation of evaporation from lower water and space heating costs. Two main methods can be used for this: analysis of physical phenomena or the use of empirical data [15].

Challenges remain with pool operation guideline orthodoxy. Many guidelines, such as the need to dump and replace 30 litres of hot water per bather [5] or guidelines on circulation rates [16]–[18], for example, are largely based on experience of good practice over the years, with little scientific underpinning. Yet, these are considered quite sacrosanct even though there is not much scientific basis for this. The general trends with operational guidelines in pools also tend to require more circulation, which inevitably means more energy use, more water dumping – both of which are in conflict of trying to run pools with minimal carbon footprint.

4 CONCLUSIONS

There is a significant potential for energy, emissions, and costs savings in leisure centres through water management, including water efficiency, use of low-carbon and renewable technology like WWRH, and through improved systems control and optimisation of water and air circulation, and through water treatment as water quality can be improved whist saving energy which can have the most impact if bundled together.

Many of these interventions are simple and available at zero or low-cost with no need to close centres and a payback within a budget year. The knowledge and the skill set to do this are available, but ambitious policy (e.g., Part L Building Regulations for commercial buildings) and financing instruments will be required to do this. In the UK, stepwise changes are moving the right direction, but it may be challenging to expect already stressed centres to buy into WWHR for example, even with rising fuel prices.

It is necessary to consider leisure centres to maximise the potential for moving towards Nearly Zero Energy Buildings (NZEB) because it is no longer sufficient to manage different areas and resources in isolation for any meaningful change in the way centres are operated and managed. Much work remains in terms of transition to electrification and decarbonisation of the grid, adequate insulation, use of heat pumps, and so on.

In a recent expert panel discussion on heat recovery potential of leisure centres we convened, the panellists agreed that it is not yet clear what the impact of the COVID-19 will be on future investment in green technology like WWHR, considering the long periods of closures and restrictions that have happened since March 2020. A lot of leisure centres in Wales are currently struggling financially as most leisure centres are LA or community owned and operate on a not-for-profit basis, so there may not to be a desire to invest until centres are back up and running and profitable again. Some leisure centres have also suffered infestation of filtration systems because chlorinated water has not been circulating during lockdown and there has been much damage to motors and electrical equipment due to being turned off for a while in cold, humid environments with a lot of plant needing to be replaced.

There is some evidence that government plan for net zero targets in the built environment and increasing austerity and cuts to public sector funding will push leisure centres towards increasingly ambitious emissions reductions to cut costs. The question remains as to whether policy will force the necessary move to electrification, particularly in rural areas that partially or fully operate on oil or gas.

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