The energy implications of using Rainwater Harvesting Systems to supplement mains water in the UK

Does this affect its place in UK future water strategy?

Thomas Young

E Futures DTC

Executive Summary

Introduction

Rainwater harvesting has been practised for millennia and has experienced resurgence in the UK in recent years due to a shift in planning policy towards sustainable development[1]. Rainwater harvesting (RWH) systems are now more advanced but the overall aim remains the same, to capture and store rainwater for use at a later time. This is seen to increase sustainability by a) reducing reliance on aging centralised water supply networks which require large amounts of energy to treat and pump water[2], b) help manage rainfall events to reduce frequency and magnitude of flood events e.g. Sustainable Urban Drainage Systems (SUDS) [3-4] and c) indirectly reducing water abstraction pressures on watercourses, thus helping to achieve 'good ecological status'[5-6].

The large centralised water supply systems typically found in developed countries require large amounts of energy in order to acquire, treat and transport water. The water industry is currently directly responsible for 0.8% of the UK's annual energy use. Rainwater harvesting systems (RWHs) may provide an alternative water supply and reduce reliance on centralised water networks.

Rainwater Harvesting Systems

RWH systems use a large surface e.g. a roof to capture any rainfall that falls upon it and then channel it into a storage container where it can be treated and then pumped to the appliances that need it at a later time.

There are three main types of RWH system[1];

1. Direct Feed Tanks-water is pumped directly from storage tank (at ground level) to appliances. Mains water is connected to storage tank and therefore also has to be pumped to appliances.

2. Header Tank System-water is pumped from main storage tank at ground level to a smaller tank set in the roof space of the building where it is feed to appliances via gravity.

3. Gravity Feed Systems-storage tank is located above the ground and feeds appliances under gravity only.

In the UK RWHs are usually used to supplement mains water supply for uses that do not require highly treated water e.g. toilet flushing[7]. A well placed and designed system can provide up to 50% of non-potable water demand, although figures of 20-30% (5-25% of total water demand) are more commonly observed and modelled[8-9].

RWHs are most effective in large non domestic buildings that have a large roof area and a large non potable demand e.g. office buildings[8], although they can still play an important role in mains demand reduction in the domestic sector[9].

Energy Implications of RWH

RWH systems are more energy intensive than mains water. The main contributor to the energy use of RWHs is the pumping of water from the main storage tank to a header tank or directly to the appliances, which consumes between 0.6-5kWh m^{-3} compared to the 0.5kWh m^{-3} that mains water typically requires[8]. If treatment from a UV lamp is also required it pushes the upper limit of energy use up to 7.1kWh m^{-3}.

Direct feed systems generally have higher energy operational costs than header tank systems due to the mains backup supplied to the storage tank resulting in higher amounts of onsite pumping[8, 10].

However there is significant scope to improve a RWH system's performance through increasing operating efficiency and careful selection of construction materials[10-11]. It is estimated that only 4% of the energy used by a RWH pump over a year is actually used to pump water, the rest lost to standby power, pump inefficiencies and supply not matching demand[10].

Previous LCAs performed on RWH systems have usually compared a 'business as usual' scenario for mains water supply against the installation and operation of a RWH. This puts RWHs at an immediate disadvantage as it assumes that the water mains did not have any initial construction or repair energy costs. In addition this approach does not account for future expansion of the water supply network in order to meet predicted increased future demand e.g. construction of a new reservoir or desalination plant both of which have significant construction and operational energy costs. It makes much more sense to view RWH systems as one method of reducing pressure on the water mains network and therefore preventing or delaying expansion of the water mains network[12].

UK Future Water Supply & Demand

Total UK water demand is expected to continue to grow, especially in areas that are already severely water stressed, e.g. SE England[13]. Nearly all of England's water companies are defined by the EA as having a water stress level of moderate or severe. Therefore the UK will have to extend its water supply infrastructure in certain areas in order to meet future demand.

Energy Costs in the Water Supply Industry

The general consensus from Life Cycle Analyses of the water supply industry is that the operational energy is by far the largest contributor to GHG emissions through electricity use[14-15]. For conventional treatment of waste/abstracted water into potable water which consumes around 0.5kWh m^{-3}, ozone generation, high speed decantation and ultra filtration are the most significant users of electricity accounting for nearly 20% of the whole water life cycle electricity use[16].

Desalination of brackish or sea water is increasingly being used around the world where freshwater levels is at a premium and is by far the most energy intensive option, accounting for as much as 90% of energy use when water is acquired through that process [14, 16]. Modern techniques typically produce water at an energy cost of between 4-6kWh m^{-3}. In addition to the high energy construction costs associated with water reservoir construction, high amounts of methane and carbon dioxide are released from reservoirs over their life time[17].

The construction and operation of extensive new water supply infrastructure will lead to higher levels of energy use, something which previous LCAs of RWH systems have not considered. For example, the energy intensity of mains water supply in Perth, Australia rose from 0.56kWh m^{-1} in 2001/02 to 0.98kWh m^{-1} in 2006/07 primarily due to the opening of a 45,000 ML/per year desalination plant near the city in 2006[18].

The EA report 'Greenhouse gas emissions of water supply and demand management' concludes that building new supply infrastructure has a high carbon cost whilst implementing simple demand management schemes does not. In addition it was concluded that RWH has a comparatively high carbon cost but can provide a similar amount of water as desalination.

UK Case Study: Thames Valley Region

Summary of Thames Water

A small comparison of four different future water supply options (desalination, reservoir construction, RWH and demand/leakage reduction) in the Thames Valley region was completed. Thames Water currently serves approximately 13.8million customers, experiences high leakage rates (30%) and is located in an area of severe water stress. It is expected to have an additional 2million customers by 2035.

Reservoir construction provides the most amount of water, although leakage reduction will provide roughly half of the amount that a reservoir provides. RWH and desalination both only provide a relatively small amount of water at high energy cost. These results support the results of the EA 'GHG of water supply report'[19] that RWH is the answer to future UK water shortages but can be useful when implemented with other demand and leakage reduction schemes.

Report Conclusions

RWH systems are more energy intensive than mains water due to the inefficiencies of localised small scale pumping. However RWH systems perform much better when compared to new water supply infrastructure like desalination and reservoir construction. Desalination has a slightly higher energy requirement for treatment than RWH whilst reservoir construction comes with high embodied carbon levels and diffuse emissions [14, 18].

The total life carbon emissions for a domestic RWH system of 800-2000kgCO_2 are equivalent to a 3.5hour flight[12]or a single years worth of energy related emissions from a house built to Code Level 3 energy efficiency standards[8]. In addition other aspects of water provision are far more energy intensive, for example, domestic hot water contributes to nearly 50% of all emissions from related to the water industry whilst water treatment and pumping only directly contributes 10%[20]. In certain remote island locations with a high renewable energy source RWH may also be more beneficial than urban areas which already have a large established water supply infrastructure. RWH can also provide important additional benefits that include providing greater individual security of supply and increased drought tolerance/stress on mains supply.

However when viewed with other water supply options, most notably demand reduction and leakage reduction RWH systems perform much better and are able to contribute to a much more sustainable method of meeting future water demand, whilst also providing additional benefits[21]. Such an approach will not provide a complete solution but may be able to reduce pressure on the water mains and offset further expansion of the network until a later date[22].

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