

PROJECT ZERO



**The Role of Water Reuse and Efficient Fixtures
in Delivering Water-Neutral Developments**

About Project Zero

Project Zero (formally Water Neutrality at NAV Sites) is funded through the Ofwat Innovation Fund and led by Affinity Water, in collaboration with partners from across the water, development, and technology sectors. The project seeks to demonstrate the feasibility of achieving water neutrality at scale, ensuring that total community water use remains the same as before new homes are built.

To achieve this ambition, Project Zero combines three core approaches:

- **Technological innovation** – exploring water reuse systems and water-efficient products.
- **Behavioural change** – supporting customers to use water more sustainably.
- **Offsetting** – reducing demand from existing customers within the local supply area.

The project is being delivered across three phases, each with a distinct focus to test solutions and create a practical industry blueprint for water-neutral development:

- **Phase 1 – Behaviour Change and Offsetting Focus:** Delivering a targeted engagement campaign to influence customer water-use behaviours in new-build homes, alongside an offsetting strategy focus on reducing demand from non-household customers.
- **Phase 2 – Technology Focus:** Testing the feasibility of communal water reuse systems and exploring supporting water efficiency products.
- **Phase 3 – Hybrid Approach:** Combining reuse systems, efficient fixtures, smart metering, behaviour change and offsetting initiatives to demonstrate a holistic model for water neutrality.

This report focuses on Phase 2 activities, examining the technical performance and feasibility of innovative water reuse systems and efficiency technologies. The findings from Phase 2 will inform the development of practical guidance and an industry blueprint for achieving water neutrality in future housing developments across the UK.

Acknowledgements

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The Project Zero team extends sincere thanks to all project partners for their collaboration and expertise, which have shaped both the Technology Workstream and the findings presented in this report.

We acknowledge the valuable contributions of Albion Water and SDS, whose technical insight and site-specific data supported WRc in undertaking the detailed analysis underpinning this work. Our thanks also go to Aquality for providing system designs and operational experience that informed our assessment of water reuse technologies.

We are equally grateful to the wider group of stakeholders, developers, and site partners who engaged openly throughout the project and supported the practical exploration of technologies that can help drive down potable water demand in new developments.

Contributors

Albion Water & SDS

- Richard Averley

Aquality

- Lutz Johnen

WRc

- Harry Brown
- Robert Fairhurst
- Larysa Prin
- Emmanuel Arthur
- Harriet Dingle

Executive Summary

Water is a fundamental requirement that underpins health, economic growth, and environmental resilience. However, England's potable water supply system is under mounting strain from population growth, industrial demand, and the increasing frequency of hotter, drier summers. The Environment Agency projects that, without decisive intervention, England could face a daily water supply deficit of up to five billion litres by 2050 (Environmental Agency, 2024). Technology has the potential to play a key role in addressing this challenge through the implementation of water reuse systems, together with continued innovation in fixtures, fittings, and appliances that enhance water efficiency and reduce overall consumption.

Phase 2 (Oaklands Hamlet in Chigwell) was established as the technology-focused workstream within Project Zero, with a primary focus on testing the feasibility of a communal water reuse system in a new development. The ambition was to demonstrate how water reuse, delivered through approaches such as stormwater harvesting and dual-supply networks could contribute to water neutrality at scale. In addition, the workstream explored the role of innovative water-efficient fixtures and fittings as a complementary measure to reduce household demand beyond standard specifications.

At project inception, it was understood that the regulatory framework would permit the implementation of a communal non-potable water system, provided that it complied with the relevant standards. However, despite strong engagement with partners and the development of early design concepts, the current legislative and regulatory frameworks - particularly restrictions under the *Water Industry Act 1991* and guidance from the Drinking Water Inspectorate (DWI), ultimately prevented the deployment of a live communal system. This outcome highlighted a critical limitation within the existing regulatory environment and underscored the need for policy reform if the benefits of water reuse are to be realised.

As on-site delivery of a live system was not feasible under the prevailing regulatory conditions, the project refocused its efforts from practical implementation to an evidence-based assessment. This assessment, undertaken by WRC, examined the performance of the site's operational dual supply network, which has been installed at construction, which is functional but does not currently have a non-potable source connected. The study evaluated the potential contribution of water reuse systems, showing that non-potable uses typically account for around a quarter of household consumption, and that integrated reuse could reduce potable demand by 20-23% under typical conditions. The Study also examined climate resilience, customer acceptance, and the interaction with sustainable drainage systems (SuDS), providing an evidence base that remains highly relevant to future Project Zero activities.

Alongside the water reuse assessment, a technology review was undertaken to evaluate the potential of high-efficiency fixtures, fittings, and appliances to further reduce household water use. The review found that advanced products can collectively reduce end-use consumption by 40–60 % compared with standard installations. These technologies demonstrate that new homes can achieve performance well beyond Building Regulations standards, providing a strong foundation for water neutrality. Importantly, when applied alongside reuse systems, these measures reinforce

each other by reducing both potable and non-potable demand, optimising system sizing, and improving overall resilience.

Although a live trial was not possible for Phase 2, the workstream has delivered valuable insights. The findings inform clear priorities for policy engagement, highlighting innovation opportunities, and point to future research needs. Taken together, they reinforce that while regulatory barriers remain, the potential benefits of water reuse supported by demand-reducing technologies are significant and unlocking them will be essential to achieving water neutrality at scale.

Conclusion

The Technology workstream has demonstrated that water reuse systems can feasibly supply 20–23 % of household water needs through non-potable sources, representing a major opportunity to reduce potable demand within new developments.

In parallel, next-generation fixtures and fittings offer further substantial savings, and together these approaches present a credible, evidence-based pathway to water-neutral communities. This reports evidence base provides a robust platform for future workstreams, further innovation projects on water reuse and supports ongoing policy dialogue with Defra, Ofwat, and the DWI on enabling safe, large-scale adoption of water reuse systems and efficiency technologies across the UK.

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Definitions

Water Neutrality - A new development where overall water demand does not increase within the existing water supply zone after completion.

Water Offsetting - The practice of compensating for any additional water demand from a new development that cannot be eliminated through reduction. This is achieved by implementing water-saving measures elsewhere in the same water supply zone.

Water Reuse - The process of capturing, treating (where necessary), and application of alternative water sources for non-potable uses such as toilet flushing, irrigation, and laundry.

Alternative Water Sources - Encompasses stormwater/rainwater harvesting, greywater recycling (from baths, showers, and wash basins), and blackwater (sewage) recycling systems. Alongside water abstracted from wells, springs, bore-holes or waters for private supplies.

Greywater Recycling - The process of collecting, treating, and reusing domestic water, typically from showers and hand basins, for non-potable uses.

Rainwater Harvesting - The collection and storage of rainwater from roof surfaces, typically followed by treatment, for non-potable uses.

Stormwater Harvesting - The collection and storage of rainwater from both roofs and hard surfaces such as pavements, roads, and car parks, followed by treatment, for non-potable uses.

Potable (Wholesome Water) - Water that is safe for human consumption

Non-Potable (Non-Wholesome Water) - Water that is not intended for human consumption

New Appointment and Variation (NAV) - Under the regulatory framework established by Ofwat, NAVs are limited companies appointed to provide water and/or sewerage services for a specific geographic area that was previously supplied by an incumbent water company.

Sustainable Urban Drainage Systems (SuDS) - A collection of water management strategies designed to utilise natural processes to manage surface water runoff, improve water quality, reduce flooding and enhance biodiversity.

Representative Climate Pathway (RCP)

- **RCP 6.0:** A moderate climate change scenario representing an average global temperature increase of approximately +2.8 °C relative to pre-industrial levels. It estimates 2050 demand applied to a synthetic 2040 – 2059 weather timeseries, uplifted from 1981 – 2000 (see Appendix A).
- **RCP 8.5:** A high emission scenario representing an average global temperature increase of approximately +4.3°C relative to pre-industrial levels. It estimates 2050 demand applied to a synthetic 2040 – 2059 weather timeseries, uplifted from 1981 – 2000 (see Appendix A). This is the most pessimistic model adopted by the UK Met Office and UK Climate Projections (UKCP18)6.

1 Introduction

1.1 Workstream Overview

The Technology Workstream of Project Zero examines how water reuse systems and water-efficient technologies can support the delivery of water-neutral developments. This workstream focuses on two primary areas:

- **Water Reuse Systems:** Assessing the operational factors and potential impacts of communal water reuse systems on new developments.
- **Emerging Water-Efficient Technologies:** Exploring innovative fixtures, fittings and appliances that can significantly reduce water demand.

This report presents the findings of these investigations, providing evidence-based insights to inform Project Zero's *Water Neutrality Blueprint* and guide future regulatory and policy development.

1.2 Drivers for Water Neutral Developments

Water stress is increasingly affecting many regions of the UK, with some areas now classified as experiencing serious water stress. This trend is driven by population growth, climate change, and environmental pressures, which place greater demands on available water resources. The Environment Agency projects that, without decisive intervention, England could face a daily water supply deficit of up to five billion litres by 2050 (Environment Agency, 2024). This stark forecast underscores the urgent need for coordinated action to reduce demand and enhance supply resilience.

In response, some local authorities have introduced planning requirements that exceed Building Regulations for water use. For example, developments in Cambridge are required to meet a target of 80 litres per person per day (l/p/d). The Government's target of 1.5 million new homes by August 2029 further intensifies the need for sustainable water management solutions. Meeting this challenge will depend on the widespread adoption of technical innovations that reduce potable water demand and support the transition to water-neutral growth.

1.3 Water Neutrality

Water neutrality is achieved when the total demand for water arising from a new development is balanced so that there is no net increase in overall water consumption within the local supply area. In practice, this means ensuring that development does not adversely affect the availability, quality, or resilience of local water resources. The approach supports sustainable water management by aligning new housing growth with long-term conservation objectives and regional resource planning.

Achieving water neutrality in new housing developments is typically guided by three core principles:

1. **Reduce:** Promote efficient water use through the adoption of high-efficiency fixtures, fittings, and appliances, supported by behavioural change initiatives, smart metering, and real-time water consumption feedback to encourage responsible usage.
2. **Reuse:** Incorporate systems such as rainwater/stormwater harvesting and greywater recycling to reduce reliance on mains water.
3. **Offset:** Compensate for any residual demand by implementing measures that reduce water use within the local supply area or through investment in conservation initiatives.

Within the Technology Workstream, the focus is on the first two principles; reducing demand through innovative technologies and reusing water through operational systems, providing tangible evidence on their feasibility and impact in new housing developments.

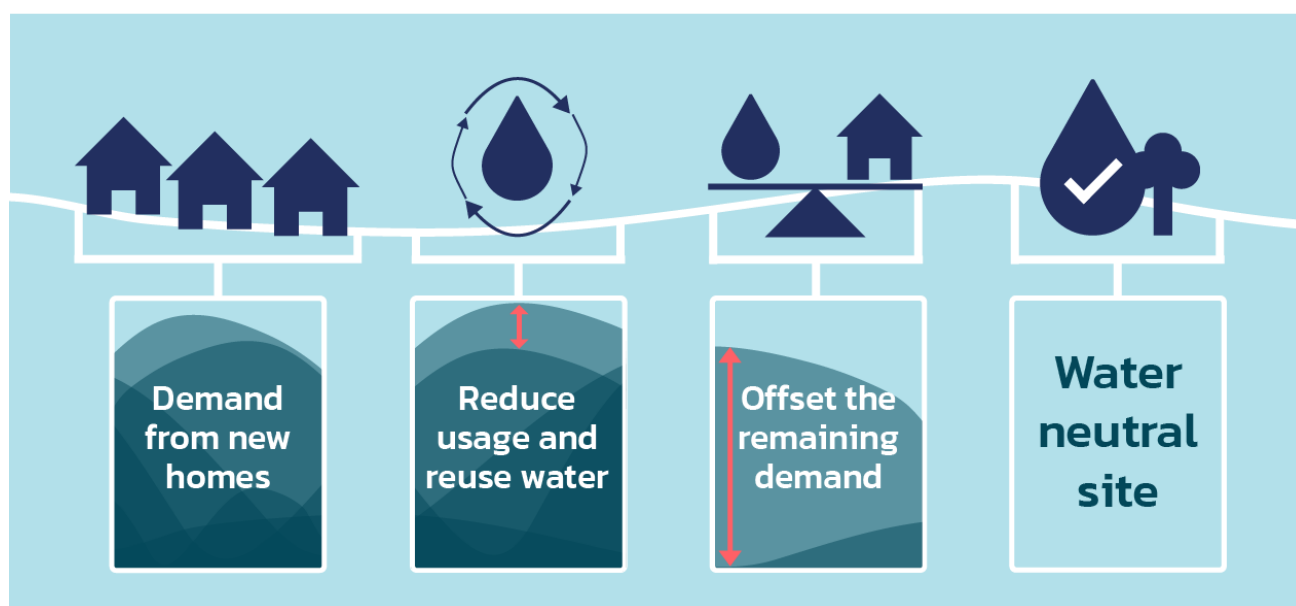


Image 1.1 Project Zero – Achieving Water Neutrality

1.4 Water Reuse

Water reuse involves capturing, treating (where necessary), and applying alternative water sources for non-potable uses such as toilet flushing, irrigation, and laundry. It encompasses:

- Rainwater/stormwater harvesting
- Greywater recycling from baths, showers, and wash basins
- Blackwater (sewage) recycling systems

While operational large-scale water reuse remains limited in the UK, early examples demonstrate its potential. For instance, the Clay Farm development in Cambridge, delivered by Aquality, has successfully operated a communal water reuse system for over five years.

Water reuse is a key contributor to Water Neutrality, offering opportunities to significantly reduce potable water demand and support sustainable development. However, its adoption is influenced by technical feasibility, regulatory compliance, and integration with wider water efficiency measures, all of which are explored in this report. □

1.5 Regulatory Context

1.5.1 Building Regulations

The Building Regulations 2010 (*Part G*), establish statutory requirements for water efficiency in new dwellings based on the water calculator approach. These are defined as follows:

- **Standard Requirement:** Maximum consumption of **125 litres per person per day (lpd)**.
- **Optional Requirement:** Reduced limit of **110 litres per person per day (lpd)**.

The optional requirement applies only when a condition specifying that a dwelling must meet the requirement is imposed as part of the planning permission process.

It is important to note that the Building Regulations reference water reuse under the term 'Alternative Sources of Water'. While there is currently no mandatory requirement for their installation through the regulations, where such systems are installed, their contribution is taken into account within the overall litres per person per day (l/p/d) calculation (Building Regulations, 2015).

1.5.2 Calculation Approach

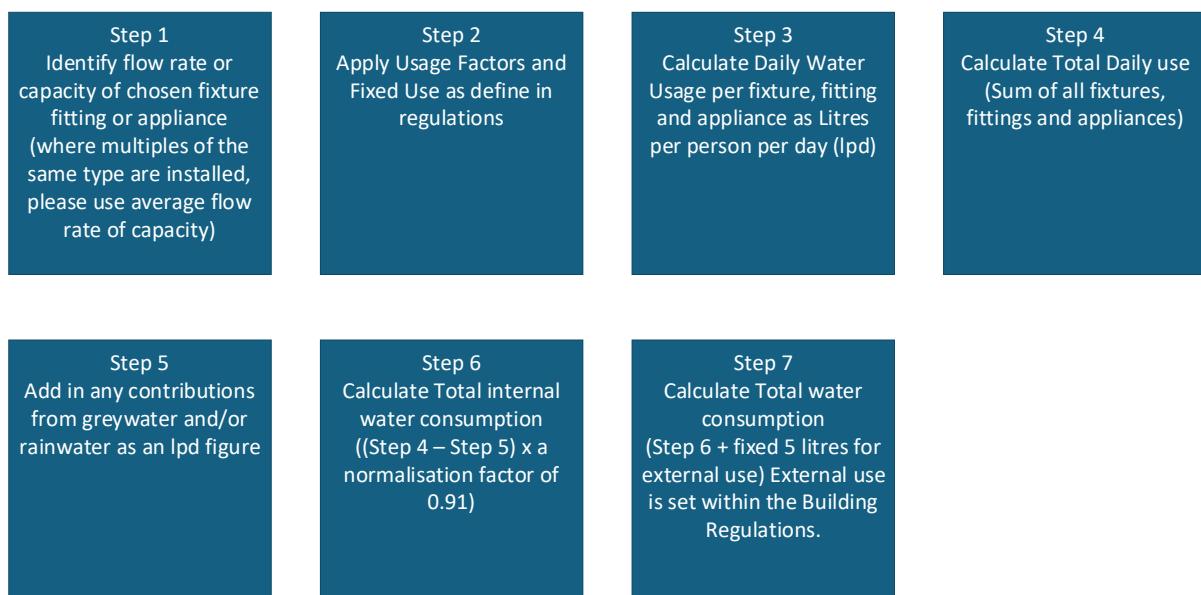


Figure 1.1 Building Regulations Calculation Approach

Installation Type	Unit of Measure	Capacity/Flow rate	Use Factor	Fixed use (l/p/d)	Litres/person/day
WC (single flush)	Flush Volume (litres)		4.42	0	0
WC (dual flush)	Full flush Volume (litres)	6	1.46	0	8.76
	Part flush Volume (litres)	4	2.96	0	11.84
Taps (excluding kitchen/utility room taps)	Flow rate (litres/min)	6	1.58	1.58	11.06
Bath (where shower also present)	Capacity to overflow(litres)	185	0.11	0	20.35
Shower (where bath also present)	Flow Rate(litres / minute)	10	4.37	0	43.7
Bath Only	Capacity to overflow(litres)		0.5	0	0
Shower Only	Flow Rate (litres/minute)		5.6	0	0
Kitchen/Utility room sink taps	Flow rate (litres/minute)	8	0.44	10.36	13.88
Washing Machine	(Litres/kg dry load)	8.17	2.1	0	17.157
Dishwasher	(Litres/place setting)	1.25	3.6	0	4.5
Waste disposal unit	(Litres/use)		3.08	0	0
Water Softener	(Litres/person/day)		1	0	0
Total Calculated use (litres/person/day)					131.25
Contribution from greywater (litres/person/day)					0
Contribution from rainwater (litres/person/day)					0
Normalisation factor					0.91
Total internal water consumption (litres/person/day)					119.43
External water use					5
Total water consumption (Building Regulation 17.K)					124

Table 1.1 Example of a calculation for a property to the Standard Requirement – 125 l/p/d

This table presents the outputs from the Building Regulations calculation approach for a property built to the standard requirement of 125 l/p/d uses the baseline where no washing machine or dishwasher is provided. An assumed figure through the Regulations is then given of 8.17 litres for washing machines and 1.25 litres for dishwashers.

1.5.3 Water Regulations

The regulatory landscape governing water use in England is defined primarily by the Water Industry Act 1991, the Water Supply (Water Quality) Regulations 2018, the Water Supply (Water Fittings) Regulations 1999 and the Private Water Supplies (England) Regulations 2016. These frameworks set the duties and regulations that are designed to safeguard public health and ensure the provision of wholesome (potable) water.

1.5.4 Water Industry Act 1991

1.5.4.1 Sections 67 & 68 – Wholesomeness and Duties of Water Undertakers

These sections of the Act impose a statutory duty on water undertakers to ensure that all water supplied for domestic purposes is wholesome. These sections require undertakers to maintain strict water quality standards and safeguard supply integrity.

1.5.4.2 Section 218 – Definition and Scope

Under Section 218, water supplied for *domestic purposes* is defined to include drinking, washing, cooking, sanitary use, and limited outdoor activities connected to household occupation.

1.5.5 Water Supply (Water Quality) Regulations 2018

1.5.5.1 Regulation 4 (Wholesomeness)

The Water Supply (Water Quality) Regulations 2018 define the standards for water considered “wholesome.” Regulation 4 establishes chemical, microbiological, and aesthetic parameters that must be met for water to be deemed safe for human consumption.

1.5.6 Private Water Supplies (England) Regulations 2016

These regulations provide the definition of “private water supply” and the requirements for water quality. It states that a private water supply is any supply of water not provided by the water undertaker and includes all physical assets from the point of abstraction to the point of use. The regulations also define wholesomeness and the conditions that must be met for water that is intended for human consumption.

1.6 Purpose of the Report

This report summarises the objectives, findings, and implications of Phase 2, the technology-focused workstream within Project Zero. It captures the workstream's contribution to testing and advancing the feasibility of water reuse systems within new housing developments, providing valuable evidence for the wider water sector.

The report draws on activity delivered by Project Zero and project partners SDS Water Group, Albion Water, and AQUALITY. The report is written in collaboration with the Water Research Centre (WRC). Together, this partnership has generated insights into how non-potable water reuse systems and water-efficient technologies could support the delivery of water-neutral developments in the UK.

Specifically, this document will:

- Present the objectives, outcomes, and lessons learned from Phase 2.
- Set out the regulatory, technical, and practical challenges encountered.
- Position Phase 2 within the wider Project Zero programme and Ofwat's Innovation Fund themes, including collaboration across the sector, resilience and future planning, and improving water efficiency.
- Highlight implications for policy engagement, innovation, and future research to advance water neutrality.

2 Phase 2 – Overview & Objectives

2.1 Site Overview

The Oaklands Hamlet development in Chigwell was delivered as a joint venture by Countryside Properties (now part of the Vistry Group) and L&Q between 2016 & 2023. The site comprises 425 properties with a mix of houses and flats.

The site is supplied by Albion Water, which operates as a New Appointment and Variation (NAV) under the regulatory framework established by Ofwat. A NAV replaces the incumbent company as the regulated water undertaker for the appointed area, providing services in full compliance with the Water Industry Act 1991 and associated regulations (Ofwat, 2025). At Oaklands Hamlet, Albion Water provides both potable water and wastewater services under its NAV appointment.

The development incorporates a dual-pipe water distribution network installed during construction. This infrastructure was purposefully designed to accommodate the supply of both potable and non-potable water through a communal water reuse system. However, while the dual network is fully operational and capable of serving both supplies, the non-potable source has not yet been installed. As a result, the system currently operates using potable water across both networks but remains ready for future installation of a non-potable source.

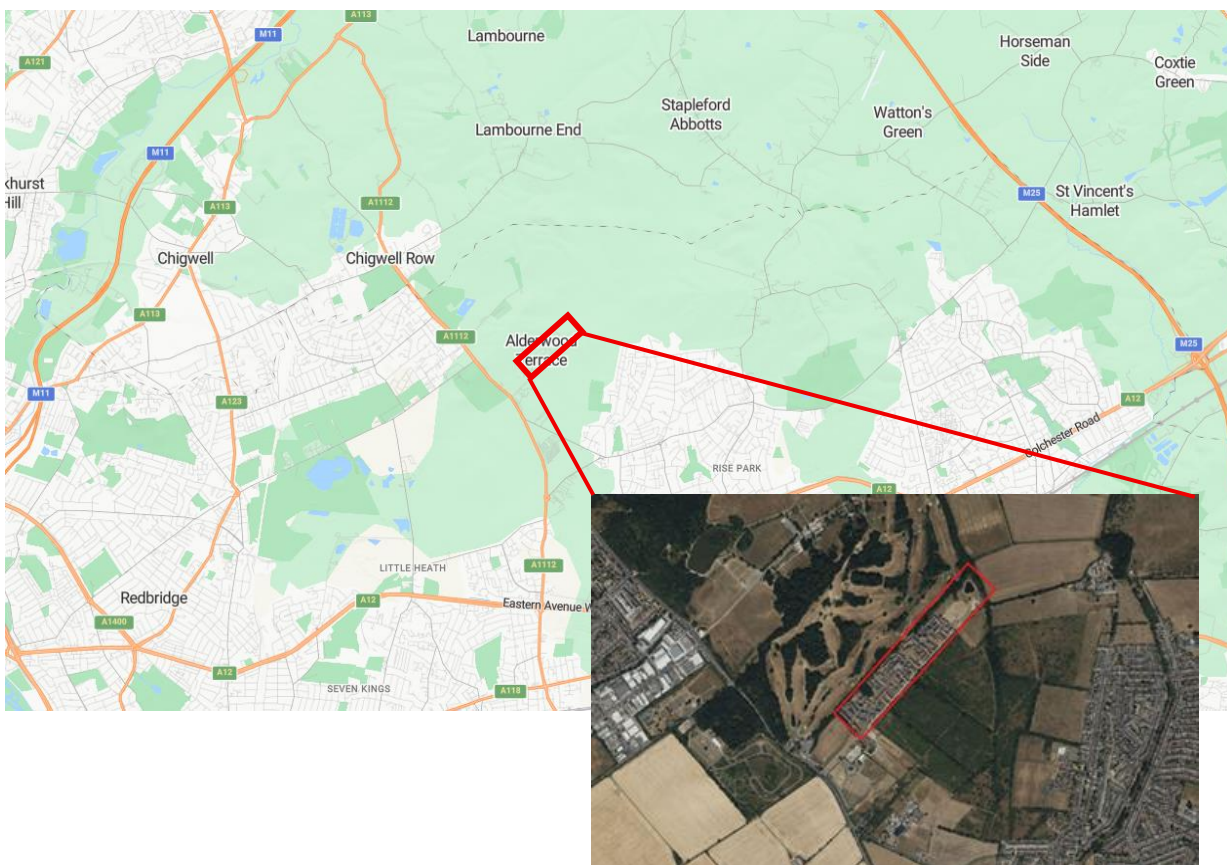


Image 2.1 Location of Oaklands Hamlet. Source: Bing Maps, 2025.

2.2 Initial Objectives

Phase 2 is the technology demonstration workstream within *Project Zero*. Its primary objective was to design and deliver a fully operational communal water reuse system within a new residential development, supporting the overarching aim of achieving water neutrality.

At project inception, the regulatory framework was understood to allow for the design and development of a communal non-potable water reuse system, provided that any non-potable supply would be managed in accordance with relevant water quality and consumer protection standards. On this basis, the initial objectives centred on physical delivery of the source for Oaklands Hamlet, with a focus on:

- **System design and installation** – developing an operational model for the delivery of a communal non-potable network suitable for integration into a new development.
- **Performance and monitoring** – establishing an evidence base for system efficiency, water quality, and customer reliability.
- **Customer engagement** – building acceptance and understanding of water reuse within new housing developments.

2.3 Legal & Regulatory Position

As the workstream progressed and detailed design discussions advanced, it became clear that existing legislative and regulatory frameworks presented significant barriers to implementation in relation to new housing developments. In particular, the Water Industry Act 1991, the Water Supply (Water Quality) Regulations 2018, and guidance from the Drinking Water Inspectorate (DWI) collectively prevent water undertakers from the operation of water reuse systems supplying non-potable water for domestic purposes in new residential developments.

Under these frameworks:

- The statutory undertaker (in this case, Albion Water) is required to ensure that any water supplied for domestic purposes meets prescribed standards of wholesomeness as defined in Sections 67 & 68 of the Water Industry Act 1991.
- “Domestic purposes,” as defined in Section 218 of the Water Industry Act 1991, includes uses such as drinking, cooking, washing, and sanitation, thereby encompassing all typical household water use.
- Regulation 4 within the Water Supply (Water Quality) Regulations 2018 defines the standard for “wholesome”. A standard that non-potable sources such as rainwater or treated greywater typically wouldn’t meet without extensive treatment.

The DWI clarified this position in communication to Albion Water, confirming that any water supplied through a dual-pipe network for domestic purpose must meet prescribed standards of wholesomeness. This interpretation prohibits water company operation of a communal non-potable dual-supply systems for domestic dwellings. This regulatory position meant that, although the physical infrastructure for a dual-supply system existed, implementation and operation of a non-potable source at Oaklands Hamlet were not permissible.

2.4 Final Objectives

In response, the workstream shifted its focus from practical delivery to an evidence-based assessment, primarily delivered through a detailed desktop study, which WRC were commissioned to deliver. The revised objectives therefore evolved to focus on evaluating the performance and potential of water reuse systems through the following areas of investigation:

- **Performance Evaluation:** Assessing the dual network using meter readings from both potable and non-potable meters at an individual property level to:
 - Quantify potential water savings and identify how reuse could reduce potable demand under different operating scenarios.
 - Model system performance under variable conditions, including historic and future climate scenarios.
 - Explore customer acceptance, drawing on evidence from previous trials and research to understand behavioural considerations.

In addition to the desktop study, the workstream also sought to:

- Review high-efficiency fixtures and fittings, that could enhance the overall effectiveness and viability of water reuse systems in future applications.

2.5 Success Criteria and Stakeholder Benefits

The workstream aimed to define clear measures of success that reflected its revised scope and objectives within the constraints of the existing regulatory environment. Although on-site installation of the non-potable source was not possible, the project sought to demonstrate how an evidence-based approach could still generate meaningful data and insights to inform future Project Zero delivery and support potential policy reform.

The primary **aims for success** were to:

- Establish a robust analytical foundation through the WRC-led assessment, capable of quantifying the potential for water reuse systems to reduce potable water demand under typical household conditions.
- Build a credible evidence base to inform future engagement with regulators, developers, and policymakers, supporting discussions on how legislative and technical barriers might be addressed.
- Strengthen collaboration between key stakeholders to ensure that future projects could draw on shared expertise and lessons learned from Phase 2.
- Identify opportunities, such as advanced fixtures and fittings, that could enhance water-efficiency performance in future developments.

Success was therefore defined by the project's ability to generate data, insights, and partnerships that would inform and enable subsequent phases of Project Zero and contribute to the longer-term goal of achieving water neutrality at scale.

The anticipated **benefits for stakeholders** were:

- **Water companies** would gain evidence to support innovation and future trials under revised regulatory frameworks.
- **Developers** would understand potential pathways to enhanced water efficiency performance within evolving planning requirements.
- **Regulators and policymakers** would have access to objective, data-driven evidence to inform consultation and policy development.

3 Technology Options

This section outlines the principal technology options considered within the Technology Workstream of Project Zero. It establishes the technical basis for subsequent analysis by identifying systems and products capable of reducing potable water demand and contributing to water neutrality in new housing developments. Detailed performance assessment and quantitative evaluation are presented later in Sections 7 and 8.

The technologies reviewed include:

- **Water Reuse Systems**, specifically:
 - Greywater Recycling
 - Rainwater Harvesting
 - Stormwater Harvesting

(Note: Blackwater reuse systems are excluded from this report as they fall outside the current scope of Project Zero.)

- **Fixtures, Fittings, and Appliances** that enhance water efficiency at the household level.

These options were selected based on their capacity to deliver measurable reductions in mains water demand, their relevance to large-scale residential development, and their alignment with current regulatory and industry practice.

3.1 Water Reuse

Water reuse offers a significant opportunity to reduce reliance on potable supplies by capturing, treating, and reusing water for non-potable applications. Three system typologies were examined.

Option 1: Greywater recycling

Greywater recycling involves the collection and treatment of “light greywater,” as defined in BS EN 16941-2, which includes wastewater from showers and wash hand basins but excludes flows from WCs, urinals, kitchens, and clothes washers.

Greywater is collected via dedicated drainage pipework separate from foul water systems. The water flows by gravity to a treatment unit where it undergoes filtration, biological treatment, and disinfection before being stored for reuse. Treated greywater is then distributed through a separate non-potable network.

Treated greywater can be used for a range of non-potable purposes including toilet flushing, laundry, and garden irrigation.

Example technology:

Hydraloop, a Project Zero partner, provides compact and modular greywater recycling systems suitable for single-family homes, multi-residential developments, and commercial buildings. Their systems integrate filtration, biological treatment, and disinfection within self-contained units, offering a low-maintenance and scalable solution.

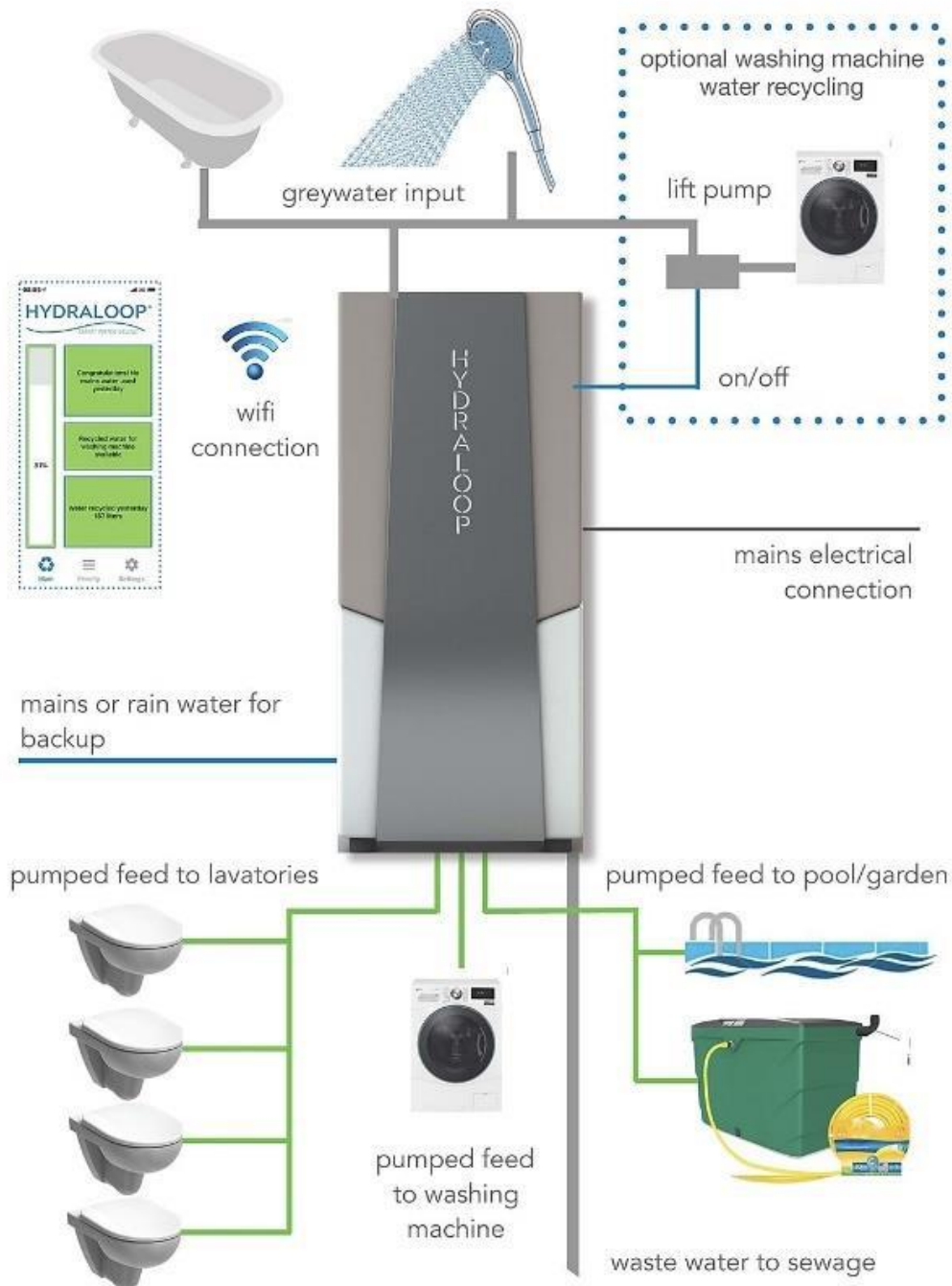


Image 3.1 Hydraloop System. Source: Freeflush Water Management Ltd, 2025.

3.1.1 Option 2: Rainwater harvesting

Rainwater harvesting involves the collection of rainwater from roof surfaces for reuse. Within this study, the scope is limited to roof runoff (excluding surface water from hardstanding areas, which is covered under stormwater harvesting).

Rainwater is collected from roofs, filtered, and stored, typically in underground tanks. The stored water is pumped through a dedicated distribution network to supply non-potable applications. Systems may be designed for individual dwellings or communal developments, depending on available roof area and demand profiles.

Rainwater is commonly reused for toilet flushing, washing machines, and garden irrigation.



Image 3.2 Courtesy of Aquality – Underground Rainwater Storage tank. Source: GRAF, 2025.

3.1.2 Option 3: Stormwater harvesting

Stormwater harvesting extends the principles of rainwater harvesting by capturing runoff from both roof and hardstanding surfaces (e.g., roads, driveways, courtyards). As these surfaces collect higher levels of pollutants, stormwater requires additional treatment prior to reuse.

Stormwater is collected and directed to a pond or underground attenuation tank for initial settlement and storage. The water is then typically treated through a multi-stage process incorporating bioretention, filtration, and disinfection. Treatment can be integrated within Sustainable Drainage Systems (SuDS), as outlined in CIRIA SuDS Manual C753, Chapter 26, whereby certain natural features will achieve a water quality that would be considered sufficient for reuse. The treated water is transferred to a break tank with a Type AA air gap for mains backup, ensuring supply continuity during dry periods. Distribution is achieved through a booster pump set to deliver water to end uses.

Stormwater systems can be configured as:

- **Passive systems**, which include additional storage within existing attenuation infrastructure, or
- **Active systems**, which use weather data and remote controls to dynamically manage storage capacity between attenuation and reuse functions.



Image 3.3 Courtesy of Aquality – Clay Farm plant room

Example:

Aquality, a Project Zero partner, has delivered numerous rainwater harvesting systems across the UK, including at **Clay Farm, Cambridge**, explored in the following case study.

3.2 Water Reuse Operational Example - Clay Farm

Cambridge City Council 'Clay Farms' project is a development with 208 homes and commercial accommodation. The residential accommodation is arranged in a grid of quads surrounding a park at the heart of the site. Each quad consists of 23 homes ranging from one to three-bedroom apartments and family houses. Each home has a private patio garden. In the heart of each quad is a moat that can store and attenuate rainwater (Aquality, 2018).

Delivered to Code for Sustainable Homes (CfSH) standard, Aquality worked with a multinational infrastructure consulting firm to deliver a strategy for this project, to come up with a water-efficient solution to this unique layout. As the design asked for CfSH level 5, the water consumption had to

be reduced to 80 litres per person per day – well below the current Building Regulations standards (Aquality,2013)

A key regulatory distinction enabling this scheme is that the non-potable water network is privately managed and not supplied by a licensed water company. As such, the system falls under the Private Water Supplies (England) Regulations 2016, rather than the Water Industry Act or public supply obligations. This regulatory route has allowed the development to implement an integrated water reuse system without contravening Building Regulations provisions relating to potable water quality and supply.

Working together, they devised a centralised stormwater harvesting system. The design allows for capturing, not only the roof rainwater, but also the surface water from the hard standing and roads.



Image 3.4 Clay Farm. Source: Aquality, 2018.

The stormwater is pre-treated in a reed bed before it enters a 240m³ in-situ concrete tank. From there the water is pumped into a small holding tank installed in a central plant room. The water is then transferred into a break tank, which also includes an emergency mains water top-up. A triple booster pump set then pumps the water to all WCs in the development through a dedicated non-potable water pipe network.

The stormwater harvesting is fully remote controlled including pressure measurements, water quality monitoring and fault reporting allowing remote diagnostics and maintenance on demand.

The development saves between 4,000 and 5,000m³ of water per year, around a 20% reduction on potable water demand through WCs only.

3.3 Fixtures, Fittings, and Appliances

In addition to water reuse systems, potable water demand in new residential developments can be reduced through the specification of efficient household fixtures, fittings, and appliances. These technologies operate at the point of use and influence baseline household demand irrespective of whether reuse systems are installed.

Within the scope of Project Zero, fixtures, fittings, and appliances are considered as complementary measures that can be deployed alongside reuse systems or independently where reuse is constrained by regulatory, technical, or cost considerations. Their role within the Technology Workstream is therefore to provide practical demand-reduction options that are compatible with current housing delivery models.

Detailed performance assessment of selected household technologies is presented in Section 8. This includes showers, toilets (WCs), and washing machines, which together represent a substantial proportion of domestic water use and offer the most immediate opportunities for efficiency improvement at scale.

3.4 Delivery and Incentivisation

While the legislative and regulatory frameworks relevant to water reuse, outlined in Sections 1.4 and 2.3, currently restrict licensed water companies from operating dual-supply systems for domestic purposes, alternative delivery models do exist. The Clay Farm development in Cambridge demonstrates that privately owned and privately managed communal systems can operate successfully under the Private Water Supplies (England) Regulations 2016. However, these privately operated systems raise important questions regarding long-term ownership, operational and maintenance responsibilities, regulatory oversight, and consumer protection. Further research is therefore required to evaluate the governance, financial, and regulatory implications of such models and their wider applicability. A more readily deployable and permissible pathway, which avoids many of the compliance and operational complexities associated with privately managed communal systems, is the installation of individual-property rainwater and greywater systems. These decentralised systems can be delivered within the current regulatory environment and offer an accessible means of reducing potable demand when combined with high-efficiency fixtures, fittings, and appliances.

Evidence indicates, however, that these technologies typically incur higher capital and installation costs compared with standard fixtures and fittings that meet minimum Building Regulations requirements (Waterwise, 2020; EWSC, 2024). Ricardo published the '*Independent review of the costs and benefits of rainwater harvesting and grey water recycling option in the UK*' reports that typical domestic rainwater harvesting system costs of £2,500–£6,000 and greywater recycling systems cost range between £900–£3,000 depending on tank size and configuration (Ricardo, 2020). A further report published by Enabling Water Smart Communities '*Water Reuse in New Housing: Understanding the Business Case*' found similar capital costs for domestic rainwater harvesting systems with costs between £1,700–£6,000 dependent on property size, however costs associated with greywater recycling were slightly higher with an average of £3,550, irrespective of size of property (Enabling Water Smart Communities, 2024). National House Builders Council (NHBC)

also notes that certain high-efficiency fixtures and fittings can carry modest price premiums compared with standard products, based on evidence summarised in the 'Water Efficiency in New Homes: An introductory guide for housebuilders' (NHBC, 2010).

To address this cost gap and encourage greater adoption of water-efficient technologies, Ofwat introduced the Environmental Incentives Common Framework (EICF), effective from 1 April 2025. The Framework aims to encourage developers to build more water-efficient new homes through the provision of financial incentives. Under this framework, all English water companies are required to offer at least one Environmental Incentive based on a common methodology, with a particular focus on fixtures and fittings that exceed building regulation standards (Ofwat, 2024).

The framework provides opportunities for water companies to adopt bespoke incentives over the mandatory incentive. Payment linked to these incentives vary between water companies and the measures they have chosen to adopt, with some only offering the mandatory incentive whilst others providing tiered programmes through bespoke offerings.

Payments range per incentive:

- **Mandatory Incentive: £71 – 600 per property**
- **Enhanced Water Efficiency Incentive: £142 - £2163 per property**
- **Water Reuse: £154 to £2,500 per property**
- **Water Neutrality: £664 to £3,200 per property**

These mechanisms help reduce the cost gap associated with advanced water-efficiency technologies and, in doing so, support more ambitious design choices. By providing structured, property-level financial incentives, the EICF improves the commercial viability of developments that exceed minimum regulatory requirements and contributes to making water-neutrality more deliverable.

4 Methodology

4.1 Introduction

This section presents the integrated methodological designed to assess potable water reduction through demand-side (reduce) and supply-side (reuse) strategies. The approach combines two strands of evidence: a desktop study evaluating system-level performance of water reuse, and a technology review examining household-scale water efficiency innovations. Presenting these methods together reflects the core principle of water neutrality, which is to prioritise demand reduction before implementing water reuse, and demonstrates how both strands were applied in parallel to generate a robust understanding of potential potable water savings.

4.2 Integrated Framework for Water Neutrality

The workstream employed a mixed-methods approach that integrated quantitative modelling with evidence synthesis to capture system-level reuse performance alongside household-level efficiency opportunities.

The Desktop Study applied a structured, analytical modelling approach to simulate non-potable water demand using metered consumption data from 425 dwellings. The modelling focused on water balance and demand-led reuse performance, enabling assessment of system behaviour across a defined range of scenarios. Metered data was used to inform representative demand profiles and key assumptions underpinning the simulations rather than as a direct time-series driver.

All input datasets, assumptions and model parameters were clearly defined and documented to support transparency and traceability, with a comprehensive list provided in Appendices B - D. Results were reviewed against published benchmarks and comparable studies to confirm the robustness and internal consistency of the findings.

In parallel, a focused assessment of fixtures, fittings, and appliances examined the scale of efficiency gains that could be achieved within current housing delivery models. Rather than undertaking an exhaustive product survey, this assessment used representative examples of innovative or emerging technologies to illustrate the upper bounds of achievable performance. Product performance was evaluated using the Building Regulations Part G water efficiency calculation methodology, ensuring consistency with recognised national standards regardless of variation in available empirical data.

For several technologies, the volume of independently verified, peer-reviewed performance data remains limited. Nevertheless, manufacturer technical documentation, industry case studies, and published test results represent the most robust evidence currently available in the public domain. These sources are collated in Appendix F to support transparency and enable scrutiny of the assumptions and parameters underpinning the analysis.

Engaging WRc ensured access to a validated analytical framework and a robust evidence base, providing assurance of methodological rigour, data quality, and comparability with wider industry benchmarks. The technology review complemented this by exploring emerging efficiency

innovations not captured in existing consumption datasets. Together, these two strands form a coherent framework for assessing interactions between demand reduction and supply-side reuse.

While this approach provides a robust integrated framework, certain analytical constraints influence interpretation of results. These primarily relate to the availability and granularity of metered data, the absence of a suitable baseline, and assumptions required for occupancy and demand estimation. These considerations do not undermine the validity of the approach but provide essential context for interpreting findings. A detailed discussion of data-specific limitations and modelling assumptions is presented in Appendix D.

The technology review draws on manufacturer-reported performance values, which may differ from observed performance in real-world settings. Although these align with the assumptions and calculation methods outlined in the Building Regulations calculation model, variance may occur under operational conditions. These limitations are acknowledged but do not compromise the assessment of relative efficiency potential or the comparative evaluation of household-scale technologies.

The two strands remained independent, with the technology review providing evidence on household-scale efficiency that informed the interpretation of system-level reuse performance without directly influencing the WRc modelling outputs.

By integrating WRc's established modelling with analysis on high efficiency fixtures and fitting, the methodology provides a coherent framework for assessing "reduce and reuse" interactions at the development scale, that is, how efficiency measures and reuse systems influence one another when applied collectively across a whole development, affecting total demand, reuse yields, and system sizing. The model ensures transparency in assumptions, consistency in data handling, and comparability between system-level and household-level interventions.

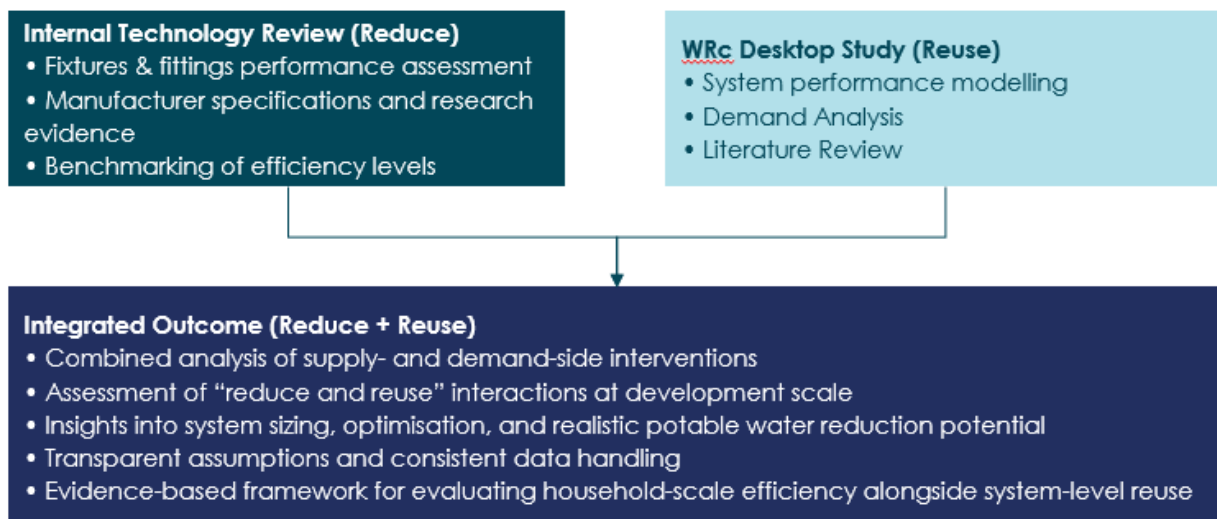


Figure 4.1 Overview of methodology

5 Water Reuse Desktop Study - Approach

5.1 Overview

This study examined the potential role of communal water reuse in new residential developments through a desktop-based assessment of stormwater harvesting within a dual-supply configuration. The assessment focused on understanding how non-potable supply could reduce potable water demand, drawing on real-world consumption data and hydrological modelling.

5.2 Aims and Objectives

The study aimed to:

- Quantify the scale of potential potable water savings achievable through the provision of a non-potable water supply.
- Examine usage patterns and behavioural considerations associated with a dual-supply network.
- Assess the theoretical performance of a stormwater harvesting system within a dual-supply configuration using real-world rainfall and household consumption data.
- Consider the broader implications for future policy, regulation, and delivery models.

These aims were addressed through two exploratory analytical phases, supported by a targeted literature review.

5.2.1 Phase 1 – Demand Analysis

This phase assessed household demand, seasonal usage and potential water savings of the dual supply system. The objectives of this phase were to:

- Quantify the potential potable demand reduction due to the availability of a non-potable supply.
- Calculate the proportion of total household demand met by the non-potable supply.
- Assess seasonal trends in non-potable usage and efficiency.
- Compare behaviour and total water use between property types.
- Investigate long-term trends and any potential 'rebound' effects whereby apparent changes are short-term.

5.2.2 Phase 2 – Systems Performance Analysis

The second phase assessed the theoretical performance of a non-potable supply system and performance through modelling of the system. The objectives of this phase were to:

- Model rainwater capture and use based on a 720m³ storage tank with a 40m³ day tank.
- Estimate number of days per year where potable top-up would be required.
- Calculate theoretical volume of potable top-up required.
- Examine seasonal variation in performance and storage sufficiency.

5.3 Methodology

The study applied a defined set of analytical methods to address the objectives set out above. These methods were applied across both analytical phases and are summarised in Figure 5.1. Full details on the Demand Analysis and Systems Performance Analysis can be found in Appendix B & C respectively.

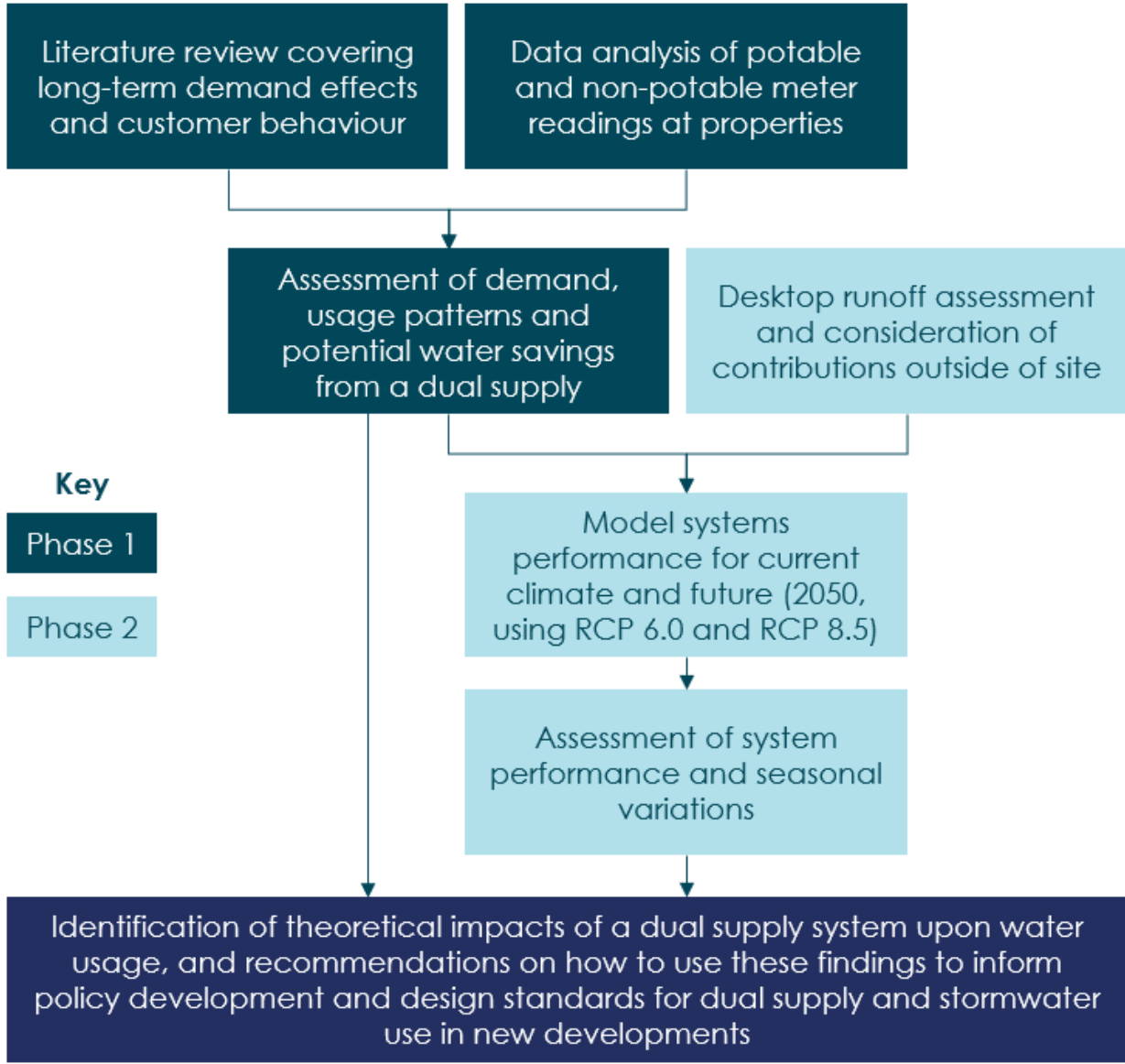


Figure 5.1 Two phase methodological framework

5.3.1 Literature Review

WRc conducted a literature review with the objective of gathering evidence regarding patterns of water usage and occupant behaviour in dual-system environments, as well as the possible rebound effect associated with the implementation of a dual water system. The methodology of the literature review phase is presented in Figure 5.2.

Full details of the approach taken for the literature review can be found in appendix E.

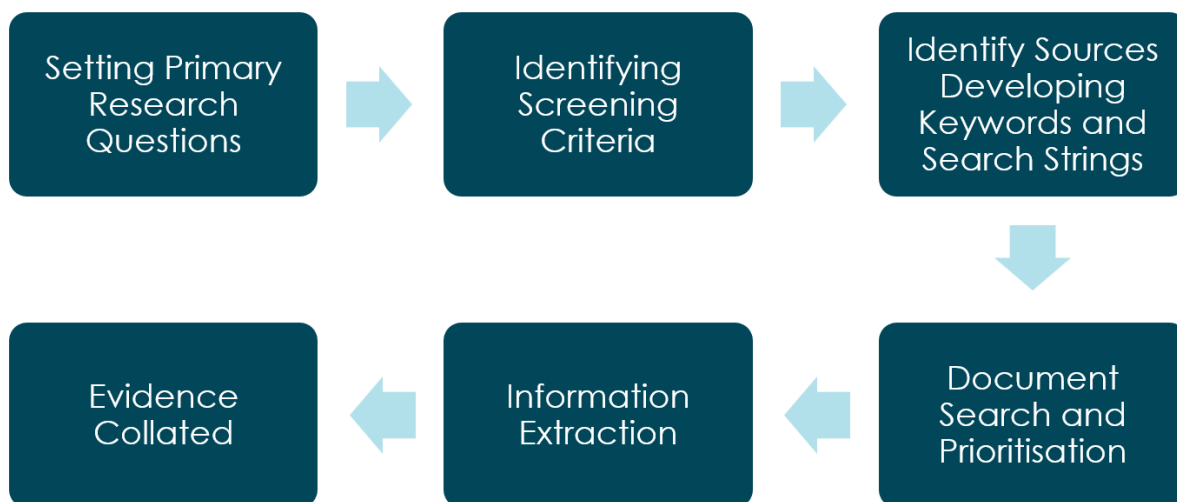


Figure 5.2 Methodology of Literature Review

5.4 Analytical Scope and Key Assumptions

The desktop study was undertaken using measured household consumption data and theoretical system modelling. Key assumptions informing the analysis include:

- Meter readings were collected at irregular intervals, limiting temporal resolution.
- No pre-occupation baseline or comparable single-supply control site was available.
- Household occupancy was estimated using bedroom count as a proxy.
- Non-potable system performance was assessed through modelling rather than live operation.

These assumptions define the scope and interpretation of the results presented in Section 7. Full details are provided in Appendix D.

6 Water Reuse Desktop Study, Literature Review

6.1 Overview

Beyond the site-specific analysis at Oaklands Hamlet, the desktop study incorporated a comprehensive review of existing literature, case studies, and international experience on water reuse and dual-supply systems. The purpose of this review was to place the site findings within a broader evidence base and to identify transferable lessons relevant to future policy development, system design, and customer engagement for water reuse and water neutrality schemes.

The literature review identified 20 documents that were relevant to the primary research questions, six of which were classed as of high relevance, eight of medium relevance and six of low relevance. A total of 10 documents were identified through Science Direct, five through Google Scholar, one document was identified through the WRc archive, and four documents were identified through an online search using Google.

Information was extracted from all high-relevance documents. Following this, an assessment was conducted to determine whether any information gaps could be filled using the medium and low relevance documents. Then, all medium-relevance documents and one low-priority document were reviewed to extract the information for the evidence database. This totalled 15 pieces of literature reviewed as part of this study.

6.2 Potential for potable water use reductions

Global case studies were identified, which demonstrated that non-potable supply systems supplied by RWH and greywater recycling (GWR) systems can deliver significant potable water savings across residential and non-residential settings as a result of changing water users' behaviour (Lees, et al., 2025). The case studies presented below provide evidence of how dual supplies may reduce potable water demand:

- Arnimplatz (Germany) saved 304m³/d of potable water across 41 flats (between 73 and 97 litres/day/property saving) using greywater reuse (no RWH) (Lees, et al., 2025).
- The Premier Inn (Doncaster and Tamworth) in the UK has managed 50% water savings from reusing bath and shower water (Lees, et al., 2025).
- Case studies for RWH systems, such as the Exploratorium in San Francisco (USA), showed a potential 30% reduction in potable demand based on an average rainfall year (Lees, et al., 2025).
- In Nye, Aarhus (Denmark), savings of 40% were seen from using stormwater and RWH for toilet flushing and laundry for 15,000 people (Lees, et al., 2025).
- Water reuse case studies from the Solaire Building, New York (USA) and Port Kembla (Australia) (Lees, et al., 2025) showed significant savings by the introduction of greywater recycling, enabling up to 75% reductions in their potable water use. The Solaire building in New York uses a membrane bioreactor and UV disinfection to treat more than 95 MI/d of wastewater, of which 34 MI/d is for toilet flushing, 43.5 MI/d is used as makeup water for the

building's cooling towers, and 22.7 Ml/d is for landscape irrigation. (Lees, et al., 2025) Scaling back to the toilet flushing volume only, this would correspond to a reduction of 27%.

- A case study conducted in the village of Bojuritsa (Bulgaria) with the population 951 people, living in 572 households found that household-level reuse of rainwater, light grey, grey and domestic wastewater in the households for toilet flushing led to a decrease in potable tap water use of "up to 60%" and a decrease of households' annual expenses for water supply of "up to" €93/household. The corresponds to potential savings of 29–35% of potable water from using GWR alone and 39–43% when combined with RWH. (Angelova, et al., 2024)
- An Australian National Water Commission study (Stewart, 2011) suggested that households with access to recycled water increased their overall demand, mainly through greater recycled water irrigation, while potable outdoor use remained only slightly lower than in potable-only schemes. This defied expectations with a very low level of potable supply; outdoor use being expected following the introduction of the recycled water supply. On average, the potable irrigation volume was found to be only 4 l/p/day lower than for the potable-only scheme. The increased total demand over the potable-only scheme is solely related to recycled water irrigation, as other end uses are similar or lower. Furthermore, this research offers some evidence suggesting that the dual-supply scheme may have led to an increased overall demand for toilets, likely because of differences in demand based on the user's perception of the source's intrinsic value (e.g. more likely to use the full flush more often for toilets supplied with recycled water). (Stewart, 2011).

Additionally, micro-component analysis could be used to infer what share of household demand could realistically be met by non-potable supplies. Bujnowicz et. al. (2012) indicate that toilet flushing and outdoor use¹¹, which are commonly targeted for GWR and RWH, account for 26–38% of household demand. Including dishwashing and laundry, which some argue are another possible candidate for non-potable water use, the percentage increases to 40–53% of household demand (Lees, et al., 2025). This implies that 26–53% of household demand could potentially be met by non-potable supplies, depending on its quality and regulatory restrictions.

Acknowledging international differences in water consumption patterns and efficiency, and the differences between water use in commercial properties like hotels and domestic households, these figures show good agreement with the case study evidence, suggesting that, at least in the short term, these case studies have managed to achieve the upper limit of potable water savings, which are likely to be achievable.

¹¹ Some outdoor use, for example filling of paddling pools, may be unsuitable for non-potable water. Research by Lees (2025) showed that was a strong opinion interviewed water companies and regulators felt that the risks posed by human behaviour cannot be controlled or managed, and so managing dual supply systems based on desired behaviours would be difficult. For example, having a label on an outside tap designating as non-potable would likely be used to fill paddling pools, whereby children have a heightened risk of ingesting the non-potable water. Risks of customer cross-connecting with the potable supply because they do not like the odour or colour of the non-potable water was also raised.

6.3 Public perceptions and behaviour

While studies have shown the potential for non-potable supply to reduce potable consumption, challenges may remain regarding public acceptance of using non-potable water. Burszta-Adamiak & Spychalski (2021) highlighted that a significant number of studies have confirmed the potential of RWH as an alternative source of potable water, referring to the functioning of these systems at a household scale. However, they claim that the lack of information on the potential benefits of RWH systems and their water savings efficiency has discouraged city dwellers and decision makers from adopting these systems. As such, barriers may include evidence of effectiveness and value for money in addition to those relating to public perception.

Studies show that customer behaviour and perceptions can undermine long-term system compliance, with issues such as unpleasant odours and cross-connections creating risks and reducing public acceptance (Jacque, et al., 2024). Other reasons for users' opposition include health risk perceptions and hygiene considerations about water quality and taste, although studies have noted public acceptance varies significantly depending on water end-use, local water availability, and level of knowledge about the technologies (Jacque, et al., 2024). For example, research conducted by WRc in 2015 found that 60% of respondents stated that they would not use recycled water for toilet flushing if it intermittently gave off a "swampy" smell (Lees, et al., 2025). As a result, were customers to have a choice of supply for their toilets, historical use of the "non-potable" supply in Oaklands Hamlet wouldn't necessarily be taken as representative of future use when potable water is replaced with harvested rainwater, which customers could perceive to be unpleasant, particularly if it has higher odour or colour than the potable supply. We understand the current arrangement does not provide customers with a choice, with toilets plumbed in only to the non-potable network. In this case, demand would be unlikely to change, but customer complaints and satisfaction could be impacted if they are unhappy with the odour.

Lees et. al. (2025) conducted a survey among stakeholders in terms of water users' behaviour when switching to a dual water supply system. The interview involved two UK water companies and one UK water regulator. The two blocks of questionnaire were prepared for water companies and the regulator separately, to gather insights on rainwater harvesting and greywater reuse for non-potable uses such as toilet flushing, outdoor taps, laundry, and dishwashing. Secondary aims included assessing water company and private operator perspectives on managing water reuse systems, determining views on the current British Standards for rainwater and greywater and consulting on whether a standard similar to high bathing water quality would be sufficient for certain water reuse systems (e.g. flushing toilets). All interviewees noted that customers expect their water to come from one source and be potable (Lees, et al., 2025), suggesting that customer messaging and terminology may be important to customer acceptance and uptake. For example, Albion Water's current terminology of drinking water and greenwater on customer bills doesn't explicitly make the customer aware that one source may not be potable should this terminology remain if the non-potable supply system ceases being fed by potable water.

Despite these concerns, studies in Australia have found that, in locations with recycled water availability, residents preferred potable taps for activities such as filling pools or for uses where recycled water was inconvenient (Stewart, 2011). Several case studies show that water users' behaviour can vary depending on factors such as building type, end-use targets, local climatic

and cultural conditions (Lee, et al., 2021). Alternatively, if reclaimed water is viewed as lower quality, households are likely to minimise its use relative to potable water, such as a reluctance to use it for irrigation (Lee, et al., 2021). Uptake of RWH and GWR systems illustrates this variability.

Broader city-scale conservation programmes, such as those in Cape Town (South Africa) (Jacque, et al., 2024), demonstrate combining education, pricing strategies, and technical interventions. In addition to promoting water reuse, the conservation programme in Cape Town also included education, a modified water tariff strategy and technical intervention such as plumbing repairs and leak detection. As a result of these combined measures, water demand growth reduced from more than 4% to 1.78%, despite population growth of 30% between 2001 and 2011, showing the extent of behavioural change that can be achieved when the public are on board (Jacque, et al., 2024).

Rupiper & Loge (2019) outlined that a general lack of knowledge of alternative water sources is often associated with a lack of knowledge about reuse potential as well as appropriate applications. Hence, water reuse has often been met with mixed public perception and concerns about health risks, particularly for indoor as opposed to outdoor use. However, despite the apprehensions voiced by some households about the safety of recycled water and their reluctance to adopt a dual water supply system, neither the literature review nor the case studies revealed significant public health issues in the USA associated with the distribution of reclaimed water. This does not mean that reclaimed water systems are free of water safety risks, but it suggests that well-managed systems can avoid public health problems (Rogers & Grigg, 2015). Further analyses are needed to understand the long-term infrastructure performance behaviour of dual systems versus the existing singular systems and on societal support for dual supply to households.

6.4 Drivers of non-potable household demand

A study of outdoor water in Cary, North Carolina (USA), shows that household behaviour is strongly influenced by perceptions, technology, and price. (Lee, et al., 2021). Households using reclaimed water tend to irrigate less than those using potable water, despite lower prices (reclaimed water was priced 40–70% lower) and fewer restrictions on use, possibly reflecting a perception of reclaimed water as an inferior substitute, in particular concerns over cleanliness and health (“yuck factor”). In contrast, in South East Queensland (Australia), residents were more willing to use recycled water for non-potable purposes, particularly when cost savings were evident, but acceptance dropped sharply for personal contact uses (e.g., drinking or showering). Public trust, risk perception, and prior water-use habits significantly influenced adoption, while factors like ethnicity, religion, or political affiliation were less relevant (James, et al., 2023).

Using household-level data in Cary, North Carolina (USA), including consumption behaviour, whether a household uses reclaimed or potable water, whether they have automatic sprinklers, Lee, et al (2021) studied statistically for variables like price of water, household and yard characteristics, etc., to isolate the behavioural effects of water quality and irrigation technology. It was compared the average outdoor (landscape) water use among households that differ in:

- the type of water source used (reclaimed or potable)
- the use of irrigation technology (automatic irrigation system or manual or none)

Outdoor water demand in Cary, North Carolina (USA) was found to be nearly unit elastic, meaning price changes linearly affect usage, but behavioural factors, such as concerns about water quality and the effort required to irrigate, play a significant role in shaping water use (Lee, et al., 2021). The two factors are not independent because the type of water and irrigation technology interact with perceptions and effort: e.g. even households with automatic systems may limit their use if they perceive the water quality to be low. However, households still reduced irrigation compared to potable water users, suggesting behaviour is influenced by perceptions, not just cost. Overall, reclaimed water programs reduce potable water consumption, but adoption and savings depend heavily on user perceptions and targeted pricing or incentives (Lee, et al., 2021). In addition, the study found that convenience strongly influences irrigation frequency and total water usage, with those with automatic systems (e.g. garden sprinklers) using significantly more water for irrigation. This finding was repeated in Australia, where households with access to recycled water tended to increase total water use, particularly for irrigation, demonstrating that user behaviour can offset some anticipated potable water savings (Willis, et al., 2011).

Other studies of dual-supply and hybrid residential water schemes in Australia have shown that households adapt their water use based on availability and perceived cost (Stewart, 2011). There are two variants of the residential Pimpama Coomera (Australia) diversified water supply scheme. Most households constructed prior to 2007 in this northern growth corridor had potable and recycled water supplies (i.e. dual supply). After 2007, the QDC MP 4.2 was introduced and the majority of dwellings constructed now have three supply sources (i.e. potable, Class A+ recycled, and internally plumbed rainwater tank to washing machine cold water feed and one external tap). In dual-supply schemes, household potable water savings were found to range from 29.5–41.1 m³/prop/year, while total recycled water demand reached 48.4 m³/prop/year. Hybrid schemes achieved higher potable water savings (59.5–70.8 m³/prop/year) but similar recycled water use. Use of recycled water for irrigation accounted for only 11.4% of total per capita consumption in the first year, well below the expected 30%. This was attributed to reflecting behavioural factors like changing irrigation habits and busy lifestyles, in addition to smaller property sizes (Stewart, 2011). However, this is still significantly higher than in South East Queensland (Australia) following the "millennium" drought, where outdoor irrigation represented a small share (4–5%) of total water use, even in summer. This suggests that outdoor irrigation is discretionary to an extent and that demand will respond to the availability of supply (James, et al., 2023).

A recycled (non-potable) water system was implemented across municipal parks in California (USA), (Maier, et al., 2022). Analysis of 2016–2018 park-level water use data found that each unit of recycled water displaced 0.817 units of potable water, suggesting that access to recycled water may encourage some additional consumption due to factors such as pent-up demand or perceptions of abundance. In addition, further tests, including restricting analysis to the first year post-conversion, peak summer months, or specific regions, failed to provide conclusive evidence that recycled water access changes total consumption. Despite this, the study period, an estimated 617,829 m³ of potable water were saved, equivalent to the daily needs of around 946 California residents (Maier, et al., 2022).

A case study conducted in Gold Coast (Australia) found that in households with dual reticulated supply systems, user behaviour strongly influenced water use patterns, particularly around irrigation and toilet flushing (Willis, et al., 2011). While toilet use with recycled water remained relatively stable

across the study, irrigation behaviour varied depending on climate, pricing, restrictions, and awareness campaigns. Another case study found a modest increase in toilet use in dual-supply homes, likely influenced by convenience and perceived lower cost of recycled water (Willis, et al., 2011). After commissioning, households in the dual system increased their use of recycled water, especially for irrigation (28.9 l/prop/d) and toilets (27.5 l/prop/d), aligning closely with predicted behavioural responses. This shows that users adapted quickly to the presence of recycled water and shifted some of their potable water demand toward non-potable sources (Willis, et al., 2011). Behavioural patterns also influenced peak demand times. In the dual system, the morning peak was reduced significantly because toilet flushing and some irrigation were supplied by recycled water, while evening peaks became more pronounced. In comparison, households in the single supply region had sharper morning peaks, reflecting different routines and dependence on potable water alone. Differences in end-use behaviours, such as higher bath use in homes with young children and lower leakage in dual-supply households, also shaped overall demand (Willis, et al., 2011).

However, other studies across the USA demonstrated societal support and public acceptance of water reuse for non-potable purposes through dual distribution systems (Rasoulkhani, et al., 2019). The results suggested that in a city-wide application, separating potable water from irrigation and fire flow is a practical solution that may be competitive with conventional water distribution.

6.5 Investigating rebound effect

The rebound effect is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioural or other systemic responses. In particular, the water rebound effect refers to the phenomenon by which water resource savings expected from improved water efficiency may be partly or wholly offset or surpassed (referred to as a “backfire” effect) by increased water demand (Zhou, et al., 2021). Wheeler et al. (2020) suggested that water savings from efficiency improvement may be overestimated if the rebound effect is not considered.

When households switch to a dual water supply, it is speculated that the rebound effect can occur, where observed short-term savings in potable water use may reduce over the long term. More broadly, increased overall water usage may be observed, mostly motivated by the availability of recycled water for outdoor irrigation. For example, households may consider recycled water as a low-cost alternative, encouraging higher consumption, particularly for outdoor uses like gardens, and in some cases, potentially increasing indoor uses such as toilets. Within this report, we shall include both of these under the umbrella term 'rebound effect' (even though increased long-term overall water usage need not necessarily be associated with a short-term reduction and thus, strictly speaking, is not a rebound).

Rebounds are linked to short-term conservation behaviours rather than long-term efficiency improvements, which are more permanent. It is possible that customer behaviour following other forms of supply change can be used to inform likely behaviour following the introduction of dual supply. For example, past research (Nemati, et al., 2023) has shown that water use increases after restrictions ease but does not fully return to pre-drought levels. Notably, higher-use households reduced water consumption more during both the mandate and post-mandate periods

compared to lower-use households, and their rebound effect was smaller. This might suggest that continued use of non-potable supply and long-term reductions in potable use are more likely to be seen at properties with higher overall use. This could likely be explained by the greater monetary gain to the householder, frequent behaviour becoming automatic, and there being more non-essential use that is suitable for non-potable supply.

Nemati, et al. (2023) also underlined in their study that water use varied hourly. Post-mandate, hourly water use rose by nearly 14.6%, with warm-season months driving most of the increase. Overall, water use in warm months rose by over 21% post-mandate compared to about 10% in cooler months, highlighting strong seasonality in rebound effects. The level of the impact varies by household type and season, with lower water-use households and warmer months typically showing greater consumption increases. It was found that the rebound effect during the warm season months is about 11.3%–12.6% higher than in non-warm season months (Nemati, et al., 2023), again suggesting that demand is highly linked to availability of supply, potentially meaning that apparent abundance of cheap non-potable water could lead to an increase in overall consumption. A study conducted in China (Zhou, et al., 2021) also showed that while water efficiency improvements reduce water consumption, their effectiveness is limited by rebound effects, where water savings are partly offset by increased demand. In contrast, during the 2004–2011 “millennium” drought in South East Queensland (Australia) (James, et al., 2023), household water restrictions effectively reduced consumption from over 300 l/h/d to around 140–155 l/h/d, and these changes persisted long-term even after restrictions eased. Behavioural shifts were reinforced by technological changes, such as rainwater tanks, efficient showers, and front-loading washing machines, often supported by government incentives (James, et al., 2023). This might suggest that continued public awareness and system improvement may be required to reinforce behavioural change.

The study, conducted by Lee, et al. (2021) in North Carolina (USA) was noted that if households perceive reclaimed (reused) water as environmentally friendly, they may increase outdoor use compared to potable water users, creating an unintended impact similar to that seen with efficient appliances, where significant rebound effects have been observed in various contexts following their implementation. Economic considerations (e.g. immediate economic expansion and increasing quality of life) typically stimulate an immediate rise in water use, particularly from households. Over the long term, however, these are partially balanced by efficiency, and the rebound effect diminishes. For example, Zhou, et al (2021).found that for a water efficiency improvement by 1%, the rebound effect of agriculture is 0.4931 in the short term and only rose to 0.6601 in the long term. The study also found that the magnitude of rebound effects grows with amount of water saved, highlighting the need to account for both short- and long-term dynamics (Zhou, et al., 2021).

However, another case study conducted in Australia (James, et al., 2023) suggested that long-term behavioural change can be achieved, demonstrating that water restrictions were effective in reducing average household water consumption, and despite the easing of restrictions, there was no immediate rebound effect in terms of a marked increase in water use. Usage dropped from over 300 l/h/day before restrictions to below 140 l/h/day at their peak. Even after restrictions were lifted, water use did not return to pre-drought levels, remaining around 150–180 l/h/day for years, though it gradually rose to about 204 l/h/day by 2020. This indicates lasting conservation

impacts despite some rebound over time (James, et al., 2023), giving confidence that long-term behavioural change can be achieved.

6.6 Summary

In summary, the primary key findings can be highlighted as follows:

- There is evidence that a significant proportion of household water use can be shifted from potable to non-potable supply, and studies have shown potable water use reductions which are as large as might be expected from micro component analysis. However, at least one study found that use of recycled water for irrigation was far less than expected, which was attributed to changing customer behaviour.
- There is evidence that dual supplies may cause total water use to increase, particularly if convenience, charged or perceived cost, or perception of environmental friendliness encourages additional use. However, other studies have found that users may underutilise cheaper recycled water due to perceived inferiority, hygiene concerns, odours, taste, and the "yuck factor".
- There is evidence that behavioural adaptation varies by building type, local climate, cultural norms, and awareness.
- Water restrictions and government incentives (including initiatives such as funding rainwater tanks) effectively reduce potable water consumption, though behaviour can rebound when restrictions and incentives end.
- There is evidence that some structural changes, such as replacing lawns with drought-tolerant landscaping, result in permanent behavioural adjustments beyond temporary restrictions, suggesting that permanent introduction of dual supply could result in permanent change.
- In dual supply systems, the morning peak was reduced significantly because toilet flushing and some irrigation were supplied by recycled water, while evening peaks became more pronounced.
- There is evidence from at least one scheme that in dual supplies, potable outdoor use remained only slightly lower than in potable-only schemes.
- Lower leakage was observed in dual-supply households.
- While toilet use with recycled water remained relatively stable across the study, irrigation behaviour varied depending on climate, pricing, restrictions, and awareness campaigns.

7 Water Reuse Desktop Study, Site-Specific Outputs

7.1 Demand Findings

WRc undertook a detailed demand analysis using 6,201 manual meter readings collected between 2018 and 2024 across 425 dwellings at Oaklands Hamlet. The development's dual-metered configuration enabled potable and non-potable water use to be analysed separately at a household level. Results were segmented by season (summer: April–September; winter: October–March) and by dwelling size, defined by number of bedrooms.

Over the six-year analysis period, recorded non-potable water use totalled 64,144 m³, representing 26% of total household consumption (246,439 m³) (Table 7.1). In the absence of baseline data or a comparable single-supply control site, it was assumed that total household demand would have remained unchanged under a single potable supply. On this basis, the observed non-potable volume represents the estimated potential reduction in potable demand achievable through a dual-supply system.

	Total (m ³)	Total (litres)	% share
Non-potable	64,144	64,144,200	26%
Potable	182,295	182,295,200	74%
Total	246,439	246,439,400	100%

Table 7.1 Potential demand reduction for Oaklands Hamlet, 2018 – 2024

Using median values to represent typical household behaviour, the analysis estimates that 22,462 litres per household per year could be supplied from a non-potable source under equivalent operating conditions (Table 7.2). This level of saving is consistent with UK micro-component evidence indicating that core non-potable end uses (such as toilet flushing and external demand) typically account for 26–38% of household water use.

	Non-potable (l)	Non-potable (%)	Potable (l)	Potable (%)	Total (l)
Median litres per day	62	25	191	75	253
Median litres per month	1,872	24	5,805	76	7,677
Median litres per year	22,462	24	69,656	76	92,118

Table 7.2 Median household demand by day, month and year

Non-potable savings varied between property size, with a general trend of increased savings with increased number of bedrooms. Despite this, a range in non-potable use was observed, with properties with more than 3 bedrooms exhibiting a wider distribution in non-potable use (Table 7.3 and Figure 7.1). The wide distribution of use by house size reflects studies showing strong variability by building type and end-use targeting (Jacque, et al., 2024).

No. bedrooms	No of Property	Median non-potable use (l)	Median non-potable share (%)	Median potable use (l)	Median potable share (%)
1	46	33	26%	122	74%
2	189	46	26%	170	74%
3	106	72	28%	214	72%
4	83	107	33%	284	67%
5	21	92	22%	340	78%

Table 7.3 Potable and non-potable water supply use by household size

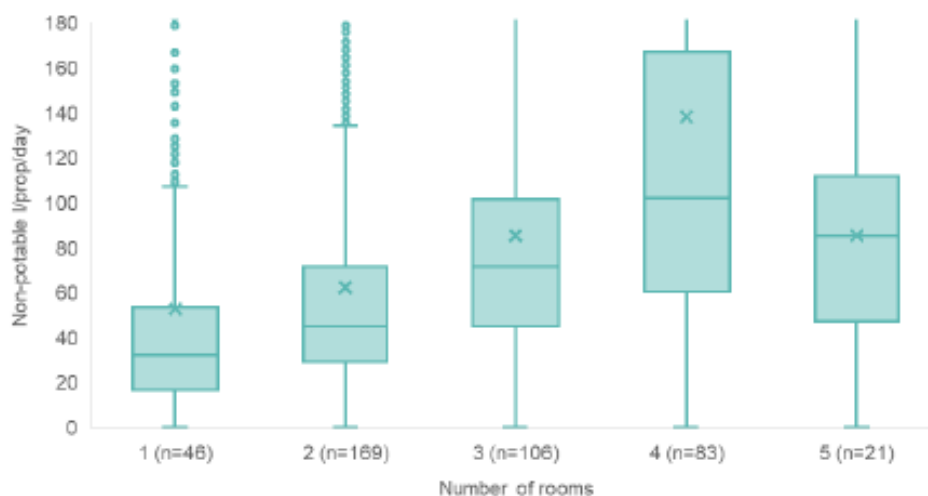


Figure 7.1 Distribution of non-potable supply water usage by household size

Total per capita consumption (PCC), defined here as combined potable and non-potable water use, was estimated at 123 litres per head per day (l/h/d) across the site. Overall PCC remained broadly stable throughout the year, with a median summer value of 120.0 l/h/d and a median winter value of 118.7 l/h/d (Table 7.4).

	Summer Median (l/h/d)	Winter Median (l/h/d)	Difference	p-value	Significantly different?
Total PCC	120.0	118.7	1.3	0.468	No
Potable PCC	84.7	85.8	-1.1	0.464	No
Non-potable PCC	27.1	25.0	2.1	0.005	Yes

Table 7.4 Comparison of household PCC by season

When disaggregated, potable PCC showed no meaningful seasonal variation. By contrast, non-potable PCC was modestly but statistically higher in summer, with a median increase of 2.1 l/h/d compared to winter. Although this difference is small in absolute terms, it indicates a consistent

seasonal signal associated with outdoor water uses (such as garden watering), while potable household demand remains stable year-round. This pattern aligns with findings from comparable dual-supply and reuse studies.

7.2 Performance Modelling and System Sizing

A simplified daily water balance model was developed to assess how a 720 m³ storage pond, supported by a 40 m³ day tank, would perform if supplying non-potable demand using harvested stormwater. Model performance was evaluated in terms of the frequency and volume of potable water top-up required to maintain non-potable supply.

The demand analysis provided the average daily non-potable demand for Summer (April to September) and Winter (October to March), as summarised in Table 7.5, for each of the scenarios to be modelled.

Scenario	Winter demand	Summer demand
Historical	23,480	31,320
Near future	23,710	32,730

Table 7.5 Average daily non-potable demand for site (l/d)

The system's performance was then evaluated under four climate scenarios:

- Historical (1970–2024),
- Baseline (1981–2000), and
- Two future projections aligned with the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP) models (RCP 6.0 and RCP 8.5) for the 2040–2059 period.

Under typical operating conditions, where a minimum storage level of 75 m³ was maintained in the pond, the system was able to meet the majority of non-potable demand throughout the year. Potable water top-ups were only required during extended dry periods, particularly in summer months when temperatures were high and rainfall was limited.

Across the full modelling period, annual potable top-up volumes were estimated at approximately 720–780 m³, equating to around 2.4–2.6% of the site's total annual potable demand. Sensitivity testing confirmed that the pond volume was broadly appropriate for the site's catchment area and demand profile, providing a balanced trade-off between storage capacity and system efficiency.

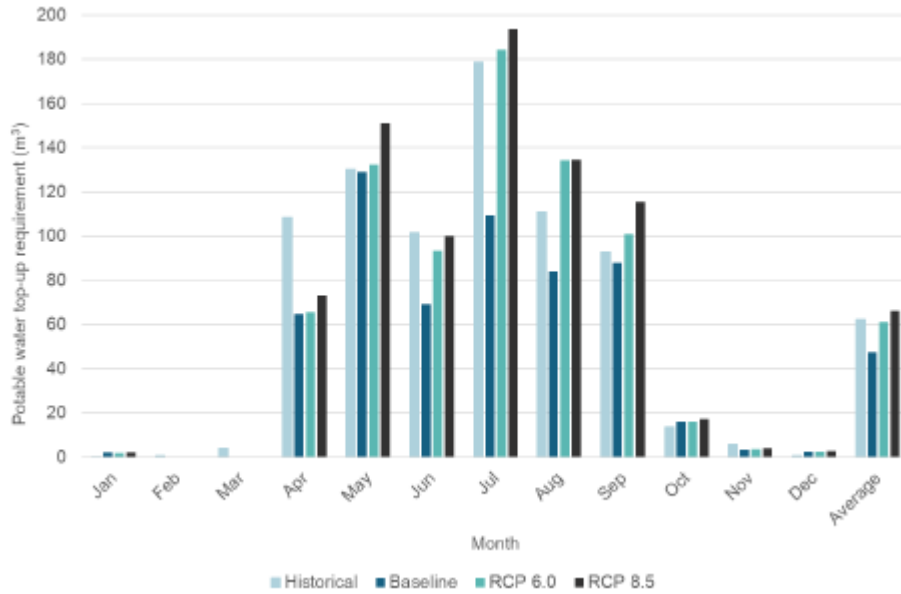


Figure 7.2 Long-term monthly average of potable water top-up requirement (l/day) under historical and future climates scenarios (RCP 6.0 and RCP 8.5)

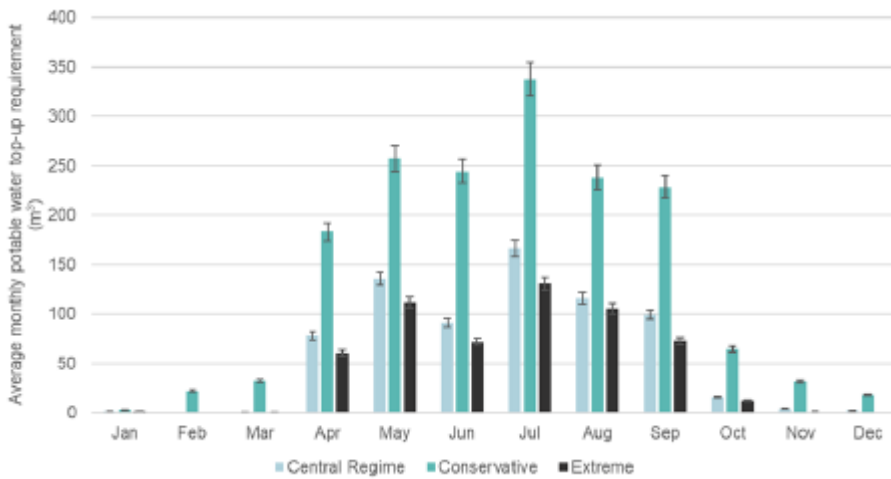


Figure 7.3 Average monthly potable water top-up requirement (m3) under baseline, historical and future climates scenarios (RCP 6.0 and RCP 8.5) across different operating regimes

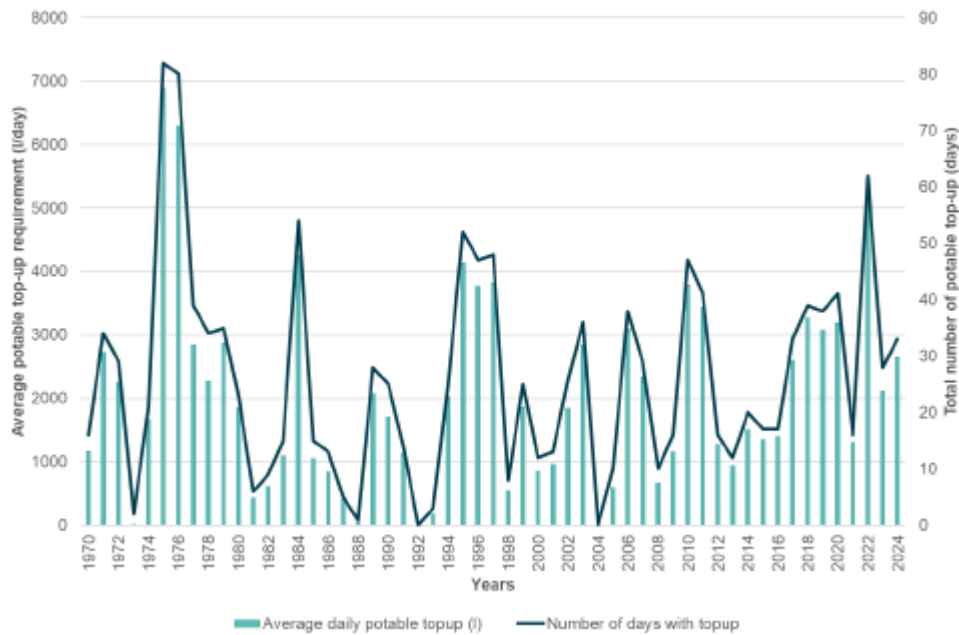


Figure 7.4 Annual top-up volumes that would have been required for each year since 1970

However, the modelling also demonstrated that potable top-up requirements tend to occur during periods of peak overall potable demand, particularly during heatwaves and prolonged dry spells. This reflects an inherent limitation of site-scale stormwater reuse systems: periods of lowest supply reliability often coincide with the times when demand on the wider potable network is greatest.

Overall, the results indicate that the Oaklands Hamlet system configuration, if supplied by harvested stormwater, would reliably offset approximately 20–23% of potable water demand in an average year. While effective in reducing baseline potable consumption, its contribution to alleviating peak summer demand pressures is constrained by climatic variability and rainfall dependency.

7.3 Performance Insights

The Oaklands Hamlet dataset provides a valuable real-world evidence base for understanding how dual potable and non-potable supply networks operate at scale within a residential development. Although the non-potable network is currently supplied by potable water due to the prevailing regulatory position, the dual-metered configuration has enabled detailed analysis of household demand patterns and robust inference of how a stormwater-fed system would be expected to perform in practice.

The combined demand analysis and performance modelling demonstrate that non-potable supply has the potential to offset a substantial proportion of household water use when applied to appropriate end uses, such as toilet flushing and external demand. The modelling further indicates that system reliability is high under average climatic conditions, but that the need for potable top-up water is most likely to arise during extended dry periods that coincide with peak overall demand on the potable network. This highlights an inherent limitation of site-scale reuse systems in mitigating peak demand pressures, despite their effectiveness in reducing baseline potable consumption.

Behavioural factors are a critical aspect of whether the theoretical savings identified through modelling are realised in practice. At Oaklands Hamlet, residents received no targeted communication regarding the purpose or operation of the dual supply network beyond standard billing information. Future reuse schemes would benefit from proactive customer engagement, clear system labelling and consistent messaging to promote confidence in non-potable water quality and to reduce the risk of rebound effects associated with perceived water abundance.

Data availability and resolution also emerged as a key consideration. While the six-year dataset was sufficient to characterise overall consumption patterns and inform system-level modelling, irregular meter-reading intervals limited the assessment of short-term variability and seasonal responses. Future schemes should incorporate smart or automated metering to provide higher-resolution data, enabling improved calibration of performance models, more accurate assessment of user behaviour, and adaptive system operation over time.

8 Household Efficiency Technologies

New dwellings in England are required to demonstrate compliance with the water efficiency provisions of Building Regulations Part G typically using the standard water efficiency calculation methodology set out in Section 1.5. Depending on planning conditions, this requires dwellings to achieve either the standard requirement of 125 litres per person per day (lppd) or the optional requirement of 110 lppd at design stage.

While this calculation-based approach provides a consistent regulatory benchmark, it does not necessarily reflect actual household water consumption in use. Metered evidence shows that real-world demand can exceed calculated values. As a result, achieving compliance at design stage does not always translate into equivalent reductions in in-use water consumption.

This section therefore focuses on opportunities to move beyond minimum regulatory compliance by examining high-efficiency household technologies with the potential to deliver sustained reductions in water use in practice. Using representative examples of innovative or emerging products rather than an exhaustive market review, the assessment concentrates on showers, toilets (WCs), and washing machines.

Technology performance has been benchmarked using the Building Regulations water efficiency calculation methodology to ensure consistency with regulatory assessment, while recognising the limitations of this approach in representing real-world performance.

8.1 Showers

Shower use is a major contributor to household water consumption. Conventional showers typically operate at 10–15 litres per minute, while efficient systems reduce this to around 6–8 litres per minute, delivering meaningful water savings. However, reduced flow rates can raise concerns around user comfort, with perceptions that lower flows compromise performance and may increase shower duration.

The Kelda air-powered shower goes beyond standard efficiency levels, operating at approximately 5 litres per minute—representing a 50–66% reduction compared with conventional

showers. Through air-mixing technology, it maintains the coverage and sensation of a higher-flow shower, supporting user comfort alongside reduced water use.

Litres per minute	Usage, litres per person per day with bath in home	Usage, litres per person per day with no bath in home
15	66	84
10	44	56
8	35	45
6	26	34
5 (Kelda)	22	28

Table 8.1 Water consumption in showers comparison using Building Regs Water Calculation approach

Independent assessments, including trials conducted by the Energy Saving Trust, have confirmed both the technical performance and positive user response to this technology. As a result, advanced low-flow systems such as Kelda offer a practical route to achieving significant efficiency gains without compromising user experience, supporting sustainability objectives while maintaining market acceptability.

8.2 Toilets

Toilet designs have evolved significantly, with dual-flush mechanisms now the market standard. Although these systems can reduce average flush volumes, their overall effectiveness is limited, based on poor performance, with leaking or unreliable mechanisms often resulting in higher than expected water consumption.

Arumloo – 2 Litres per flush

The Arumloo toilet, developed in Southern Africa, achieves a 2-litre flush volume, providing substantial water savings compared to even high-performance dual-flush systems. The technology currently doesn't have UK Building Regulations approval for adoption in the domestic market.

Jet Vacuum Toilet – 1 Litre per flush

Jet Vacuum Sanitary Systems utilise an advanced vacuum drainage system to achieve a 1-litre flush, enabling significant reductions in total household water use and supporting applications where space or drainage gradients are restricted. The product is approved for the UK market.

Litres per flush	Water Usage
6/4 Dual Flush	21
4/2.6 Dual Flush	14
2 (Arumloo) Single Flush	9
1 (Jet Toilet) Single Flush	4

Table 8.2 Water Consumption in Toilets comparison using Building Regs Water Calculation approach

8.3 Washing Machines

Washing appliances are a significant contributor to household water consumption within the Building Regulations water efficiency calculation. Where a washing machine is not specified by the developer, the methodology applies a default assumption of 8.17 litres per kilogram of dry load

to represent typical laundry demand. Where a specific appliance is installed, the calculation instead uses the manufacturer-declared water consumption value.

In practice, modern washing machines typically perform well below the default assumption, with eco-programme water use commonly in the range of 5–6.5 litres per kilogram. These improvements reflect ongoing advances in load sensing, cycle optimisation and drum design. The water consumption values referenced in this assessment are manufacturer-reported figures derived from standardised test conditions, consistent with regulatory and comparative evaluation requirements.

Xeros – 4 litres per kg dry load

The Xeros washing system uses patented XOrb™ polymer bead technology to achieve a manufacturer-declared water use of approximately 4 litres per kilogram of dry load under eco operating conditions. This represents a 20–40% reduction compared with efficient conventional drum machines, and around a 50% reduction relative to the regulatory default assumption.

Litres per kg dry load	Water Usage
8.17 (Default)	17
6	14
5	10
4 (Xeros)	8

Table 8.3 Water Consumption in Washing Machine comparison using Building Regs Water Calculation approach under ECO setting.

8.4 Summary

This assessment demonstrates that substantial reductions in household water demand are achievable through the specification of high-performance fixtures, fittings, and appliances. Using representative examples of innovative or emerging technologies, the analysis illustrates the scale of efficiency gains that can be delivered within existing housing delivery models when performance beyond minimum regulatory compliance is targeted.

When assessed using the current Building Regulations water efficiency calculation methodology, combinations of advanced shower, toilet, and washing machine technologies can achieve calculated consumption below 85 litres per person per day (Table 8.4), approximately 23% beyond the Part G optional benchmark. While calculated outputs do not fully capture real-world behaviour, they provide a consistent and recognised basis for comparing relative performance and demonstrate that materially tighter efficiency levels are technically achievable within the established regulatory framework.

Installation Type	Unit of Measure	Capacity/Flow rate	Use Factor	Fixed use (l/p/d)	Litres/person/day
WC (single flush)	Flush Volume (litres)	2	4.42	0	8.84
WC (dual flush)	Full flush Volume (litres)		1.46	0	0
	Part flush Volume (litres)		2.96	0	0
Taps (excluding kitchen/utility room taps)	Flow rate (litres/min)	5	1.58	1.58	9.48
Bath (where shower also present)	Capacity to overflow(litres)	170	0.11	0	18.7
Shower (where bath also present)	Flow Rate(litres / minute)	5	4.37	0	21.85
Bath Only	Capacity to overflow(litres)		0.5	0	0
Shower Only	Flow Rate (litres/minute)		5.6	0	0
Kitchen/Utility room sink taps	Flow rate (litres/minute)	6	0.44	10.36	13
Washing Machine	(Litres/kg dry load)	4.00	2.1	0	8.4
Dishwasher	(Litres/place setting)	1.25	3.6	0	4.5
Waste disposal unit	(Litres/use)		3.08	0	0
Water Softener	(Litres/person/day)		1	0	0
Total Calculated use (litres/person/day)					84.77
Contribution from greywater (litres/person/day)					0
Contribution from rainwater (litres/person/day)					0
Normalisation factor					0.91
Total internal water consumption (litres/person/day)					77.14
External water use					5
Total water consumption (Building Regulation 17.K)					82

Table 8.4 Example Building Regulations Calculation incorporating the Arumloo, Kelda shower and Xeros washing machine into Building Regulations Table 2.2 – Maximum fittings consumption optional requirement level)

9 Results Summary

This report generates a defined set of quantitative results describing household water demand, non-potable substitution potential, and indicative reuse system performance. Delivery was undertaken as a desktop study following regulatory clarification; all revised analytical outputs were completed.

Household water demand

- Non-potable end uses represented approximately 26% of total household water consumption.
- Median non-potable demand was approximately 22,500 litres per household per year.
- Total per-capita consumption across potable and non-potable supplies was approximately 123 litres per person per day, with limited seasonal variation.
- Non-potable per-capita consumption was higher in summer than winter.
- Non-potable demand generally increased with property size, with greater variability observed in larger dwellings.

Reuse system performance

- A reuse system of the assessed scale supplied approximately 20–23% of total household demand when potable top-ups were included.
- 2–3% of total annual demand was met through potable water top-ups.
- Potable top-ups occurred primarily during extended dry periods.
- Reuse system performance was broadly consistent across historical and future climate scenarios, with reduced performance during drier years.

Household efficiency technologies

- Demonstrated 40–60% reductions in end-use water consumption relative to standard specifications.
- Combined application of these technologies resulted in total household water use below 85 litres per person per day under Building Regulations calculation assumptions.

Data characteristics and constraints

- Results are derived from long-term household consumption data with limited temporal resolution.
- System performance results are model-based and reflect assumed occupancy and climate inputs.

These results define the quantified outputs of Phase 2. Their interpretation, implications for policy and regulation, and relevance to future delivery phases are set out in the Conclusions and Recommendations.

10 Discussion

10.1 Reflection on Findings

The Desktop Study confirms that communal water reuse can reliably offset a substantial proportion of household non-potable demand in new developments, with stable performance observed over multiple years of operation. The Oaklands Hamlet data demonstrates that dual-network systems can operate effectively with minimal potable top-up, even without structured behavioural engagement, providing confidence that predicted potable savings are achievable under real operating conditions.

The consistency of demand patterns over time indicates that system performance is driven primarily by design and infrastructure configuration rather than short-term behavioural effects alone. This reinforces international evidence that well-designed reuse systems can provide dependable non-potable supply while maintaining service reliability.

10.2 Integrated Efficiency and Behavioural Effects

While reuse systems can offset a meaningful share of demand, the findings indicate that the greatest long-term reductions are achieved when reuse is deployed as part of a broader, integrated efficiency strategy. Evidence from the Technology Review shows that advanced fixtures and appliances can substantially reduce baseline household demand for key end-uses, enabling reuse infrastructure to be correctly sized and operated more efficiently.

Behavioural factors remain influential in shaping outcomes. User confidence in non-potable water quality, clarity of system labelling, and access to feedback mechanisms all affect uptake and long-term performance. Conversely, poorly managed systems or a lack of engagement can introduce rebound effects, particularly for discretionary uses such as irrigation. Embedding engagement measures from the outset is therefore critical to sustaining savings.

10.3 Technology and System Design Implications

The combined outputs of the Desktop Study and Technology Review highlight the importance of sequencing in development design. Delivering high-efficiency homes first allows reuse systems to be sized against a lower demand profile, reducing capital costs, operational complexity, and reliance on potable back-up. Integration with SuDS and robust operational controls further enhances resilience and delivers additional environmental benefits.

International experience indicates that dual-supply systems can operate safely when supported by appropriate monitoring, maintenance, and safety controls. These operational considerations are central to long-term performance and must be embedded alongside technical design.

10.4 Regulatory Barriers and Technical Feasibility

The evidence from this study confirms that communal water reuse at development scale is technically viable and operationally robust. Dual-network systems can reliably meet non-potable

demand, with potable top-up required only during prolonged dry periods. The principal constraint on wider adoption is therefore regulatory rather than technical.

Current statutory duties relating to wholesomeness, as set out in the Water Industry Act 1991 and associated drinking water regulations, prevent licensed undertakers from supplying non-potable water for domestic use. As a result, reuse schemes are limited to privately managed models operating under the Private Water Supplies (England) Regulations 2016. While these arrangements demonstrate that non-potable reuse can be delivered safely, they represent a fragmented and transitional solution rather than a scalable national framework.

International experience and UK case studies show no evidence of public health impacts where systems are appropriately designed, operated, and monitored. This highlights a clear misalignment between regulatory risk perception and demonstrated operational performance, suggesting that a risk-based regulatory approach could unlock wider deployment without compromising safety.

10.5 Enabling Policy Reform

The findings indicate that enabling water reuse at scale will require targeted policy reform focused on regulatory clarity and proportional risk management. The current regulatory framework effectively restricts reuse to niche or bespoke developments, limiting its contribution to national demand reduction objectives.

Proposed revisions to Building Regulations Part G provide an important opportunity to address this gap. While tightening efficiency standards is necessary, the evidence shows that efficiency measures alone will not deliver the scale of potable demand reduction required. Policy mechanisms that explicitly support or require the integration of reuse systems at the design stage would normalise adoption, reduce delivery risk, and provide greater certainty for developers and water companies.

Clear national guidance on ownership, operation, and assurance of non-potable systems would further support consistent delivery and enable reuse to transition from pilot projects to mainstream infrastructure.

10.6 Operational Governance & Delivery Models

Long-term system performance depends as much on governance as on technical design. Clear responsibility for operation, maintenance, monitoring, and customer communication is essential to sustaining performance and maintaining public confidence in non-potable supply.

The current split between licensed undertakers and privately managed systems creates uncertainty around long-term accountability, particularly where responsibilities are transferred post-construction. Without defined governance models, there is a risk that maintenance regimes, monitoring, and engagement deteriorate over time, undermining system reliability and safety.

Embedding governance requirements at the planning and design stage would allow regulators and approving bodies to assess operational readiness alongside technical feasibility. This includes confirming operator competence, lifecycle funding arrangements, and monitoring protocols before schemes are brought into service.

10.7 Strategic and Sustainability Implications

The performance outcomes observed at Oaklands Hamlet provide useful context within regional and national water efficiency frameworks. Total per capita consumption, incorporating both potable and non-potable sources, was approximately 123 litres per person per day, notably below current national and regional potable-only averages. This reinforces the contribution that dual-supply systems and efficient fixture specification can make to reducing overall household water demand.

While water reuse systems and household efficiency technologies were assessed through separate analytical components within this study, their combined interpretation highlights important strategic implications for future delivery. The evidence indicates that reductions in baseline household demand achieved through high-efficiency fixtures and fittings have the potential to improve the performance, sizing, and resilience of non-potable reuse systems when considered together at the design stage.

More broadly, the findings suggest that early consideration of reuse alongside demand reduction measures during masterplanning can support more efficient infrastructure design and operational outcomes. Although these interactions were not tested through a fully integrated system within Phase 2, the consistency of results across the Desktop Study and Technology Review provides a credible basis for exploring integrated approaches in future phases.

From a sustainability perspective, the evidence indicates that combining non-potable substitution with demand reduction can deliver benefits beyond potable water savings alone, including reduced abstraction pressures, lower energy use, and reduced carbon emissions associated with water treatment and distribution. International experience further supports the conclusion that sustained demand reduction is most effective where technical measures are accompanied by user understanding and trust.

Taken together, the findings indicate that water reuse and household efficiency measures, while assessed independently within this study, are mutually reinforcing when considered strategically. This interpretation provides a robust foundation for the lessons identified in Phase 2 and for the development of integrated pilots and delivery models in subsequent phases of Project Zero.

11 Lessons Learnt

This section consolidates the key lessons emerging from the Technology Workstream, drawing on programme delivery experience, technical analysis, regulatory engagement, site feasibility assessments, partnership working, Risk, Assumptions, Issues and Dependencies (RAID) log entries, and internal reflection.

The lessons are grouped into six themes and presented as clear, actionable insights to inform future phases of Project Zero and wider governance, planning and innovation processes.

11.1 Programme & Governance Management

Phase 2 demonstrated the importance of robust governance, early decision points and structured contingency planning when delivering innovation within an evolving regulatory environment. While the workstream ultimately adapted through re-scoping to a desktop study, the absence of early-stage gateway reviews and formal triggers for reassessment led to a prolonged period of uncertainty following regulatory clarification from the Drinking Water Inspectorate (DWI).

Lessons to carry forward

- Programme objectives must be revisited at defined governance checkpoints, particularly when key external risks (e.g. regulatory approval) materialise.
- Formal stage gates and decision triggers are essential to avoid extended periods without a viable delivery pathway.
- Contingency options should be identified at project initiation for all critical dependencies, including regulatory outcomes, site availability and data quality.
- Resource planning should be built into early workstream design to ensure sufficient capacity to respond to change.
- Clear documentation and communication of decisions supports transparency and maintains stakeholder confidence during re-scoping.

11.2 Technical and Analytical Insights

Phase 2 delivered a detailed technical assessment of a domestic-scale dual network system in the UK context. Although analysis was constrained by data limitations, the findings were consistent with international evidence and provide a credible foundation for future reuse or combined efficiency-and-reuse approaches.

Lessons to carry forward

- Communal dual networks have the potential to supply a meaningful proportion of household demand with non-potable water, delivering material potable water savings.
- Achievable savings are highly sensitive to system design choices, including storage capacity, potable top-up logic and end-use allocation.

- High-resolution consumption data (e.g. smart or automated metering) is critical for understanding behaviour, diagnosing system performance and supporting robust evaluation.
- Behavioural considerations should be embedded into technical assessment and future pilot design, rather than treated as a secondary issue.
- Future modelling should consider the combined effect of reuse systems and high-efficiency fixtures and fittings to reflect real-world deployment scenarios.

11.3 Regulatory and Policy Environment

Regulatory constraints were the dominant factor shaping Phase 2 delivery. The interpretation of existing legislation prevents water companies and NAVs from owning or operating non-potable water systems for domestic use, fundamentally limiting on-site implementation despite the presence of suitable infrastructure.

Lessons to carry forward

- Regulatory feasibility must be treated as a primary dependency and tested early through structured engagement with DWI, Defra and Ofwat.
- Innovation programmes should include a clear regulatory engagement strategy rather than relying on assumptions or informal interpretation.
- Alternative delivery models (e.g. private water supplies or third-party operation) introduce additional governance, operational and public health considerations that require early evaluation.
- Evidence generated through desktop studies and trials should be explicitly framed to support future regulatory consultation and policy development.

11.4 Stakeholder and Customer Engagement

Effective collaboration between WRc, Albion Water and SDS Infrastructure strengthened analytical quality and delivery. However, customer understanding of dual networks at Oaklands Hamlet was assumed rather than evidenced, creating potential risks around perception, behaviour and billing fairness.

Lessons to carry forward

- Customer awareness and understanding of innovative water systems should be validated rather than assumed.
- Clear, accessible communication materials are required to explain system operation, billing arrangements and intended use.
- Engagement with land promoters and site promoters at an early stage is significantly more effective than retrospective engagement following planning submission.
- Early alignment with developers supports smoother transition between project phases and delivery stages.

11.5 Technology Adoption Dependencies

Phase 2 highlighted both the benefits and risks of reliance on external technical expertise and innovative products. While the Water Reuse Desktop Study met quality expectations, dependency on a single analytical approach limited opportunities for comparative validation.

Lessons to carry forward

- External commissions should include clearly defined success criteria, quality assurance steps and scope boundaries.
- Where feasible, light-touch internal modelling or peer review should be used to strengthen confidence in externally generated outputs.
- Innovative technologies should be assessed early for UK regulatory compliance to avoid uncertainty for developers and delivery partners.

Incentive mechanisms such as EICF can play a key role in supporting adoption of compliant, high-performing technologies.

11.6 Transition Between Phases

The re-scoping of Phase 2 and subsequent realignment of Phase 3 highlighted the importance of structured transition management between programme phases.

Lessons to carry forward

- Dependencies between phases should be actively tracked and reviewed through formal transition checkpoints.
- Regulatory alignment should be confirmed before committing to delivery-focused innovation bids.
- Future phases should be designed with sufficient flexibility to incorporate emerging evidence and changing external constraints.

11.7 Summary

The lessons demonstrate that while technical solutions for non-potable reuse and advanced water-efficient technologies are feasible, successful delivery depends on regulatory clarity, strong governance, early stakeholder engagement, customer understanding and effective management of external dependencies. By embedding these lessons into future phases, Project Zero can strengthen delivery confidence, improve adaptability and build a robust evidence base to support long-term progress towards water neutrality.

12 Conclusion

The Technology Workstream has delivered a robust analytical evidence base on household water demand, non-potable substitution potential, and the indicative performance of site-scale water reuse systems within new residential developments. Following regulatory clarification, the workstream was re-scoped from a live installation pilot to a desktop study, enabling delivery of a structured programme of demand analysis, performance modelling and targeted technology assessment.

The results confirm that non-potable end uses represent a material proportion of household demand and that reuse systems, when appropriately sized and operated, can supply a substantial share of this demand with limited reliance on potable top-up. Performance modelling shows that potable water savings of approximately 20–23% are achievable at site scale, with system reliability influenced by seasonal demand patterns, storage capacity and climatic variability. These findings align with published benchmarks and international experience, reinforcing confidence in the technical potential of reuse systems in new developments.

The study also demonstrates that high-efficiency household fixtures and appliances can materially reduce baseline water demand. When deployed alongside reuse systems, these technologies could reduce pressure on non-potable infrastructure and improve overall system efficiency. While the technology assessment was deliberately targeted rather than exhaustive, it provides clear evidence that consumption levels well below current Building Regulations benchmarks are achievable through innovative products, however these need more simplified pathways to enable availability in the market.

Regulatory constraints remain a barrier to delivery. Current legislation prevents undertakers and NAVs from supplying non-wholesome water for domestic purposes, while Building Regulations do not require the inclusion of reuse systems or ultra-efficient fixtures. These constraints shaped the analytical focus of Phase 2 and underline the importance of regulatory engagement to enable controlled pilots, clarify compliance pathways and explore future reform.

The evidence generated through Phase 2 establishes a credible technical foundation for Phase 3 of Project Zero. It provides quantified insight into demand, system performance limits and efficiency interactions, while also identifying the key uncertainties that require validation through live pilots. The following recommendations set out how this evidence can be translated into practice and where further research is required to support scalable, safe and economically viable deployment.

13 Recommendations And Future Research

13.1 Translating Evidence into Practice

System design and deployment

- Future projects should treat high-efficiency fixtures and fittings as the baseline specification, with reuse systems designed around reduced demand profiles.
- Modular reuse systems serving WC flushing, irrigation and, where feasible, washing machines should be prioritised to enable right-sizing of storage and treatment components.
- Smart metering, performance monitoring and fault detection should be embedded to verify savings, support operational learning and provide assurance to regulators.

Policy instruments: incentives and standards

- Incentives alone are unlikely to deliver consistent uptake at scale. While strengthened incentive mechanisms (e.g. EICF-style approaches) can support early adoption and commercial viability, these should be viewed as transitional tools.
- In parallel, consideration should be given to progressively strengthening mandatory standards, including:
 - tighter Part G performance requirements;
 - clearer planning expectations for water reuse and efficiency in water-stressed areas; and
 - defined regulatory pathways for communal non-potable supply.
- A combined approach, using incentives to accelerate early delivery and standards to normalise practice, offers a credible route to mainstream adoption.

Regulatory engagement and pilots

- Controlled pilot schemes delivered under agreed regulatory exemptions should be progressed to test treatment performance, monitoring regimes, cross-connection safeguards and customer interfaces under real operating conditions.
- Evidence from pilots should directly inform ongoing consultations on Building Regulations, reuse standards and risk-based compliance frameworks.

Integration with SuDS

- Reuse systems should be planned in coordination with Sustainable Drainage Systems to maximise combined benefits, including runoff reduction, water quality improvement, flood resilience and additional non-potable supply.
- Integrated design guidance and consistent technical standards are needed to support safe and cost-effective delivery.

Planning, business cases and WRMPs

- Phase 2 evidence should be incorporated into Water Resource Management Plans and business planning to improve quantification of demand reduction, resilience benefits and capital efficiency.
- This will support more robust investment cases and clearer engagement with developers and planning authorities.

Governance and operational models

- Future delivery should explore a range of ownership and operating models, including adopted assets, accredited third-party operators and hybrid partnerships.
- In all cases, long-term maintenance funding, clear accountability and customer protection must be embedded from the outset.

13.2 Future Research

To address the evidence gaps identified in Phase 2, future research should focus on the following areas through monitored live pilots and supporting analysis:

Integrated reuse and SuDS performance

- Hydraulic, environmental and cost–benefit assessment of co-optimised reuse–SuDS systems.

Water quality and public health

- Evaluation of treatment reliability, microbiological stability and point-of-use risks across different storage and treatment configurations.

Customer experience and behaviour

- Investigation of customer understanding, trust, usability, billing impacts and behavioural responses to reuse and efficiency measures.

Cross-connection prevention

- Testing of installation standards, inspection regimes and monitoring tools to minimise public health risk.

Maintenance and whole-life costs

- Assessment of operational performance, asset degradation and lifecycle costs relative to conventional supply solutions.

Ownership and governance models

- Comparative evaluation of private, adopted and hybrid delivery models in terms of cost, risk, resilience, compliance and customer outcomes.

14 Appendices

14.1 Appendix A: Climate change factors

UKCP18 produced summary statistics of future climate changes at administrative region-level for 2020-2039, 2030-2049, 2040-2059, 2050-2069, 2060-2079, 2070-2079 and 2080-2099. The predictions are provided in the form of a series of percentiles with the 50th percentile value reflecting a median change that is likely be observed. We applied these median change factors to create future weather timeseries for the medium (RCP 6.0) and high emissions (RCP 8.5) scenarios. The changes are relative to a baseline of 1981-2000. Note that precipitation change factors are expressed in percentage terms, and are therefore multiplicative, while temperature changes are absolute so are additive.

Spatial domain	Region name	Variable	Time Horizon (relative to 1981-2000)	Emissions Scenario	50th percentile change
Administrative region	London	mean annual temperature	2040-2059	RCP 6.0	+1.3°C
Administrative region	London	mean annual temperature	2040-2059	RCP 8.5	+1.9°C
Administrative region	London	mean winter temperature	2040-2059	RCP 6.0	+1.2°C
Administrative region	London	mean winter temperature	2040-2059	RCP 8.5	+1.7°C
Administrative region	London	mean summer temperature	2040-2059	RCP 6.0	+1.8°C
Administrative region	London	mean summer temperature	2040-2059	RCP 8.5	+2.5°C
Administrative region	London	mean winter precipitation	2040-2059	RCP 6.0	+8%
Administrative region	London	mean winter precipitation	2040-2059	RCP 8.5	+11%
Administrative region	London	mean summer precipitation	2040-2059	RCP 6.0	-15%
Administrative region	London	mean summer precipitation	2040-2059	RCP 8.5	-20%

Table A.1 Relevant 50th percentile change factors for RCP 6.0 and RCP 8.5 emissions scenarios

14.2 Appendix B: Data Analysis Approach

B.1 Data collation

The majority of the data used within the demand analysis was provided by Affinity Water but sourced from Albion Water, with WRc obtaining additional information via freely available sources online. Table B.1 contains a list of data used with the applicable source.

Data name	Data description	Source
Meter readings	Meter readings data from 2018 to 2024 for new development site including property ID, number of bedrooms, meter ID, meter read date, meter read source, and whether meter for the potable or alternative supply system.	Provided by Affinity Water (sourced from Albion Water)
Water bill	An example water bill with all sensitive information removed.	Provided by Affinity Water (sourced from Albion Water)
Planned demand	Demand planned for in accordance with Albion Water WRMP24.	Albion Water website [online]

Table B.1 Demand analysis data sources

B.2 Data cleaning and transformations for meter readings

To clean the meter reading data, with confirmation from Affinity Water and Albion Water, the following readings were removed from the original files:

- Property IDs starting with Countryside, Ops Oaklands or FOB as these were assumed to relate to the network and not to properties.
- Meter readings with the following sources as the accuracy in many cases was questionable when in comparison with actual meter reads: Customer Move Out, Albion Estimate, Developer, Estimate, Estimate Move In, Estimate Move Out, Estimated, Estimated move read.
- Properties that had more than two Meter ID values, ensuring that each property had one potable and one non-potable meter. This had minimal impact on the overall findings and simplified analysis by reducing the need for considerable manual manipulation of data, which could be prone to human error.
- Readings where only one of the household's two meters was read on a particular day, ensuring that reading dates for the potable and non-potable meters occurred at the same time.
- Erroneous data readings where a reading value was lower than the previous reading.

- Meter readings before a property's occupation were identified by continuous readings with zero value from both supplies and were removed from the data.

The steps below show how we cleaned and organised the meter readings, so they were ready for analysis. Items marked with an asterisk (*) include more detail on the calculations used.

- We reorganised the data table so it shows one row per property for each reading date (rather than one row per meter). Each row now contains both the potable and non-potable readings side by side.
- Additional fields were calculated:
 - **Number of days between each meter read:** Reading date – (Previous reading date + 1)
 - **Change in reading (amount of water used):** Current reading – Previous reading
 - **Total litres used (potable, non-potable, total):** Change in reading x 1,000
 - **Percentage share of water used (potable, non-potable):** Non-potable volume / Total litres used and Potable volume / Total litres used
 - **Litres used per day (potable, non-potable, total):** Total litres used / Number of days between each meter read
 - **Estimated occupancy*:** See detailed explanation below.
 - **Per capita consumption (l/h/d) (potable, non-potable, total):** Litres used per day / Estimated occupancy
 - **Usage season*:** See detailed explanation below.
 - **Days in summer and winter:** We took each reading's start and end dates and counted how many of those days fell inside the summer dates and the winter dates. If a reading period spanned several years, we added the days from each year's season.
 - **Water used in Summer and Winter* (total PCC and per property for both potable and non-potable meters):** The total litres used for the period were split between summer and winter proportionally based on the days in summer and winter. The summer and winter volumes could then be divided by the number of days in each season to calculate the summer and winter litres used per day, and the litres used per day could be divided by the occupancy rate to calculate the summer and winter PCC.

B.3 Estimated occupancy

A proxy value was used for occupancy rate as no occupancy data was available. It was noted in Albion Water's WRMP24 that the development has a total average occupancy of 2.36 (Albion Water Limited, 2024). From this, the method outlined in Appendix A was used to create plausible occupancy rates for properties based on the number of bedrooms in each property (Table B.2).

No. of bedrooms	Count of properties	Estimated occupancy	Population
1	46	1.29	59
2	169	1.92	324
3	106	2.56	271
4	83	3.2	266
5	21	3.84	81
Total	425	2.36	1,001

Table B.2 Estimated occupancy rates

B.4 Categorising seasonality

To carry out seasonal analysis, meter read data was attributed to a season, where summer usage runs from April to September and winter usage runs from October to March. The following two methods were developed and compared against each other to assign water usage values to the seasons, with the second method being selected for use throughout the analysis.

Method 1: Assigning a usage season

Readings were categorised by season based on the number of days between readings that were in either summer or winter e.g. if usage was from March 2022 to June 2022, it was allocated to Summer 2022.

Since, winter spans across years, with winter 2020 including January to March 2021, if usage was from January to March 2021, it was allocated to the winter 2020.

Method 2: Calculating estimated litres used in a season

For each reading, the number of days in summer and the number of days in Winter were recorded, and the seasonal usage was calculated using the average water use per day. For example, if usage covered 1st March 2022 to 15th April 2022, the reading would be allocated 31 days as Winter 2021 and 15 days as Summer 2022. Total litres and litres per day were then prorated based on the percentage of usage that fell within each season. Property level water use and PCC could then be calculated accordingly.

B.5 Final data set

The final data set contained a total of 6,201 meter readings for 425 properties, with an average of 3.8 months between meter reads. A breakdown of property size (number of bedrooms) can be seen in Table B.3 along with the number of readings taken in summer and winter (Table B.4).

No. of bedrooms	Count of properties
1	46
2	169
3	106
4	83
5	21
Total	425

Table B.3 Data Coverage

Season	Count of readings
Summer	3,292
Winter	2,909

Table B.4 Number of reading taken in summer and winter

B.6 Data analysis

The following is a description of the analysis used to answer the core research questions.

Quantify potable demand reduction from non-potable use

There was no pre-existing data to serve as a control or baseline, nor was any data provided from comparable sites in the area (see appendix C). It was therefore assumed that the total water demand from both sources (potable + non-potable) would be the same if Oaklands Hamlet was served by a single potable service. Under that assumption, the entire non-potable volume represents the potential decrease in potable demand. To quantify the potential potable demand reduction, the total non-potable volume from the point of occupation was used (October 2018). The median daily non-potable use was reported, as mean daily values were skewed by occasional high-volume days.

Calculate percentage of total household demand met by the non-potable supply system

As stated above, the total potable and non-potable volumes from when the development became occupied were used. The overall share of demand met by the non-potable supply system was calculated as the total non-potable volume divided by the total water volume (potable + non-potable). This figure was not adjusted for seasonality.

Assess seasonal trends in non-potable usage and efficiency

Seasonal trends were assessed by categorising the data into two seasons: summer and winter. Mean and median l/h/d for total, potable and non-potable demand were calculated for each season per year. Results were then compared categorically (summer versus winter) to assess the difference and in volume and the statistical confidence in the difference.

Compare behaviour and total water use between property types

To compare between property types, the data was categorised based on the number of bedrooms, with median household daily use, l/h/d and percentage share of potable and non-

potable use calculated for each property category. No additional property information was available at the time of this study.

Investigate long-term trends and any potential 'rebound' effects whereby apparent changes are short-term.

The rebound effect describes when a change is made, such as an efficiency improvement, but consumption increases (rather than the expected decrease) as user behaviour adjusts. For instance, occupants of households receiving a dual supply may spend longer in the shower, as they perceive that they have more potable water available now that they're not using potable water for toilet flushing or outdoor use. Similarly, a household may start watering their lawn during dry periods, as they perceive the non-potable supply to be abundant. This can negate some or all of the initial savings.

The original aim of the study was to see if residents' behaviour changed as a result of having a dual supply system. Despite this, we were unable to conduct a formal rebound analysis due to data limitations (see appendix C). In absence of quantifying any potential rebound we do, however, provide observations about the information that residents received, which may, or may not, have influenced their behaviour. While this is not provided as evidence, it may be useful when considering future communications to residents if the supply to the non-potable system is ever switched to a RWH source.

14.3 Appendix C: System performance modelling Approach

C.1 Data collation

Data in addition to that used in the demand data analysis was required for the system performance assessment. Table C.1 contains a list of data used with the applicable source.

Data name	Data description	Source
Non-potable water demand.	Demand inferred from water meter readings, processed as per Section 2.2.	Estimated by WRc during Phase 1
Drainage system details	Designed and 'as built' plans of the new development's drainage system.	Provided in the form of 'as built' and 'design plan' documents by Affinity Water (sourced from Albion Water)
Alternative (non-potable) supply system storage details.	Volume of storage tank and day tank.	Provided by Affinity Water (sourced from Albion Water)
GIS layer of new development site	Site digitised from Google Earth, capturing buildings, property boundaries, roads, and land cover such as water bodies (ponds), trees etc.	Produced by WRc
	Property boundaries were further classified into front and back gardens.	
Historical weather data.	Daily precipitation, maximum temperature and minimum temperature for 1976 to 2023.	HadUK
UKCP18 probabilistic projections	50 th percentile change factor for RCP 6.0 and RCP 8.5 for mean annual temperature, mean summer temperature, mean winter temperature, mean summer precipitation and mean winter precipitation.	UKCP18, Met Office

Table C.1 Systems performance modelling data sources

C.2 Modelling approach - water balance

Given the site's characteristics, including its location and spatial extent, a water balance modelling framework was selected for modelling non-potable supply system. At each daily time step, pond storage was updated as the sum of existing storage (previous day's storage) and new inflows, minus outflows. This approach is governed by Equation C.1.

Equation C.1 Water balance equation

$$S_t = S_{t-1} + I_t - O_t$$

Where,

- S_t is the storage at time t ,
- S_{t-1} is the storage from the previous time step,
- I_t is the inflow at time t ,
- O_t is the outflow at time t .

In this study, inflows and outflows are represented through a combination of process-based and empirical formulations. Specifically, evapotranspiration and effective rainfall were estimated using process-based methods, while runoff generation and pond balance dynamics were described empirically (Appendix C.5). This integrated approach provided a robust framework for assessing the interactions between water availability and demand, and for assessing system performance under present and future climate conditions.

C.3 Performance modelling scenarios

Four scenarios were modelled to simulate behaviour at a daily timestep over the input timeseries. These scenarios include two historical datasets and two future climate projections based on the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP) models. The RCPs are internationally recognised climate scenarios developed by the IPCC, representing different greenhouse gas concentration trajectories and corresponding levels of global warming by 2100.

The four scenarios are as follows:

- **Historical:** Observed demand applied to a historical weather series from January 1970 – December 2024, used to analyse the performance of the system over a range of previously observed weather patterns, including significant droughts of 1975/76, 2011/12, 2018 and 2022.
- **Baseline:** Observed historical demand data applied to the 20-year 1981 – 2000, to provide a "stable baseline" and against which the RCP climate scenarios are defined.
- **RCP 6.0:** A moderate climate change scenario representing an average global temperature increase of approximately +2.8 °C relative to pre-industrial levels. It estimates 2050 demand applied to a synthetic 2040 – 2059 weather timeseries, uplifted from 1981 – 2000 (see Appendix A).
- **RCP 8.5:** A high emission scenario representing an average global temperature increase of approximately +4.3°C relative to pre-industrial levels. It estimates 2050 demand applied to a synthetic 2040 – 2059 weather timeseries, uplifted from 1981 – 2000 (see Appendix A). This is the most pessimistic model adopted by the UK Met Office and UK Climate Projections (UKCP18)6.

In addition, three operating regimes were considered (Appendix D.2) reflecting the minimum water storage that was permitted in the storage pond.

C.4 Storage

Within the theoretical non-potable supply system there is a storage pond that can store up to 720 m³ (720,000 l), and there is a 40 m³ (40,000 l) day tank fed from the storage pond. An initial pond storage of 150 m³ was modelled, and the day tank was assumed initially to be full, holding 40 m³. The size of the pond was defined by Albion Water, based on 18 days storage, as recommended in BS EN 16941-1:20247.

C.5 Inflows

Within this model, the inflow into the non-potable supply system is rainfall runoff, directed into the pond storage. Runoff is calculated from:

- Precipitation
- Evapotranspiration
- Runoff surface area
- Land surface type (and the resulting runoff coefficient)

Due to the small surface area of the storage pond, rainfall directly onto the pond was not considered as an inflow. No water was assumed to enter the pond via infiltration.

Precipitation, evapotranspiration and effective rainfall

Effective rainfall is defined within this study as the rainfall available for refill of the storage pond. Not all rainfall becomes surface water runoff, and therefore the storage pond may not refill every time it rains due to losses such as infiltration, evaporation, and groundwater recharge. In this study, groundwater recharge was assumed to be negligible due to the loamy and clayey soil with impeded drainage to the surface water network (Cranfield University, 2025) and was not included within the model. Infiltration was accounted for using runoff coefficients and evaporation was estimated using an effective rainfall method. Both daily effective rainfall and monthly effective rainfall were calculated. Daily effective rainfall was calculated as precipitation (rainfall) minus the daily reference evapotranspiration (ET_0), Equation F.1 in Appendix F. Monthly effective rainfall was calculated using the USDA SCS method, Equation F.2 in Appendix F, which accounts for reduced effectiveness of small rainfall events and a saturation limit for large storms. Comparative analysis showed that the two methods yielded similar results, so daily effective rainfall from the water balance method was used as model input.

As listed in Table C.1 Precipitation data was sourced from HadUK for assessment against past weather conditions, and transformed using **UKCP18 50th percentile change factors** from the probabilistic projections for time horizon 2040 to 2059 (**based on 1981 to 2000 historical data**) (see Appendix A).

ET_0 was calculated using the FAO Penman-Monteith method (see Equation F.3 in Appendix F), implemented in the CROPWAT 8.0 tool⁸. This method depends solely on climatic parameters, which make it a robust measure of atmospheric evaporative demand (Allen et al., 1998). It was selected because it combines physiological and aerodynamic factors, has been widely validated, and addresses the limitations of earlier empirical approaches.

Runoff surface area and land surface type

A desktop site assessment was completed to identify runoff surface area and land surface type. The site was digitised into a GIS layer, as specified in Appendix C.1. Through discussion with Affinity Water and Albion Water it was identified that the site was designed so water within the site flowed to the storage pond, however, a desktop study was required to identify whether there would be contribution from outside of the site and the proportion of this contribution. Slope and terrain of surrounding areas were identified using Google Earth data, and the watershed delineation tool within ArcGIS⁹ was used to assess the storage pond's watershed. The contribution of water from outside of the site was then identified using expert judgement, the watershed area, slope of the watershed area and terrain type.

Runoff coefficients were identified from the State Water Resources Control Board (SWRCB) fact sheet (Construction Industry Research and Information Association, 2015; State Water Resources Control Board, 2011) based on and surface type as identified within the GIS layer. Surfaces with low permeability, such as concrete or asphalt, contribute high runoff coefficients, whereas vegetated or permeable areas tend to reduce runoff through interception and infiltration. Nine land surface types shown in Figure C.1 were identified within the site with the area shown in Table C.2. Each surface type was assigned a runoff coefficient and a single runoff coefficient for the site, 0.43, was calculated as described in Appendix C.5. This indicates that, on average, 43% of effective rainfall within the site is expected to directly runoff to the storage pond.

Land surface type	Approximate area (m ²)	Runoff coefficient
Back Garden	24,325	0.35
Building	22,664	0.95
Car Park	8,559	0.90
Front Garden	9,953	0.35
Grass	69,957	0.20
path	2,350	0.90
Pavement	5,789	0.90
Road	25,430	0.90
Trees	52,725	0.20
Area-weighted average		0.43

Table C.2 Weighted runoff coefficient for the Chigwell site based on land surface type

PROJECT ZERO



Figure C.1 Digitisation of Chigwell Site

A single runoff coefficient for the site was then calculated using Equation C.2.

Equation C.2 Overall runoff coefficient

$$C_{overall} = \frac{\sum(C_i \times A_i)}{A_i}$$

Where,

- A_i is the area of land use class i
- C_i is its corresponding runoff coefficient

Flow to storage pond

The inflow to the storage pond was calculated using Equation C.3, as a function of effective rainfall, site area, and the weighted runoff coefficient. Higher runoff coefficients and larger areas contributed to greater inflows, while lower coefficients and smaller areas reduced inflows.

Equation C.3 Inflow to storage pond

$$I = \frac{P_{eff} \times A \times C_{overall}}{1000}$$

Where,

- I is the inflow (m^3/day)
- P_{eff} is the effective rainfall (mm/day)
- A is the area of rainfall capture (m^2)
- $C_{overall}$ is the weighted runoff coefficient

C.6 Outflows

Within this study, the outflow is the non-potable service demand calculated from the demand analysis within this study. Process losses are currently unknown so this study assumes no process losses for simplification. Due to the small surface area of the storage pond, evaporation directly from the pond is not considered as an outflow, and it is assumed that infiltration out of the pond is negligible due to the storage pond theoretically being lined.

C.7 Potable top up required

The water balance effectively provides a daily supply demand balance for the non-potable service. This is calculated daily to identify the number of days demand of the non-potable service cannot be met by the storage pond (potable top up is required), as well as the volume of top-up required. That is, when the balance is negative, top-up is required with the extent of the shortfall indicating the top-up requirement on that day.

Potable top-up was estimated by comparing demand¹⁰ with the available storage in the day tank ($S_{daytank}$), which had a maximum capacity of $40 m^3$. The day tank was filled from the pond

each day, being filled to capacity or as full as permitted by the available volume in the pond. Modelling pond overflow was not within the scope of this study. In the model, daily demand never exceeded the maximum day tank capacity meaning that the filling regime of the day tank did not need to be considered and, if the day tank was able to be fully filled, demand would always be met. However, when full-top up could not be achieved from the pond, shortfalls could occur; whenever daily demand exceeded the volume in the day tank, potable water supplementation was required (Equation C.4).

Equation C.4 Potable top-up requirement

$$TopUp_t = \max (avg.demand_t - S_{daytank,t}, 0)$$

Where:

- $TopUp_t$ is the potable water supplement required on day t,
- $avg.demand_t$ is the relevant seasonal-average non-potable water demand at time t,
- $S_{daytank,t}$ is the available storage in the day tank at time t.

14.4 Appendix D: Limitations and assumptions

D.1 Data Assumptions and Limitations

Baseline data: Oaklands Hamlet was plumbed from the outset with the dual-supply system and the meter readings provided start from when the site was first occupied, meaning there is no baseline data from the site itself. Nor was any meter reading data provided from a comparable development within the vicinity that had a single-plumbed system that could have served as an alternative baseline. The baseline would have provided a more accurate assessment of the behavioural differences between single and dual supply systems. This affects the ability to perform rebound analysis (see below) and how we calculate potential demand reduction. For demand reduction calculations, it is assumed that the total water demand from both sources (potable + non-potable) would be the same if Oaklands Hamlet was served by a single potable service.

Occupancy: All properties with the same bedroom count share the same assumed occupancy, while “real-world” occupancy is expected to vary. This affects the PCC calculated at an individual household level, however the aggregated values should be more representative with a small margin of error.

Categorising seasonality: Due to the infrequency of meter readings, neither approach presented in Appendix B.2 to assign seasonality gave a true reflection of seasonal usage. Both approaches include a constant daily water use over the study period, where one would expect daily usage to fluctuate. The results for both methods compared closely aligned, but small differences remain due to interval timing (Figure D.1). Method 2 was used for all seasonality analysis because it provides a fairer usage allocation across seasons: Method 1 assigns the entire volume to the season with the most days, which can overstate a season, while Method 2 splits the volume by actual days. Although both methods apply a constant usage across the season or seasons, Method 2 applies a fairer balance for reading periods that are roughly equally split. Since the results for both methods were similar, where they differed, Method 2 gave a marginally more balanced allocation.

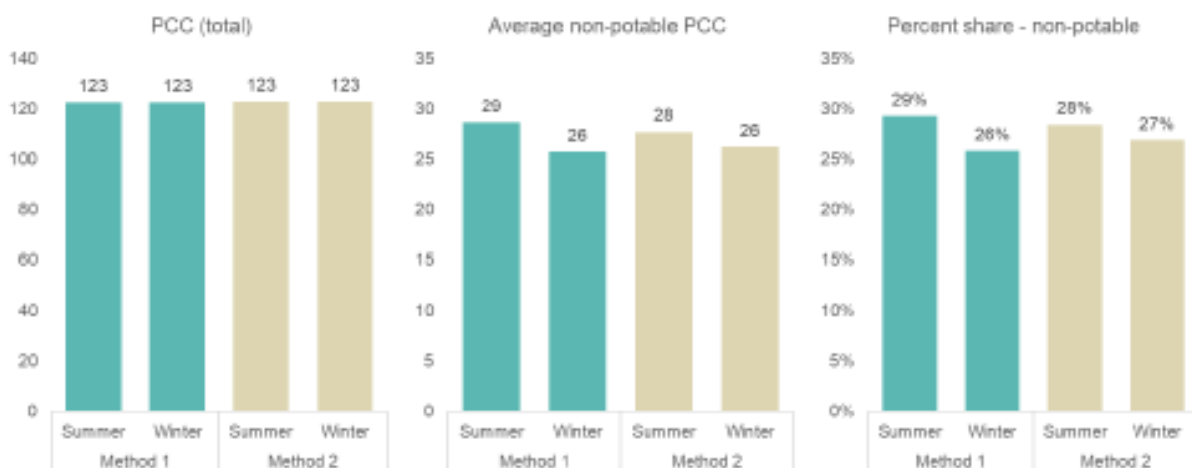


Figure D.1 Comparison of methods to assign seasonality

Reading frequency: With 37% of intervals between meter reads less than 3 months and 25% over 6 months, short and long gaps can both bias period averages and seasonal splits. The influence of weather (such as temperature) on water use was not explored as meter readings were too infrequent and irregular to provide sufficient granularity.

Rebound analysis: Assessment of the rebound effect has not been possible due to the following constraints. In lieu of this, we have provided observations about the information that residents received that may or may not have influenced their behaviour.

Baseline/Control: No baseline data or control group was provided and a before and after analysis was not possible as the site was not occupied prior to the installation of the dual supply network.

Resident communication: Albion Water verbally informed WRc that no targeted messaging had been given to residents regarding their dual supply. Only general billing information was provided. The only communication that residents received about their dual supply was on their bill. There is no explicit definition of “Drinking water” and “Greenwater”.

Sample size: Oaklands Hamlet contains a relatively small number of households and is not representative of England (or the UK) at large in terms of housing stock. There are also likely to be systematic differences in demographics between occupants of the area and other parts of the country. As such, care should be taken extrapolating findings to England and the UK at large. The small sample size also means that, when the data is segregated, for example looking at demand by size of property, there is significant opportunity for results to be impacted by outliers or for the subset not to be representative of the population group as a whole.

D.2 Modelling Assumptions and Limitations

The following initial assumptions were applied to each scenario:

- Pond capacity 720m³
- Day tank capacity 40m³
- Commissioning date 01 January
- Minimum volume permitted in pond 75m³
- Pond fill at day zero 150m³

Sensitivity analysis was performed on the latter 2 assumptions. The model was not found to be sensitive to how full the pond was on day zero due to the model start date being in January, when demand is low and recharge is high. However, sensitivity analysis on the minimum volume permitted in the pond is incorporated into the analysis below by means of two alternative assumptions reflecting reasonable minima and maxima; pond storage level maintained above 50% to reflect cautious operation (**conservative operating regime**) and level allowed to drop to zero to reflect absolute system capacity (**extreme operating regime**). The **central operating regime** with a minimum volume of 75m³ reflected the fact, that for most reservoir developments, around 25% of storage is reserved as dead storage to ensure sediments, nutrients, and contaminants are diluted, while maintaining a base level of water to support biodiversity during dry periods. However, given the supply is non-potable, and that the pond size and site characteristics do not indicate significant sedimentation, 75 m³ (10%) was deemed more suitable and has been adopted as a safeguard to balance water reuse with environmental sustainability. The 50% level for the conservative operating regime was chosen as a realistic upper bound for how a water storage system might be operated.

In addition, the model contained the following assumptions and simplifications:

- Daily and diurnal variations in demand were not considered and a constant daily demand during summer, and another during winter, was assumed.
- The filling regime of the day tank from the pond was not considered.
- No losses were assumed within the system upstream of the customer.
- Non potable demand was assumed to rise in line with overall consumption as estimated within Albion Water's WRMP24.
- No groundwater recharge was assumed.
- Pond filling due to direct incident rainfall was ignored.
- The impact of operations (e.g. to maintain water quality or de-silt) were ignored.

The impact of precipitation falling as e.g. snow or hail and the impact of changing ground conditions to infiltration was ignored.

14.5 Appendix E: Literature Review Search Approach

E.1 Primary questions

Before initiating the literature search, the primary questions were established in accordance with the project objectives. They were formulated as follows:

- What is the long-term impact on total water demand when supplies are switched from a single potable supply to a dual potable and non-potable supply system?
- How do water use behaviours change when supplies are switched from a single potable supply to a dual potable and non-potable supply system? For example, do property details or the number of people occupying the property have a large influence?

The primary questions were used to determine the online sources searched, the keywords and search strings used, the screening criteria established and the information outflow.

E.2 Screening criteria

Screening is required to shortlist relevant documents to review. The screening was based on the published date, title and geographic areas. The following screening criteria were used:

- the source must provide information which helps to answer at least one of the primary questions,
- information relating to the South East or East of England shall be prioritised,
 - secondary priority geographic areas are Germany and Switzerland,
 - other geographic areas of potential interest in Europe (England, France, Belgium, the Netherlands) and globally (the USA, Australia, Singapore, Israel, Namibia),
- the study shall be published in the last 10 years; priority shall be given to relevant studies from the last 5 years,
- the source shall be written in English.

E.3 Sources, keywords and search strings

WRc conducted the search for academic literature via ScienceDirect and Google Scholar. To search for grey literature³, WRc used Google's search engine. Additionally, WRc conducted a search for relevant recent research within WRc's own project archive.

³ grey literature is material and research produced by organisations outside of the traditional commercial or academic publishing and distribution channels, including reports (annual, research, technical, project, etc.), working papers, blog posts, government documents, white papers and evaluations

Two search sets were developed for each primary question.

Set 1 outlined the keywords and search strings for the primary question: *What is the long-term impact on total water demand when supplies are switched from a single potable supply to a dual potable and non-potable supply system?*

Set 2 for the primary question: *How do water use behaviours change when supplies are switched from a single potable supply to a dual potable and non-potable supply system? For example, do property details or the number of people occupying the property have a large influence?*

Table E.1 lists the search strings and keywords for both Set 1 and Set 2 used in the online search across different sources. *Affinity Water*

Primary Questions	Source	Keywords / Search Strings
Set 1	Science Direct	("dual water supply" OR "non potable supply") AND ("rebound effect" OR "water demand rebound")
		("potable and non-potable supply" OR "change to dual water supply") AND ("rebound effect" OR "water demand rebound")
		("dual water supply" OR "potable and non-potable supply") AND ("rebound effect" OR "water demand rebound")
		("dual water supply" OR "change to dual water supply") AND ("rebound effect" OR "water demand rebound")
	Google	Dual water supply rebound effect
		Dual water supply rebound effect in Europe
		Dual water supply rebound effect in the UK
		Non potable supply water demand rebound
		Potable and non-potable supply rebound effect
		Change/switch to dual water supply rebound effect
Set 2	Science Direct	("dual water supply" OR "non potable supply") AND ("behaviour" OR "behaviour change")
		("potable and non-potable supply" OR "change to dual water supply") AND ("behaviour" OR "behaviour change")
		("dual water supply" OR "potable and non-potable supply") AND ("water use change" OR "micro component water use" OR "micro component behaviour")
		("potable and non-potable supply" OR "change to dual water supply") AND ("water use change" OR "micro component water use" OR "micro component behaviour")
		"Water use behaviour important variable"
		"Water use behaviour important parameter"
		"Water use behaviour property details impact"
		"Importance of property details for understanding water use"
		"Importance of occupancy data for understanding water use"
	Google	Dual water supply water use behaviour
		Dual water supply water use behaviour in Europe
		Dual water supply water use behaviour in the UK
		Water use behaviour important variable
		Water use behaviour important parameter
		Water use behaviour property details impact
		Importance of property details for understanding water use
		Importance of occupancy data for understanding water use
		Water use behaviour property details impact
		Potable and non-potable water supply and behaviour change

Table E.1 Literature sources, keywords and search strings

E.4 Document prioritisation

Based on the established criteria, WRc conducted the search of relevant documents using the methods outlined above. Documents were prioritised into high, medium and low-priority documents according to the screening criteria based on the abstract or first paragraph, as appropriate.

High and medium-prioritised documents were reviewed first. It was determined that the aspects where information was lacking were unlikely to be addressed by the lower-priority documents; therefore, some of the low-priority documents were excluded from the desktop review.

E.5 Information extraction and evidence database

Documents were reviewed, and relevant text was extracted and added to the evidence database, categorised according to the aspect of the primary questions being addressed and outlined which primary questions the text referred to. A technical review of the evidence database was conducted and extracts not deemed relevant were excluded.

The classifications included:

- author
- title
- year of publication
- geographical location
- years of research conducted
- the relevant information extraction for specific primary questions
- the rationale for putting the extracted text into the specific primary question.

It is important to highlight that a single piece of evidence may have been included multiple times if it pertained to both primary questions. Each document generally contained several pieces of evidence.

14.6 Appendix F: Reference evaporation and effective rainfall equations

Effective rainfall is defined as the portion of total rainfall that is available for plant growth after accounting for losses such as runoff, deep drainage (percolation beyond the root zone), and evaporation. It represents the water that actually infiltrates and is retained in the root zone where plants can use it. Factors influencing effective rainfall include climate, soil texture and structure, land slope, and management practices like ground cover and soil conservation techniques. Daily effective rainfall was estimated using Equation F.1

Equation F.1 Daily effective rainfall equation

$$P_{eff,daily} = P - ET_o$$

where P is daily rainfall and ET_o is daily reference evapotranspiration.

For monthly estimates, the USDA Soil Conservation Service (SCS) method, Equation F.2, was applied (Allen, et al., 1998).

Equation F.2 USDA Soil Conservation Service (SCS) method equation

$$P_{eff} = \frac{P_{month} \times (125 - 0.2P_{month})}{125} \text{ for } P_{month} \leq 250 \text{ mm}$$

$$P_{eff} = 125 + 0.1 \times P_{month} \text{ for } P_{month} > 250 \text{ mm}$$

The USDA SCS method accounts for rainfall thresholds, assuming reduced effectiveness of small rainfall events and a saturation limit for large storms.

ET_o represents the evaporative demand of the atmosphere from a reference crop not short of water, independent of crop type, growth stage, or management practices. The concept allows the separation of atmospheric demand from soil and crop characteristics, ensuring that ET_o values are comparable across different locations and times.

The Penman-Monteith method was selected because it integrates both physiological and aerodynamic parameters and has been extensively validated against experimental data worldwide, overcoming limitations of earlier empirical methods. The required climatic inputs included daily minimum and maximum temperature, relative humidity, wind speed, and sunshine hours. The Penman-Monteith method is expressed in Equation F.3

Equation F.3 Penman-Monteith equation

$$ET_o = \frac{0.408\Delta(R_n - G) + y \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + y(1 + 0.34U_2)}$$

Where:

ET_o reference evapotranspiration [mm day⁻¹],

R_n net radiation at the crop surface [MJ m⁻² day⁻¹],

G soil heat flux density [MJ m⁻² day⁻¹],

T mean daily air temperature at 2 m height [°C],

u_2 wind speed at 2 m height [ms⁻¹],

e_s saturation vapour pressure [kPa],

e_a actual vapour pressure [kPa],

$e_s - e_a$ saturation vapour pressure deficit [kPa],

Δ slope vapour pressure curve [kPa °C⁻¹],

g psychrometric constant [kPa °C⁻¹].

14.7 Appendix G: Technology Review supporting documentation

Arumloo (low-flush toilet)

- **Manufacturer / Datasheet:** Arumloo technical pages (specification sheets & product info). [Arumloo, https://www.arumloo.com/techinfo](https://www.arumloo.com/techinfo)
- **Independent reference / case study:** Toilet Board Coalition / Water Research case study summarising Arumloo performance and wider trials. <https://www.toiletboard.org/case-study-sustainable-flushing-a-case-study-of-water-research-comission-and-arumloo-pty-ltd/>

Jets (vacuum toilets)

- **Manufacturer / Datasheet:** Jets product pages and brochure (Jets® vacuum toilets; model specs and brochure). [Jets® Group | High quality vacuum toilets by Jets® JETS Brochure Toilets-02_2024_web.pdf](#)

Kelda (Air-Powered™ shower)

- **Manufacturer / Datasheet:** Kelda Air-Powered™ shower product & technical guide (specification PDF). [Kelda Showers Kelda Air-Powered Shower Guide v1.5](#)
- **Independent reference / case study:** Energy Saving Trust / UKGBC case note summarising Kelda performance and estimated water/energy savings. [Kelda Showers: an innovative shower system - Energy Saving Trust https://ukgbc.org/resources/water-and-energy-efficient-showers](https://ukgbc.org/resources/water-and-energy-efficient-showers)

Xeros (bead / polymer-assisted washing technology)

- **Manufacturer / Datasheet:** Xeros product pages (Laundry Care System / XOrb technology and product overview). [Xeros – The Future of Laundry | Revolutionising Traditional Laundry Methods](#)
- **Independent reference / case study:** Independent coverage and commercial trial summaries <https://www.theguardian.com/business/2014/oct/19/xeros-bead-washing-machine-system-save-water-energy-home> [Ecoprod - Xeros washing machines](#)

References

AQUALITY (2013) *Cambridge – Clay Farm: The Quad*. Available at: <https://www.aquality.co.uk/6354/cambridge-clay-farm-the-quad-2013> (Accessed: 10/12/2025)

Department for Communities and Local Government. (2010) *Code for Sustainable Homes – Technical Guide*. November. Available at: https://assets.publishing.service.gov.uk/media/5a74b01b40f0b619c86599ff/code_for_sustainable_homes_techguide.pdf.

Energy Saving Trust. (2023). *Kelda showers*. <https://energysavingtrust.org.uk/case-study/kelda-showers/>

Energy Saving Trust. (2024) 'Kelda Showers: an innovative shower system uses significantly less water', *Energy Saving Trust*. Available at: <https://energysavingtrust.org.uk/case-study/kelda-showers/>.

EWSC (2024) *Water Reuse in New Housing: Understanding the Business Case*. Available at: <https://static1.squarespace.com/static/65a8f1c60057e116c14c4600/t/67533f2d8d6e8273ab95b15a/1733508911324/Water+reuse+in+new+homes+-+business+case+report.pdf> (Accessed: 10/12/2025).

Freeflush Water Management Ltd. (2025) *Hydraloop H300 UK Grey Water Recycling System*. Available at: <https://www.freeflush.co.uk/products/hydraloop-uk-grey-water-recycling-system>.

GRAF. (no date) *Platin package House Eco+ – suitable for pedestrian loading*. Available at: <https://www.graf.info/en/rainwater-harvesting/tanks-underground/rainwater-flat-tank-platin/platin-package-house-eco-plus/platin-package-house-eco-plus-suitable-for-pedestrian-loading.html>

NHBC. (no date) *Water efficiency in new homes*. Available at: <https://www.nhbc.co.uk/kontentdocuments/32083174-a3e0-49db-a390-9b845ca41c2c/water-efficiency-in-new-homes.pdf> (Accessed: 28 November 2025).

Ofwat (2024) *Environmental Incentives Common Framework – English New Connection Rules (effective April 2025)*. Water Services Regulation Authority. Available at: <https://www.ofwat.gov.uk/wp-content/uploads/2024/10/Environmental-Incentives-Common-Framework-%E2%80%93-English-New-Connection-Rules-%E2%80%93-effective-April-2025.pdf> (Accessed: 10/12/25).

Ofwat. (2024) *Environmental Incentives Common Framework – English New Connection Rules*. Available at: <https://www.ofwat.gov.uk/wp-content/uploads/2024/10/Environmental-Incentives-Common-Framework-%E2%80%93-English-New-Connection-Rules-%E2%80%93-effective-April-2025.pdf> (Accessed: 28 November 2025).

Ofwat. (2025) *New Appointments and Variations (NAVs)*. <https://www.ofwat.gov.uk/regulated-companies/markets/nav-market/>.

Ricardo Energy & Environment (2020), *Independent review of the costs and benefits of rainwater harvesting and grey water recycling options in the UK — Final Report for Waterwise*. Available at: https://database.waterwise.org.uk/wp-content/uploads/2022/08/Ricardo_Independent-review-of-costs-and-benefits-of-RWH-and-GWR-Final-Report.pdf (Accessed: 28 November 2025).

The Private Water Supplies (England) Regulations 2016, S.I. 2016/618. Available at: <https://www.legislation.gov.uk/uksi/2016/618/contents> (Accessed: 10/12/2025).

UK Government (2015) *Approved Document G: Sanitation, hot water safety and water efficiency – incorporating 2016 and 2024 amendments* (PDF). Available at: https://assets.publishing.service.gov.uk/media/66f6c6ce3b919067bb4828cc/ADG_with_2024_amendments.pdf (Accessed: 18 November 2025).

UK Government (2015) *Approved Document G: Sanitation, hot water safety and water efficiency – incorporating 2016 and 2024 amendments* (PDF). https://assets.publishing.service.gov.uk/media/66f6c6ce3b919067bb4828cc/ADG_with_2024_amendments.pdf (Accessed: 18 November 2025).

UK Government. (1991) *Water Industry Act 1991*. <https://www.legislation.gov.uk/ukpga/1991/56/contents>.

UK Government. (2018) *Water Supply (Water Quality) Regulations 2018*, Regulation 4. <https://www.legislation.gov.uk/uksi/2018/647/contents>.

UK Government. (2024) *A summary of England's revised draft regional and water resources management plans*. GOV.UK. Available at: <https://www.gov.uk/government/publications/a-review-of-englands-draft-regional-and-water-resources-management-plans/a-summary-of-englands-draft-regional-and-water-resources-management-plans> .

UK Government. (2024) *A summary of England's revised draft regional and water resources management plans*. GOV.UK. <https://www.gov.uk/government/publications/a-review-of-englands-draft-regional-and-water-resources-management-plans/a-summary-of-englands-draft-regional-and-water-resources-management-plans> .

Water reuse in new homes – Business Case Report. (no date) *Water reuse in new homes – business case report*. Available at: <https://static1.squarespace.com/static/65a8f1c60057e116c14c4600/t/67533f2d8d6e8273ab95b15a/1733508911324/Water+reuse+in+new+homes+-+business+case+report.pdf> (Accessed: 28 November 2025).

Waterwise (2020) *Independent Review of Costs and Benefits of RWH and GWR Options in the UK*. Report prepared by Ricardo Energy & Environment (Ref: ED 13617100, Issue number 1, 04 September 2020). Available at: <https://database.waterwise.org.uk/knowledge-base/independent-review-of-costs-and-benefits-of-rwh-and-gwr-options-in-the-uk/>.