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Engaging stakeholders in adopting rainwater harvesting through a digital decision-aid tool

A qualitative study of stakeholder perception of rainwater harvesting for urban resilience and circular water use

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Abstract

Rainwater harvesting (RWH) represents a potential measure to reduce potable water demand and contribute to stormwater management in urban areas, yet its implementation in Sweden remains limited and largely experimental. This thesis investigates key barriers, drivers and decision factors associated with RWH adoption through literature review and five semi-structured interviews with practitioners representing engineering, property management and supplier perspectives. The results show that lack of standardized methods, insufficient regulatory clarity, economic uncertainty and low market maturity are major constraints. Legislative requirements for stormwater detention currently form the strongest implementation driver, whereas low water tariffs and uncertainty regarding technical performance and design limit wider uptake. To address part of this knowledge gap, a visual decision-support tool, *Tyréns Recirculation tool* (renamed as TRICS), was improved on and developed to enable simplified early-stage evaluation of RWH feasibility and water saving potential. The tool was developed and increased in its viability to support stakeholders by increasing awareness, enhancing comparability between options and reducing entry barriers during the early planning phase. While the tool currently focuses on potable water substitution, future development should integrate flood risk reduction and lifecycle environmental impacts. The study concludes that RWH can play a meaningful role in sustainable and climate-adapted urban development in Sweden, but requires clearer guidance, standardized routines, economic incentives and decision-support to transition from isolated pilot projects to mainstream practice.

Keywords:

Rainwater harvesting (RWH), Stakeholder engagement, Urban flooding, Stormwater management, Decision-aid, Cost-benefit, Interactive map. Circular water use. Sustainable urban development. Climate adaptation. Design tool.

Sammanfattning
Regnvatteninsamling har potential att minska behovet av dricksvatten samt bidra till dagvattenhantering i urbana miljöer. Dock är implementeringen av det i Sverige fortfarande begränsad och i huvudsak experimentell. Denna studie undersöker centrala barriärer, drivkrafter och beslutsfaktorer kopplade till införandet av RWH genom litteraturstudie och fem semistrukturerade intervjuer med aktörer inom ingenjörsteknik, fastighetsförvaltning och leverantörsledet. Resultaten visar att avsaknad av standardiserade arbetsmetoder, otydlig reglering, ekonomisk osäkerhet och en omogen marknad utgör betydande hinder. Lagkrav på dagvattenfördröjning är idag den starkaste drivkraften, medan låga vattenpriser och osäkerhet kring teknisk prestanda begränsar bredare införande. För att åstadkomma delar av detta kunskapsgap utvecklades ett befintligt visuellt beslutsstöd, Tyréns Recirkuleringskarta (nämndes om till TRICS), för att möjliggöra förenklad tidig utvärdering av RWH och dess vattenbesparingspotential. Verktyget utvecklades och förbättrades vidare till att stödja beslutsfattare genom att öka kunskap, förbättra jämförbarhet och minska trösklar i tidiga planeringsskeden. Även om verktyget i nuläget främst fokuserar på minskad dricksvattenförbrukning bör framtida utveckling inkludera översvämningsriskreducering och livscykelmässiga miljöeffekter. Studien drar slutsatsen att regnvatteninsamling kan spela en viktig roll i ett hållbart och klimatanpassat stadsbyggande i Sverige, men kräver tydligare vägledning, standardiserade arbetssätt, ekonomiska incitament och beslutsstöd för att gå från enstaka pilotprojekt till en etablerad praktik.

Nyckelord:
Regnvatteninsamling. Dagvattenhantering. Intressentengagemang. Klimatanpassning. Beslutsstöd. Cirkulär vattenanvändning. Dimensioneringsverktyg. Interaktiv karta. Kostnadsnyttoanalys. Hållbar stadsutveckling.

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Definitions

Rainwater harvesting (RWH)	The collection and storage of rainwater from roofs or other catchment surfaces for later use. RWH systems may include conveyance, storage, filtration and treatment stages and supply non-potable or, in some cases, restricted potable uses.
Stormwater / Rainwater / Runoff	Surface water generated by precipitation (rain and snowmelt) that flows over impervious and pervious surfaces toward drains, soakaways or receiving bodies. Stormwater and rainwater are used interchangeably in this study.
Local On-site Detention (LOD)	Measures implemented at the property level to temporarily retain and attenuate stormwater runoff to reduce peak discharge to the public drainage system.
Cost-benefit analysis (CBA) / Payback time	Economic evaluation comparing system costs with monetized benefits (water savings, avoided flood damage); payback time is the period until cumulative benefits equal initial investment.
Decision-support tool (DST) / Decision-aid	A software or interactive platform that assists stakeholders by integrating data, models and visualizations to inform early-stage feasibility and comparisons.
Recirculation Map / TRICS (*Tyréns Recirculation tool*)	The interactive map-based decision-aid developed in this thesis that visualizes local RWH potential, estimates water balances and provides simplified economic indicators for early planning.
Resilience / Climate adaptation	The capacity of urban systems to anticipate, absorb and recover from climate-related disturbances (e.g., pluvial flooding); measures that enhance resilience reduce vulnerability to climate change.

Contents

1. Introduction

In this chapter, an overview of the topic researched in this study, background, motives, research gap as well as the aim and scope of the study are given. This serves as a familiarization step for the reader before delving deep into the research topic of this study.

Climate change is expected to intensify climatic variability, resulting in more frequent and severe extreme weather events such as storms, droughts and flooding throughout the 21st century (IPCC, 2012). Flooding is particularly critical for urban environments, where green permeable surfaces are continuously replaced by impervious buildings, streets and parking areas. This disrupts the natural water cycle and, combined with intensified precipitation, increases the exposure of cities to pluvial flooding and the associated economic losses and risk to human life. In Sweden, floods occur either along rivers and coasts (fluvial flooding) or as surface flooding during high-intensity rainfall events when rainfall exceeds soil infiltration and drainage capacity (pluvial flooding) (SMHI, 2025a; Miller & Hutchins, 2017). Pluvial flooding has been identified as the most damaging form of flooding in terms of human and economic consequences (Miller & Hutchins, 2017; SMHI, 2025b).

Historically, Swedish stormwater management has relied on linear drainage systems where runoff is conveyed through pipes and discharged directly to local recipients (Gästrike Vatten, 2025). In older areas, stormwater can still be mixed with municipal wastewater and treated before release (Dala Vatten och Avfall, 2025). These conventional structures do not consider the potential resource value of stormwater as a substitute for potable water in non-potable applications such as irrigation, cleaning or toilet flushing.

A more integrated approach to stormwater management, where stormwater is not only detained but also harvested and reused, could therefore contribute simultaneously to increased climate resilience and more sustainable water resource efficiency. This addresses both goal six and eleven in the United Nation's sustainability development goals (SDGs), where clean water and sustainable and resilient cities and communities are sought after (UN, 2025). Few large-scale projects have been carried out in Sweden addressing both functions at the same time. Buildings such as Citypassagen in Örebro, Celsius in Uppsala and Sergelhuset in Stockholm demonstrated how stormwater can be successfully harvested and reused (Holm, 2021). By reducing potable water demand while buffering local runoff volumes, stormwater harvesting becomes both a climate adaptation measure and a circular resource strategy (Jamali et al., 2020). Strengthening this dual function through local implementation, policy support and decision-aid could therefore help cities transition away from linear, vulnerable stormwater infrastructure toward more resilient and sustainable urban water systems.

1.1 Water usage for daily activities

In Swedish households, the average water use is approximately 140 liters per person per day. The distribution of this use shows that only a small share is for drinking and cooking, while most is for activities where potable quality is not strictly required (Svenskt Vatten, 2025a). The distribution of water use is given in Table (1).

Table 1: A breakdown of water uses in a typical Swedish household.

Freshwater use	Personal hygiene	Toilet flushing	Dishwashing	Laundry	Food and drink	Other purposes
Perc. %	43	21	11	11	7	7
Liters (l)	60	30	15	15	10	10

This breakdown shows that nearly two-thirds of domestic water consumption could, in principle, be substituted by alternative sources such as harvested stormwater, particularly for toilet flushing and laundry where high water quality is less critical as illustrated in Jamali et al., (2020).

1.2 *Drizzle*

Even though current stormwater management is linear in nature, some projects have been promoted to increase the sustainability and circularity of stormwater management (e.g. stormwater reuse). An example of such projects is the collaborative approach *Drizzle* (Centre for Stormwater Management) which is a research project funded by Vinnova, Sweden's agency for innovation and research, led by Luleå University of Technology with collaborators including Tyréns Sverige AB and several other stakeholders and companies. *Drizzle*'s main goal is to determine sustainable ways to manage, treat and reuse stormwater, materialized in ice melt and surface runoff in different viable use-case scenarios. Delay of stormwater, flood risk reduction, treatment and reuse of stormwater and new treatment technologies are all part of the research effort of *Drizzle* (Luleå University of Technology, 2025).

1.3 Problem formulation

1.3.1 Incentives and decision factors

One of the challenges in fighting off urban flooding is incentivizing stakeholders to take responsibility towards transition and climate resilience. Having impervious surfaces on the property such as roofs, asphalted patches of land and stone slabs (e.g. properties with asphalted parking spots), decreases water infiltration rate to the soil and risks gathering of large water volumes caused by surface runoff (Gästrike Vatten, 2025). The Planning and Building Act strictly enforces that property owners have the responsibility of preventing flooding on their own property. This includes drainage and disposal of stormwater even if the property is connected to the municipal stormwater network, as the municipal stormwater network shall not be overloaded (Swedish housing administration (Boverket), 2023).

Proposed solutions to decrease flood risks are either to decrease impervious surface area on the property allowing stormwater to infiltrate or implement a stormwater retaining solution such as a water tank. By encouraging property owners to combine local stormwater management (i.e. LOD, lokal omhändertagande av dagvatten) such as a water tank that can gather and harvest stormwater with reuse of stormwater, urban flooding could be managed on a local scale. Besides reducing flood risks, reusing stormwater is good practice as it can enable property owners to reuse stormwater as a resource in a circular process. This includes decrease of large stormwater volumes entering municipal networks thus saving fees, decrease of freshwater use and costs, as well as use for watering plants and trees in the time of drought, or it can even be used to fight off fires (Oscarson, 2024). Overflowing stormwater can be disposed of by infiltrating it to the ground which replenishes ground water extracted from wells.

As of the date of writing this paper, there are no statistics surrounding the use of storm- and rainwater harvesting in properties in Sweden, indicating a small engagement of stormwater harvest as a viable alternative. Investigating what property owners' decision factors (challenges and driving forces) when they choose to implement (or avoid) stormwater harvesting and reuse in Sweden, is a key goal of this paper.

1.3.2 *Tyréns Recirculation tool*

To appeal to property owners, the advantages of harvesting and reuse of stormwater, an interactive online tool was created by Oscarson (2024) in collaboration with the consulting company Tyréns Sverige AB. By inputting basic parameters of one's own property, the tool gives annual/monthly estimates of stormwater volumes that can be harvested through the property's roofs, as well as suggesting a suitable volume for a water tank for the reuse purpose. The tool will serve as a role of decision-aid for property owners, municipal planners and other stakeholders and a first step when deciding for adoption of rain- and stormwater harvest systems (RWH).

While the *Tyréns Recirculation tool* provides necessary information about possible stormwater harvesting, the tool in its current state is partly functional and needs refinement to increase its viability. The current version of the tool lacks several key components that would enable it to function as a comprehensive decision-aid for stakeholders. These include more detailed consideration of economic factors (such as investment costs, payback time and preliminary RWH system design), and technical parameters (such as water use-cases and comprehensive system costing). By refining these aspects, the tool could not only provide quantitative estimates but also support qualitative evaluation of different implementation scenarios, thereby increasing user confidence and facilitating broader adoption of rainwater harvesting systems in Swedish property development.

1.4 Aim and scope

This study aims to explore the engagement and perceptions of stakeholders toward the concept of rainwater harvesting and reuse, supported using a decision-aid tool. The study is conducted through semi-structured interviews, seeking to understand critical decision factors regarding adoption of rainwater harvesting in Sweden, as well as explain its current challenges and driving forces. In addition, the study seeks to understand what decision-aid is through the lens of stakeholders and how the *Tyréns Recirculation tool* addresses those needs by gathering expert feedback and integrating their perspectives into the further development of the tool. Furthermore, by comparing the *Tyréns Recirculation tool* to tools with similar purposes, a basic understanding of what a decision-aid tool is achieved. The stakeholder definition of a decision-aid tool and the comparison with said tools provides a foundation and justifies the further refinement of the tool. These refinements aim to enhance the tool's usability and relevance, encouraging stakeholders to adopt practical measures for reducing urban flooding and promoting the reuse of stormwater in various application scenarios.

The overarching objective is to identify, assess, and evaluate critical decision factors influencing the adoption of rainwater harvesting systems in Sweden and to understand the challenges stakeholders face during the decision-making and adoption processes of RWH systems. Specifically, the study seeks to:

- Examine how stakeholders perceive and prioritize different decision factors related to the implementation of RWH systems, answering the following research question:

How do stakeholders value adoption of RWH, and what are the main challenges and driving forces leading to adoption/not adopting RWH in its current state in Sweden?

- Develop and refine a decision-aid tool, materialized in the *Tyréns Recirculation tool*, that meets stakeholders' needs and serves as an initial step and screening towards RWH adoption, answering the following research question:
  What is a decision-aid tool according to the stakeholders, and how can Tyréns Recirculation tool address their needs in the context of a decision-aid?

This research endeavor was made in collaboration with the consulting and expert company Tyréns Sverige AB. Tyréns Sverige AB is lead expert in consulting services for infrastructure, stormwater modelling and solutions as well as expertise in many different technical fields.

1.5 Limitations

This study is limited by the small number of existing pilot RWH projects in Sweden, which constrains the generalizability of findings and reduces the statistical robustness of comparisons. Interview data reflects the perspectives of a select group of early adopters and industry actors, meaning that broader market attitudes and institutional resistance may not have been fully captured. The economic and technical data reported from the case studies also vary in detail and accuracy, as many installations lack long-term monitoring and standardized cost reporting. Furthermore, the evaluation of the *Tyréns Recirculation tool* was based on a limited set of participants and only assessed short-term perceived usability rather than long-term practical effectiveness in decision-making. Finally, the study primarily assessed RWH from a water-saving perspective and therefore did not incorporate all potential system benefits such as flood-risk reduction, CO_2 and energy consumption reduction and municipal infrastructure relief. These named limitations highlight the need for continued empirical research and broader stakeholder testing to strengthen external validity and support future tool refinement.

2. Literature overview

This chapter presents an overview of literature that forms a basis to be in line with the purpose of the study, as well as creating focal points and a comprehensive understanding of the topic.

2.1 Stormwater and urban flooding risks

Stormwater, by definition, is an umbrella term for urban runoff caused by precipitation and snowmelt that collects from roofs, roads and parking lots (Ekholm et al. 2023). Several factors contribute to the frequency and magnitude of stormwater which in return controls the risk of urban flooding and the severity of its consequences. Small infiltration rates, impervious surface areas, duration and intensity of the storm as well as the inadequacy of stormwater drainage systems. Short duration high intensity storms overwhelm the drainage systems and network, causing disturbances and shutdown of drainage networks (Miller & Hutchins, 2017; Swedish Meteorological and Hydrological Institution, 2025b). Climate change is a major factor contributing to increase in both intensity and duration of storms and is predicted to further increase with time (IPCC, 2012).

In 2021, a storm hit the counties of Gävle and Dalarna in central Sweden, precipitating more than 160 mm of rainfall over a 12-hour period. This caused major disturbance to the drainage systems and networks and a flood with severe consequences where over 8 000 insurance cases were issued and a total estimate of 1.8 billion SEK in damages (Moberg, 2022). This example illustrates how detrimental storms can be to unexpected/unprepared societies, reflected in damage costs of the flood that hit Gävle and Dalarna counties.

2.1.1 Rainwater harvesting and risk reduction

In an assessment by Jamali et al. (2020) of rainwater harvesting (RWH) tanks, a simulation study was carried out of a suburban catchment area in Melbourne, Australia to deduce the potential of RWH tanks of reducing flood risks. The authors conducted an integrated approach, focusing on RWH tanks' ability to mitigate urban flooding, while also considering water supply benefits. The framework links two components, a semi-continuous mass-balance model that simulates tank storage capacity based on rainfall and household water demand, and a flood model that combines the Storm Water Management Model (SWMM) with a Cellular-Automata model (cell-based calculation) to simulate surface flooding. Flood damages were estimated using stage-depth damage curves in Australian dollars, allowing cost-benefit analysis of RWH tank implementation. Although the difference in flood extent between having an RWH tank and not having one is small, results showed that widespread use of RWH tanks could reduce expected annual flood damage by up to 30% for larger floods. Furthermore, flood risk reduction was most significant for storms with return periods between 2 - 20 years. The study highlights that the effectiveness of RWH depends strongly on the availability of tank storage before storm events and the temporal distribution of rainfall within events.

Similarly, Lin et al. (2025) evaluated the performance of smart rain barrels (SRBs), rainwater storage units that are a subset of RWH tanks but are equipped with pumps and smart switches that use local weather forecasts to automatically empty before rainfall events. Using PySWMM, a Python interface to the US EPA's SWMM model, they simulated SRB behavior in three densely populated residential zones in Saitama City during different storm scenarios (e.g. high intensity, short duration as well as lower intensity long duration storms). Compared to traditional rain barrels, SRBs achieved a 2-10 % reduction in total runoff volume during heavy rain. Importantly, the effectiveness of SRBs increased with capacity, indicating greater benefits with larger storage. The study shows that smart, forecast-driven control significantly controls stormwater retention capability, contributing to reducing large runoff volumes.

Another approach of measuring the effectiveness of water retaining structures was made by Cristiano et al. (2023). The authors investigated how green roofs and RWH tanks systems can jointly reduce urban stormwater runoff. They simulated various configurations, such as extensive, intensive, and multilayer "blue" green roofs on flat structures, and RWH systems on sloped roofs, across multiple cities representing diverse climates. Although green roofs showed higher retention capacity per building, cost-efficiency analysis revealed that RWH systems provide better large-scale performance at lower cost, largely due to the distribution of sloped roofs across urban areas which contribute to high peaks earlier during a storm. Consequently, combining multilayer blue-green roofs with rainwater harvesting tanks consistently reduced urban runoff by about 5%, even during extreme rainfall events. The study highlights mainly that while green roofs are effective individually, RWH systems offer superior efficiency when deployed city-wide, and the combination of both technologies delivers measurable flood mitigation benefits under extreme conditions.

2.2 Rainwater harvesting (RWH), water reuse acceptance and stormwater management

2.2.1 Globally

In a recent study by Snelling et al. (2024), *Public Perceptions of Rainwater Harvesting (RWH)*, investigated how people in the UK perceive domestic RWH systems, distinguishing between users (households with installed systems) and non-users. Interestingly, the findings showed that implicit perceptions (subconscious attitudes measured through indirect questioning) were generally more favorable than explicit, stated opinions, especially among non-users. While users had higher trust in the reliability and benefits of RWH, non-users often expressed concerns about practicality, hygiene, and economic viability. Importantly, RWH was perceived as more suitable for outdoor uses such as gardening and washing cars, while indoor applications like toilet flushing or laundry faced greater skepticism. The study suggests that public acceptance may be higher than explicit opinions indicate, and that targeted communication and demonstration of successful systems could help reduce hesitancy.

Similarly, a study by Stec (2023), *Public perception of rainwater and greywater reuse across 12 countries*, compared perceptions of rainwater reuse with greywater reuse. Across all contexts, rainwater reuse received greater acceptance than greywater reuse, with 54% of respondents open to using rainwater as a substitute for tap water, compared to only 39% for greywater. Acceptance was especially strong in water-scarce regions, where residents had practical experience with shortages and were more willing to overcome perceived hygiene risks. A finding was that financial incentives matter, where more than 75% of respondents stated they would be more willing to adopt RWH systems if subsidies or rebates were available. The study also found that knowledge gaps and lack of trust are major barriers, showing that clear communication, awareness campaigns, and visible government backing are essential to improve adoption.

Another research by Shalamzari et al. (2016), *Public acceptability of domestic RWH in Golestan*, explored public perception in a semi-arid region where RWH has potential to relieve stress on municipal supplies. The study revealed a strong divide between adopters and non-adopters. Non-adopters tended to view RWH as costly, technically complicated, and high maintenance, whereas adopters, those with firsthand experience, valued the independence, water savings, and resilience it provided. Social influence was a factor, by seeing neighbors or peers use RWH increased the likelihood of adoption, highlighting the importance of community demonstration projects. Moreover, adopters placed more importance on government support and technical expertise, suggesting that institutional involvement can legitimize and accelerate adoption. Exposure and social proof are critical in overcoming resistance to adoption.

Furthermore, a study by Cools et al. (2023) of 2013 residents in Finland (Lappeenranta) and Norway (Gjøvik) explored their willingness to invest in stormwater management solutions on private properties. The study found strong public support, especially for permeable pavements, which were favored over options like RWH tanks, rain gardens, green roofs, green walls, and green ditches. Popular reasons included their ability to reduce flood risk, low maintenance needs, improved aesthetics, and runoff reduction. Support tended to be higher among younger respondents, individuals with higher education or property value, and those with flood experience. While interest was high, cost and maintenance concerns, notably among lower-income groups, were significant barriers. The study suggests that financial incentives and targeted education campaigns could help foster broader engagement in private stormwater solutions.

The studies presented in this section highlight the positive attitude towards RWH and reuse and its benefits, concern rises when it comes to cost and maintenance, usage indoors or as a drinking water alternative, as well as lack of knowledge of management and role of RWH solutions in flood risk reduction.

2.2.2 Sweden

In a 2022 survey by Gullberg et al. (2022) of 1 001 randomly selected adults in Knivsta municipality explored public perceptions of rainwater reuse under the assumption that the water was "clean and safe". Participants rated their attitudes toward using rainwater for drinking, handwashing, or flushing toilets, and their trust in institutions like municipalities, utilities, and suppliers. The study also examined perceived risks, benefits, and personal value orientations (altruistic, egoistic, biospheric, hedonic) to understand behavioral drivers. Findings indicate that rainwater reuse is still in an early niche phase in Knivsta, with positive public acceptance and understanding for different intended purposes of water reuse. The authors, however, highlight that the municipality of Knivsta regarded alternate water management solutions as supplements to the current ones instead of viable alternatives.

As for the local perception of governance framework and stormwater management, Glaas et al. (2025a), conducted an interview-study of several stakeholders, including municipalities and real estate companies in Sweden. The study explored how Swedish municipalities and property owners (e.g. property companies) can collaborate to improve climate-robust stormwater management. Interviews with municipalities and property companies revealed barriers to said collaboration: unclear legislation, limited municipal authority and funding, organizational silos, and uncertainty over roles. These hinder coordinated action in adapting to increased flood risks. Suggested enablers include clearer legal frameworks, designated municipal coordinators, long-term collaborative platforms, and transparent financial cost-sharing models. The study concluded that stronger institutional clarity and formal structures for cooperation are needed to accelerate resilient stormwater solutions in urban Sweden.

Another study by the same authors (Glaas et al., 2025b), investigated the perception of private property owner associations and revealed that many tenant-owned housing associations in Sweden significantly underestimate the risk and responsibility for pluvial flooding; even when their buildings have already experienced repeated flooding. A desk analysis of pluvial flood exposure across 69 apartment buildings, along with eleven interviews with association chairpersons, showed that low awareness of risk, limited knowledge about adaptation options, and undervaluation of preventive benefits constitutes surprisingly low proactive adaptation, even among those familiar with flooding. Despite clear guidance in Planning and Building Act, associations tend to rely on generous insurance coverage and perceive flood prevention as less urgent is what the authors deduced.

Glaas et al.'s research highlights the importance of adequate governance framework, public awareness and cooperation for sustainable stormwater management and flood prevention. While this study's main goal is to investigate RWH harvest, reuse and implementation from a property owner's perspective, it is nonetheless important to consider deficiencies in governance framework and stormwater management as it could be a factor of decision for a property owner to implement said systems. Aside from Gullberg et al. (2022), there is unfortunately no equivalent comprehensive specific research and evaluation of stakeholders' willingness on RWH and reuse adoption specifically.

2.3 Overview of critical decision factors reported in literature

In this section, the critical decision factors for adoption of RWH systems are reported and summarized (Table 2). The challenges, barriers and driving forces of municipal and private property owners to implement rainwater harvest and reuse are given based on the reviewed literature.

2.3.1 Economic factors

High upfront costs and uncertain payback times are a well-documented barrier. In the UK perception study (Snelling et al., 2024), non-users cited cost as one of the strongest deterrents, while users emphasized long-term savings. Similarly, the TransformAr Finland-Norway survey (Cools et al., 2023) showed that cost and maintenance concerns, particularly among low-income groups, were major barriers to investing in private stormwater measures like permeable pavements. Swedish property associations, as studied by Glaas et al. (2025b) often rely on insurance instead of proactive investment, showing how financial safety nets reduce perceived economic and resilience necessity. Conversely, subsidies and reduced fees have been highlighted in several studies (e.g. Stec, 2023) as critical to motivating adoption.

2.3.2 Social factors

Perceptions around labor, water quality, and aesthetics strongly shape decisions. In the UK study (Snelling et al., 2024), outdoor uses like garden irrigation were well accepted, while indoor uses (toilet flushing) faced more skepticism, reflecting perceived "ick factors." Aesthetics also emerged in the Finland-Norway survey, where respondents preferred solutions like permeable pavements, which blend into the built environment, over visually dominant options like green roofs or tanks (Cools et al., 2023).

Lack of awareness consistently emerges as a major barrier. The tenant-owner association study (Glaas et al., 2025b) further showed that low awareness of pluvial flood risks prevents proactive measures like RWH. The TransformAr Finland-Norway survey (Cools et al., 2023) showed that willingness increases with better information on risk reduction and benefits, and that education campaigns combined with financial incentives are important drivers. International studies highlight the role of marketing: Snelling et al. (2023) found that RWH users held more positive implicit perceptions, suggesting that once adopted, systems are seen favorably, indicating a gap in effective promotion and demonstration. The Iranian case study (Shalamzari et al., 2016) found that public support increased when RWH was visibly demonstrated in communities, showing the value of previous exposure and social proof.

2.3.3 Legislative factors

Institutional ambiguity plays a large role in Sweden. The studies by Glaas et al. (2025a) highlight how the Planning and Building Act and municipal frameworks leaves it unclear who is responsible for stormwater management costs. Many property owners assume municipalities should manage flooding, even though national policy emphasizes property-level responsibility. The EU Water Framework Directive and Floods Directive provide broad goals but no binding requirements for local-scale RWH adoption. Without clear mandates, RWH remains a voluntary and rarely prioritized option. Trust in municipal leadership, identified in the Knivsta water reuse survey (Gullberg et al., 2022), is essential for property owners to consider action.

2.3.4 Technical factors

Perceived technical difficulties often outweigh real ones. In Sweden, RWH remains viewed as niche or experimental compared to conventional drainage infrastructure (Glaas et al., 2020). Owners worry about system reliability, sizing, and maintenance. Retrofitting is particularly challenging in existing dense urban areas, as noted by Glaas et al. (2025a), making adoption more feasible in new developments.

2.3.5 Miscellaneous factors

Additional factors that could contribute to decision surrounding procurement of an RWH and reuse system could be:

- Psychological perceptions: Risk denial is common. Swedish tenant-owner associations often downplay flood risks, relying on insurance instead of prevention (Glaas et al., 2025b).
- Cultural and contextual factors: In water-scarce regions (Iran, parts of southern Europe), RWH is culturally normalized, whereas in Sweden, with abundant cheap freshwater, framing it as flood management rather than water supply might be more effective.
- Demographics: Younger, highly educated, and environmentally motivated groups (Cools et al., 2023) show higher willingness to adopt, while older or lower-income groups remain hesitant due to cost and risk concerns.
- Spatial and physical factors: Detached houses with garden space are more likely to adopt RWH (UK and Knivsta studies), whereas dense housing associations often lack space and shared governance hinders investment decisions.

Table 2: An overview of the important decision factors.

Factor	Evidence from Studies	Barrier / Driver	Factor	Evidence from Studies	Barrier / Driver
Economic - Costs & subsidies	Snelling et al. (2024, UK): Non-users cite high upfront costs; Cools et al. (2023, Finland–Norway): cost & maintenance concerns strongest barrier for low-income groups.	Barrier: High upfront cost, long payback time. Driver: Subsidies, rebates, fee reductions.	Social - Aesthetics	Cools et al. (2023, Finland–Norway): permeable pavements preferred for blending in; visible tanks/green roofs less appealing.	Barrier: Visual impact of tanks. Driver: Integrated or underground designs.
Social - Labor of construction & operation and maintenance	Glaas et al. (2025b, Sweden): Associations view adaptation as burdensome. Snelling et al. (2024, UK): perceived complexity deters non-users.	Barrier: Installation and maintenance perceived as time-consuming.	Legislation - Governance ambiguity	Glaas et al. (2020, 2025b, Sweden): Planning and Building Act allegedly leaves unclear cost responsibilities; associations assume municipalities responsible.	Barrier: Unclear mandates, fragmented responsibility.
Social - Exposure & social proof	Shalamzari et al. (2016, Iran): Communities more willing when exposed to working systems. Snelling et al. (2024, UK): RWH users have stronger positive implicit attitudes.	Driver: Seeing peers/neighbors adopt encourages uptake.	Legislation - EU Directives	Water Framework Directive, Floods Directive: Encourage sustainable water use but no binding RWH requirements.	Barrier: Weak enforcement, voluntary adoption.
Social - Water quality & acceptable uses	Snelling et al. (2024, UK): Outdoor use widely accepted; indoor use (toilets) less accepted. Gullberg et al. (2022, Knivsta survey): trust in "safe and clean" water critical for acceptance.	Barrier: Skepticism for indoor/potable use. Driver: Outdoor uses broadly supported.	Legislation - Trust in institutions	Gullberg et al. (2022, Knivsta survey): Higher trust in municipalities/utilities correlates with higher willingness to reuse water.	Driver: Clear municipal guidance and backing.

Social - Responsibility & sustainability	Glaas et al. (2025b, Sweden): Often shift responsibility to municipalities. Broader EU studies: Framing RWH as climate adaptation increases willingness.	Barrier: Responsibility shifting. Driver: Sustainability framing.	Technical - Reliability & technology	Glaas et al. (2020, Sweden): RWH seen as “niche” compared to traditional drainage.	Barrier: Perception of unreliability, uncertainty on tank size.
Social - Awareness	Gullberg et al. (2022, Knivsta survey): Public has limited knowledge of reuse benefits. Glaas et al. (2025b): Associations underestimate flood risk and undervalue adaptation measures.	Barrier: Low awareness, risk denial.	Miscellaneous - Psychological perceptions	Glaas et al. (2025b, Sweden): Flood risks downplayed, reliance on insurance instead of prevention.	Barrier: Risk denial, reliance on insurance.
Social - Marketing & innovation appeal	Snelling et al. (2024): Users hold more positive implicit perceptions → framing RWH as innovative builds appeal.	Driver: RWH as innovation and sustainability branding.	Miscellaneous - Demographics	Cools et al. (2023, Finland–Norway): Younger, higher-educated, environmentally oriented individuals more receptive.	Barrier: Older, lower-income groups more hesitant. Driver: Target younger/educated groups.
Social - Risk vs. benefit framing	Cools et al. (2023, Finland–Norway): Willingness increases when framed as flood risk reduction + co-benefits.	Driver: Linking RWH to risk reduction and resilience.	Miscellaneous - Spatial & physical factors	Snelling et al. (2024): Detached houses are more likely to adopt RWH. Associations/apartment blocks face governance and space barriers.	Barrier: Limited space in dense housing. Driver: Feasible in detached homes with garden space.

2.4 Overview of tools with similar purpose

While the studies highlight the benefits of rainwater harvesting structures, platforms that communicate these insights to stakeholders remain limited in Sweden beyond the *Tyréns Recirculation tool*. Some tools offer basic estimates of rainwater harvesting potential, and a few aim to raise awareness and promote implementation through stakeholder decision-aid.

2.4.1 Non-Potable Environmental and Economic Water Reuse (NEWR) Calculator

The NEWR Calculator is a decision-support tool developed in the United States to evaluate the feasibility and benefits of non-potable water reuse at building or community scale (U.S. EPA, 2025). It was created through collaboration between the U.S. Water Research Foundation (WRF), utilities, and academic partners. The tool allows users to compare different alternative water sources (such as rainwater, stormwater, greywater, and condensate) with conventional potable water supplies. It does so by assessing both environmental impacts (e.g. reductions in freshwater demand, energy use, greenhouse gas emissions) and economic costs/benefits (e.g. capital and operating costs, payback periods). The tool is comprehensive, offering a wide range of options to include/not include in the calculations, as well as providing an exhaustive list of results covering benefits and costs. While reliable, it lacks for the most part visual enhancements that would appeal to stakeholders such as map functionality; and it relies on the property's postcode to determine the required automated inputs such as precipitation, demand and costs. It requires many inputs, but it is, nonetheless, a useful tool for screening goals and decision-making.

2.4.2 Rainwater Harvesting Calculator - U.S. Federal Energy Management Program (FEMP)

The U.S. Federal Energy Management Program (FEMP) offers a rainwater harvesting calculator to estimate monthly rainwater collection from rooftops, based on historic or user-provided rainfall data (U.S. Department of Energy, 2025). It is designed for U.S. federal facilities and is therefore localized to American contexts. The tool is Excel-based and technical, focusing on storage sizing for non-potable applications. However, it does not include decision-support capabilities, such as cost estimations or system design alternatives, nor does it provide map-based interactivity to enhance user-friendliness and broader stakeholder engagement.

2.4.3 Rainwater Harvesting Design and Costing Tool - The Sustainable Technologies Evaluation Program (STEP)

The Sustainable Technologies Evaluation Program (STEP) in Canada provides an Excel-based tool for designing and costing rainwater harvesting systems (Toronto and Region Conservation Authority (TRCA), 2025). It allows users to input roof area, occupancy, and water use to estimate optimal tank sizes and system costs, hence being a decision-aid tool. While useful for localized Canadian conditions it lacks interactive features such as map-based visualization or stakeholder-oriented usability, which could make the tool more accessible to non-expert users.

2.4.4 Poseidon - Decision Support Tool for Water Reuse

Poseidon is an Excel-based decision support tool designed to evaluate the feasibility of water reuse systems. It was originally developed within European research projects such as COROADO and MadforWater, focusing on the Mediterranean and developing regions where water scarcity is a pressing issue. The tool integrates technical, economic, and environmental criteria to help users compare different water reuse options. It allows for the assessment of treatment technologies, water quality requirements, and potential end uses (e.g. irrigation, industrial processes, urban non-potable supply). Poseidon provides a structured framework to perform multi-criteria decision-aid, considering not only cost and performance but also sustainability aspects such as energy use and environmental impact. By enabling side-by-side evaluation of alternatives, Poseidon supports decision-makers, such as municipalities, utilities, and planners, in selecting the most appropriate and sustainable reuse strategy for their specific context (Oertlé et al., 2019).

Poseidon is, however, not designed for rainwater reuse, making it less relevant for property-scale rainwater harvest. Like other reuse calculators, it is structured as a technical evaluation tool and does not include map-based interactivity or user-friendly decision-support functions that would engage a broader range of stakeholders.

2.4.5 VisAdapt (Local)

VisAdapt is a visualization tool developed in 2014 by Linköping University, providing adaptation measures and guidelines given the user provides simple inputs (e.g. the location of the house, roof and facade materials as well as foundation type etc.) to upcoming climatological changes in precipitation, temperature and flood frequency. The tool considers climate change in the Nordic climate as well as the simple inputs to provide change maps, risk maps and suggestions to avoid damage and harm of increasing extreme events (Linköping University, 2025).

While the tool is purposed as an informative and mitigations suggesting tool connecting simple inputs with user interactivity and map-based visualization, it isn't connected to RWH systems or provide suggestions for adoption/installation of RWH systems. The tool lacks decision-support part, cost suggestion and feasibility of implementation of RWH systems, making it more of an informative, visualization and mitigation suggestion tool.

2.4.6 Where *Tyréns Recirculation tool* bridges the gap

While STEP Design & Costing Tool is practical for Canadian conditions, it functions as a technical calculator only and lacks interactive, map-based visualization for non-expert users. FEMP Rainwater Harvesting Calculator is similar to STEP's Design & Costing Tool but simplified. It is a localized and spreadsheet-based tool, without integrated decision-aid or user-friendly map interfaces that could support stakeholder decision-making. The Non-Potable Environmental and Economic Water Reuse (NEWR) Calculator provides a structured way to compare alternative water sources, including rainwater, stormwater, and greywater. It evaluates both economic and environmental aspects of reuse, making it more advanced than STEP or FEMP. However, it is localized to U.S. contexts and remains a calculator rather than an interactive, stakeholder-oriented decision-support system. Meanwhile, Poseidon does not address stormwater or RWH and similarly lacks map-based interactivity proposed for a broader range of stakeholders, such as property owners or municipalities. VisAdapt combines easy visualization materialized in a map-based interactivity with crises reducing measures suggestions for local resilience. While it provides important results on climate change and how it affects individual properties, it lacks preliminary decision-aid capabilities, manifested as design and costing parts, and doesn't have any particular focus on RWH systems.

In contrast, the *Tyréns Recirculation tool* developed in this study aims to fill these gaps by combining RWH evaluation and decision-aid with an interactive, map-based platform. Unlike the existing localized calculators, the tool is designed to be user-friendly and visually intuitive, making it accessible to a wider audience of stakeholders. In this way, it bridges the divide between purely technical sizing tools at the cost of user interactivity and appeal and the need for practical, decision-aid systems for sustainable stormwater management. A summary comparison is made in Table (3).

Table 3: A comparison of the six tools mentioned, where x indicates success in a given aspect and - indicates absence.

Tool | Aspect	Map-based	Decision-aid	Technical and requires advanced input	Relevant	Appealing
NEWR	-	x	x	x	-
FEMP	-	-	-	x	-
STEP	-	x	x	x	-
Poseidon	-	x	x	- (greywater specific)	-
VisAdapt	x	-	-	x	x
Tyréns Recirculation tool	x	x	-	x	x

2.5 System components and costs of RWH in Sweden

Many components exist in a RWH system, and they can either be basic or complex depending on the use-case. Below are some examples of main components of RWH systems.

2.5.1 Tanks

A tank is a crucial component in a RWH system, as all inflows and outflows through the system passes at least once through a tank. The tank is a storage medium, storing either raw rainwater as in an Outer tank or it could be an Inner tank, storing clean water after filtration and treatment where water then is delivered to the user. Outer tanks could either be cast concrete (e.g. Eloy's waterfix series) or high-grade polyethylene (PE) plastic tanks (e.g. Älvestadtanken's rainwater tanks), above ground or underground, whereas inner tanks are exclusively high-grade polyethylene plastic (PE) existing inside the building RWH system is to be implemented in.
In some cases, inner tanks could be skipped if the system is small enough and the user relies on the built-in storage of the treatment apparatus. In some models of Conclean for instance, an inner tank is skipped where water is delivered directly after filtration and treatment (e.g. Conclean Garden series, 2025). In almost all investigated examples in Sweden, the systems had an inner tank serving as an intermediary medium, storing clean water and topping up with municipal freshwater in case of rainwater shortage.

2.5.2 Piping

Piping is needed to transport the water from the roof to the tank, named conveyance piping, and from the tank to the user where it is named supply piping. Leading from the tank to the user is so-called service piping and lastly, overflow piping carrying water from the tank to the city's stormwater drainage network. Overflowing water from the tank could also be infiltrated to the ground by a soakaway medium where overflowing water passes through soil and percolates to groundwater (TRCA STEP tool's database on component prices, 2025).
Conveyance and supply pipes could be made of PVC, PE and PEX pipes where pressure is almost non-existent, from the roof to the tank and to filtration and treatment, whereas pressurized piping is required in the service pipes to properly deliver water to the user. Service pipes could be made of high-grade copper pipes that can stand high pressure of around 3 bar to 5.5 bar, which most households in Sweden use (Grundfos, 2025).

2.5.3 Pumps and hydrophore

Pumps are essential, as they are required to transport the water around the system and to the user. In most cases where an inner tank is a part of the system, two pumps are required; where one pump pumps the water from the outer tank to the filtration and treatment which is then delivered to the inner tank, where it is then pumped with the second pump to a pressurized tank, a "hydrophore" and then lead to the user (Respondent 1, 2025).
Systems with inner tanks require a pump with higher pumping capacity and effect to compensate for head drop through filtration, treatment and the pipes. If the treatment apparatus isn't connected in-line but to the clean water tank where water continuously recirculates between treatment apparatus and the tank, a third pump might be needed to pump the water from the treatment to the inner tank.

2.5.4 Filters and water treatment

Filters and treatment of rainwater could be done in various forms, where it ranges from basic filtration of larger suspended particles, leaves and dust, to high-level UV-rays/ozone treatment neutralizing bacteria and microbes depending on the use-case and where in the system filtration occurs.
Screen filters and traps are common as a first step where rainwater passes through a trap or a screen at the gathering point of a gutter and downspouts, filtering the water from larger particles and leaves. Suspended particles, which are the main cause of water discoloration, aren't captured by the screen and the trap, requiring a second step of filtration to neutralize the color of the water (Jephson & Kristiansson, 2023; Respondent 1, 2025; Holm, 2021).
The second step of filtering could be a sand filter, an activated charcoal filter or a finer screen, capturing particles with micro-meters in diameter depending on the filter. Capturing suspended iron and soil organic particles reduces the discoloration of water significantly and in some cases, is sufficient for use-cases not requiring further purification, like toilet-flushing and washing.
The third step is water treatment where water gets treated with ozone or UV-rays to kill bacteria and fungi and limit microbial growth. It can also be used to precipitate dissolved substances e.g. heavy metals turning them into non-soluble metal oxides, purifying the water further (Jephson & Kristiansson, 2023).

2.5.5 Accessories and other components

Top-up and backflow prevention are needed accessories in the case of an inner tank in the system. Both mechanisms could be implemented using a one-way valve that is opened when water level gets low in the inner tank preventing the pumps from dry pumping in which they are unnecessarily

damaged. Backflow is a complementary step to prevent water from re-entering the municipal freshwater network, causing unnecessary disturbance to the water-meter that is continuously monitoring the water volume of the water supplied from the municipality (TRCA STEP tool's database on component prices, 2025).
Other accessories could be a manhole for larger scale outer tanks, cleanout T-section of pipes, top-up pipes if the inner tank requires separate pipes to transport water from the municipal freshwater network.

2.5.6 Costs of implementing an RWH system

Implementing an RWH system is an investment, and costs of such a system are valued by stakeholders as a deciding factor. Table (4) compiles inflation-adjusted SEK costs for typical RWH systems by component, tank, pump, piping, filter, installation, and maintenance, across two use cases, a single-family house and a multi-family house. The prices are given by several sources where some cells are intentionally left blank when a study didn't report on said cost. The costs are assumed to hold for newer constructions.

Table 4: A breakdown of typical price ranges for RWH systems.

Approximate prices in SEK accounted for inflation	Tank	Pump	Piping	Filter	Installation	Maintenance	Total investment (rounded to nearest thousand)	Source
Single family house (3 residents, 100 m^2 catch. area, laundry and toilet flushing)	43 000-190 000 (98 000, 15 m^3)	11 200	4500	6000	10 500	750	76 000 - 223 000 (131 000, 15 m^3)	(Domènech & Saurí, 2011)
	50 000 (13 m^3)	6200	8700	11 000	8500	-	84 000	STEP tool
	65 000			3 000	20 000	-	88 000	Forsberg et al. (2025)
Multi-family house (43 residents, 625 m^2 catch. area, irrigation and laundry)	43 000-190 000 (152 000, 30 m^3)	30 000	18 000	6000	10 500	4500	108 000 - 255 000 (217 000, 30 m^3)	(Domènech & Saurí, 2011)
	84 000 (31 m^3)	6200	65 500	28 800	33 000	-	218 000	STEP tool
	84 000 (9.3 m^3)	70 000		5600	-	-	160 000	Gyllensvärd (2009)

Across all rows, the tank is the dominant cost and varies widely with volume and material, followed by piping/installation which rises notably in the multi-family case due to longer runs and internal distribution. Pump/control packages are the next major line item, filters are comparatively small, and annual maintenance is a minor share of lifecycle costs where previous RWH system users stated that minor maintenance expenses were due (Forsberg et al. (2025); Gyllensvärd (2008)) and in some cases not even considered. Differences between sources (e.g., STEP, Domènech & Saurí, Forsberg et al., Gyllensvärd) explain the spread, where each uses its own assumptions about tank size, siting (above-/underground), and scope of what's included in the installation, as well as daily water usage per capita.

2.6 Pilot projects of rainwater harvesting systems in Sweden

2.6.1 Citypassagen in Örebro

In the report *Vattenbesparande åtgärder - Exempelsamling för kommuner och hushåll* by Holm (2021), the author investigates some Swedish examples by conducting interviews, where one of which is Citypassagen in Örebro city. Citypassagen is a building located in the municipality of Örebro, built by the building company Castellum and serving as a designated office and restaurants building where the large roof area is utilized to harvest rainwater. The main purpose of the system in Citypassagen was to provide stormwater detention, entailing one of the requirements for the building in the detailed development plan of the area. The system gathers rainwater in a large tank (180 m^3) located outside of the building which is then delivered inside the building through a pump to the mini water treatment facility. The treatment consists of a sand filter, a UV-apparatus and a microfilter (1µm) to filter out the suspended particles. The water then is delivered to a clean water tank of 9 m^3 in volume which serves as a main supply unit of water to the 72 toilets considered in the project with a daily need of 10 m^3 of toilet-flushing water. The system is considered to have an overflow subsystem when the harvested water exceeds the capacity of the tank; as well as a top-up system with municipal freshwater to the inner tank to compensate in case of shortage of rainwater. At the time of constructing the system in 2020, the project team didn't find any shortage of materials in the market as conventional ready-to-use components, such as tanks, pipes and pumps were used. The system's cost was around 1.2 million SEK and operation costs leading at around 23 000 SEK where reduced municipal water considered as revenue, compensates with around 16 000 SEK, giving a total of 7 000 SEK in yearly operation costs. Operation costs include UV-lamps, filters, service and energy consumption for the pumps (Holm, 2021).

Common problems encountered with the project are water discoloration, varying with time, as it was assumed that pollen is the cause of it. Dead birds taking the roof as shelter was also an observed phenomenon, however, it wasn't a significant problem in this case as the water was being purified nonetheless and wasn't situated for drinking purposes. Constructing the system on green roofs as in Sedum roofs which are common in Sweden isn't feasible as the rainwater gets polluted with organic materials from the soil. RWH systems could only be achieved on newer construction projects (Holm, 2021).

Legislative discussions with the municipality occurred mainly about reused rainwater going to the municipal sewer system after flushing; this could be a basis for a legal misconduct and a fine by the building inspection board as it isn't allowed to drain rainwater/stormwater to the municipal sewer network in Sweden. Another legislative discussion occurred about mainly that freshwater fees should be reduced because of lower municipal freshwater consumption as well as, that the water going through the municipal sewer network is getting purified for free by the municipal water treatment facilities. This occurs mainly due to how the municipal freshwater is delivered in Sweden where the water supplied by the municipality is paid for both in freshwater consumption and treatment and purification of the same volume of water (Holm, 2021).

Concluding remarks by the expert interviewed at Castellum in the report were to increase awareness and knowledge about these systems if they were to be implemented in more construction projects as a viable alternative for municipal water; as well as to clarify the legislative framework to account for alternative water sources in the municipal water treatment facilities.

2.6.2 Celsius in Uppsala

The building Celsius in Uppsala bears a similar story. It was originally designed to be an office building with a section for laboratories as the Swedish Food Agency (Livsmedelsverket) decided to occupy the building. The responsible building company and owner Vasakronan wanted an environmental profile for the building with emphasis on social responsibility, driving the market forward and developing the building sector (Holm, 2021). The building also is located above the Uppsala esker making drainage and disposal of rainwater safely relatively important. The roof area is around 2 390 m^2 harvesting around 1 000 m^3 yearly and covering around 60% of yearly water demand for toilet flushing for a total of 42 toilets (Sweden Green Building Council, 2022). The system implemented follows a similar structure where snowmelt and rainwater are gathered, filtered and transported to the large 60 m^3 tank which is then filtered again with a sand filter and treated with UV-rays to prevent microbial growth. After treatment the water is transported to a clean water inner tank of 12 m^3 in volume, ready to supply the toilets in the building with flushable water where water could be topped off with municipal water in case of need (Sweden Green Building Council, 2022).

The filtration process and treatment are required for the social factor, preventing the water that reaches the toilets from being discolored when flushed which might raise concern for the occupants. Even though the water still gets treated, the occupants of the building are notified of the nature of the water used in toilet flushing. As for the legislative side of the project, the project didn't require any special permission or any need for inspection, yet the reused rainwater sparked signs of curiosity and positive reactions from the different people interacting with it (Holm, 2021).

Concluding remarks included the non-economic nature of the building yielding no revenue or payback factor, the need for subsidies to compensate for water saving solutions such as the system at Celsius, and the pressing economic aspect of the building sector. Such systems would see widespread use if they were more economically and functionally viable (Holm, 2021).

2.6.3 Sergelhuset in Stockholm

Sergelhuset is an office building in Central Stockholm where rainwater harvesting was implemented during its recent renovation project by the real estate company Vasakronan in 2022. The harvested rainwater covers around 30% - 40% of the toilet-flushing water demands for a total of 54 toilets and is also used to water the newly constructed green roof on the building (Kirkhoff, 2025). The roof area is more than 6 000 m^2 which harvests rainwater and is then transported to a system of eight smaller tanks giving rise to a storage capacity of around 110 m^3. The water is filtered and treated, by several filters, mainly sand, activated charcoal and finer grain filter (1-5 µm and ultra-fine 0.02 µm), and treated by a UV-apparatus to treat color and smell of the water (Jephson & Kristiansson, 2023).

There is unfortunately no data regarding the efficiency and total harvested rainwater volumes since the building is relatively newly renovated and is one of the few examples of large-scale rainwater harvesting in Sweden.

2.6.4 Property Katedern 12 in Gamleby, Västervik

Katedern 12 is a block located in the town of Gamleby in the municipality of Västervik which was developed by the municipal real estate company Västerviks Bostads. The block was finalized in construction between 2023 and 2024, and it consists of a health care center, a specialized housing unit and a senior housing unit with the purpose of providing health care services and sustainable housing for the residents of Gamleby (Västerviks kommun, 2020). A rainwater harvesting system was implemented in the project due to the legal requirement of reduced stormwater runoff to the town's drainage network, and the pollution in the soil, making stormwater detention and infiltration unviable. After some tinkering and research, the only viable solution turned out to be recycling of rainwater through a conventional rainwater harvesting system where the project team did a study visit to Citypassagen in Örebro to learn about the system in question (Respondent 1, 2025).

The rainwater harvesting system at Katedern 12 is used exclusively for toilet-flushing with a large 60 m^3 concrete tank placed underground for aesthetic, hydraulic and water quality reasons. The water from the roof is gathered and transported to the storage tank where it is then transported inside the building for filtering and treatment. The water is pumped through two separate sand filters where it is then stored in a clean water tank of 2 m^3. The clean water tank is connected to an Ozon-treatment device where water circulates and gets treated by Ozon continuously. Ozon was chosen to avoid discoloring of water which was observed in other systems utilizing UV-rays treatment. The clean water tank is connected to the municipal freshwater supply where it gets topped up in case of rainwater shortage, and a one-way valve to stop the water from going back into the supply system (Respondent 1, 2025).

Commonly occurring problems in the project were mistakenly producing chlorine gas where it damaged the pumps, as well as smell of Ozon coming from the tank which was solved with ventilation. Organic materials and tree leaves gathering in the storage tank were also common which opted the team to study implementing filters and traps when water gets transported to the tank to reduce sludge build up. The project costs were estimated to be around 1.5 million SEK (Respondent 1, 2025).

Final recommendations included that obtaining subsidies can be a key decision factor when it comes to implementing rainwater harvesting systems as well as clarity of legislation and legal requirements as those were the main purpose of implementing the system at Katedern 12. Usefulness of rainwater harvesting systems is dependent on the use-case, where continuously inhabited residential buildings with high and steady demand are more suitable than office buildings with less demand during weekends or at night for instance. At the same time, the market for rainwater harvesting is immature at its current stage where incentives for environmental transition exist but knowledge, competition, marketing and a clear sustainable goal towards such solutions is lacking (Respondent 1, 2025).

2.7 Essential functional concepts

2.7.1 Water balance

The *Tyréns Recirculation tool* utilizes a daily water balance approach as described and implemented by Oscarson (2024), accounting for precipitation, snow accumulation and snowmelt, storage dynamics, and user demand. All volumes were expressed in cubic meters (m^3). For deeper understanding and detail of water balance, it is recommended to read Oscarson (2024). The daily change of water in the tank is described as (changed notations from Oscarson (2024) but otherwise same calculations, equation 1):

$$V_i = A.\varphi.(P_i + SM_i) - R_i - U_i + V_{i-1} \quad (1)$$

Where, V is stored water in the tank, P is daily precipitation, SM is daily snowmelt, R is daily overflow from the tank, U is daily water demand and A (m^2) and φ are provided roof area and runoff coefficient respectively. For each day i, the precipitation P (mm) and temperature T (°C) were used as meteorological inputs imported from SMHI's historical database of climate in Sweden. The precipitation P and snowmelt SM were implemented as follows (equations 2-5):

$$P_i = P_i \; if \; T_i > 0, else \; 0 \; || \; (2)$$
$$SM_i = SM_i \; if \; T_i \; and \; S_i > 0, else \; 0 \; || \; (3)$$
$$S_i = S_{i-1} + P_i \; if \; T < 0, else \; S_i = S_{i-1} - SM_i \; || \; (4)$$
$$R_i = max(V_{i-1} - tankvolume + P_i + SM_i, 0) \; || \; (5)$$

The water balance used in the *Tyréns Recirculation tool* forms a basis for visualization of rainwater harvest, demand, overflow etc. as well as its output is part of the cost-benefit calculation used in the refined tool.

2.7.2 Cost-benefit and payback time

The cost-benefit analysis implemented in the tool is simplified, as the only monetary benefit considered in this study is reduced municipal freshwater use and wastewater discharge, as reducing use of municipal freshwater corresponds with 1:1 reduced cost for wastewater treatment in Swedish context (equations 6 and 7).

$$Total\ investment\ cost\ [SEK] = Tank\ cost\ + pump\ systems\ +\ filters +\ piping\ +\ installation \quad (6)$$
$$Benefits\ [SEK] = Reduced\ municipal\ freshwater\ volume\ [m^3]\ * VA\ \ tariff\ per\ water\ volume\ [SEK\ /m^3\ ] \ (7)$$

Since RWH projects seem with longevity, it is more beneficial to simplify the calculations to calculate payback time directly by dividing total investment cost by yearly savings in municipal freshwater and wastewater reduction. If the denominator in equation (8) is negative, then the system doesn't payback for the investment.

$$Payback\ time\ [year] = \frac{Total\ investment\ cost\ [SEK]}{Benefits - maintenance\ cost\ [SEK/year]} \ (8)$$

3. Analytical framework

This chapter presents the analytical framework used to evaluate and interpret the Tyréns Recirculation tool refinement process. The framework combines four complementary components: the System Usability Scale (SUS), which provides a standardized quantitative assessment of usability complemented with significance testing to validate the assessment; Minimalist design principles, which serve as a qualitative lens for understanding how visual simplicity and structure influence users' perception of digital decision-aid tools, as well as an interpretivist approach to strengthen the minimalist design principles implemented in refining of the Tyréns Recirculation tool.

3.1 System Usability Scale - SUS

The System Usability Scale (SUS) is a widely used and validated method for measuring the usability of digital tools and interfaces. It consists of a short questionnaire with ten statements that respondent's rate on a five-point scale, ranging from "strongly disagree" to "strongly agree." (Hartson and Pyla, 2019; Brooke, 1996). The SUS provides a standardized score between 0 and 100, where higher values indicate better usability. While being simple, it captures critical aspects of the user experience, such as ease of use, complexity, consistency, and confidence in using the system. Because it is technology-independent, reliable, and quick to administer, SUS is frequently used for benchmarking new digital tools and comparing usability across different versions of the same system.

In the methodology of SUS, it captures user's experience through the life cycle of a webpage, an app or simply any usable system or an artefact that can be scored based on complexity, performance and user experience. The 10 questions used in SUS are alternating in nature, where odd-ranked questions are positive, while even-ranked questions are negative, where then the score of each individual question is taken into consideration when calculating the final evaluation score based on the following rewritten formula (equation 9) (Brooke, 1996):

$$\textbf{\textit{Final score}} = \mathbf{2.5} * (\textbf{\textit{Sum of scores of positive questions}} - \mathbf{5} + (\mathbf{25} - \textbf{\textit{Sum of scores of negative questions}})) \quad (9)$$

In the context of this study, English questions given in Brooke (1996) were translated as is to Swedish to evaluate the performance and development of the tool (appendix A.1). By using the acceptability measure developed in *Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale* by Bangor et al. (2009), a SUS score of 70 and higher constitutes an acceptable usability. Systems with scores less than 70 should be a goal for further improvement and are considered marginal.

In this study, SUS is applied to measure users' experience with the *Tyréns Recirculation tool* before and after refinement. The original English questions provided by Brooke (1996) were translated directly into Swedish to ensure clarity for respondents. SUS results provide a quantitative baseline that reflects how stakeholders perceive usability in terms of ease of use, learnability, efficiency, and overall satisfaction.

3.2 One sample t-test for significance

The one-sample t-test is a parametric statistical method used to determine whether the meaning of a sample differs significantly from a known or hypothesized population mean (Field, 2013; Rumsey, 2016). In the context of this study, it is employed to evaluate whether the average SUS score of the *Tyréns Recirculation tool* demonstrates a statistically significant improvement relative to the benchmark threshold of 70, which represents an acceptable level of usability (Bangor et al., 2009).

A positive and statistically significant p-value ($p < 0.05$) indicates that the tool's average usability score exceeds the acceptable benchmark, supporting the hypothesis that the refined version provides a measurably improved user experience. Conversely, a non-significant result ($p \geq 0.05$) suggests that the improvement may not be statistically reliable and that further refinements are necessary. Integrating this test provides quantitative validation of the tool's performance improvements, complementing the qualitative insights from stakeholder interviews.

3.3 Minimalist design

Minimalistic design, as described in *Aesthetic Experience and User Perception in the Use of Minimalism in Contemporary Web Design* by Okoro & Alabi (2025), is a design approach that emphasizes visual simplicity, clarity, and functionality. It focuses on using only essential elements while removing unnecessary details to create clean and distraction-free layouts. Minimalist design reduces visual complexity, lowers users' mental effort and enhances comprehension. Users exposed to minimalist interfaces perceive them as more elegant, professional, and trustworthy, leading to higher satisfaction and usability ratings compared to more cluttered designs. However, successful minimalism requires a balance between aesthetic reduction and clear communication, as noted in Okoro & Alabi (2025), which is achieved through effective visual hierarchy, typography, visual cues and structure.

In this study, minimalist design principles are employed both as a developmental guide and an interpretive framework. During tool refinement, they inform layout, labeling, and graphical choices intended to increase accessibility and perceived professionalism. Analytically, they are used to interpret stakeholders' qualitative feedback, explaining why certain features enhance or hinder usability according to principles such as clarity, balance, and informational sufficiency.

3.4 Interpretivist approach

The interpretivist philosophical stance supports the qualitative component of this research. Interpretivism emphasizes context, perception, and the co-creation of meaning between researcher and participants (Saunders et al., 2023; Creswell & Creswell, 2018). In this study, the interpretivist approach guides the analysis of semi-structured interviews conducted with stakeholders. The goal is not to generalize findings statistically but to understand how participants perceive, interpret, and assign value to the adoption of rainwater harvesting systems and digital decision-support tools. This approach allows for flexibility in questioning and responsiveness to emergent themes, aligning with the study's exploratory nature.

By integrating the System Usability Scale, one-sample t-test, minimalist design principles, and an interpretivist perspective, this analytical framework combines quantitative rigor with qualitative depth. The SUS and t-test provide measurable evidence of usability and statistical confidence, while the interpretivist approach and minimalist design principles offer interpretive insight into users' perceptions and experiences. Together, these perspectives create a comprehensive understanding that integrates both subjective interpretation and empirical measurement.

4. Method

This chapter presents the research design and methodological framework used in this study, illustrated in Figure (1).

4.1 Research design

The study adopts a qualitative, interpretivist, interview-based research strategy supported by a literature foundation. The mixed qualitative strategy allows for both theoretical exploration and empirical insight into stakeholder engagement, decision factors, challenges, and motivations regarding RWH adoption. The interpretivist stance was chosen because the study seeks to understand subjective experiences and contextual interpretations rather than to generalize numerical results (Saunders et al., 2023; Creswell & Creswell, 2018).

The research process began with an extensive literature review focusing on stormwater management and reuse and decision-support methods. The outcomes of the literature study served as a foundation for identifying knowledge gaps, predicting key decision factors, and informing the continued development of the *Tyréns Recirculation tool*. Subsequently, semi-structured interviews were conducted to cross-validate findings from literature, investigate barriers and drivers for adoption of RWH, and gather feedback to refine the tool.

The study also integrates a System Usability Scale (SUS) survey to evaluate the tool's user experience and functionality. This multi-method design ensures both theoretical depth and practical validation, providing insights into how decision-aid systems can facilitate stakeholder engagement in RWH implementation. The research concludes with a discussion of findings, recommendations for future tool development, and proposed directions for further research in this field.

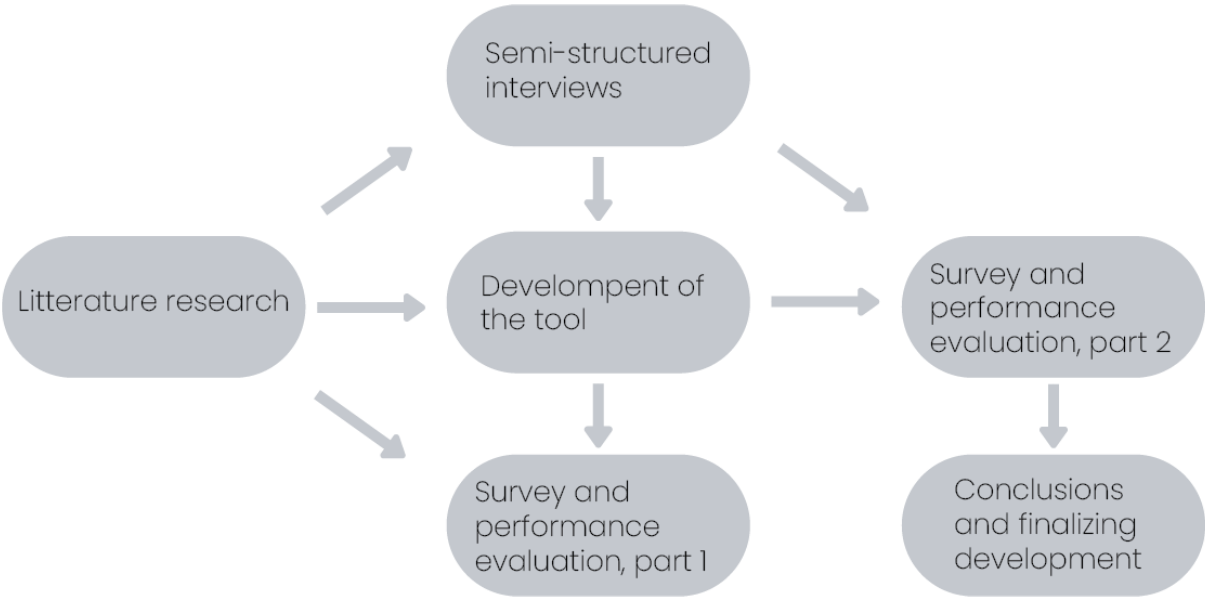

Figure 1: A flowchart over the methodology used in this paper.

4.2 Literature research

The literature research forms the theoretical foundation of this study and is used to contextualize the concept of stormwater harvesting and reuse within Sweden's current urban water management framework. The review emphasizes five main themes:

1. RWH systems' risk reduction of urban flooding.
2. Users' perceptions of RWH
3. Critical decision factors and willingness of stakeholders to adopt RWH.
4. Tools with similar purpose to *Tyréns Recirculation tool*.
5. RWH system components and pilot projects in Sweden.

Sources were identified using academic databases such as Google Scholar and ScienceDirect, as well as internal project documents from Tyréns AB's *Drizzle* project. The collected literature guided the identification of decision factors (economic, social, technical, and regulatory) and supported the conceptual development of the decision-aid tool.

4.3 Semi-structured interviews

Semi-structured interviews are a qualitative research method that balances predefined guiding questions with flexibility to explore emerging themes during conversation. This method is particularly suited for studies investigating complex or context-dependent phenomena such as stakeholder attitudes toward environmental innovations (Saunders et al., 2023).

Following the literature phase, semi-structured interviews were conducted with experts and stakeholders. The purpose of the interviews was to cross-validate insights from literature, explore the challenges and drivers influencing RWH adoption, and gather feedback to refine the decision-aid tool. Semi-structured interviews were chosen to enable both predefined and follow-up questions, allowing participants to elaborate on their experiences and perceptions (Saunders et al., 2023). The interviews were analyzed through thematic analysis, identifying recurring themes related to decision factors such as economic, technical, social, and regulatory aspects.

The general interview questions were structured while considering the main themes and topics of the study. A general structure for questions was produced (appendix A.3 & A.4) and questions were adjusted when needed (e.g. asking the suppliers about sales related to RWH systems and indirectly assessing property owners' opinions of RWH). The interviewees were selected based on their relevance to stormwater management and expertise on RWH and reuse in Sweden, representing a balance between municipal, private, and supplier perspectives. The interviewees were asked to participate through phone calls and the communications app Teams. The predefined questions were sent to the interviewees prior to the interview. All interviews were conducted after obtaining informed consent from participants. Permission was sought to record, transcribe, and document responses for analytical purposes. Table (5) summarizes the interview participants.

Table 5: A table of contacted stakeholders.

Interview	Organization	Role	When
1	Municipal real estate company	Real estate engineer	17/09-2025

2	Supplier	CEO	27/10-2025
3	Supplier	Sales specialist	27/10-2025
4	Municipal real estate company	Building project lead	06/11-2025
5	Private real estate company	Property manager	04/11-2025

4.4 Coding in Python and Streamlit

Because the existing *Tyréns Recirculation tool* is based on Python and Streamlit (Oscarson, 2024), the tool's further development was carried out through direct modification, debugging, and enhancement of the existing code. The tool integrates precipitation and cost data to provide decision-support for property owners considering RWH adoption. The tool uses databases such as SMHI's daily precipitation dataset (covering a nine-year period from 2014) to calculate average monthly water availability. This is combined with Svenskt Vatten (2025b) data on municipal stormwater treatment costs, allowing the tool to estimate potential economic savings from rainwater reuse. The updated version introduces improved visual output and interactivity, simplifying user input and providing clearer cost-benefit feedback for stakeholders.

4.5 Tool performance evaluation with digital survey (System Usability Scale)

To evaluate the tool's performance and user-friendliness, a System Usability Scale (SUS) evaluation framework was prepared in Google Forms. The SUS method provides a standardized and reliable measure of perceived usability through a short survey (Brooke, 1996), allowing quantitative comparison between the current and improved versions of the tool, using acceptability criteria. In its initial state, the tool required extensive manual input and technical interpretation, which limited accessibility for users unfamiliar with RWH systems. Following redevelopment, new features such as interactive map interfaces, integrated cost-benefit visualization, and simplified outputs were introduced.

The SUS survey is designed to be conducted before and after the tool's improvement phase. A measurable increase in SUS scores will indicate enhanced usability and confirm that the redesign effectively addresses stakeholder needs. To minimize bias and confirmation effects, the survey will be distributed to different user groups at the two stages. Interviewees will initially score the original tool and describe their interpretation of decision-aid in the RWH context; their feedback will then inform the updated version. The improved tool will later be tested and scored by a broader group of random participants to evaluate general usability and comprehension. This is because the improved tool is generalizable and can be used by a broader range of people. The SUS survey was sent out to a general text channel on Tyréns' group on the communications app Teams with a link to the refined tool to test out and score.

4.6 Analysis of data

The collected qualitative data from interviews were analyzed using thematic analysis to identify recurring patterns and key decision factors related to RWH adoption. The analysis followed the process described by Braun and Clarke (2006): familiarization with the data, coding, identifying themes, reviewing and defining themes, and producing final results.

Each theme was categorized according to the framework established in the literature review (economic, technical, social, and regulatory). This analytical approach enabled cross-validation between literature-based assumptions and real-world stakeholder perspectives. For the SUS data, the results were processed using standard SUS scoring formulas to calculate usability indices (0-100 scale). These scores were then compared with acceptability ratings (70<) from Bangor et al. (2009), to provide a comprehensive evaluation of the tool's performance. The results from SUS were analysed for significance with 95% significance level using a one sample statistics test with a null hypothesis average score of 70, and alternative hypothesis average score larger than 70.

4.7 Quality of research

Validity was strengthened by combining multiple data sources, literature review, semi-structured interviews, and usability testing, allowing the research questions to be approached from several perspectives. Interview questions were designed to be directly linked to the study's aim and research questions, ensuring content validity. External validity limitations are acknowledged, as the interviews represent a limited number of organizations; however, their diversity (municipal, private, and supplier perspectives) improves the transferability of findings to similar contexts.

Reliability and consistency were ensured by maintaining consistent interview procedures: all participants received similar introductory information, were asked comparable questions, and gave consent for recording and transcription. A structured documentation process was followed for all interviews, and analysis was performed systematically using thematic analysis (Braun & Clarke, 2006). Notes, transcripts, and coding structures were stored in shared documents to ensure traceability. Triangulation between the literature findings, stakeholder interviews, and preliminary System Usability Scale (SUS) results enhances the credibility of conclusions and mitigates researcher and confirmation bias (Yin, 2018).

4.8 Ethical considerations

Ethical guidelines were followed throughout the research process in accordance with KTH's research ethics policy. All participants were informed about the purpose and scope of the study, their right to withdraw participation at any time, and how their data would be stored and used. Personal information has been handled in compliance with GDPR. Consent was requested before recording or transcription of any interview material, and participants were offered the opportunity to review summarized transcripts to ensure accurate representation of their statements. No sensitive personal data were collected, and the results are presented in a way that protects the privacy of individuals and organizations.

5. Results

This chapter provides results over both decision factors influencing stakeholders' adoption of RWH systems in the conducted interviews and development of the tool with corresponding SUS results.

5.1 Interview results

This section provides the results from the interviews conducted with the various stakeholders. The results are summarized in Table (6).

5.1.1 Interview 1 Västerviks Bostads AB (Respondent 1, 2025)

The background to implementing a rainwater harvesting system in the project at property Katedern 12, was primarily the requirement in the detailed development plan stating that stormwater discharge to the municipal network must not increase compared to pre-development conditions. Infiltration was further restricted due to soil contamination, making traditional local infiltration solutions unfeasible. To comply with the regulation while simultaneously reducing municipal freshwater use, the lead team at Västerviks Bostads AB chose to implement a rainwater harvesting and reuse system for toilet flushing.

The installation consists of a buried concrete tank of approximately 60 m^3 connected to a separate greywater pipe network within the building. The collected rainwater is circulated through an ozone-based treatment system, where the water is disinfected and decolorized before being pumped into a 2 m^3 clean-water tank. The system includes a recirculation loop to keep processed water continuously treated and cool (around 11-12 °C). In addition, a drinking-water bypass with backflow protection is installed to ensure operational reliability in case of low rainfall or maintenance. The tank overflow is directed through a vegetated structure (skelettjord) and parking surfaces before any control release to the stormwater network, thereby meeting both hydraulic and environmental criteria.

During commissioning, a short pump failure occurred during summer but was quickly corrected. Since then, the system has operated reliably. One critical social decision factor was water appearance. Experiences from earlier projects showed that discolored or turbid flushing water caused dissatisfaction among users. Consequently, the ozone system was prioritized over simpler UV or sand filtration but nonetheless included sand filtration for coarser particles. The result has been high user acceptance where most building occupants do not notice that the flushing water originates from rainwater, which was considered a positive outcome.

From an economic perspective, the system involved a higher initial investment compared to a pure detention facility but avoided costly excavation and soil remediation. Rising municipal water tariffs and the relatively high wastewater fees further strengthened the long-term value of the project. In terms of legislation and planning, the system was fully compatible with the requirements in the detailed development plan and was viewed favorably by the authorities. The sustainability rationale was also strong, describing flushing toilets with potable water as "irrational" from a resource-efficiency standpoint.

The project's RWH solution emerged from specific constraints of which are legal limits on discharge, contaminated soil, and architectural layout, rather than from a general methodology. The team performed their own rough economic and technical assessment to estimate storage size, water balance, and payback, but this was not supported by any standardized tool. He also described difficulties in obtaining market information and supplier guidance, suggesting that engineers often must rely on ad hoc judgments. A structured tool that integrates local hydrological data, soil conditions, water tariffs, and usage profiles could make the early evaluation more systematic. It could also quantify trade-offs (e.g., tank volume vs. overflow frequency or cost vs. municipal water savings) and compare RWH against alternative stormwater measures. Such transparency would help justify RWH decisions to planners and investors while reducing the uncertainty that Respondent 1 encountered in supplier selection and design choices.

However, Respondent 1 also emphasized that market maturity remains low. It was difficult to obtain reliable supplier support, and available maintenance contracts were expensive. Despite these challenges, the project successfully demonstrated how legislative drivers and sustainability goals can align to enable a technically robust and socially acceptable solution for water reuse.

5.1.2 Interview 2 Conclean AB (Respondent 2, 2025)

Respondent 2 reports that many systems installed today are designed for irrigation, while indoor reuse (e.g. for toilet flushing) is still emerging but increasing. Conclean delivers systems to both private and public clients, with reference projects such as Nyköping Travel Centre, where rainwater is used for flushing.

The dominant decision factors are economic and administrative. For private homeowners, the return on investment is weak unless local incentive schemes are available, such as grants per connected downpipe, as is the case with central and southern municipalities of Sweden. In the public sector, financial barriers are less critical, instead, there exists a knowledge gap regarding design, procurement, and operation of RWH systems that often slows implementation. Clearer national guidelines and standardized routines would therefore facilitate wider adoption.

In terms of legislation, Respondent 2 explains that there are no fundamental legal obstacles as long as stormwater and wastewater systems remain separate. Technically, the systems rely on established components: coarse filtration (~3 mm) for irrigation systems, and an additional fine-particle filter for indoor applications. Tanks operate to overflow approximately twice per year to flush out pollen and sediment, ensuring water freshness. Recommended maintenance includes rinsing indoor filters about every six months and cleaning tanks every five years. For reliability, systems are designed to withstand 30-40 days without rainfall.

The technical limitations are primarily logistical where plastic tanks of up to roughly 32 m^3 can be delivered as single units, but larger systems quickly become expensive to transport and assemble. Socially, the response from clients has been predominantly positive, particularly among environmentally conscious property owners. Occasional concerns about hygiene are addressed through clear communication that the water is non-potable and limited to toilet or irrigation use.

Respondent 2 pointed out that in the public sector, the barrier is not primarily financial but cognitive, many municipalities and consultants simply lack experience in designing or procuring RWH systems. There is also inconsistent knowledge about technical configurations and maintenance. A decision-aid tool could serve as both a knowledge base and calculation platform, guiding users through questions such as:
“What is my building’s potential annual yield from roof runoff?”

“How many days of storage should I design for given local rainfall variability?”
By embedding these principles in a transparent and user-friendly interface, such a tool could standardize the design logic and make municipalities, engineers, and property owners more confident in approving RWH projects. It could also include case studies and example configurations (like those from Conclean’s installations) to visualize performance in real contexts.

The sustainability rationale is straightforward, if a property must already detain its rainwater, it makes sense to reuse it. This approach creates both an environmental and personal incentive. Decision-aid in the form of design and dimension values (e.g. required tank size, filters and piping etc.), as well as revenue and costs of the system could be a first step towards adoption of such systems. Overall, Respondent 2 characterizes the Swedish market as being in an early development phase, where progress depends on bridging knowledge gaps, financial incentives, and credible pilot projects.

5.1.3 Interview 3 Uponor Infra AB (Respondent 3, 2025)

According to Respondent 3, current market practice in Sweden remains dominated by stormwater detention and attenuation systems, largely driven by municipal planning requirements to limit peak stormwater discharge. These systems typically range from 50 to 200 m³ in volume, sometimes considerably larger for major developments. In contrast, rainwater reuse is frequently discussed in early design phases but rarely implemented in practice. The main economic barrier is the low price of municipal freshwater, which makes the payback time for rainwater reuse installations unattractive. Construction costs for excavation and installation are significant. As a result, reuse systems are often designed and cost-estimated but not realized.

On the social and contextual side, Respondent 3 observes that interest in reuse increases temporarily during periods of drought or irrigation bans, especially in regions such as Öland and Gotland. Private developers tend to ask more questions about reuse than municipalities, but once the immediate water scarcity subsides, projects generally revert to conventional detention-only solutions. Technically, the systems for reuse are entirely feasible, but sizing is highly site-specific which depends on roof area, occupancy, and water-use profile, and this complexity adds further design cost. Furthermore, there is no standardized method to design tanks, making uncertainty high.

From a sustainability perspective, there is a growing awareness that municipal freshwater should be conserved for drinking and hygiene, while non-potable uses (e.g. toilet flushing) could rely on rainwater. Nevertheless, this awareness rarely translates into investment decisions without explicit incentives or regulatory requirements. Respondent 3 believes that introducing financial mechanisms, such as reduced water fees or state subsidies, would significantly improve adoption. Decision-aid in the form of bridging the knowledge gap of users’ water consumption and needs, and how it relates to the required system dimensions is key towards acceptability and adoption.

Respondent 3 emphasized that most reuse ideas are stopped at the feasibility stage, often because designers and clients cannot demonstrate clear economic or functional benefits compared with conventional detention. The economic and technical uncertainties, how large the tank should be, what the maintenance cost is, what savings to expect, are reasons why reuse “stays on paper.” In practice, there is no standardized way to compare RWH to conventional local stormwater management (e.g. LOD lokal omhändertagande av dagvatten) solutions in procurement.

A well-designed decision-aid could provide quantitative comparisons between detention-only and reuse alternatives, showing when reuse becomes beneficial under certain rainfall patterns, water tariffs, or building occupancies. Including cost-benefit analysis and scenario modeling (e.g., with climate or tariff increases) could demonstrate long-term value that is not visible through short-term cost focus. For suppliers like Uponor, a standardized decision-support platform could also help clients identify suitable system sizes and components more confidently, thereby lowering the perceived risk of investing in reuse.

In summary, Respondent 3 describes a market where legislative frameworks currently promote detention as standard practice, while reuse remains an optional enhancement that depends on economic feasibility and local motivation. Only in contexts with high water stress or clear sustainability ambitions does progress reuse from concept to implementation.

5.1.4 Interview 4 Junehem AB (Respondent 4, 2025)

The rain- and greywater reuse project in Taberg, Jönköping, was initiated by the municipal housing company Junehem as part of a broader ambition to create a sustainable and innovative residential area. The development consists of eleven buildings, each equipped with its own greywater recycling system. Greywater from showers and sinks is treated and reused for toilet flushing, while rainwater is collected in four external tanks (~5 m^3 each) for irrigation and outdoor cleaning. The project represents one of the few full-scale residential applications of such systems in Sweden.

The primary drivers were environmental and ideological rather than financial. The decision to invest in greywater reuse emerged from the company's sustainability vision and the severe drought of 2018-2019, which underscored the need to reduce potable water consumption. As Respondent 4 explains, "flushing toilets with drinking water simply felt wrong." The project's planning phase intentionally incorporated these values, and the long project timeline allowed iterative learning between construction phases, refining the system as new houses were added.

From a technical perspective, each building's system includes pumps, filters, and a treatment unit that recirculates treated water for flushing. Initially, tanks were placed outdoors, but subsequent phases moved them indoors to improve maintenance and energy efficiency. This adjustment later motivated reinvestment in the earlier buildings to standardize performance. The system operates reliably overall, although minor technical issues, mainly related to pump failures, have occurred during start-up. Challenges of adoption of the system included lack of knowledge and immature market at the time of project start-up.

Operational and maintenance factors remain significant. Annual service costs are estimated at around 10 000 SEK per building, mostly for filter cleaning, inspections, and technical monitoring. Over the long term, filter replacement every ten years could cost up to 70 000 SEK. Maintenance routines are gradually being optimized as staff gain experience.

Economically, the project was not profitable as a standalone investment, the greywater system added roughly 500 000 SEK per building, or about 5.5-6 million SEK total. However, it was justified as part of Junehem's broader sustainability agenda. Respondent 4 stresses that the investment was viewed as a long-term innovation, not a short-term return generator, and large costs associated with these projects are often a deterrent factor, where priority is given to other parts of the project.

In terms of legislation, no specific barriers were encountered beyond the general requirements for wastewater separation. Reusing greywater for uses other than toilet flushing would have required additional approval due to unclear classification of reused water quality under Swedish drinking-water regulations. Consequently, Junehem chose to limit reuse to toilet flushing only. Other barriers included the use of a water-meter to measure wastewater outflow as reused water would decrease freshwater demand which in return causes the outflowing water to be treated essentially for free by the municipal treatment facility.

Social acceptance among residents has been high; few tenants are even aware of the system, as a drinking-water bypass automatically activates if the recycling system stops. This ensures continuity and prevents complaints. Minor odor issues have been rare and quickly resolved, and treated grey water might give off an odor if it has been still for some time, but the treated water is definitely not a suitable medium for biological growth.

Respondent 4 believes that decision-support tools could play a vital role in making similar systems more widespread. He points out that early design and cost evaluation are complex and uncertain, and that a tool offering automated calculations of storage needs, payback time, and environmental benefit would be invaluable. He adds that the most decisive indicators would be economic payback period, energy balance, and CO_2 impact, which would help convince property owners and consultants.

5.1.5 Interview 5 Castellum AB (Respondent 5, 2025)

Respondent 5 is one of the managers of Citypassagen in Örebro, one of Sweden's earliest large-scale buildings using rainwater harvesting for toilet flushing. The system consists of a 180 m^3 storage tank collecting runoff from the building's roof, treated through UV disinfection and microfiltration ("filter socks") before use. Overflow is diverted to the municipal stormwater network. The project's origins lie in municipal requirements under the detailed development plan that all new central buildings must retain or delay stormwater on-site. Castellum decided to go further by reusing the stored water indoors.

The system's operation and maintenance have proven straightforward. The sediment chamber at the tank's base requires sludge removal every 5-6 years, while filters are replaced every 5-6 weeks, increasing in frequency during the pollen season, when incoming water carries organic particles causing temporary discoloration. UV lamps are replaced every 18 months at a cost of approximately 10-12 000 SEK, while filters cost around 150 SEK each. Overall, the system is considered low-maintenance and reliable.

During spring, the water occasionally takes on a yellowish hue due to pollen, but occupants of the building, mainly government agencies with long leases, have accepted this variation after explanation. Acceptance is maintained through communication and predictability; users are informed that the water's color changes seasonally. Respondent 5 notes that such acceptance would be harder to achieve in residential buildings with frequent tenant turnover.

From a legislative perspective, there are no direct national rules encouraging reuse, but municipalities require local detention to prevent network overload. Castellum's system thus fulfills this regulatory demand while providing additional environmental benefits. No special permits were required for the components.

The project's economic factors are significant, the installation cost approximately 1.6 million SEK. For Castellum, this was justified by corporate sustainability goals and public visibility. The installation attracted considerable attention, generating publicity, study visits, and academic collaboration, positioning the company as a sustainability leader. However, Respondent 5 acknowledges that for smaller property owners, such investments would be difficult to justify financially without subsidies.

From a sustainability standpoint, Respondent 5 strongly supports expanding RWH, calling it "nonsensical to flush toilets with potable water." He predicts rising water tariffs will make reuse more attractive in the future, especially for large commercial buildings with high occupancy. Castellum now focuses primarily on green roofs as a cheaper way to meet regulatory retention goals but is open to future reuse solutions in new constructions.

He also sees value in decision-support tools that could offer cost benchmarks, design templates, and water-balance simulations, helping property managers quickly evaluate feasibility. A tool providing key financial and environmental metrics would simplify early decisions and potentially encourage more companies to adopt reuse.

Table 6: A summary table of contacted stakeholders and decision factors.

Person|Factor	Legislative	Economic	Social	Technical	Sustainability	Misc.
Respondent 1	Driver: Detailed plan required no increase in discharge; infiltration limited by contaminated soils ⇒ reuse chosen over pure detention.	Mixed: Upfront higher than "just detention," but avoids costly excavation/remediation; rising tariffs further incentivizes.	Driver: Aesthetics of toilet water matter; ozone added to ensure "normal-looking" water and acceptance.	Setup: ~60 m^3 concrete tank; dual-piping to toilets; ozone loop with fast residence; process water ~11–12 °C; overflow to vegetated structure; top-up with backflow protection; one pump downtime resolved.	Driver: Strong view that flushing with municipal freshwater is wasteful; RWH framed as part of sustainability profile.	Barrier: Immature market, weak supplier support, costly service proposals; contractor bankruptcy created delivery risk.
Respondent 2	Driver: No legislative barriers regarding use for irrigation; Standards for potable uses are outside the scope of RWH for irrigation purposes.	Barrier: Household payback is difficult without incentives; Driver: grants and subsidies (e.g., per downpipe) unlock projects; public sector is often blocked by lack of knowledge rather than money.	Driver: Environmental interest; market today = irrigation-first; toilet reuse now appearing (e.g., Nyköping).	Practice: Irrigation → ~3 mm pre-filter; indoor → add particle filter; design for overflow ~2×/year to purge pollen; maintenance: filter rinse ~6 mo, tank clean ~5 yr; sizing: buffer ~30-40 rain-free days; largest delivered single plastic tank ~32 m^3.	Driver: "If we already detain, why not use it?"- Respondent 2 resource-efficiency framing resonates with clients.	Market: Adoption accelerates with incentives and better client guidance/templates.

Respondent 3	Driver: Municipal rules commonly push detention/attenuation; reuse often only “on the table,” not executed.	Barrier: Water is cheap; tanks + excavation costly; large products add heavy logistics and price.	Situational driver: Interest rises with drought/watering bans; private side asks more than municipalities.	Reality: Detention often 50-200 m^3 (can be much larger); reuse design is site-specific;	Conditional: Sustainability resonates, but economics dominate unless scarcity is salient.	The design of tanks doesn’t use any standardized methods. Uncertainty and hesitation regarding design details.
Respondent 4	Constraint: General wastewater separation rules limited combining greywater and rainwater; no explicit national reuse regulation.	Barrier: High upfront investment (~500 000 SEK/building) and maintenance costs (~10 000 SEK/year); project not profitable short-term, justified as long-term innovation.	Driver: Automatic drinking-water bypass ensures reliability and acceptance.	System: Eleven houses with greywater reuse for toilets; four external rainwater tanks for irrigation; iterative improvements (indoor tanks, pumps, filters); occasional pump failures.	Driver: Project anchored in sustainability policy and lessons from drought; reduces municipal freshwater use and raises awareness.	Need for decision-support: Respondent 4 emphasized the lack of structured tools; a decision-aid for cost, payback, energy and CO_2 savings to aid early planning and convince investors.
Respondent 5	Driver: Municipal requirement to manage stormwater on-site; reuse chosen instead of simple detention; no special permits needed.	Barrier: High cost (~1.6 million SEK); viable mainly for large commercial buildings; future water tariff increases may improve payback.	Driver: Acceptance high among long-term tenants; color variation during pollen season accepted after communication.	System: 180 m^3 roof-runoff tank; UV + microfilter treatment; filters replaced every 5-6 weeks; UV lamps every 18 months; minor pollen-related discoloration.	Driver: Seen as irrational to flush with potable water; part of Castellum’s sustainability profile; meets detention requirements while reusing water.	Need for decision-support: highlighted the value of ready-made tools with cost templates, design examples, and feasibility estimates to help property managers evaluate reuse options.

5.2 Tool design choices and SUS results

This section includes results and descriptions of the *Tyréns Recirculation tool* before improvement. The version of the Recirculation tool from before improvement lacks a version number, therefore it is named version 1.0 as shorthand.

5.2.1 Version 1.0, *Tyréns Recirculation tool*

The tool before improvement (i.e. version 1.0) is meant to be a decision-aid tool with the ability to compare different procurement alternatives of RWH systems with the help of a multi-criteria analysis. However, it lacked major functions and was partially functional as some inputs weren't working as intended, as well as many visualization inputs required manual input of values which became a target to correct and improve upon. The multi-criteria analysis implemented in this version is convoluted, requiring many user inputs with no real incentives for it to be performed by users.

5.2.1.1 Start page

The start page is a simple page, containing simple elements such as a heading, a description text, two input boxes, a hyper-link, as well as an image with PNG format and a save button. The input boxes are non-functional, as they are not connected to the logic of the code, the same applies to the save button. The image has a white background on a black page background when changing to a dark theme with dark elements. The hyper-link leads to a home page describing *Drizzle* as a collaboration project.

Figure 2: An image of the Start page in Recirculation tool version 1.0.

5.2.1.2 Procurement alternatives page

The procurement alternatives page is where all required calculations occur. It consists of many basic inputs, a map, as well as diagrams and water-balance simulation. The procurement alternatives page consists of five parts, separated by green lines:
1- Input of water usage
2- Map part and input of roof area

3- Tank size diagram and numeric results
4- Diagrams and tank water level simulation
5- A combined diagram of monthly water usage, and how many times the water can suffice for a given usage

Input of water usage

The first section on this page consists of two numerical input boxes and three selection boxes, two of which are one-select only boxes, the harvested-water's use-cases and tank placement (e.g. above or below ground). The third selection box contains months of the year when harvested water is to be used in the simulation. The two numerical boxes are used to input the irrigation area and how many times irrigation occurs per year. Even though this section serves as an input section, no elements were functioning as they were not connected to the code in any way.

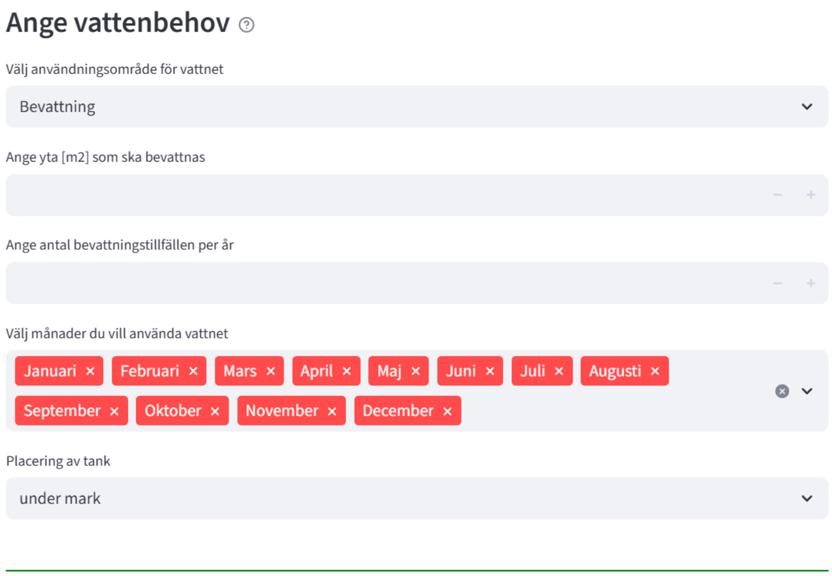

Figure 3: An image of the first section on the procurement alternatives page in Recirculation tool version 1.0.

Map part and input of roof area

The second section on this page consists of two selection boxes, where one can choose between two possible choices, a buildings layer and a property layer, and the other gives a selectable type of roof, with either hard or green roof. The map is zoomed in on the city of Västervik where the user can choose a building and it gives the area of the roof automatically, however, it only works in Västervik municipality as the buildings layer in the municipality was provided in a. Json format. The map also presents convenience, where the model imports data over precipitation and temperature for a chosen pin on the map. Three more numerical input boxes exist where one is used to input roof area, one for daily water usage and the last one is for runoff coefficient. The section ends with a "Show results" button.

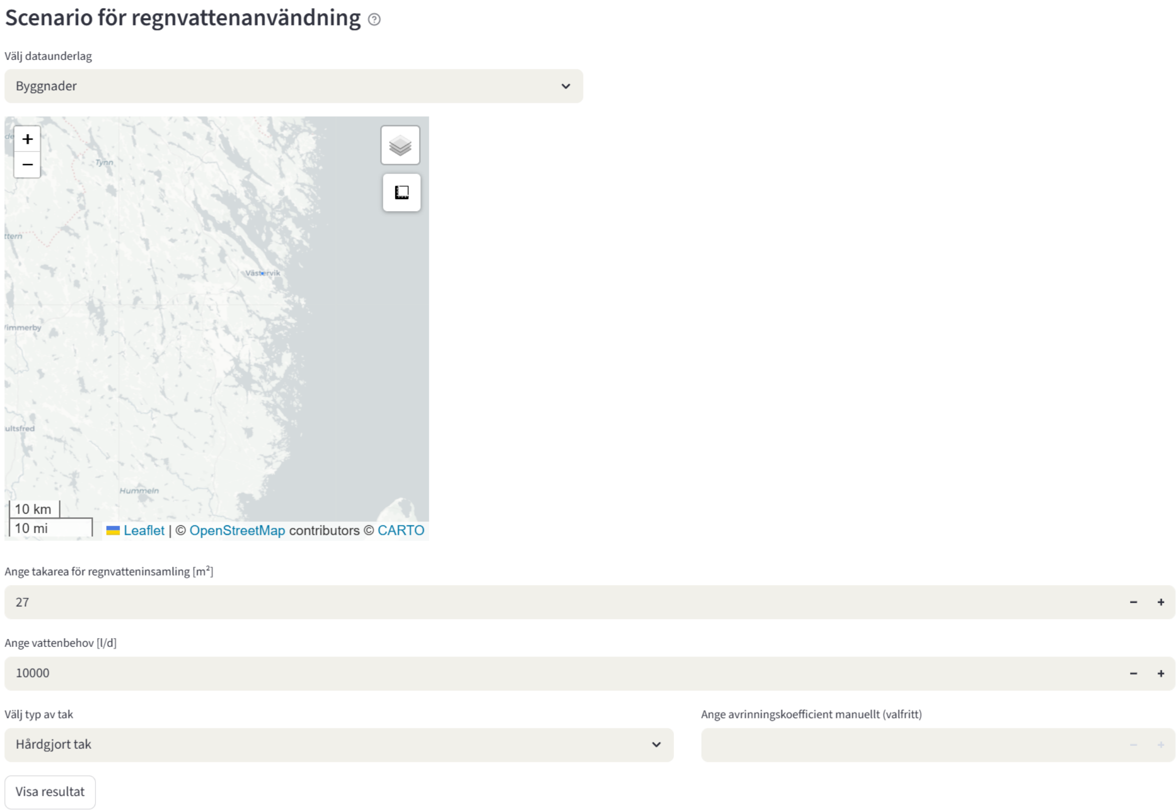

Figure 4: An image of the second section on the procurement alternatives page in Recirculation tool version 1.0.

Tank size diagram and numeric results

The third section in this page consists of a diagram of where it shows the average water coverage of needed rainwater per year as a function of tank size, an input box for tank size where diagrams in later sections depend on the tank size given in this section. The code suggests an optimal tank size where the optimal tank size is the tank size that achieves the maximum average water coverage of rainwater needed. This diagram is the result of the simulation running for all possible tank sizes between 1 and 1 000 with 1 m^3 step size, making this part of the code quite slow each time a calculation is performed. This is followed by a header named “Results” and a sentence giving the possible harvestable water volume from the roof.

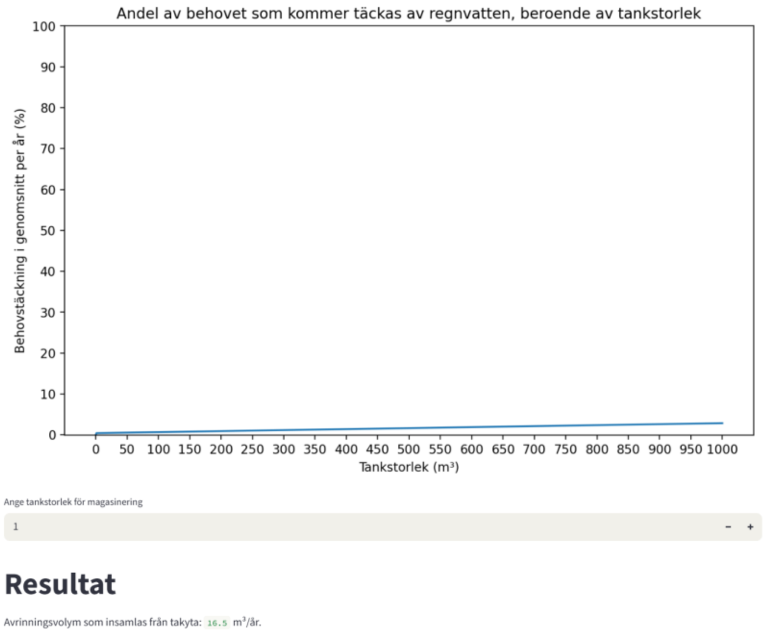

Figure 5: An image of the third section on the procurement alternatives page in Recirculation tool version 1.0.

Diagrams and tank water level simulation

The fourth section consists of a continuation of the numerical results, sort of a summary of possible water volumes (i.e. yearly needed rainwater volume, delivered water from the tank, water needed to top-up and cover the rest of the need, as well as the percentage of the water needed covered by harvested rainwater. The diagrams are three, where one gives monthly average water harvest, storage and overflow over the entire simulation period, the second gives total monthly water need, rainwater use and the volume of water needed to cover the rest of the need. The third diagram shows daily water volume in the tank during the simulation period. The logic of the diagrams is flawed as neither monthly water need is considered in the first diagram, nor overflow volume is considered in the second. The three diagrams could be replaced with one or two comprehensive diagrams as the monthly average water volume in the tank is more interesting than a daily one over the simulation period.

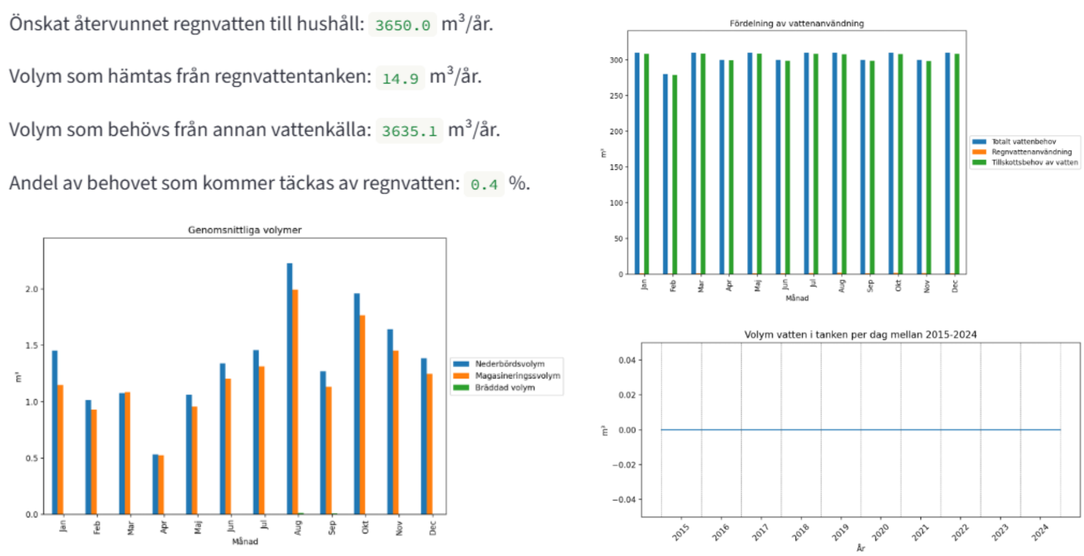

Figure 6: An image of the fourth section on the procurement alternatives page in Recirculation tool version 1.0.

A combined diagram of monthly water usage, and how many times water can suffice for a given usage

The last section of this page is a diagram where daily water usage of different use-cases can be inputted which creates a bar chart over the number of times the daily water use inputted in section three suffices for a given use-case. The idea is indeed interesting, however, the logic is flawed as it should be monthly harvested water instead of daily water use to give an accurate number of uses per month for instance, whereas now, this section doesn't provide any insights as it is.

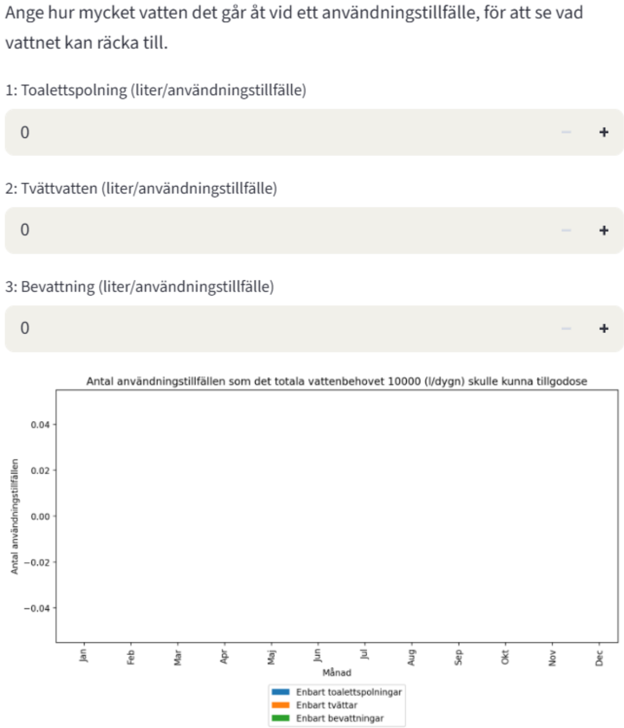

Figure 7: An image of the fifth section on the procurement alternatives page in Recirculation tool version 1.0.

5.2.1.3 Multi-criteria decision-aid part and comparison of purchase alternatives page

This heading consists of two different pages that were merged, as they serve the same purpose which is to compare different procurement based on some criteria, hence a multi-criteria decision-aid.

The criteria page

The criteria page consists of questions categorized by Technical, Social, Environmental and Economical. Under each category a number of three questions are asked where the user could move around a slider that indicates the score for each procurement alternative; The number of procurement alternatives are five by default. The scores vary between -10 to 10 and are used in a later step to compare and visualize the different procurement alternatives based on the categories and thus a recommended procurement alternative is generated based on the highest score a procurement alternative achieves. The criteria enlisted are as follows (Table 7):

Table 7: Criterion questions, translated from Swedish to English, for procurement alternatives in criterion page in Recirculation tool version 1.0.

Dimension	**Criterion**	**Description**
Technical criteria	Water saving	How can the need for drinking water be reduced if this water is used?
Technical criteria	Availability	How reliable is it that the water is available when needed?
Technical criteria	Operation and maintenance	How easy will operation and maintenance of the system be?
Social criteria	Acceptable water quality	Will users accept the quality?
Social criteria	Chemical health safety	To what extent can the chemical health risk be reduced if this water is used?
Social criteria	Microbiological health safety	To what extent can the microbiological health risk be reduced if this water is used?
Environmental criteria	Energy saving from water source to user	How much energy can be saved, from water source to user, if this water is used?
Environmental criteria	Relief of the stormwater network	To what extent can peak flows to the stormwater network be reduced?
Environmental criteria	Fewer greenhouse gases	To what extent can greenhouse gas emissions be reduced if the system is installed?
Economic criteria	Investment cost	Cost of installing the system (SEK/year)
Economic criteria	Operating cost	Cost for operation and maintenance of the system (SEK/year)

The score of each criterion can then be saved later to use in the Results page where diagrams and charts are generated based on the scoring done.

The results page

The results page consists of a chart for each category where criteria are weighed based on the users' preference. Each criterion is weighed separately which then is reflected in the specific score the procurement alternatives get in said category and visualized in the chart. The procurement alternatives are later compared and weighed based on weights for each category as a whole.

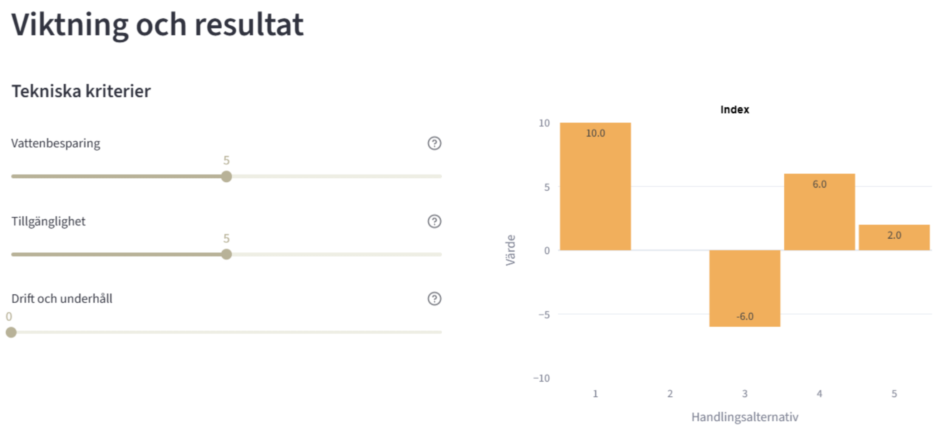

Figure 8: Criteria based weighting of procurement alternatives in Recirculation tool version 1.0.

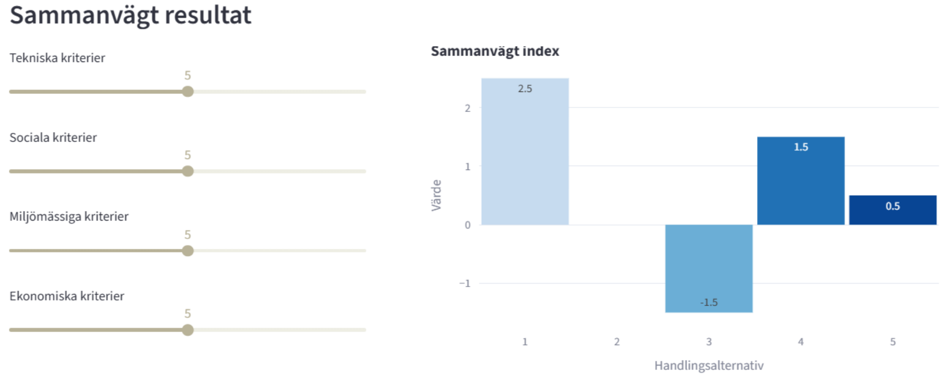

Figure 9: Whole category-based weighting of procurement alternatives in Recirculation tool version 1.0.

Only the technical criteria are functioning both in the criteria page, and on the results page. While this system offers an objective score-weight based ranking of procurement alternatives, it is ditched in the later version of the tool. This is because of its non-functionality, many input requirements and convolutedness of the system making it obsolete.

Recirculation tool version 1.0 offers overall a partly functioning tool serving no more than a mere calculator and map-based interactivity, requiring plenty of user input with redundant charts and diagrams. Aesthetically, it requires modern and pleasing design, emphasizing and informing of the importance of RWH as a viable solution and alternative to use instead of municipal freshwater.

5.2.1.4 SUS results

The System Usability Scale was used to evaluate the performance of the tool before the development in the form of a survey given to the interviewees. Only one out of the five interviewees answered the survey where the version before the development got a score of 60 (Table 8), incentivizing the development and improvement of the tool. Because of a shortage of data points, a one-sample test of significance was unfortunately not feasible, as it requires at least two data points to perform.

Table 8: SUS scoring in Recirculation tool version 1.0.

Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Score
1	2	2	4	4	4	4	3	2	5	2	60

5.2.2 Version 2.0, *Tyréns regnvatteninsamling och cirkuleringssystem - TRICS*

The development of the Recirculation tool to version 2.0 was to address the flaws of the previous version, increase accessibility and simplification of the tool, as well as increase its aesthetic value and viability of it being a decision-aid. The tool was renamed to *Tyréns regnvatteninsamling och cirkuleringssystem - TRICS* to reflect uniqueness and character.

In order to achieve this goal, a front home page with clean and minimal design was created incorporating Tyréns' own color palette to reflect the modernity of the tool (appendix A.6, Figure (3)). An informational page concerning the components of an RWH system and how they work with real life examples was added (appendix A.6, Figure (4)). The calculation and report generation page was updated to increase functionality of the tool, as well as cost-benefit sub-section with detailed calculations to address the need for economic estimation of RWH systems (appendix A.6, Figures (5-7)).

5.2.2.1 Start page

The start page was updated to increase modernity of the tool, incorporating elements such as overlayered cards, transitions, shadows, logos, frequently asked questions (FAQ), hyper-links and real-life examples of successful RWH systems.
Overlayered cards include info about the *Drizzle* project and some of the RWH system examples listed in this paper. A footer was added to mimic the footer used in Tyréns existing homepage, with complete info about the company. Buttons were used to transition between pages for easier navigation as well as modern, fade-in transitions for the different elements, such as cards, section dividers and text. Non-functioning text input boxes were removed to serve a role more of an informational homepage rather than an input-oriented one. Tyréns logo was used both at the introduction card, as well as in the footer to reflect originality and rights to the tool.

5.2.2.2 Component page

Component page was created to increase the tool's informational value, knowledge, inform the users of RWH systems and their components, as well as aid the users in estimating costs of the system in the later steps. It consists of a flowchart simulating a typical RWH system setup, an explaining text of each component of an RWH with corresponding real-life images of the same component. At the end of the page, a button leading to the calculation page was created (appendix A.6, Figure (4)).

5.2.2.3 Calculation and report generation page

The calculation and report generation page is the rename of the Procurement alternatives page in the earlier version. This page was updated the most, covering a wide range of visual and functional changes (appendix A.6, Figure (5, 6 and 7)).

Harvested rainwater use-cases were reworked, simplified and automated with usage values described in this paper, so no user input or knowledge is needed aside from clicking and choosing. Three main water use-cases were kept, toilet flushing, cloth washing and irrigation, as well as a manual use-case where the user could freely choose an input not listed above. The use-cases are now in a selectable box format, combining different use-cases, as it was an exclusive use-case in the previous version, accounting for the number of people and residence days in the week to reflect a more realistic use of the property. The water usage demand is now automated and doesn't require the users' previous knowledge of water consumption, as average water estimations were used.

The map is zoomed out and shows the whole of Sweden when it initializes, and a polygon draw feature was introduced to cut down on loading time and optimize the code to work in all of Sweden. The tank size recommendation in this version is based on efficiency drop-off where the optimal suggested tank size is given by the highest tank size where increasing the tank size by 1 m³ doesn't correspond with an increase of 1% efficiency, reflecting actual realistic tank sizes (appendix A.6, Figure (5)).

Charts and diagrams utilize a different charting library (Plotly), causing them to be more interactive than still images in the previous version. Two of the four charts were kept in this version, where daily water volume in the tank during the simulation was deleted as it offered no value for the user, as well as the number of uses of each use-case per month as a function of water demand for the same reason. The water-balance simulation is now on a monthly basis as well as was combined with monthly rainwater needs in one chart. The second chart gives a distribution of monthly average harvested rainwater as well as the monthly average need of top-up water from municipal freshwater. Two new charts were added where one shows monthly utilization rate of the tank (outflow from the tank divided by tank volume), to inform of when to expect water to be still (i.e. if the tank needs to be emptied and rinsed to avoid use of water contaminated with microbial growth); as well as a chart visualizing average overflow events per year given precipitation intervals (in mm) (appendix A.6, Figure (6)). This serves as an informational chart helping property owners to choose an optimal tank design, as lower overflow event count indicates higher utilization of the tank volume.

A newly added section concerning the economy of the system as it is one of the important factors of decision and a main demand point from the stakeholders. It is meant to be an estimation of costs, estimate the payback time (if it exists at all) and offer aid in system design (appendix A.6, Figure (7)).

Cost estimation starts with a slider for the cost of the tank as a function of size in m³, where it takes into consideration the recommended tank size in the previous section. The function was obtained by doing small market research of tank costs per m³ through RWH system distributors and fitting a linear curve through the data points (appendix A.5), the rest of the tank costs were obtained from STEP's calculator database. The form of the function is given in Table (9). Other identified costs associated with the tank were also included.

Table 9: Tank price estimate assumed in Recirculation tool version 2.0.

	Volume (x $in\ m^3$)	Transport if precast	Access riser	Craning if precast (1 hour assumptio n)	Excavation (x $in\ m^3$)	Bedding (x $in\ m^3$, 1 meter tank depth assumption)	Backfill (x $in\ m^3$)	Tot (SEK)
Tank price	6207.3*x+ 9112	2188	3925	1456	98.3x	103.4x	26.5x	6435.5x +16981

Following tank prices, a cost estimation for piping and needed where it takes into consideration building size (i.e. three categories where it is ordered as small, medium and large buildings) based on default values obtained from STEP tool. Pump costs were also considered where the cost of the pump depends on its water flow capacity, and the type of building (i.e. small, medium or large). Costs for accessories were also added where this category includes top-up system and valve, and backflow prevention to municipal freshwater network. Lastly, costs for filtering and treatment of water (pre- and post-storage) were also considered. Prices were obtained through STEP tool's design and price database (TRCA, 2025). Revenue in the form of reduced municipal freshwater and wastewater was also considered taking into consideration municipal costs in all of Sweden's municipalities and averaging over their treatment and freshwater costs (Obtained through Svenskt Vatten, (2025b)). Operation and maintenance costs were assumed to be around 500 SEK which can be changed by the user. The page concludes with a button to download a summary report over the whole page (appendix A.6, Figure (7)).

5.2.2.4 SUS results

The System Usability Scale was used to evaluate the performance of the tool after development. A total of 5 anonymous participants submitted the survey, where it was later evaluated with a one sample t-statistic test for significance in RStudio (Appendix A.2, Table (10)). The null hypothesis (denoted with H_0) was chosen to be a score average of 70 (denoted by μ) in SUS results which is the minimum score required for acceptability according to Bangor et al. (2009). The alternative hypothesis (denoted with H_a) was chosen to have an average score of 70 and larger in SUS results. The test showed a p-value less than the significance level (95% significance level), giving enough and sufficient evidence to reject the null hypothesis (score average of 70), and indicating that the score average is at least 70 or higher.

Table 10: SUS scoring in Recirculation tool version 2.0.

Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Score
1	5	1	4	1	5	2	4	2	4	2	85
2	3	1	5	2	5	1	5	1	5	1	92.5
3	4	2	4	1	5	1	5	1	5	1	92.5
4	1	2	3	3	3	1	3	2	4	2	60
5	4	2	4	2	4	1	4	1	5	1	85
Average	3.4	1.6	4	1.8	4.4	1.2	4.2	1.4	4.6	1.4	83
$H_0: \mu = 70$						$H_a: \mu > 70$					
N = 5				T-statistic = 2.1704				P-value = 0.048<0.05			

6. Discussion

This chapter provides a discussion over recurring themes observed during analysis of the data, analyzed through the analytical framework used in this study, and cross-validated with the researched literature.

Despite increasing interest in circular water solutions, the number of realised large-scale rainwater harvesting (RWH) projects in Sweden remains very limited. As a result, there is currently no established standard, methodology or routine practice for planning, designing, and implementing RWH systems in either municipal or private development processes. Instead, implementation to date has been largely driven by project-specific trial-and-error, which introduces significant uncertainty, technical risk, legislative ambiguity and economic inefficiency. Critical design parameters, such as storage dimensioning, are frequently based on guesses rather than systematic assessment, which further increases performance uncertainty and weakens the predictability of expected outcomes.

In this context, RWH is still perceived as an unfamiliar niche rather than a mainstream viable alternative. Without clearer national regulatory guidance, consistent enforcement, and standardization of construction and integration methods, the technology risks remain peripheral. Increased knowledge, transparency in benefits, and practical tools are therefore necessary to support municipal planners and property owners in evaluating and adopting RWH as a viable and sustainable stormwater and water-supply measure.

The *Tyréns Recirculation tool* (TRICS) was therefore developed to address this knowledge gap. It functions as a decision-support tool intended to increase understanding of RWH, visualize its potential advantages, and serve as an early-stage aid to facilitate broader adoption and informed decision-making.

6.1 Drivers, barriers and decision factors

The interviews confirmed that rainwater harvesting (RWH) in Sweden remains a niche practice, largely shaped by local circumstances, individual initiative, and fragmented regulation rather than standardized routines. Both literature and practice reveal that the current landscape is characterized by experimentation and uncertainty. Without clear legislative frameworks, economic incentives, or industry standards, each new project, from Katedern 12 in Gamleby to Citypassagen in Örebro and Junehem's Taberg housing, has relied on trial-and-error and project-level innovation. This lack of streamlining raises technical, economic, and legal risks, as also pointed out by Glaas et al. (2025a, 2025b) and Holm (2021).

Legislative drivers remain the strongest external motivators. The legal requirement in detailed development plans to maintain or reduce stormwater discharge ("oförändrat utsläpp") directly triggered the installations at both Katedern 12 and Citypassagen. However, as interviewees emphasized, these rules primarily aim at detention not reuse, meaning RWH adoption is still voluntary and often underexplored by municipalities. Where the law leaves ambiguity, projects depend on individuals who "dare" to test new ideas (Respondent 1, 2025; Respondent 4. 2025; Respondent 5, 2025).

Economic feasibility emerged as the decisive factor across all cases. Interviewees from both municipal and private real estate sectors agreed that current water tariffs are too low to justify investment on purely financial grounds. As Respondent 2 (2025) and Respondent 3 (2025) noted, the costs lying in excavation, piping, and treatment dominate the budget, while the water itself remains cheap. Only when additional drivers such as site constraints, sustainability branding, or subsidies exist does the business case become viable. Castellum's Citypassagen and Vasakronan's Celsius building illustrate this, where neither project achieved financial payback but were realized to strengthen corporate sustainability profiles and attract environmentally conscious tenants. This coupled with environmental certificates granted to both Citypassagen and Celsius (Silver certified in Miljöbyggnad for Citypassagen, and Platinum certified in LEED for Celsius), enables vast economic benefits in terms of higher property value and attraction in the selling and hiring process; as well as access to "green loans" where some banks offer improved loan conditions for environmentally certified properties (Nordea, 2025; Swedbank, 2025). In Katedern 12, only when soil pollution risks and remediation costs were realized, RWH became a possibility. At the same time, economic factors for private property owners exist, albeit at a lower rate where grants are given to disconnect properties from municipal sewer networks for older properties (Dala Vatten och Avfall, 2025). The grants, however, pale in comparison to system costs for private property owners, especially when retrofitting older properties. Nonetheless, there still is willingness to adopt RWH in the private sense for irrigation purposes as noted by Respondent 2 (2025).

Social acceptance is intertwined with water quality and aesthetics. Several interviewees emphasized that users expect "normal-looking" water. Systems that avoid discoloration through advanced treatment (ozone or UV) received few complaints, while those that left yellowish traces faced skepticism. This mirrors findings by Snelling et al. (2024) and Gullberg et al. (2022), showing that trust and perceived cleanliness are key determinants of acceptance. At Junehem, tenants were largely unaware of using recycled water because the system seamlessly switched to potable supply when needed, illustrating how invisible reuse fosters acceptance.

Technical and operational maturity varies widely. Suppliers and property owners alike described an immature market, where component sourcing, service routines, and design procedures still evolve project by project. Yet robust sizing heuristics have begun to form, for toilet reuse, tanks should cover 30-40 precipitation-free days and overflow twice per year to maintain freshness and purge pollen (Respondent 2, 2025). Maintenance, while present, is manageable, filters every few months, tank rinses every five years, suggesting that operational barriers are more perceived than actual once systems are properly designed.

Finally, sustainability and long-term vision surfaced as critical motivators, particularly among municipal actors. Junehem's Taberg project and Västerviks Bostads' Katedern 12 both pursued reuse as an ethical commitment to reduce drinking water use and climate vulnerability. Interviewees often described RWH as a symbolic step toward circular water use rather than an immediate economic advantage and a viable alternative. In this sense, RWH occupies the same transition stage as electric cars once did, initially costly, technically uncertain, yet increasingly inevitable as climate adaptation accelerates.

6.2 TRICS as a decision-aid

The refined *Tyréns Recirculation tool* (TRICS) directly addresses the gaps identified by both literature and interviewees: lack of accessible knowledge, uncertainty in cost-benefit evaluation, and the absence of a standardized decision process. Previous tools like NEWR or STEP (U.S. EPA 2025;

TRCA 2025) focus on technical or economic assessment but remain non-visual and region-specific. In contrast, TRICS merges interactive design, minimal user input, and automatic water-balance and payback estimation to serve as a gateway for awareness and early feasibility screening fitting for the Swedish context.

Stakeholders consistently expressed a need for simple tools that could quantify storage needs, costs, and payback periods while visualizing environmental benefits. The interviewees highlighted, while sometimes implicit, that clear guidance, minimized uncertainty and knowledge gaps, and easy summaries, rather than exhaustive inputs, is what drives engagement and actualizes projects. The minimalist design principles implemented in TRICS therefore align with user needs: quick orientation, clear metrics, tangible results and aesthetic simplicity. The tool addresses this by enabling rapid screening of storage needs, expected water saving potential and basic economic comparison. Rather than replacing detailed engineering calculations, TRICS serves as an early-stage entry point for stakeholders who lack the technical expertise, economic modelling capacity, or prior experience required to evaluate RWH. This aligns well with observations from industry: many projects fail to progress beyond concept phase because the feasibility assessment is too abstract, uncertain or time-consuming.

However, the current tool version mainly considers water-saving benefits, overlooking risk reduction potential, a central argument in both literature (Jamali et al., 2020; Lin et al., 2025) and stakeholder interviews. Future development should integrate a risk-reduction educational module that demonstrates how cumulative adoption of RWH tanks across properties can reduce pluvial flood peaks. By visualizing both individual-property benefits (freshwater substitution) and societal benefits (reduced discharge peaks), TRICS could reposition RWH from a purely “green feature” toward a climate adaptation measure. In this sense, the tool becomes not only a decision-aid but also a reframing mechanism for RWH in Swedish planning practice, directly contributing to sustainability.

6.3 Sustainable development

Implementing RWH in Sweden represents a transitional pathway toward sustainable urban water management. Just as renewable energy transformed the energy sector, decentralized water reuse has potential to redefine urban resilience. The current phase mirrors the early market diffusion of electric vehicles, driven by innovation leaders, not by regulation or profit. As costs of water and flood damages rise, RWH may evolve from supplementary to essential infrastructure.

Furthermore, certification systems (e.g. Miljöbyggnad, BREEAM, LEED) already reward water-efficiency features with lower loan costs and sustainability ratings, providing indirect economic motivation (Nordea, 2025; Swedbank, 2025). The projects studied illustrate how early adopters use environmental certification as a branding and financial tool, bridging sustainability values with business competitiveness. In this sense, RWH serves both ecological and reputational functions, aligning property management with the UN’s sustainability development goals (SDG), particularly Goal 6 (Clean Water) and Goal 11 (Sustainable Cities).

6.4 Uncertainties

The study is limited by its small number of case studies and by the novelty of the subject in Sweden. Both interviews and tool evaluation (SUS) before the tool development were conducted with a relatively narrow group of professionals familiar with the topic, as to interpret and understand current challenges with RWH in Sweden and address what's possible as solutions in the scope of this study, in the refining process of the tool. The SUS results before the refining of the tool, only manifested with a singular measure point where it scored 60 on SUS, indicating a non-acceptable usability as per Bangor et al. (2009). As such, t-test for significance was not feasible yet the existence of a measure point with score average of 60 means that there is at least one case where the tool was unacceptable, justifying the needed development and improvement of the tool. However, distributing the usability survey (SUS) to participants outside the initial interviewee group after development of the tool improved validity of the results as *Tyréns Recirculation tool* (TRICS) was meant to be used by a broad group of people with different backgrounds. This also made it possible to avoid confirmation bias, as the interviewees might intentionally score the tool after development higher simply because they observed both tool versions and noticed a greater change in the newer version. The t-test for significance also resulted in statistically significant results for the average score being larger than 70 indicating a measurable difference in usability and signifying the success of the tool development.

Technical and economic data from existing projects also vary in accuracy, as many installations lack long-term monitoring or standardized cost reporting. Moreover, because only the water-saving dimension was quantified in the tool, potential co-benefits such as flood mitigation, groundwater recharge, and CO_2 reduction remain unaccounted for. These uncertainties emphasize the need for continuous field validation and collaboration with municipal data sources.

7. Conclusion

This chapter concludes the research procedure, summarizing findings, discussions and suggesting recommended research paths as well as general recommendations for the future development of Tyréns Recirculation tool (TRICS).

This thesis set out to investigate the drivers, barriers and decision factors associated with the adoption of rainwater harvesting (RWH) systems in Sweden, and to develop a decision-support tool to support stakeholders in evaluating the feasibility of RWH in an early project stage. Through literature research, multiple expert interviews, and iterative prototyping of the *Tyréns Recirculation tool*, the study demonstrates that although the technical potential for RWH in Sweden is significant, implementation remains limited due to fragmented knowledge, low economic incentives, and the absence of standardized planning procedures.

The findings clearly show that the strongest enabler for adoption today is regulatory pressure in the form of stormwater detention requirements, while the greatest barrier is economic feasibility under current water tariff structures. Social acceptance is closely tied to perceived water quality and aesthetics, and technical feasibility relies heavily on robust dimensioning and reliable maintenance routines. The market for RWH solutions is still immature, with large uncertainty among both property owners and municipal actors regarding costs, service needs, and legal responsibilities. Interviews revealed that many decisions are currently based on guesses and experimental judgement rather than standardized assessment, which reinforces the risk of project variability and slows adoption.

The *Tyréns Recirculation tool* developed in this thesis, courtesy of Oscarson (2024), contributes by addressing part of this knowledge gap and barriers. The tool provides a simplified, visual and user-friendly entry point into RWH assessment, enabling stakeholders to quickly explore storage potential and water-saving benefits in specific building contexts. While limited in scope and primarily focused on municipal freshwater substitution, this tool demonstrates how decision-support can reduce complexity, increase awareness of RWH opportunities, and help guide early-stage decision-making. With further development, including integration of flood mitigation and lifecycle performance metrics, such tools have the potential to become an important catalyst for mainstreaming RWH into Swedish planning practice.

Lastly, rainwater harvesting should not be viewed solely as an optional sustainability feature, but rather as a future-oriented resilience measure aligned with national climate adaptation goals and circular water principles. To transition from experimental projects toward broader implementation, Sweden needs clearer guidance, standardized methods, incentives, and empirical evidence. This thesis provides an initial foundation and practical contribution toward that transition.

7.1 Recommendations

For policymakers, establishing clear national guidelines and incentives, similar to energy-efficiency subsidies, would normalize RWH in construction. Municipalities should incorporate reuse clauses in detailed development plans and provide financial or administrative support for pilot projects, such that RWH and sustainable water use becomes an integral part of projects. For property owners and developers, combining RWH with green roofs or greywater reuse increases technical robustness and cost-efficiency, especially in mixed-use buildings with steady water demand. For future development of TRICS, a new round of a SUS survey should be conducted where it measures how stakeholders directly respond to the new version of the tool and not a broad group of people. This should confirm if decision-aid described by the interviewees is sufficient and integrated in the tool. For the tool development part, future iterations of TRICS should include:

- A risk-reduction simulation module to highlight flood-mitigation benefits.
- Lifecycle cost and CO_2 footprint estimates to strengthen the sustainability narrative.
- Benchmark datasets for comparison between building types and geographic regions.
- Energy use estimates and cost reduction of energy.

Many of these features were part of a complete decision-aid process described by the interviewees.

7.2 Research recommendations and opportunities

Future research should expand empirical data collection on:

- Longitudinal monitoring of existing Swedish RWH installations to determine real performance, maintenance regimes and cost development.
- Methods to monetize flood-risk reduction benefits in municipal planning contexts.
- Comprehensive willingness study of RWH adoption in Sweden.
- Integration of AI-driven precipitation prediction and smart control (as in Lin et al., 2025) for proactive tank management.
- Legal harmonization pathways between stormwater governance and drinking-water supply regulation.

Future research should focus on these areas because they directly address the current knowledge and implementation gaps that prevent rainwater harvesting from scaling beyond isolated pilot projects. Long-term monitoring of existing systems is needed to generate reliable performance and cost data that support standardized design and procurement practice, outside of basic estimates and assumptions. Research that quantifies and monetizes flood-risk reduction could make RWH economically defensible within municipal adaptation budgets, rather than remaining a voluntary sustainability measure. Better understanding of social acceptance and communication is needed to overcome perception barriers linked to water aesthetics and trust. Development of standardized sizing heuristics, governance models, and predictive operational control can reduce technical uncertainty and improve economic feasibility. Lastly, developing a unified national database of RWH projects, combined with tools like TRICS, would help Sweden transition from isolated pilots to standardized practice, transforming rainwater from a by-product of storms into a strategic urban resource. It enables RWH to shift from project-specific experimentation toward a mainstream, resilient and evidence-based water management strategy in Sweden.

References

Bangor, A., Kortum, P. T. & Miller, J. T. (2008). An Empirical Evaluation of the System Usability Scale. *International Journal of Human–Computer Interaction*, 24(6), 574–594. doi:10.1080/10447310802205776.

Boverket. (2023). *Ansvar för dagvatten i detaljplan*. https://www.boverket.se/sv/PBL-kunskapsbanken/detaljplan/lamplighetsbedomning/dagvatten-i-detaljplan/ansvar-for-dagvatten-i-detaljplan/ [2025-07-28].

Braun, V. & Clarke, V., (2006). *Using thematic analysis in psychology. Qualitative Research in Psychology,* 3(2), 77-101.

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability evaluation in industry*, *189*(194), 4-7.

Cools, J., Yu, H., Severijns, R., & Du-Ikonen, L. (2023). *Citizens' willingness to act on stormwater management in Finland and Norway*. EU Horizon 2020 TransformAr Project (Grant Agreement No. 101036683). Published on Climate-ADAPT. Retrieved from https://climate-adapt.eea.europa.eu/en/mission/solutions/mission-stories/citizens-willingness-to-act-story48

Creswell, J.W. & Creswell, J.D., (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* 5th ed. Thousand Oaks, CA: SAGE Publications.

Cristiano, E., Farris, S., Deidda, R. & Viola, F. (2023). How much green roofs and rainwater harvesting systems can contribute to urban flood mitigation? *Urban Water Journal*, 20(2), 140–157. doi:10.1080/1573062X.2022.2155849.

Dala Vatten och Avfall. (2025). *Håll koll på dina stuprör*. https://www.dalavattenavfall.se/vatten-och-avlopp/tips-for-hallbar-vattenanvandning/hall-koll-pa-dina-stupror.html [2025-10-30].

Domènech, L. & Saurí, D. (2011). A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs. *Journal of Cleaner Production*, 19(6), 598–608. doi:10.1016/j.jclepro.2010.11.010.

Ekholm, H. M., Nordlöf, B., Råberg, T., Snellström, J. & Lidén, P. (2023). *Robusthetshöjande åtgärder i ett förändrat klimat.* https://skr.se/download/18.565a1fb118a82e14f67c85a/1694509004593/Robusthetshöjande%20åtgärder%20i%20ett%20förändrat%20klimat.pdf

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics.* 4th ed. London: Sage Publications.

Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, and New York, NY, USA. https://books.google.se/books?id=nQg3SJtkOGwC [2025-09-02]

Forsberg, A., Johansson, E., Persson, I. B., Elving, J., Engblom, L. & Wennerholm, M. (2025). *En robust vattenförsörjning - vägledning och åtgärdsförslag för verksamheter som är beroende av dricksvattenförsörjning*. www.sva.se/media/ii4dowmf/en-robust-vattenfoersoerjning-svas-rapportserie-119.pdf [2025-09-09]

Glaas, E., Bohman, A. & Karlson, M. (2020). Integrating Sustainable Stormwater Management in Urban Planning: Ways Forward towards Institutional Change and Collaborative Action. *Water*, 12(1), 203. doi:10.3390/w12010203.

Glaas, E., Storbjörk, S. & Hjerpe, M. (2025a). Municipality–Property Owner Collaboration for Climate-Robust Stormwater Management: Experiences and Perspectives from Swedish Actors. *Water*, 17(7), 925. doi:10.3390/w17070925.

Glaas, E., Hjerpe, M. & Storbjörk, S. (2025b). The Patronization of Pluvial Flood Risk and Adaptation Among Tenant-Owned Housing Associations in Sweden. *Buildings*, 15(2), 300. doi:10.3390/buildings15020300.

Grundfos. (2025). *Kontrollera vattentrycket*. https://www.grundfos.com/se/learn/research-and-insights/how-to-check-water-pressure [2025-10-23].

Gullberg, Y., Samuelsson, K. & Brandt, S. A. (2023). Key perceptions associated with attitudes towards water reuse in a Swedish town. *Water Reuse*, 13(4), 507–524. doi:10.2166/wrd.2023.010.

Gästrike Vatten. (2023). *Koppla dagvatten rätt.* https://www.gastrikevatten.se/vattenavlopp/dagvatten/koppladagvattenratt.1569.html [2025-07-27].

Hartson, R. & Pyla, P. (2019). Chapter 24 - Empirical UX Evaluation: Data Collection Methods and Techniques. In Hartson, R., & Pyla, P. (eds.). *The UX Book (Second Edition)*. Boston: Morgan Kaufmann, ss.505–543.

Holm, C. (2021). *Vattenbesparande åtgärder Exempelsamling för kommuner och hushåll*. Fyrisåns Vattenförbund. https://vaguiden.se/wp-content/uploads/2020/09/Rapport-Vattenbesparande-tgrder-Exempelsamling210122.pdf

IPCC (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp. https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/ [2025-11-2].

Jamali, B., Bach, P. M. & Deletic, A. (2020). Rainwater harvesting for urban flood management – An integrated modelling framework. *Water Research*, 171 115372. doi:10.1016/j.watres.2019.115372.

Jephson, T. & Kristiansson, A. (2023). *Inspirationsguide för användning av regn- och dagvatten i fastigheter*. REWAISE. www.vasyd.se/-/media/Rewaise-Documents/Inspirationsguide-regnvatten-230704.pdf [2025-10-21].

Kirkhoff, E. (2025). *Lösning på vattenbristen – spola toaletten med insamlat regn - P4 Stockholm*. https://www.sverigesradio.se/artikel/losning-pa-vattenbristen-spola-toaletten-med-insamlat-regn [2025-10-21].

Lin, J., Taguchi, H. & Nakamura, H. (2025). Effectiveness of smart rain barrels for urban pluvial flood mitigation in densely built-up residential areas: a case study of Saitama City near Tokyo. *City and Built Environment*, 3(1), 1–13. doi:10.1007/s44213-025-00053-8.

Linköping University (2025). *VisAdapt*. https://citizensensing.itn.liu.se/visadapt/ [2025-10-23].

Luleå tekniska universitet. (2025). *DRIZZLE.* https://www.ltu.se/en/research/research-subjects/urban-water-engineering/drizzle [2025-07-28].

Miller, J. D. & Hutchins, M. (2017). The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *Journal of Hydrology: Regional Studies*, 12 345–362. doi:10.1016/j.ejrh.2017.06.006. [2025-07-28].

Moberg, S. (2025). *Rekordhöga skadebelopp efter översvämningar 2021*. https://www.svenskforsakring.se/aktuellt/nyheter/2022/rekordhoga-skadebelopp-efter-oversvamningar-2021/ [2025-08-26].

Nordea. (2025). *Grönt bolån – lägre boränta för dig som bor energieffektivt*. https://www.nordea.se/privat/produkter/bolan/grona-bolan.html [2025-11-8].

Oertlé, E., Hugi, C., Wintgens, T. & Karavitis, C. A. (2019). Poseidon—Decision Support Tool for Water Reuse. *Water*, 11(1), 153. doi:10.3390/w11010153.

Okoro, U. & Alabi, T. S. (2025). Aesthetic Experience and User Perception in the Use of Minimalism in Contemporary Web Design. *Proceeding of the International Conference on Art, Design, and Visual Communication*, 1(1), 53–60.

Oscarson, E. (2024). *Recirkuleringskartan - Utveckling av ett interaktivt dimensioneringsverktyg för regnvattenanvändning*. Student thesis at Uppsala University. https://www.diva-portal.org/smash/get/diva2:1864713/FULLTEXT01.pdf [2025-07-28].

Rumsey, D. (2016). *Statistics for Dummies.* 2nd ed. Hoboken, NJ: Wiley.

Saunders, M., Lewis, P. & Thornhill, A., (2023). *Research Methods for Business Students.* 9th ed. Harlow: Pearson Education.

Shalamzari, M. J., Sheikh, .V., Sadoddin, A. & Sarvestani, A. A. (2016). Public Perception and Acceptability toward Domestic Rainwater Harvesting in Golestan, Limits to Up-Scaling. *Ecopersia*. 4. 1437-1454. 10.18869/modares.ecopersia.4.3.1437.

SMHI. (2025a). *Översvämningar*. . https://www.smhi.se/kunskapsbanken/hydrologi/oversvamningar [2025-07-27].

SMHI. (2025b). *Olika typer av översvämningar*. https://www.smhi.se/kunskapsbanken/hydrologi/oversvamningar/olika-typer-av-oversvamningar- [2025-07-27].

Snelling, A. M., Lamond, J., Everett, G., O’Donnell, E. C., Ahilan, S. & Thorne, C. (2024). Public perceptions of rainwater harvesting (RWH): comparing users and non-users of RWH systems. *Urban Water Journal*, 21(2), 181–189. doi:10.1080/1573062X.2023.2281310.

Stec, A. (2023). Rainwater and Greywater as Alternative Water Resources: Public Perception and Acceptability. Case Study in Twelve Countries in the World. *Water Resources Management*, 37(13), 5037–5059. doi:10.1007/s11269-023-03594-x.

Svenskt Vatten. (2025a). *Fakta om dricksvatten, vårt mest kontrollerade livsmedel*. https://www.svensktvatten.se/om-oss/verksamhet-och-strategi/fakta-om-vatten/dricksvattenfakta/ [2025-09-8].

Svenskt Vatten. (2025b). *Resultatrapporter Taxeundersökningen*. https://www.svensktvatten.se/vara-sakomraden/va-statistik-och-rapporter/resultatrapporter/ [2025-10-29].

Swedbank. (2025). *Gröna lån – låna klimatsmart.* https://www.swedbank.se/foretag/foretagslan-och-finansiera/grona-lan [2025-11-8].

Sweden Green Building Council. (2025). *Innovation inom dagvattenåtervinning: I Celsiushuset spolas det med regnvatten* - Sweden Green Building Council. https://www.sgbc.se/nyheter/innovation-inom-dagvattenatervinning-i-celsiushuset-spolas-det-med-regnvatten/ [2025-10-21].

Toronto and Region Conservation Authority (TRCA). (2025). *Rainwater Harvesting Design and Costing Tool*. https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/rainwater-harvesting/rainwater-harvesting-design-and-costing-tool/ [2025-08-27].

United Nations. (2025). *THE 17 GOALS | Sustainable Development*. https://sdgs.un.org/goals [2025-09-24].

U.S. Department of Energy. (2025). *Rainwater Harvesting Calculator*. https://www.energy.gov/femp/articles/rainwater-harvesting-calculator [2025-08-27].

U.S. Environmental Protection Agency. (2025). *Non-Potable Environmental and Economic Water Reuse (NEWR) Calculator*. https://www.epa.gov/water-research/non-potable-environmental-and-economic-water-reuse-newr-calculator [2025-08-27].

Västerviks kommun. (2019). *PLAN- OCH GENOMFÖRANDEBESKRIVNING Detaljplan för Katedern 11 m.fl. Centrumkoppling och särskilt boende Gamleby*, Västerviks kommun, Kalmar län. https://www.vastervik.se/globalassets/bygga-bo-och-miljo/kommunens-planarbete/detaljplaner/gallande-planer/0883-p2020-2b.pdf [2025-10-21].

Yin, R.K., (2018). *Case Study Research and Applications: Design and Methods.* 6th ed. Thousand Oaks, CA: SAGE Publications.

Interviews:

Respondent 1. (2025). Real estate engineer. *Interview with Västerviks Bostads AB*. Teams. 17 September.

Respondent 2. (2025). VD at Conclean AB. *Interview with Conclean AB*. Teams. 27 October.

Respondent 3. (2025). Sales specialist at Uponor Infra AB. *Interview with Uponor Infra AB.* Teams. 27 October.

Respondent 4. (2025). Building project lead at Junehem AB. *Interview with Junehem AB.* Teams. 06 November.

Respondent 5. (2025). Property manager at Castellum AB. *Interview with Castellum AB* Teams. 04 November.

RWH system components:

Conclean (2025). *För bevattning.* [2025-10-21]. https://www.conclean.shop/sv/tankar-under-jord/tankar-under-mark

Eloywater (2025). *Tank för regnvattenåtervinning: waterfix* [2025-10-21]. https://www.eloywater.com/se/losningar/regnvattenatervinning/waterfix

Älvestadtanken (2025). *Regnvattentankar & trädgårdsbevattning.* https://www.alvestadtanken.se/produkt-kategori/regnvattentankar-tradgardsbevattning [2025-10-21].

Appendix

A.1 SUS Questions for the *Tyréns Recirculation tool*

(1 = strongly disagree / instämmer inte alls, 5 = strongly agree / instämmer helt).

English	Swedish
1. I think I would like to use the *Tyréns Recirculation tool* frequently.	1. Jag tror att jag skulle vilja använda Tyréns recirkuleringskarta ofta.
2. I found the *Tyréns Recirculation tool* unnecessarily complex. *(negative)*	2. Jag upplevde att Tyréns recirkuleringskarta var onödigt komplicerat. *(negativ)*
3. I thought the *Tyréns Recirculation tool* was easy to use.	3. Jag tyckte att Tyréns recirkuleringskarta var lätt att använda.
4. I think I would need the support of a technical person to be able to use the tool. *(negative)*	4. Jag tror att jag skulle behöva stöd från en teknisk person för att kunna använda verktyget. *(negativ)*
5. I found the various functions in the tool were well integrated.	5. Jag upplevde att de olika funktionerna i verktyget var väl integrerade.
6. I thought there was too much inconsistency in the tool. *(negative)*	6. Jag tyckte att det fanns för mycket inkonsekvens i verktyget. *(negativ)*
7. I imagine most people (including property owners or planners) would learn to use the tool very quickly.	7. Jag föreställer mig att de flesta (inklusive fastighetsägare eller planerare) skulle lära sig använda verktyget mycket snabbt.
8. I found the tool very cumbersome to use. *(negative)*	8. Jag upplevde att verktyget var mycket krångligt att använda. *(negativ)*
9. I felt very confident using the tool.	9. Jag kände mig mycket trygg när jag använde verktyget.
10. I needed to learn a lot of things before I could get going with the tool. *(negative)*	10. Jag behövde lära mig många saker innan jag kunde börja använda verktyget. *(negativ)*

A.2 One sample t-statistic test results in R

```
> t.test(sample$data,mu = 70, alternative = "greater")

        One Sample t-test

data:  sample$data
t = 2.1704, df = 4, p-value = 0.04788
alternative hypothesis: true mean is greater than 70
95 percent confidence interval:
 70.23115      Inf
sample estimates:
mean of x
       83
```

Figure 1: The one sample t-test for significance performed in RStudio with the scores of SUS used as a sample.

A.3 Interview questions (English)

Perceptions of rainwater harvesting

Goal: Explore stakeholder opinions, experiences, and decision factors.

1. **General awareness**
   - How familiar are you with rainwater harvesting systems?
   - Have you seen or used such a system before?
2. **Decision factors**
   - What would motivate you (or your organization) to implement a rainwater harvesting system?
   - What would prevent you from doing so?
3. **Economic aspects**
   - How important are costs, savings, or subsidies in your decision-making?
4. **Practical and social aspects**
   - What are your thoughts on installation and maintenance work?
   - Would aesthetics or the appearance of the system influence your opinion?
5. **Trust and responsibility**
   - Who do you think should be responsible for promoting or supporting rainwater harvesting: property owners, municipalities, or someone else?
6. **Water quality and use**
   - For which purposes do you think rainwater can be used safely (e.g., outdoor use, toilet flushing, laundry)?

A.4 Intervjufrågor (Swedish)

Uppfattningar om regnvatteninsamling

Mål: Utforska åsikter, erfarenheter och beslutsfaktorer.

1. **Allmän kännedom**
    - Hur bekant är du med system för regnvatteninsamling?
    - Har du sett eller använt ett sådant system tidigare?
2. **Beslutsfaktorer**
    - Vad skulle motivera dig (eller din organisation) att installera ett regnvatteninsamlingssystem?
    - Vad skulle hindra dig från att göra det?
3. **Ekonomiska aspekter**
    - Hur viktiga är kostnader, besparingar eller eventuella bidrag i ditt beslutsfattande?
4. **Praktiska och sociala aspekter**
    - Vad tänker du om arbetet som krävs för installation och drift/underhåll?
    - Skulle utseendet eller systemets estetik påverka din inställning?
5. **Ansvar och förtroende**
    - Vem tycker du bör ha huvudansvar för att främja regnvatteninsamling: fastighetsägare, kommunen, eller någon annan aktör?
6. **Vattenkvalitet och användningsområden**
    - Till vilka ändamål anser du att regnvatten kan användas på ett säkert sätt (t.ex. utomhus, toalettspolning, tvätt)?

A.5 Tank price as a function of size

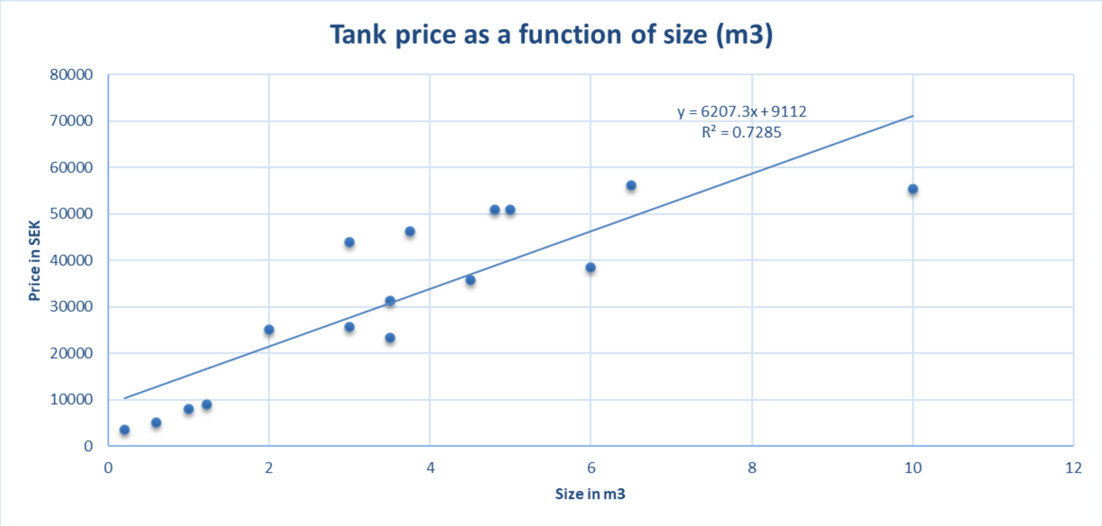

Figure 2: Tank prices as a function of size in the Swedish market.

A.6 Screenshots from the refined version of *Tyréns Recirculation tool* (TRICS)

Start page

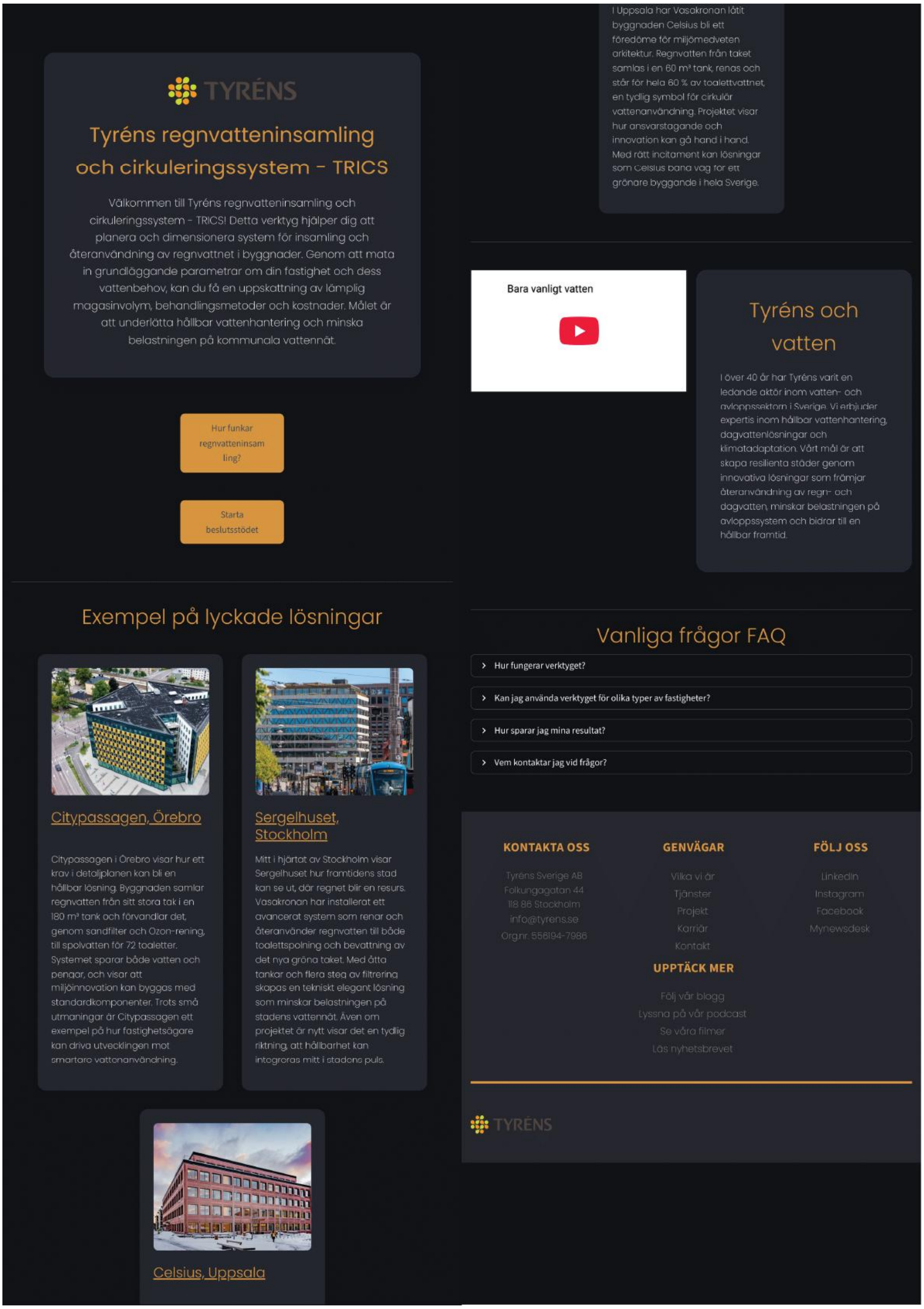

Figure 3: The start page in the refined version of Recirculation tool (2.0).

Components page

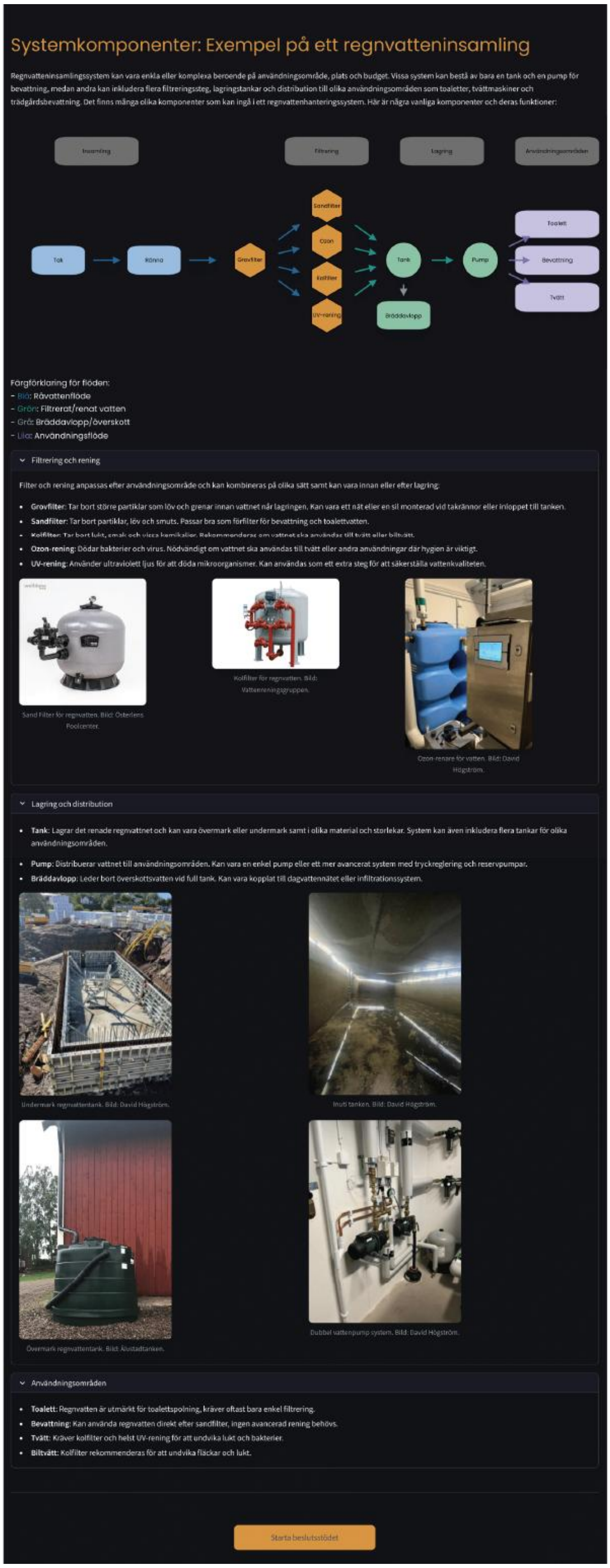

Figure 4: The system components page in the refined version of Recirculation tool (2.0).

Calculation and report generation page

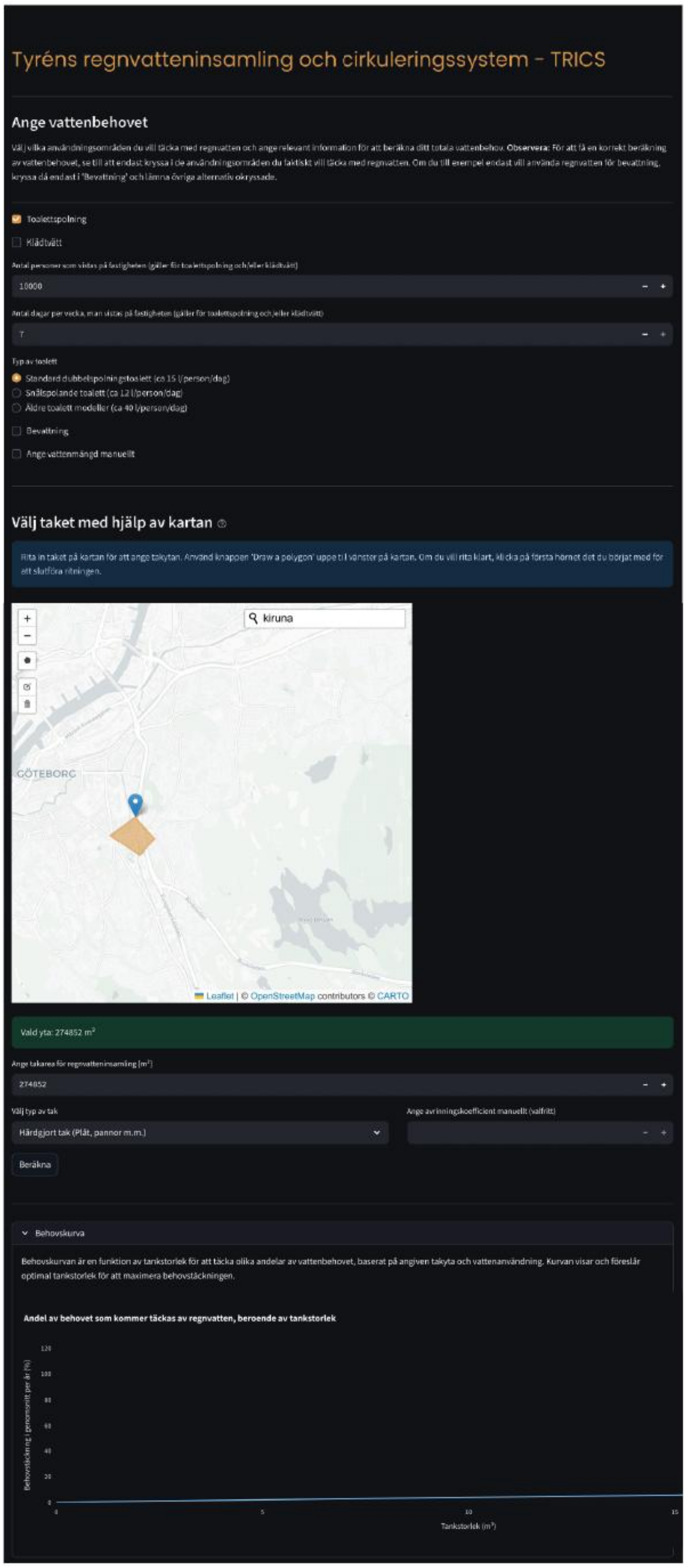

Figure 5: The first part of the calculator page in the refined version of Recirculation tool (2.0).

Figure 6: The second part of the calculator page in the refined version of Recirculation tool (2.0).

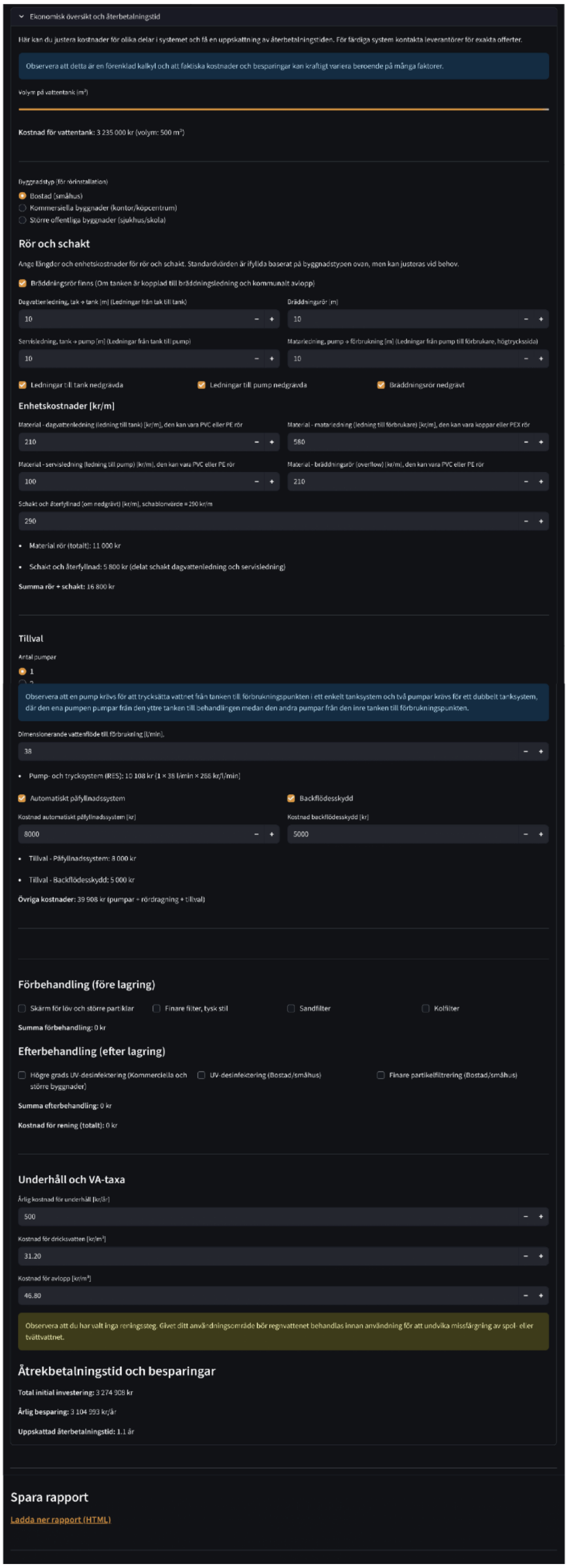

Figure 7: The first part of the calculator page in the refined version of Recirculation tool (2.0).

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