

Article

Financial Feasibility of Basic Rainwater Harvesting Systems in Small Residential Communities in Germany: A Secondary Data and Sensitivity Analysis

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Abstract

The study examines the financial feasibility of basic rainwater harvesting systems (RHS) in small German household communities. The objective is to see if RHS is a financially rational household investment under prevailing tariffs and policies. Structured secondary data analysis combined with financial modelling is used in this study. A baseline German scenario is developed using available data on water tariffs, household consumption, and installation costs. The financial performance is assessed using net present value, internal rate of return (IRR), and discounted payback period. A one-variable-at-a-time sensitivity analysis is presented in terms of the effects of tariffs, subsidies, system cost, and discount rate. The results show RHS is financially feasible conditional on some events. With current German tariffs (EUR 5.80-6.40/m³), the systems generate a small positive net present value over 30 years of operation with a discounted payback period of 14-22 years. Reports reveal that financial performance improves significantly under higher tariff scenarios, the availability of installation subsidies, and a lower discount rate. Higher discount rates and lower tariffs, on the contrary, lower viability. The results suggest that RHS is technically feasible and cost-effective; however, its widespread adoption will depend on policies and market conditions that enhance financial attractiveness. The findings of the study will help the policymakers, housing associates, and households to implement targeted subsidies, favorable tariff regimes, and access to low-cost finance for decentralized water management systems.

Keywords: rainwater harvesting; financial feasibility; net present value; water tariffs; decentralized water management

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1. Introduction

The world's freshwater resources are becoming strained because of population growth, urbanization, climate change, and enhanced standards of living. These patterns are putting pressure on the availability of dependable water supplies and posing serious problems to sustainable water management across the world. According to recent research, water insecurity has emerged as an increasingly significant issue on the international agenda, not only in developing countries but also in developed ones (Shemer et al., 2023). The research question emphasizes whether a basic rainwater harvesting (RHS) system is a financially rational investment for a household under real-life conditions in residential neighborhoods in Germany. This research

clearly distinguishes between financial feasibility and environmental value, in that while a system may be environmentally beneficial, it may not be financially attractive given current economic conditions.

Rainwater harvesting systems (RHS) approaches currently is getting increased attention. Such systems collect rainfall on our roofs and reuse it in non-drinking domestic tasks like toilet flushing, irrigation in gardens, and household cleaning (Raimondi et al., 2023). Rooftop harvesting systems can contribute to water conservation and improve urban water resilience by decreasing reliance on the municipal water supply systems (Ssekyanzi et al., 2024). Yet, the economic justification of RHS as an investment by the household is analytically different from environmental benefits. It calls for assessment using performance indicators.

Even though Germany can be traditionally viewed as a water-secure country, recent climatic crises and urban flooding issues have brought to focus the necessity of more adaptive water management measures. To illustrate, the extreme flooding cases in western Germany showed that the current drainage-oriented infrastructure systems are susceptible (Bosseler et al., 2021). Concurrently, the relatively high combined water and wastewater tariffs in Germany (as compared to other European nations) can also offer a potentially favorable basis to RHS investment that has not been assessed in a systematic manner through rigorous financial appraisal tools. The National Water Strategy (2023) and DIN 1989 technical guidelines offer a liberal regulatory framework around residential RHS, but its adoption is still limited, which indicates that the financial case around residential investors has not been clearly made (DIN, 2012).

Although technological feasibility is growing the financial feasibility of basic RHS in small residential situations has been underexplored. The literature review describes the environmental performance or engineering design but does not assess financial indicators of payback period, net present value, and tariff sensitivity in household investment decision-making (Muhirirwe et al., 2022). Additionally, regulatory frameworks and governance considerations, which influence adoption, are normally analyzed separately in the economic feasibility studies (Nandi & Gonela, 2022).

In a bid to bridge this gap, the study prepares an integrated analytical framework in the three dimensions of (i) financial performance (net present value, IRR, and discounted payback), (ii) regulatory conditions (tariffs and subsidies), and (iii) behavioural factors (cost perceptions and adoption barriers). The system framework makes use of secondary data on tariffs and consumption as well as costs and applies financial evaluation techniques to produce viability indicators for an overall RHS assessment in residential Germany.

2. Literature Review

2.1. Technical Performance of RHS

Empirical research evidence suggests that residential rainwater systems can supply about 50-70 % of non-potable water, based on the rainfall pattern, the rainwater collection area on the roof, and tank size (Raimondi et al., 2023). Such performance bears witness to the technicality of the decentralized water reuse in urban areas. Non-potable uses such as toilet flushing (approximately 23% of household water consumption), laundry (19%), and garden irrigation are a major portion of residential water demand, which creates a structurally positive supply-demand relationship of RHS implementation (Ssekyanzi et al., 2024). Table 1 present TRHSs applied in several regions.

Table 1. TRHSs applied in different regions.

TRHS	Region Applied	Role in Water Management	Limitations
Tanks and Ponds	South Asia	Store water for drinking and farming during dry periods.	Water loss from seepage and evaporation; contamination risk.
Stepwells	India	Collect runoff to support communities and livestock in dry seasons.	Limited capacity and possible water quality issues.
Zib Systems	Sahel, Africa	Small systems providing water for irrigation, households, and livestock.	Water shortages during prolonged droughts.
Chultuns	Central America	Capture and store rainwater for domestic and agricultural use.	Limited storage and contamination risk.
Qanats	Middle East, North Africa	Underground channels supplying water for irrigation and drinking.	Complex maintenance and declining use today.
Berkads	Somalia	Reservoirs storing rainwater for household and farming needs.	Limited storage and contamination risk.
Ahar-Pyne System	Eastern India	Collect and store rainwater for irrigation and domestic use.	Limited capacity, sometimes causing drought or flooding.

Source: (Ssekyanzi et al., 2024).

Nevertheless, a critical difference should exist between theoretical performance in idealized conditions and practical performance, where behavioral variation exists, rainfalls vary with seasons and there is a gap between maintenance work. Numerous empirical investigations are based on simulation instead of observed field data, which tends to exaggerate possible efficacy (Bosseler et al., 2021). The seasonal variability in the temperate climate of Germany is moderate with respect to the case studies of the tropical environment; however, it is a non-trivial risk factor to the reliability of the yield of the system.

2.2. Economic Feasibility of RHS

Common indicators of feasibility evaluation in economic analysis include net present value, internal rate of return (IRR), and discounted payback period. Simulation analysis shows that residential RHS can generate positive financial returns when favorable tariffs are present. As an example, the study of various buildings indicates that 60-75 % of residential systems have the capacity to be cost-effective, and that discounted payback durations are between 4.8 and 8.6 years based on system design and water pricing frameworks (Raimondi et al., 2024). The applicability across studies is, however, hampered by inconsistent assumptions such as discount rates (3-10%), system lifetime (20-30 years), maintenance costs (0.5-2%), and tariff escalation. The majority of the financial literature is Brazilian, where extreme block-rate tariffs will cause more savings compared to the flat pricing in Germany, making it difficult to directly extrapolate the results to that environment.

The standard net present value decision rule requires that net present value > 0 . In reviews of decentralized water technologies, it is observed that economic calculations can be highly inconsistent because of different modelling assumptions and cost parameters, which restrict the cross-study comparison (Muhirirwe et al., 2022). The RHS literature does not always apply these rules consistently. A number of the studies have positive financial results without specifying the discount rate used or testing sensitivity to its change, a methodological weakness that this study specifically covers using sensitivity analysis over a range of discount rates between 2 and 8, which is within the range of discount rates that German residential investors might reasonably experience between low-cost KfW-funding and unsubsidized private capital.

2.3. Adoption and Policy Drivers

According to survey research, unlike households that are aware of the environmental advantages of rainwater systems, their real installation levels are low because of the perceived cost, complexity of the regulations, and low awareness (McLeod et al., 2024). Market segmentation research also indicates that households differ greatly in their readiness to use RHS, and there are supportive, receptive, and reluctant user groups that have various motivations and obstacles.

Applying a technology acceptance model have established that positive attitudes towards RHS have a significant effect on behavioral intentions to install this sort of system, where perceived costs and technical requirements may deter adoption (Sun et al., 2025). In the case of Germany, behavioral evidence is not very transferable because most adoption studies are associated with water-intensive areas with increased perceived urgency. With a reliably supplied environment, as in Germany, there is a weak adoption attitude under lower urgency, and financial incentives will have to counter motivation gaps which cannot be filled by environmental concern alone.

2.4. Research Gap and Hypotheses Development

The literature considers the technical performance, economic feasibility and behavioural adoption as distinct streams. There is mainly non-German, simulation-based financial studies; behavioural studies nearly never correlate attitudes with financial thresholds, and governance studies scarcely ever rely on investment measures. There is no unified viability framework of the small German residential communities – this work fills that gap. The study proposes the following hypotheses for financial and behavioural analysis of the RHS in residential areas.

- H1: The financial viability of RHS is positively related to higher municipal water tariffs.
- H2: Subsidies improve net present value and investment attractiveness.
- H3: Higher discount rates reduce financial feasibility.

3. Methodology

The research uses a secondary data analysis method to assess the financial viability of basic RHS in small residential housing areas in Germany. In Wickham's (2019) view, secondary data analysis means making use of existing material, which include academic literature, policy documents and industry reports. According to Kaushik and Walsh (2019), the research study adopts a pragmatist research paradigm that emphasizes practical problem-solving and the relevance of policy rather than a single theoretical framework. The intersections of the economic, regulatory, and behavioural domains make this approach appropriate for sustainability research. The use of secondary data is justified because in Germany national-level statistics on water tariffs and consumption patterns, as well as technical standards, are reliable to enable the construction of a valid baseline scenario. This study combines a quantitative financial assessment with qualitative context, which assesses the feasibility of RHS under real-world conditions.

3.1. Financial Evaluation Model

The financial feasibility is assessed using three common investment appraisal indicators, including net present value, internal rate of return (IRR), and discounted payback period. This is applied to a rebuilt German baseline scenario based on public data. The baseline references water tariff information from the German Federal Environment Agency, household consumption statistics, and system cost benchmarks from DIN 1989 technical guidelines, all of which have a basis in recognized engineering standards. Among key parameters, installation costs level at EUR 3,500–5,000 ES. That is for a 3,000 L tank, pump, and filtration; maintenance costs approximately 1% per year; system lifetime 30 years; average household 3 persons. The non-potable demand for the year is estimated at 59 m³... RHS will supply 50-60% of this. Combined tariffs come out to EUR 5.80–6.40/m³. A standard lifespan for infrastructure is 30 years. A baseline discount rate of 4% refers to the financing conditions for long-term residential support, especially subsidized support such as KfW. The rates are between 6-8% in the case of private financing. While 2% in the case of favourable macroeconomic conditions. Sensitivity analysis tests these assumptions.

3.2. Financial Evaluation Model

The OVAT sensitivity analysis is performed to detect the financial viability. This technique isolates the influence of a single variable while keeping others stable. Essential variables are water prices (EUR 4.50–8.00/m³) to be paid by customers, installation costs (EUR 2,500–6,000) after subsidies, subsidies (EUR 0–1,000), and the discount rate, which ranges from 2 to 8%. They were selected based on their relevance in the literature and linkage to the studied hypotheses. The analysis consists of four steps: data selection, baseline scenario construction, financial calculation, and sensitivity test. This approach enhances transparency and reproducibility. On the downside, OVAT does not take into consideration interaction effects of variables, and this is a limitation that has been acknowledged and which has space for more research.

4. Results

4.1. Technical Effectiveness of RHS in Meeting Non-Potable Water Demand

The data establishes that standalone RHS is able to satisfy about 50-70% of the non-portable residential water requirements (Dashti et al., 2025) with at least 67% performance in residential buildings in case of combined greywater reuse (De et al., 2023; Stec, 2023). Non-potable demand – toilet flushing (23%) and laundry (19%) – is also a large enough portion of the overall consumption to render RHS technically significant as a supply supplement. The leading performance determinants are storage tank volume and roof catchment area, with tanks constituting 50-70 per cent of the overall system cost (Istchuk & Ghisi, 2022). Not only has seasonal variation in rainfall brought about yield uncertainty, which is especially applicable to financial forecasts: water savings in similar temperate investigations have varied between 27% in dry seasons and more than 70% in wet months (Borgert & Ghisi, 2024). In the case of the German financial model, the baseline uses a conservative mid-range effectiveness of 55%, and sensitivity tests determine 45% and 65%.

4.2. Economic Viability: Cost, Returns and Investment Risk

In a reconstructed scenario under baseline German conditions, the estimated net present value of the reconstructed scenario is EUR 800-2,100 over 30 years at a 4% discount rate, and the discounted payback period is 14-22 years and a discounted IRR of about 3.5-5.5. Using the standard IRR decision rule, the financial non-viability at the lower end of the estimation range is an IRR of 3.5%, which is below the 4% base rate discount; financial viability at the upper end is marginal with an IRR of 5.5%, which is above the base rate. The investment is thus more or less viable than obviously viable or not viable given the prevailing circumstances. Table 2 summarises the financial performance RHS under baseline and alternative scenarios.

Table 2. Baseline financial performance of RHS.

Scenario	Tariff (EUR/m ³)	Net Present Value (EUR)	IRR (%)	Payback Period (years)
Low Case	5.80	800	3.5	22
Base Case	6.10	1,400	4.5	18
High Case	6.40	2,100	5.5	14

It is through sensitivity analysis that viability is shown to be on the tariff level. At EUR 8.00/m³ – a realistic situation with the inflation-plus inflationary price trend in Germany – IRR is over the 7% mark, and payback is under ten years, which is a distinctively viable investment as per the normal decision-making criteria. A sensitivity analysis was carried out to assess robustness further in Table 3. Net present value becomes negative at EUR 4.50 /m³ in most situations. An ER 500 to 1,000 installation subsidy is enough to lower the effective capital outlay so as to push IRR above the 4% level in most base settings. The second most influential factor is variation in discount rates: net present value at 7-8 is negative at an optimistic tariff value as well, which proves that access to cheap finance is not a marginal supplement to structural viability. This indicates that findings are robust to alternative measure specifications. According to the results of H1, H2, and H3, higher tariffs increase NPV (net present value) and IRR (internal rate of return); subsidies make the activity attractive for investment; and higher discount rates will make the activity less financially feasible.

Table 3. Sensitivity analysis of key variables.

Variable	Low Scenario	Base Scenario	High Scenario	Impact on Feasibility
Tariff (EUR/m ³)	4.5	6.1	8	Strong positive effect on net present value and IRR Higher cost reduces viability
Installation Cost (EUR)	2,500	4,000	6,000	
Subsidy (EUR)	0	500	1,000	Improves IRR and reduces payback
Discount Rate (%)	2%	4%	8%	Higher rates reduce net present value significantly

4.3. Adoption Drivers and Barriers

There are low adoption rates in urban residential settings despite technical practicability and a conditional positive financial case. According to survey evidence, the perceived cost of installation, regulatory complexity and space constraints are the main obstacles, as well as low perceived urgency in water-secure environments (McLeod et al., 2024; Suni et al., 2025). The gap in the adoption between the stated willingness and actual installation rates (the adoption gap) can be analytically explained by financial outcomes: a payback period of 14-22 years with the base conditions is longer than the investment horizon of most private residential decision-makers, notwithstanding the attitudinal willingness. This suggests that the promotion strategies based on environmental communication mainly are too small; the financial argument should be enhanced significantly by modifying subsidies or tariffs before attitude willingness becomes installation behavior on a large scale. The results of the study indirectly support H3, indicating that investors find risky projects less attractive.

5. Discussion

The study findings present that the basic RHS in Germany are conditionally financially viable but not clearly profitable now. International studies, however, report more positive results than these. For instance, unlike the Brazilian studies (Raimondi et al., 2024), which indicate a significant financial return due to progressive tariff structures, the German case shows milder outcomes. Germany has an almost flat-water tariff, which limits marginal savings from rainwater substitution.

One important finding from the study was that water tariffs significantly influence financial performance. Higher tariffs reduce municipal water consumption, causing savings that improve NPV and shorten payback periods. On the contrary, lower tariffs reduce financial attractiveness. According to H1, the feasibility of RHS is shaped by pricing conditions rather than technological capability. Likewise, credit conditions determine the discount rates that matter. Higher discount rates lead to lower long-term returns and adversely impact feasibility as supported by H3. The results were more pronounced for households whose investment horizons are shorter.

Subsidies also act as an important enabling factor. Even small upfront subsidies, which lower capital costs, a well-known barrier in capital-intensive systems like RHS, improve investment performance substantially. This result provides support for H2, in addition to being backed by previously published work that indicates the usefulness of financial incentives. Although these are technically feasible, with moderate to high returns, the technologically oriented solutions are the least used today. Structural and behavioral factors can explain this, including high upfront costs and regulatory complexity and low perceived urgency in water-secure settings such as Germany (McLeod et al., 2024; Suni et al., 2025). The long payback period diminishes the appeal of the choice as it exceeds the investment horizon of typical households.

There are several implications suggested. Policymakers could significantly improve the adoption of NERs by raising subsidies, restructuring tariffs, and simplifying regulations. For households, RHS is a long-term financial commitment that can be affected by financing conditions. In the view of investors and housing associations, viability is determined by favorable economic and policy environments. However, the findings should be interpreted with caution due to factors such as reliance on secondary data and lack of real environment validation. Moreover, one-variable-at-a-time sensitivity analysis does not account for interaction effects. It is likely that technological factors with respect to RHS will become secondary to policy and financing conditions.

6. Conclusions

This paper discussed the financial viability of simple RHS in small residential construction projects in Germany by considering technical, economic, regulatory, and behavioral approaches. The results suggest that RHS is a conditionally viable long-term investment and not always profitable in present circumstances. Systems are sensitive to financial performance, although they can supply up to approximately 50-70 percent of non-potable household demand. The current tariff rates indicate relatively long payback rates with a modest positive net present value of using the base results in 30 years. The sensitivity analysis proves that the determinants that have the strongest effect on financial feasibility are water tariffs, installation subsidies, and discount rates. Moreover, adoption is still limited due to high initial costs, regulatory density, and lack of perceived urgency within a water-secure situation. There are limitations in this study, though. It is based on secondary data, which is not the most accurate in reflecting real-life variability, and empirical validation with field data. In addition, one-variable-at-a-time sensitivity analysis neglects interaction effects among variables. In future studies, primary data collection, household surveys, and real case studies should be included to test the findings. Further sophisticated modelling techniques, including dynamic or multi-variable modelling, would give further insights on the investment behavior and system performance under fluctuating economic states.

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