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Financial and Social Factors Influencing the Use of Unconventional Water Systems in Single-Family Houses in Eight European Countries

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Abstract: A modern model of water management should take into account, first of all, its responsible consumption of both tap water and water from unconventional sources. With this in mind, a study was conducted to determine the financial efficiency of rainwater harvesting systems (RWHSs) and greywater recycling systems (GWRSs) in residential buildings located in eight European countries. At the first stage, volumetric reliability was determined for different tank capacities for actual precipitation data. An economic analysis was carried out for six variants in which rainwater and greywater were used in various combinations for toilet flushing, washing, and garden watering. The implementation of alternative water systems was found to be financially unprofitable in four cities: Warsaw, Bratislava, Budapest, and Stockholm. For these cities, the variant with the lowest life cycle cost (LCC) level was always Variant 0, with conventional installations. The opposite situation was observed in the other four locations (Lisbon, Madrid, Rome, and Prague), where Variant 0 was not found to be financially profitable for any of the calculation cases analyzed. Additionally, a survey was conducted to determine the effect of social aspects, which is often the greatest barrier to the implementation of new or unknown technologies. In most of the countries surveyed, rainwater is more acceptable to society as an alternative water source than greywater. For hygiene reasons, the use of these two systems for washing clothes was of greatest concern.

Keywords: rainwater; greywater; life cycle cost analysis; volumetric reliability; social awareness and acceptance; survey research

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1. Introduction

For more than the last two decades, the world has faced severe environmental problems mainly caused by climate change, urbanization, and population growth. The condition of the environment is also influenced by the overexploitation of natural resources resulting from constantly growing demand for a variety of raw materials. Increasingly frequent attention is paid to the fact that responsible exploitation and protection of natural resources are key to the existence and development of future generations [1,2]. According to Yang et al., the current international efforts to mitigate the effects of climate change may depend primarily on the level of resource use and the level of emissions in industrialized and urbanized countries [3]. Sustainable management of natural resources can be achieved by implementing environmentally friendly technologies in all sectors of the economy. This also applies to the construction sector, which uses enormous amounts of water [4,5]. It is estimated that residential buildings alone make up about 10% of the total global water demand [6]. The increasing consumption of water means that, in many countries, it is scarce and, therefore, a very valuable commodity [7].

Urbanization and industrialization are seen as the main factors that increase the degree of environmental pollution [8] and deteriorate the quality and quantity of water resources [9,10]. In addition, the availability of water resources is also significantly affected by excessive and unsustainable use of water. It is observed, inter alia, in residential buildings, where more than 50% of fresh water is consumed for purposes that do not require it to be of potable quality. In addition, world population growth at the current level of 1.1% per year is expected to increase the human population to 9.7 billion by 2050 [11], and this, according to some forecasts, will result in a 55% increase in the world's water demand [12]. As the population grows, more buildings will also be constructed over the coming decades. The consequences of this will be especially noticeable in regions where no sustainable model of water source use is applied, or the performance of the water supply system is insufficient [13].

Reliability of water supply, regarding its accessibility, quantity, and quality [14,15], as well as protection of water resources through their proper management, is essential to support all aspects of human life and economic development. Water consumption and its availability across Europe vary greatly. This is mainly due to climatic and natural conditions, habits and customs of the inhabitants, as well as economic and cultural conditions. In Europe, water resources per inhabitant are around 6879 m^3/year [16], but in many regions, water resources are lower than half of this amount, for example, in Poland, Hungary, the Czech Republic, Malta, and Cyprus. Annual water resources in Spain, Italy, Belgium, and France are determined at around 2500 m^3/inhabitant [16]. Scandinavian countries have the largest water resource on the European continent. Due to the unequal availability of water resources, in many European countries, there is a problem of water scarcity either permanently or periodically.

The law regulations in force in the European Union, especially the Water Framework Directive, require water to be managed in a sustainable manner [17]. Climate changes and the changing availability of freshwater resources in Europe should also be an impulse to protect them [18]. Recent history has shown that frequent extreme droughts and floods, which may be exacerbated by a changing climate, can place additional strain on water supplies in many European countries [19]. The sustainable management of water resources is, therefore, a key issue in Europe, and to achieve this, it is necessary to put in place mechanisms and strategies to ensure the responsible use of water. Taking this into account, it is incomprehensible why so many constraints exist in the implementation of alternative water sources in Europe, which was highlighted by Cipolletta et al. [20].

In the search for unconventional sources of water that can be used in buildings, special attention has been paid to rainwater that is slightly contaminated, especially coming from the roofs of buildings [21]. Rainwater is increasingly being perceived as a valuable resource rather than waste that should be disposed of as soon as possible [22]. The methods of its management in a given place are influenced by many factors, including technical, environmental, social, and political aspects [23,24]. A sustainable model of rainwater management should be based on its retention, infiltration, and, above all, economic use [25–27].

Rainwater can replace fresh water, both for consumption and for non-potable uses [28,29]. The possibilities of implementing rainwater harvesting systems (RWHSs) in buildings have been widely explored throughout the world. Researchers have considered different types of buildings, for example, office buildings [30,31], single-family homes [32,33], multistory residential buildings [34], university facilities [35], schools [36], dormitories [37], sports facilities [38], airports [39], petrol stations [40] and hospitals [41]. Treated rainwater is mainly used as non-potable water for toilet flushing [42,43], watering and irrigation [44,45], household cleaning, washing [46,47], and car washing [40]. In developing countries, and in regions where main water supply networks could not be designed, rainwater is a valuable source of drinking water [36].

Apart from rainwater, greywater also offers significant opportunities for saving tap water in buildings [48]. In addition, according to the idea of sustainable development, greywater recycling systems (GWRSs) reduce the burden on wastewater treatment plants and are seen as one of the fundamental elements of water source management [49]. Treated greywater is used mainly for toilet flushing and garden watering [50], and sometimes, in hybrid systems together with rainwater [51,52]. GWRSs are used in residential buildings [53], office buildings [54], schools and universities [55,56], and airports [57].

A literature review of research on RWHSs and GWRSs showed that this subject has, thus far, received limited interest in Europe. It can be seen that these systems are implemented quite rarely, and research into their performance and profitability of use has been conducted on a smaller scale than, for example, in Australia, Brazil, or Japan. The analysis of the research results published so far has shown that designing rainwater harvesting systems and greywater recycling systems is not an easy issue, because the effectiveness of these systems is influenced by many factors. The most important of these include the amount of rainfall, the type of building, and the related water demand, as well as the purchase price of water. Acceptance by society is also important. Therefore, research was carried out to determine the hydraulic and financial efficiency of alternative water systems located in eight European countries. Moreover, survey research was conducted in these countries, and its purpose was to learn about awareness and opinions among the public on the use of rainwater and wastewater as unconventional water sources. Considering that RWHSs and GWRSs are not very popular solutions in many European countries, this investigation is very important since public acceptance can be of decisive significance in the implementation of unconventional solutions in the construction industry. The financial analysis, for which the life cycle cost method was applied, reveals research results of scientific character but also practical. The research results presented in this paper may be useful to investors, designers, and decision makers, at an early stage of investment planning and developing water management strategies in urban areas. The novel contribution to the research published so far is the discovery of the hydraulic and financial aspects, as well as the social aspects of using alternative water systems and their comparison in different locations in Europe.

2. Materials and Methods

2.1. Installation Variants

In this paper, there were selected water-saving scenarios that took into account the guidelines for human health and safety and the opinions of the society expressed in surveys conducted in selected European countries (Section 3.3). This research is based on the assumption that rainwater and greywater will be used in the analyzed buildings only as non-potable water. The RWHS was designed as an alternative water source for toilet flushing, washing, and garden watering, while GWRS was intended to be used only for toilet flushing. Survey research has shown that the respondents had the greatest concerns about using greywater for washing. Taking into account the content of certain substances in wastewater and their possible negative impact on vegetation in a garden, this wastewater was also not considered for garden watering. Environmental Protection Agency's guidelines for the reuse of greywater recommend not to use treated wastewater for domestic use other than toilet flushing and subsurface irrigation. [58,59]. According to the discussion above, the following installation variants were accepted for testing:

- Variant 0—traditional solution of installations (Figure 1a);
- Variant 1—rainwater harvesting system implemented only for toilet flushing (Figure 1b);
- Variant 2—rainwater harvesting system implemented for toilet flushing and washing (Figure 1c);
- Variant 3—rainwater harvesting system implemented for toilet flushing, washing, and garden watering (Figure 1d);
- Variant 4—greywater recycling system implemented for toilet flushing (Figure 1e);
- Variant 5—rainwater harvesting system used for washing and garden watering and a greywater recycling system for toilet flushing (Figure 1f).

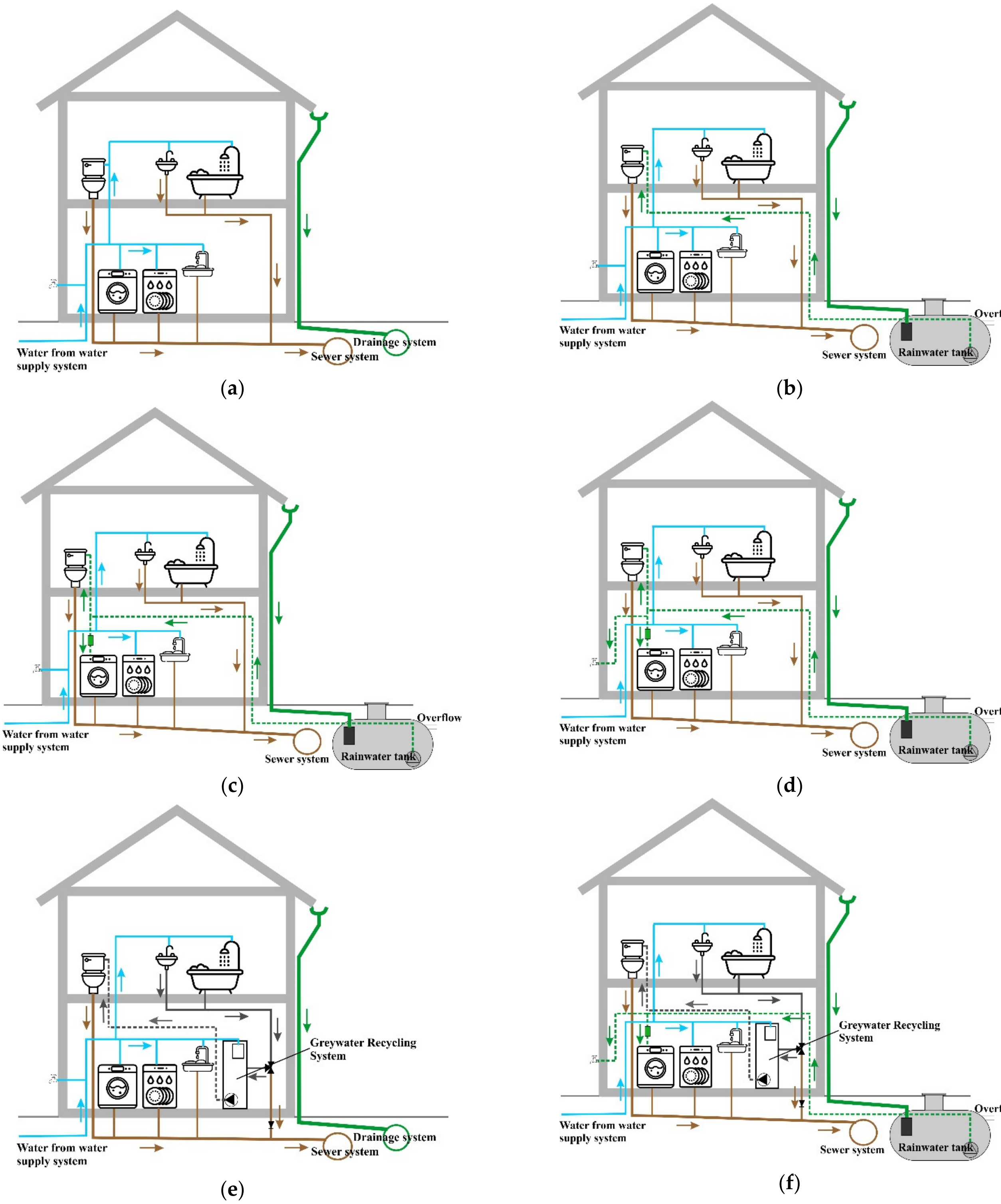

Figure 1. Diagrams of analyzed variants of installations in single-family houses. (**a**) Variant 0, (**b**) Variant 1, (**c**) Variant 2, (**d**) Variant 3, (**e**) Variant 4, (**f**) Variant 5.

2.2. Model Descriptions

For research on RWHS efficiency, the simulation model by Słyś [60] was applied. In the model, the calculation algorithm based on the YAS operating rule was used. It is the same as recommended in the standard EN 16941-1:2018 [61]. The tanks used in the analyzed rainwater harvesting systems were closed. Therefore, the simulation model ignored the evaporation of water and precipitation onto the water surface in the tank. Thus, the daily balance equation that was used in the model assumed the form (1). The quantity of runoff I_t was calculated from Equation (2).

$$V_t = V_{t-1} + I_t - O_t - Y_t \tag{1}$$

$$I_t = \psi \cdot A \cdot R_t \tag{2}$$

where ψ is runoff coefficient, and A is the roof area (m^2).

Similar to the simulation models of other researchers [62,63], the quality of rainwater was not taken into account in the used model.

Daily demand for non-potable water D was estimated in terms of the number of inhabitants, unit water consumption for particular purposes, and the area of the garden. This demand was determined from Equation (3) for Variant 1, Equation (4) for Variant 2, and Equation (5) for Variant 3.

$$D_{t1} = O_c \cdot q_t \tag{3}$$

$$D_{t2} = O_c \cdot q_t + O_c \cdot q_w \tag{4}$$

$$D_{t3} = O_c \cdot q_t + O_c \cdot q_w + G_s \cdot q_g \tag{5}$$

where O_c is the number of occupants; q_t is water consumption for toilet flushing per day (dm^3/person); q_w is water consumption in washing machines per day (dm^3/person); q_g is water consumption for garden watering per day (dm^3/m^2); G_s is garden surface (m^2).

The optimal tank capacity was adopted on the basis of the volumetric reliabilities V_r. It was assumed that the capacity of the tank would be optimal when its further increase in the calculations resulted in changes in volumetric reliability no more than 1%. V_r was determined from Equation (6).

$$V_r = \frac{\sum_{t=1}^{T} Y_t}{\sum_{t=1}^{T} D_t} \times 100 \tag{6}$$

where V_r is the volumetric reliability of RWHS (%); Y_t is the yield from storage during time interval t (m^3); D_t is the water demand during time interval t (m^3).

The efficiency of greywater recycling systems results mainly from the water demand for non-potable uses and the amount of wastewater supplied to the tank in this system. In this study, it was assumed that greywater from bathing, or bathing, and handwashing would be fed to a treatment system, and then, the treated wastewater would be transported to toilets. These systems differ in the points at which greywater is collected and used. This was due to the different unit water consumptions for particular purposes in the cities under study. The efficiency of the greywater recycling system was calculated from Equation (7) or (8).

$$Y_{G1} = O_c \cdot q_s, \tag{7}$$

$$Y_{G2} = O_c \cdot q_s + O_c \cdot q_h \tag{8}$$

where Y_{G1} is the greywater inflow to the tank for systems installed in Lisbon, Rome, Madrid, and Stockholm (dm^3/day); Y_{G2} is the greywater inflow to the tank for systems installed in Bratislava, Budapest, Prague, and Warsaw (dm^3/day); q_s is water consumption for showering or bathing per day (dm^3/person); q_h is water consumption for handwashing per day (dm^3/person).

The number of occupants O_c and water consumption for bathing q_s and washing hands q_h determine the inflow of greywater to the tank. These are usually constant amounts, which change slightly under certain conditions. Due to the fact that greywater was used only for toilet flushing, its daily requirement was determined from Equation (3).

2.3. Life Cycle Cost Analysis

The life cycle cost methodology was used to determine the financial indicators of selected variants of the installations. This methodology takes into account the initial capital costs (ICCs) as well as utility costs (UCs) and disposal costs (DCs) [64]. In this paper, the LCC analysis was performed using Equation (9). DC costs were not included in the financial analysis. Such an assumption is consistent with the guidelines [65] as well as with the research of other authors [66].

$$LCC = ICC + \sum_{t=1}^{T} (1 + r)^{-t} \cdot UC_t, \tag{9}$$

where UC_t—utility costs in a year t (EUR); T—the number of years of the system's existence; r—constant discount rate.

2.4. Survey Research

The public opinion research was conducted with the use of questionnaires, sent mainly by the Internet. This method of obtaining the samples was chosen because it is flexible and allows collecting a large amount of information. Personal surveys are expensive and very time consuming [67]. An online questionnaire was prepared in Google Form in Polish (research conducted in Poland) and English (research conducted in other seven countries) and was sent to the respondents in 2019. A similar test method was chosen, for example, by [68,69]. The questionnaire consisted of 10 questions: 4 general and 6 concerning the possibilities of saving water and rainwater and greywater systems (Figure 2). Taking into account the research subject, the statistical units for the research sample were chosen in a deliberate way. The survey results were developed in the Statistical Package for Social Sciences (SPSS). It is a common tool for statistical analysis, in medical and social research, as well as technical sciences [70]. The survey results enabled the calculation of non-measurable statistical features; therefore, the significance of differences between qualitative variables was determined using the Pearson test (chi-squared test) of independence. Its value was calculated using Equation (10). In statistical tests, the significance index was assumed to be lower than 0.05. This assumption is the same as in other publications, for example, [71].

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}, \tag{10}$$

where O_i—observed value; E_i—expected value.

2.5. Case Study

Research on the possibility of using rainwater and greywater was conducted for single-family homes located in eight European cities. These were the capitals of the following countries: Poland, The Czech Republic, Slovakia, Hungary, Spain, Italy, Sweden, and Portugal. The research focused mainly on small buildings because more than 34% of Europeans live in single-family houses. In Poland, Hungary, and Slovakia, it is over 50% [72].

2.5.1. The Data Used in RWHS Hydraulic Model

A simulation study of an RWHS model was carried out using historical daily precipitation data measured at meteorological stations located in the analyzed cities. They were 10-year precipitation data (2003–2012), whose annual sums are summarized in Table 1. It was decided to use this period for the study because the length of a precipitation series of 10 years or more leads to results similar to those for longer time series, which is confirmed by the research of other scientists [73,74].

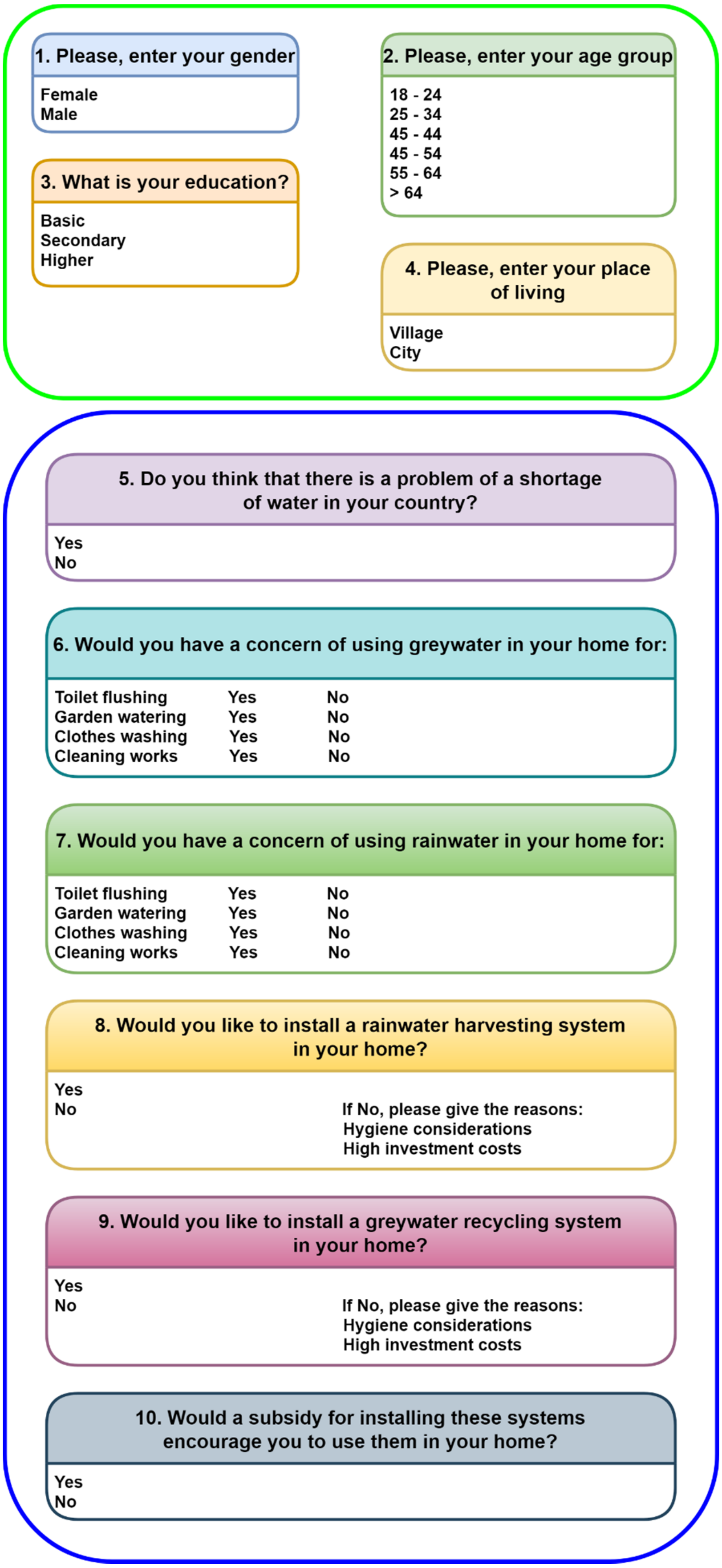

Figure 2. The questionnaire survey questions.

Table 1. Annual precipitation.

Country/City	Rainfall R (mm)										
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
The Czech Republic/Prague	309	477	486	480	487	476	646	452	524	672	501
Hungary/Budapest	838	688	711	515	295	784	831	370	614	670	631
Italy/Rome	635	679	322	673	740	894	539	656	700	1033	687
Poland/Warsaw	545	519	514	482	593	547	653	789	601	537	578
Portugal/Lisbon	850	446	853	375	672	665	1029	741	581	719	693
Slovakia/Bratislava	326	529	536	568	557	573	583	770	475	561	548
Spain/Madrid	414	466	423	359	486	290	424	314	213	271	366
Sweden/Stockholm	545	658	536	564	430	646	614	523	470	502	549

The efficiency of systems using rainwater is mainly determined by parameters such as roof area, rainfall, tank capacity, and demand for water of lower quality [75]. These parameters were included in the efficiency analysis of rainwater harvesting systems located in different cities. The research was carried out using the data shown in Table 2. The roof area in houses is usually between 100 m^2 and 200 m^2; hence, an average roof size of 150 m^2 was used in the calculations. The volumetric reliability of rainwater tanks was calculated for common tanks of sizes ranging from 1 m^3 to 21 m^3 offered by European producers. The demand for rainwater resulted from the assumed water saving scenarios.

Table 2. Data used in the RWHS simulation model.

Parameter	Value
Number of occupants ($O_{c)}$	2, 3, 4
Runoff coefficient ψ	0.9
Garden area G_a (m^2)	250
Water consumption for toilet flushing per day q_t (dm^3/person)	35
Water consumption in washing machine per day q_w (dm^3/person)	16
Water consumption for garden watering in Lisbon, Madrid, and Rome (dm^3/m^2/day)	2.5
Water consumption for garden watering in Bratislava, Warsaw, Budapest, Stockholm, and Prague (dm^3/m^2/day)	1.25

The amount of water used for watering green spaces depends on the type of soil and frequency of rainfall [76]. When analyzing these conditions and the literature data available, the unit irrigation water demand, along with the frequency and period during the year when this procedure was performed for the buildings under study [77–79], was adopted. It was assumed that in Warsaw, Prague, Bratislava, Budapest, and Stockholm, gardens would be watered for four months from June to September, whereas in Madrid, Lisbon, and Rome, watering gardens would also occur in May. Taking into account the density of buildings in the largest European cities and the availability of space for domestic gardens, the average area of green space for watering with rainwater was determined.

2.5.2. Input Data for GWRS Calculations

The optimum efficiency of greywater recycling systems should be designed considering the peak capacity treatment rate, demand for greywater, and habits of the users of the installation [80]. It is advisable that the retention time of treated wastewater is minimized by storing only the amount needed for immediate use. Keeping untreated greywater should be avoided, while treated wastewater is most often stored in a tank for one day. Taking these guidelines into account, a greywater recycling system was designed with the assumption that the performance of this system results only from the treated greywater demand, and the excess of greywater will be directed to the sewer system. Therefore, GWRSs were selected to ensure the constant performance of the system, which was established on the basis of the need for treated greywater. Table 3 contains the data used for these calculations.

Table 3. Data for GWRS efficiency calculations.

Parameter	Value
Number of occupants (O_c)	2, 3, 4
Water consumption for toilet flushing per day q_t (dm^3/person)	35
Water consumption for showering or bathing per day q_s (dm^3/person)	30 (Warsaw, Prague, Bratislava, Budapest) 42 (Stockholm, Madrid) 70 (Lisbon, Rome)
Water consumption for handwashing per day q_h (dm^3/person)	10

2.5.3. Data Used in the LCC Analysis

The financial analysis takes into account the expenditure incurred for the execution of the traditional water and sewage installation in a building (ICC_0). Additionally, options 1, 2, and 3 include the costs of RWHS, whereas option 4 indicates the costs of installing GWRS. Option 5 includes installation costs for both alternative solutions.

In all of the options of the installations under study, utility costs were calculated. These were the fees incurred each year for the purchase of tap water and the costs of discharging sanitary sewage into the network. Additionally, in cities where fees for the discharge of rainwater to the sewage system were enforced, they were included in the calculations. Unit prices were established for these services on the basis of information provided by water companies from the selected European cities. Operating costs of variants of installations with unconventional water sources also included charges for electricity consumed during pumping of rainwater and greywater from tanks to their use points. These options also took into account the costs of replacing pumps and filters, in line with the manufacturers' recommendations. The GWRS, which was used in this study, is a professional solution with advanced cleaning and disinfection methods. The cost of the rainwater harvesting systems was dependent on the tank capacity. On the basis of volumetric reliability, rainwater harvesting systems intended for small buildings and offered by European producers were selected with capacities from 1 m^3 to 11 m^3. A discount rate of 5% was adopted in the research, similarly to other researchers [81–83]. The financial analysis also takes into account the annual increase in unit prices. To account for the service life of currently used installation materials, the length of the LCC analysis was determined as T = 30 years. The data used to calculate the LCC costs are presented in Tables 4 and 5.

Table 4. Financial outlays incurred for the implementation of the analyzed variants of the installation.

The Financial Outlays of Analyzed Solutions	Value
The sanitary systems INV_0	EUR 2500
GWRS INV_{GWRS}	EUR 5500
RWHS $INV_{RWHS\_1\ m^3}$	EUR 2216
RWHS $INV_{RWHS\_2\ m^3}$	EUR 2259
RWHS $INV_{RWHS\_3\ m^3}$	EUR 2313
RWHS $INV_{RWHS\_4\ m^3}$	EUR 2421
RWHS $INV_{RWHS\_5\ m^3}$	EUR 2569
RWHS $INV_{RWHS\_7\ m^3}$	EUR 2729
RWHS $INV_{RWHS\_9\ m^3}$	EUR 3106
RWHS $INV_{RWHS\_11\ m^3}$	EUR 3647

Table 5. Unit prices and their annual growth adopted for LCC analysis.

City	The Unit Price of Tap Water and Sewage Discharge to the Network, EUR/m^3	The Annual Increase in the Water and Sewage Prices, %	The Unit Price of Electricity, EUR/kWh	The Annual Increase in Electricity Price, %	The Unit Price of the Rainwater Discharge to the Drainage System
Bratislava	2.23	2	0.15	2	-
Budapest	2.94	2	0.11		-
Lisbon	2.26	20	0.23		-
Madrid	3.16	12	0.25		-
Prague	3.49	9	0.16		-
Rome	3.50	6	0.22		0.23 EUR/m^3
Stockholm	2.30	4	0.20		38.76 EUR/year/house
Warsaw	2.31	4	0.14		-

3. Results and Discussion

3.1. *Efficiency of Systems with Rainwater*

The research carried out on the simulation model allowed us to determine the efficiency of rainwater harvesting systems located in the chosen cities in Europe. The main purpose of these analyses was to calculate the volumetric reliability for the considered tanks, which made it possible to establish the optimal tank capacity for the adopted installation variants. The results of this part of the research are shown in Figure 3.

The research results for Variant 1, in which rainwater was used for toilet flushing, showed that the highest volumetric reliability at a level of 99% was obtained in Rome (Figure 3a) for 7 m^3 tank capacity (two persons). A larger number of people causes an increase in the required tank capacity to 13 m^3 (three persons) and 15 m^3 (four persons) along with a slight decrease in volumetric reliability. A similar trend in the graphs was obtained for the RWHS located in Lisbon (Figure 3b). An increase in the tank capacity results in a sharp increase in volumetric reliability, ranging from 67% (tank volume 1 m^3) to 98% (tank volume 9 m^3) for two persons. In the case of the rainwater harvesting system installed in Madrid (Figure 3c), the highest value of V_r was 90%, with a toilet flushing requirement of 70 dm^3/day. The optimal tank capacity was 9 m^3. With a greater water demand, the efficiency of the RWHS was lower by 2% and 11%, for the optimal tanks of 13 m^3 (three persons) and 15 m^3 (four persons), respectively. A slightly lower efficiency of the rainwater harvesting system, amounting to a maximum of 84%, was observed for systems located in Prague and Budapest, which is shown in Figure 3f,h. In these two cases, the level of V_r for different rainwater demands was very similar. Only differences in optimal tank capacity for the maximum V_r values were observed. In Prague, the capacity was 5, 11, and 17 m^3 for two, three, and four persons, respectively. In turn, in Budapest, it was 3, 5, and 7 m^3. In analyzing the results of the research for RWHS located in Bratislava (Figure 3d), Warsaw (Figure 3e), and Stockholm (Figure 3g), no significant differences were observed. The maximum level of volumetric reliability for these locations was 80%. For the next two cities, Bratislava and Warsaw, the highest RWHS efficiency was obtained for a 7 m^3 tank (q_t = 70 dm^3) and for q_t = 140 dm^3/day (four persons) for a 13 m^3 tank. The maximum V_r for the RWHS located in Stockholm was observed for a 5 m^3 tank (two persons). However, in the case when the installation is used by four persons, the optimal capacity of the tank is 9 m^3.

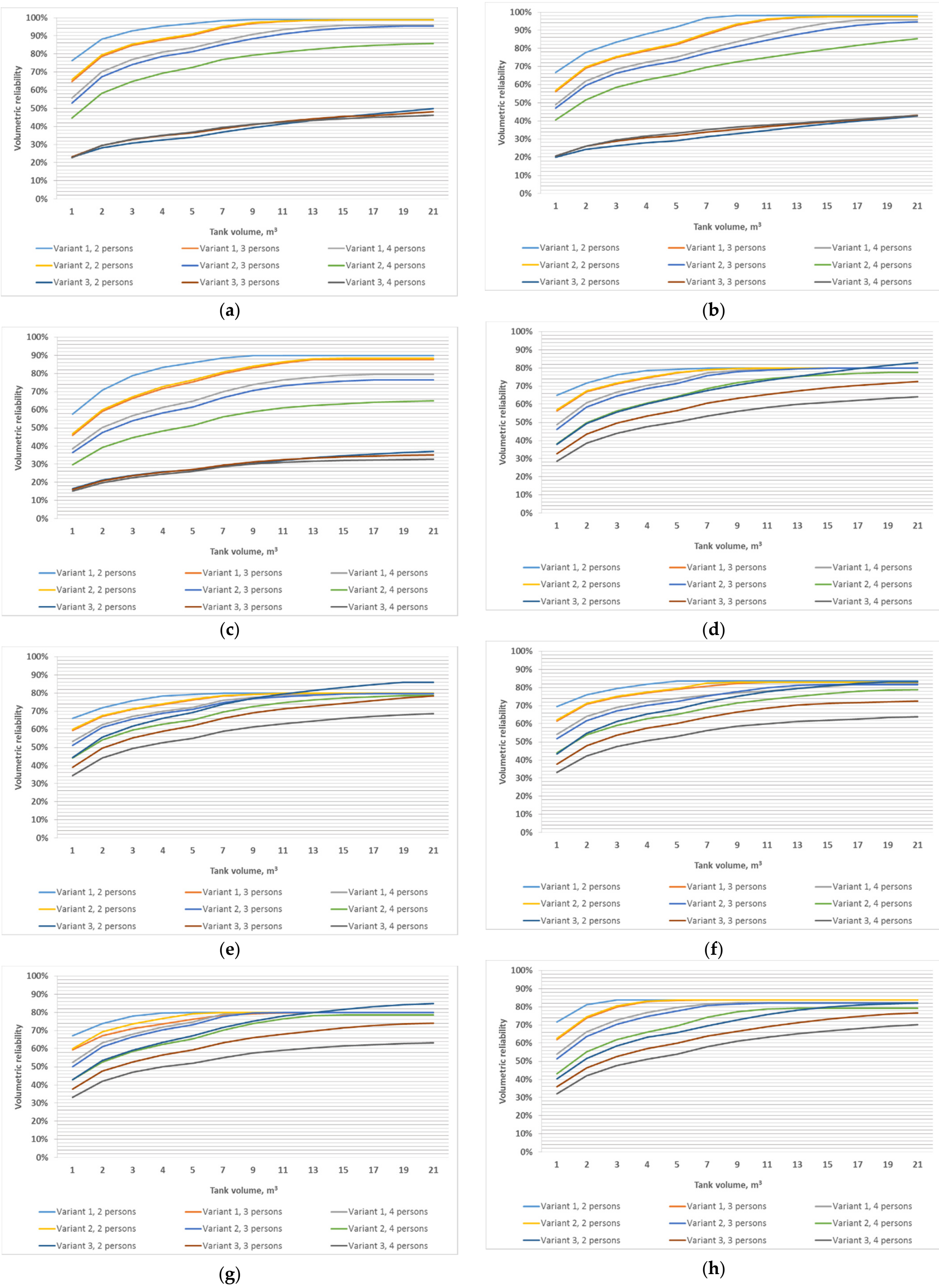

Figure 3. Efficiency of rainwater harvesting systems located in different cities in Europe: (**a**) Rome, (**b**) Lisbon, (**c**) Madrid, (**d**) Bratislava, (**e**) Warsaw, (**f**) Prague, (**g**) Stockholm, and (**h**) Budapest.

In Variant 2, rainwater for toilet flushing and washing was used. Rainwater demand was 102 dm^3, 153 dm^3, and 204 dm^3 per day, for two, three, and four persons, respectively. In the analysis of the results of the research for Rome (V_r = 99%), Lisbon (V_r = 97%), and Madrid (V_r = 88%), similar trends were observed in the graphs as for Variant 1, but the maximum V_r was obtained for larger tank capacities. Larger differences were also observed for Variant 2 in the levels of V_r between the RWHSs used for two and four persons, compared with those for Variant 1. The results of the research for rainwater harvesting systems located in Bratislava, Warsaw, and Stockholm show that the highest V_r levels in Variant 2 (80%) were similar to those obtained in Variant 1. This was especially noticeable in cases where the RWHS was used by two persons. Differences in volumetric reliability values between these two variants can be observed in the situation of using installation by three and four persons. It results from higher demand for water in Variant 2.

Variant 3 assumed the use of rainwater in the analyzed houses for toilet flushing, washing, and watering gardens. In contrast to Variant 1 (rainwater for toilet flushing) and Variant 2 (rainwater for toilet flushing and washing), in Variant 3, RWHSs located in Lisbon, Rome, and Madrid were characterized by lower levels of V_r. In Madrid, the volumetric reliability value was 37% (two persons), 35% (three persons), and 33% (four persons). Overall, for these three locations, no significant variation in V_r was observed between installations serving different numbers of users. The location of an RWHS in Lisbon or Rome would allow an efficiency level of around 45%. In this case, the effect of the number of residents on RWHS efficiency was also small. For the remaining four cities, the results of the research were similar. Where the installation was used by two persons, the maximum value of volumetric reliability for these cities ranged from 82% to 86%. An increase in the number of people to four resulted in a decrease in V_r of between 7% and 12%, depending on the location.

Taking into account the research results obtained for all the European locations under study, it was found that Variant 1 and Variant 2 were mainly influenced by the periods in a year without precipitation, which, in turn, significantly limited the supply of rainwater to the tank. Such variability of rainwater inflow is caused by different climatic conditions in the analyzed countries. The highest level of V_r was achieved for RWHS installed in Rome and Lisbon, and it was 99% and 98%, respectively. Such high efficiency of these systems is influenced by high annual rainfall and warm winters during which rainwater flows from the roof to the reservoir. Madrid had the lowest annual rainfall of all the cities considered, but nevertheless, volumetric reliability was around 90%. This level of Vr was mainly caused by the fact that rainwater flows into the tank for about 10 months a year. In the other five locations, where winters are longer and annual precipitation is at an average level, the differences in the value of volumetric reliability were not significant. In the case of Variant 3, it was found that the demand for water used for watering gardens had a decisive influence on the results. For the rainwater harvesting systems implemented in Rome, Madrid, and Lisbon, the amount of water used for this purpose accounted for between 75% and 86% of the daily rainwater requirement, depending on the number of occupants. For other cities, this proportion ranged from 61% to 75%. This effect was most noticeable for locations where, due to climatic conditions, large amounts of water are used in gardens to water plants.

3.2. Financial Efficiency of the Analyzed Variants of the Installation

The financial analysis shows that the selection of the appropriate investment variant has a decisive impact on the total costs incurred during the lifetime of the water and sewer system in the residential buildings under study. The results of the LCC calculations obtained for various installation usage conditions indicate that the profitability of using particular alternative water systems in the chosen European cities is determined by the number of occupants and the prices of tap water and wastewater discharged into the sewage system.

The highest LCC costs were obtained for the building located in Lisbon (Table 6). The research results for this location showed that Variant 0 was not profitable in any of the analyzed calculation cases. This is due to very high 30-year operating costs in this variant, which significantly exceeded the costs of options of installations with unconventional water systems, despite the fact that it is necessary to incur higher financial outlays for these installations. Regardless of the number of people, Variant 5, with 11 m^3 tank capacity, was found to be the best option. The LCC costs for this variant, depending on the number of people, were approximately EUR 21,000–43,000 lower than for the traditional variant, despite the fact that the investment costs in Variant 5 were five times higher than in Variant 0.

Table 6. Results of LCC analysis for a building located in Lisbon (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	2	3	4	5	7	9	11
2	0	**186,193**							
	1	180,552	179,202	178,510	178,071	177,721	177,235	177,462	178,003
	2	178,512	176,118	175,127	174,539	174,040	173,156	172,588	172,631
	3	177,667	175,073	173,933	173,196	172,647	171,713	171,045	170,592
	4	181,038							
	5	171,912	169,319	168,179	167,442	166,893	165,959	165,291	**164,837**
3	0	**259,379**							
	1	251,499	249,055	248,014	247,426	246,877	246,043	245,425	245,369
	2	249,161	245,722	243,886	242,899	242,251	241,217	240,600	240,195
	3	248,464	244,876	242,990	241,954	241,306	240,322	239,704	239,250
	4	247,891							
	5	236,378	232,790	230,854	229,867	229,220	228,235	227,618	**227,213**
4	0	**332,028**							
	1	322,407	319,167	317,530	316,643	316,095	315,110	314,493	314,039
	2	319,821	215,735	313,302	311,868	310,872	309,639	308,872	308,467
	3	319,224	315,038	312,556	311,072	310,076	308,893	308,125	307,771
	4	314,188							
	5	300,785	296,600	294,117	292,633	291,637	290,454	289,687	**289,332**

In the case of Madrid, Variant 0 was also not the most profitable investment, and it had the highest LCC costs for three or four persons (Table 7). When the installation served two users, the least profitable option was Variant 4, in which the alternative water source was only GWRS, and the most profitable was Variant 3, which used rainwater for toilet flushing, washing, and watering gardens. Similar to the case of Lisbon for three and four occupants, it was found that the financially optimal solution was the installation with both an RWHS and a GWRS (Variant 5). Such a hybrid system made it possible to achieve the highest water savings, which, in turn, resulted in the lowest operating costs in the 30-year analysis period. For this location, a tank volume of 9 m^3 is optimal from the financial point of view.

Variant 3, in which an RWHS was implemented for toilet flushing, washing, and watering gardens, was also found to be the option with the lowest level of LCC costs for the buildings located in Prague (Table 8) and Rome (Table 9). For both cities, the lowest LCC costs were obtained for a rainwater tank with a capacity of 7 m^3, regardless of the number of occupants. The highest value of the LCC costs for all the calculation cases for these locations was found for the variant in which the only additional source of water was greywater (Variant 4).

Table 7. Results of LCC analysis for a building located in Madrid (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	**2**	**3**	**4**	**5**	**7**	**9**	**11**
2	0	51,004							
	1	50,372	49,618	49,203	49,030	49,037	49,033	49,340	49,881
	2	49,739	48,633	48,054	47,694	47,513	47,298	47,394	47,724
	3	49,411	48,165	47,539	47,131	46,927	46,595	**46,503**	46,646
	4	**52,581**							
	5	50,366	49,120	48,517	48,109	47,906	47,573	47,482	47,601
3	0	**66,330**							
	1	65,018	63,866	63,310	62,926	62,746	62,484	62,579	62,886
	2	64,385	62,998	62,185	61,754	61,456	60,936	60,798	61,011
	3	64,151	62,694	61,857	61,355	61,034	60,444	60,282	60,471
	4	64,923							
	5	62,145	60,688	59,851	59,349	59,005	58,438	**58,276**	58,442
4	0	**81,656**							
	1	79,852	78,512	77,769	77,314	77,064	76,614	76,522	76,759
	2	79,290	77,692	76,784	76,236	75,892	75,208	75,069	75,235
	3	79,079	77,481	76,573	75,978	75,587	74,856	74,717	74,907
	4	77,255							
	5	74,079	72,481	71,574	70,978	70,564	69,833	**69,718**	69,807

Table 8. Results of LCC analysis for a building located in Prague (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	**2**	**3**	**4**	**5**	**7**	**9**	**11**
2	0	20,298							
	1	21,196	21,067	21,024	21,067	21,161	21,321	21,698	22,239
	2	20,625	20,302	20,205	20,216	20,278	20,319	20,686	21,227
	3	19,591	18,707	18,244	18,008	17,929	**17,766**	17,895	18,232
	4	**25,120**							
	5	23,813	22,929	22,466	22,230	22,151	21,988	22,117	22,454
3	0	27,145							
	1	27,428	27,083	26,976	26,987	27,049	27,079	27,435	27,976
	2	26,846	26,286	26,017	25,953	25,971	25,937	26,174	26,597
	3	25,995	24,929	24,369	24,132	24,032	**23,837**	23,955	24,313
	4	**30,595**							
	5	28,846	27,769	27,209	26,983	26,883	26,687	26,806	27,164
4	0	33,989							
	1	33,831	33,324	33,098	33,045	33,085	33,073	33,320	32,807
	2	33,324	32,538	32,172	31,978	31,921	31,823	31,963	32,342
	3	32,646	31,536	30,954	30,696	30,564	**30,347**	30,498	30,899
	4	**36,063**							
	5	34,121	33,011	32,429	32,171	32,050	31,833	31,973	32,374

Table 9. Results of LCC analysis for a building located in Rome (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	2	3	4	5	7	9	11
2	0	32,336							
	1	32,695	32,431	32,366	32,415	32,523	32,644	33,011	33,552
	2	32,190	31,728	31,564	31,563	31,612	31,624	31,922	32,433
	3	32,012	31,451	31,208	31,118	31,097	30,950	31,060	31,373
	4	37,380							
	5	36,457	35,896	35,653	35,563	35,543	35,406	35,505	35,819
3	0	43,218							
	1	43,042	42,560	42,377	42,376	42,425	42,426	42,714	43,216
	2	42,577	41,818	41,505	41,356	41,355	41,307	41,506	41,899
	3	42,438	41,630	41,278	41,098	41,048	40,892	40,991	41,324
	4	47,002							
	5	45,623	44,814	44,472	44,283	44,233	44,076	44,186	44,509
4	0	54,099							
	1	53,566	52,866	52,584	52,484	52,513	52,475	52,684	53,086
	2	53,091	52,124	51,693	51,474	51,384	51,227	51,426	51,838
	3	52,972	51,975	51,524	51,286	51,186	50,970	51,109	51,472
	4	56,618							
	5	54,892	53,896	53,445	53,206	53,107	52,890	53,030	53,392

Similar research results were obtained for the systems located in Bratislava (Table 10), Budapest (Table 11), Warsaw (Table 12), and Stockholm (Table 13). For these cities, the solution with the lowest LCC level was always Variant 0, with conventional installations. The number of users of the system had no significant impact on the results or the profitability hierarchy of particular variants. The largest differences in the amount of LCC costs were found in a comparison of Variant 0 with Variants 4 and 5, in which a greywater reuse system was implemented. This was due to the high capital expenditure that must be incurred when applying this system. In the case of these locations, the implementation of unconventional water sources in single-family houses was found to be entirely unprofitable since the water savings obtained over the period of 30 years did not cover the capital expenditure and operating costs related to the replacement of filters and pumps in the RWHS and GWRS. Comparing the two systems, it can be inferred that much more favorable financial parameters were obtained for variants with RWHS. The difference in the amount of LCC costs between Variant 3 and Variant 4 was over 50%.

The results of the financial analysis for all the cities under study show that the implementation of alternative water sources in houses is profitable only for locations where the unit prices of tap and wastewater are high (Madrid, Prague, and Rome) or significantly increasing annually (Lisbon, Portugal). The situation was different for other cities, where the use of alternative water sources was unprofitable because, in these locations, unit prices and their annual increase were lower, resulting in lower annual operating costs.

3.3. Public Opinion in Selected European Countries

In total, 485 respondents participated in the survey. Table 14 presents demographic data concerning the studied group of respondents. The percentage of the Poles and the Czechs in the research group was the highest and amounted to 14% and 13.4%, respectively. The fewest respondents came from Portugal (11%) and Hungary (11%). Men made up a slightly larger proportion of the research group (51%) in most of the countries. No statistically significant differences between countries were observed (χ^2 = 1.74, p = 0.973). People aged up to 35 years old constituted the largest age group (41%). People between 35 and 45 years old constituted 37% of the respondents, and over 45 years old, 22%. Similar distributions were observed among respondents in Italy, Poland, and Portugal. On the other hand, the largest group of respondents in Slovakia, Hungary, and Spain were in the range of 35–45 years. In the Czech Republic, the numbers of people aged up to 35 and between 35 and 45 years were similar. The statistical analysis did not show any significant differences in terms of age between the analyzed countries (χ^2 = 9.82, p = 0.776). The majority of respondents, both in terms of the total number of respondents and in the breakdown by country, had higher education (χ^2 = 3.87, p = 0.793). In terms of place of residence, the majority of the respondents were people living in cities, and this was the case both for the total number of respondents and for particular countries. The chi-squared test also did not show any statistically significant differences (χ^2 = 6.34, p = 0.500). Considering the above, it can be concluded that the groups in the analyzed countries were very similar to each other, in terms of age, sex, place of residence, and education. The next questions in the survey allowed us to learn about the respondents' level of knowledge regarding the possibilities of protecting water resources by implementing alternative water systems in buildings. To the question "Do you think that there is a problem of a shortage of drinking water in your country?", more than half of the respondents answered yes. Figure 4 shows these results broken down by country. The respondents from Portugal (76%) and Spain (76%) most often answered affirmatively, while the Swedish and the Slovaks indicated this least frequently. The differences in the answers are statistically significant (χ^2 = 63.40, p < 0.001).

Table 10. Results of LCC analysis for a building located in Bratislava (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	**2**	**3**	**4**	**5**	**7**	**9**	**11**
2	0				**6836**				
	1	9283	9288	9318	9414	9557	9713	10089	10415
	2	9181	9140	9156	9238	9364	9513	9882	10197
	3	8986	8818	8752	8781	8876	8974	9301	9606
	4				13,847				
	5	15,398	15,230	15,164	15,193	15,285	15,385	15,711	**16,210**
3	0				**8604**				
	1	10,940	10,894	10,910	10,989	11,115	11,262	11,632	12,171
	2	10,846	10,739	10,715	10,774	10,889	10,996	11,344	11,876
	3	10,707	10,517	10,435	10,457	10,547	10,634	10,958	11,459
	4				15,333				
	5	16,836	16,644	16,565	16,587	16,677	16,764	17,090	**17,589**
4	0				**10,372**				
	1	12,634	12,542	12,529	12,593	12,710	12,825	13,187	13,719
	2	12,556	12,409	12,354	12,389	12,479	12,566	12,892	13,393
	3	12,448	12,240	12,150	12,160	12,251	12,337	12,659	13,153
	4				16,817				
	5	18,217	17,960	17,837	17,820	17,880	17,922	18,224	**18,703**

Table 11. Results of LCC analysis for a building located in Budapest (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	**2**	**3**	**4**	**5**	**7**	**9**	**11**
2	0	**7462**							
	1	9803	9781	9820	9928	10,076	10,236	10,613	11,154
	2	9674	9603	9597	9679	9822	9982	10,359	10,900
	3	9441	9246	9147	9162	9258	9341	9645	10,116
	4	**14,378**							
	5	13,542	13,304	13,152	13,059	13,007	12,929	12,852	12,787
3	0	**9475**							
	1	11,677	11,601	11,595	11,675	11,815	11,975	12,352	12,893
	2	11,550	11,412	11,370	11,416	11,520	11,636	12,003	12,536
	3	11,372	11,146	11,037	11,039	11,111	11,173	11,478	11,951
	4	**16,062**							
	5	15,144	14,875	14,712	14,606	14,531	14,432	14,360	14,293
4	0	**11,488**							
	1	13,592	13,469	13,438	13,492	13,603	13,737	14,107	14,648
	2	13,475	13,280	13,208	13,238	13,319	13,386	13,706	14,221
	3	13,330	13,079	12,957	12,956	13,026	13,060	13,343	13,817
	4	**17,745**							
	5	16,772	16,477	16,301	16,193	16,113	15,988	15,895	15,828

Table 12. Results of LCC analysis for a building located in Warsaw (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	**2**	**3**	**4**	**5**	**7**	**9**	**11**
2	0	**7779**							
	1	10,197	10,203	10,233	10,327	10,470	10,625	11,002	11,543
	2	10,067	10,044	10,065	10,147	10,274	10,415	10,787	11,324
	3	9753	9562	9494	9519	9603	9685	9996	10,483
	4	14,753							
	5	16,129	15,938	15,869	15,894	15,979	16,061	16,372	**16,861**
3	0	**9967**							
	1	12,246	12,218	12,237	12,319	12,446	12,587	12,957	13,493
	2	12,109	12,022	12,015	12,080	12,200	12,313	12,659	13,186
	3	11,878	11,654	11,573	11,594	11,676	11,744	12,057	12,553
	4	16,641							
	5	17,953	17,729	17,648	17,669	17,751	17,818	18,129	**18,628**
4	0	**12,156**							
	1	14,331	14,258	14,258	14,330	14,452	14,567	14,925	15,452
	2	14,196	14,064	14,021	14,075	14,176	14,263	14,585	15,088
	3	14,021	13,785	13,691	13,709	13,788	13,856	14,172	14,673
	4	18,528							
	5	19,794	19,559	19,464	19,482	19,562	19,629	19,945	**20,446**

Table 13. Results of LCC analysis for a building located in Stockholm (green color—the lowest value of LCC, red color—the highest value of LCC).

Persons	Variant	Life Cycle Cost LCC, EUR							
		Tank Volume (m^3)							
		1	2	3	4	5	7	9	11
2	0	**10,406**							
	1	11,942	11,945	11,973	12,069	12,217	12,377	12,754	13,295
	2	11,819	11,782	11,798	11,878	12,002	12,157	12,534	13,075
	3	11,533	11,366	11,307	11,341	11,433	11,531	11,856	12,350
	4	17,380							
	5	17,909	17,741	17,682	17,717	17,808	17,907	18,232	**18,723**
3	0	**13,470**							
	1	14,873	14,845	14,864	14,948	15,073	15,214	15,584	16,120
	2	14,750	14,649	14,630	14,688	14,799	14,897	15,251	15,792
	3	14,535	14,342	14,280	14,308	14,402	14,484	14,811	15,307
	4	20,143							
	5	20,610	20,417	20,353	20,383	20,477	20,561	20,886	**21,382**
4	0	**16,533**							
	1	17,842	17,753	17,701	17,809	17,926	18,034	18,402	18,943
	2	17,719	17,590	17,542	17,582	17,678	17,753	18,064	17,560
	3	17,559	17,354	17,283	17,315	17,411	17,500	17,823	18,324
	4	22,905							
	5	23,332	23,129	23,056	23,088	23,184	23,273	23,596	**24,097**

Table 14. General information about the surveyed groups of respondents.

Country	Number of Respondents									
	Total	Gender		Age			Education		Place of Living	
		Female	Male	<35 Yrs Old	35–45 Yrs Old	≥45 Yrs Old	Secondary	Higher	Village	City
The Czech Republic	65	33	32	25	25	14	19	44	30	35
Spain	60	29	31	20	27	13	16	44	21	39
Poland	70	34	36	33	27	10	19	51	27	43
Portugal	55	27	28	23	18	14	14	41	23	32
Slovakia	70	34	36	27	24	18	15	55	19	51
Sweden	50	22	28	19	20	11	8	42	17	33
Hungary	55	25	30	22	23	10	14	41	22	33
Italy	60	33	27	27	16	17	16	44	22	38

Other main questions of the survey are as follows: The respondents were asked if they had concerns about using these sources, and if so, for what purposes (clothes washing, toilet flushing, watering gardens, and household cleaning). The next two questions were related to the willingness to use the rainwater harvesting system and greywater recycling system in their homes. If the respondents did not want to use such systems, they could indicate the reasons for this: high investment costs and hygiene considerations. Multiple-choice responses were possible in answers to these questions.

The analysis of the total number of respondents (Figure 5) showed that over 60% were afraid of using greywater in their homes (60%). The highest levels of concern were found among people in Hungary, Slovakia, and the Czech Republic, while those in Italy, Portugal, and Spain showed the lowest levels of concern. The Pearson test showed that the differences were statistically significant ($\chi^2 = 48.63$, $p < 0.001$). The respondents indicated the highest levels of concern regarding the use of greywater for washing (55%) and household cleaning (38%) and the lowest for watering gardens (24%) and toilet flushing (20%). These answers are presented in detail in Figure 6.

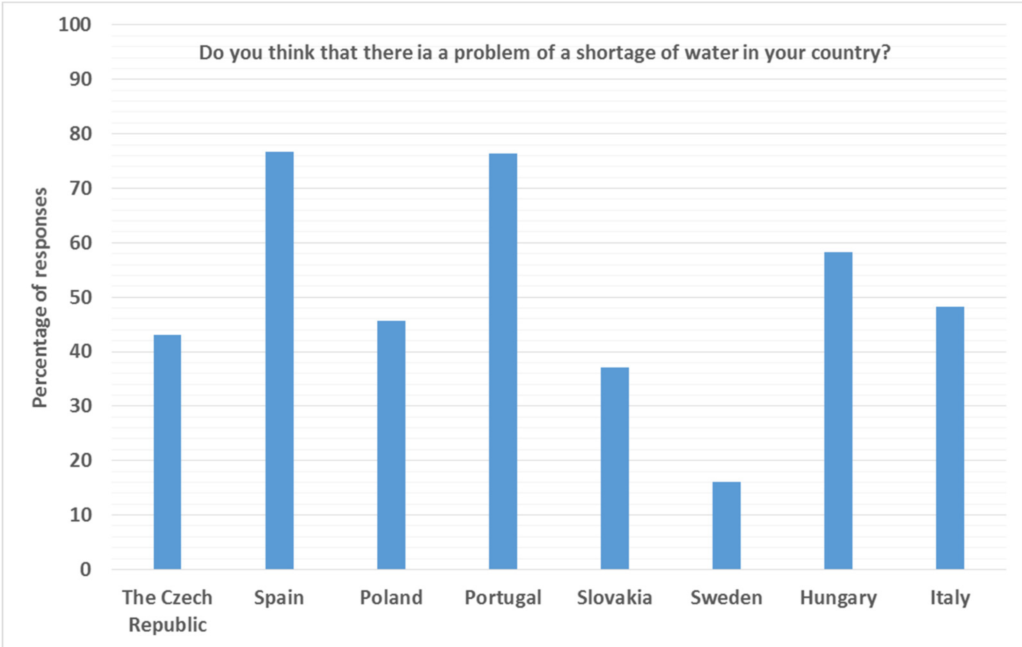

Figure 4. Affirmative answers to the question about the problem of water deficits in the respondent's country.

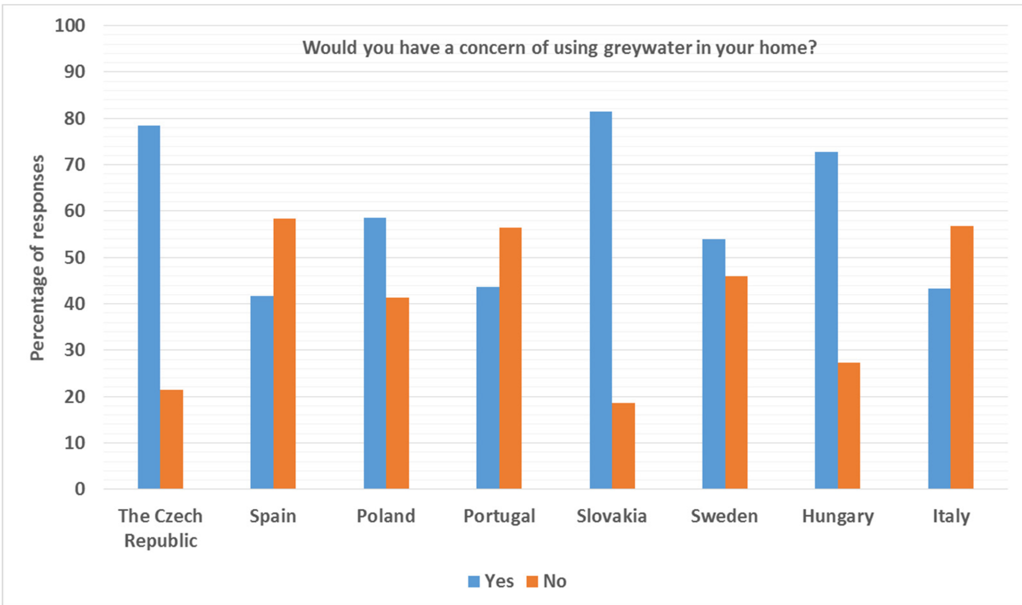

Figure 5. Answers to the question about concerns of using greywater in respondent's house.

The answers to the question about willingness to use a GWRS in respondents' houses showed that 47% of them expressed such willingness. This was indicated most frequently by the Spaniards (55%), the Italians (65%), and the Poles (56%). The Swedes (38%) and the Hungarians (27%) indicated it least frequently. The differences are statistically significant ($\chi^2 = 24.19$, $p = 0.001$). Hygiene considerations were the main reason for the lack of interest in the implementation of GWRS, as indicated by 2/5 of the respondents. Chi-square analysis showed differences between respondents from particular countries in the frequency at which they indicated hygiene reasons. They were most often given by persons from Hungary (60%), Sweden (52%), Slovakia (49%), and The Czech Republic (42%), and least by the Portuguese (29%), the Spaniards (27%), and the Italians (28%).

The research results showed also that 58% of all respondents had no concerns to use rainwater in their houses. Participants from Hungary, The Czech Republic, and Slovakia had the greatest concerns, with 44%, 57%, and 63% of respondents, respectively. The analysis with the chi-squared test showed that the differences are statistically significant ($\chi^2 = 26.81$, $p < 0.001$). Figure 7 illustrates this in detail. The highest levels of concern (Figure 8) were indicated by the respondents in the use of rainwater for washing (40%) and household cleaning (21%), while less frequently for toilet flushing (14%).

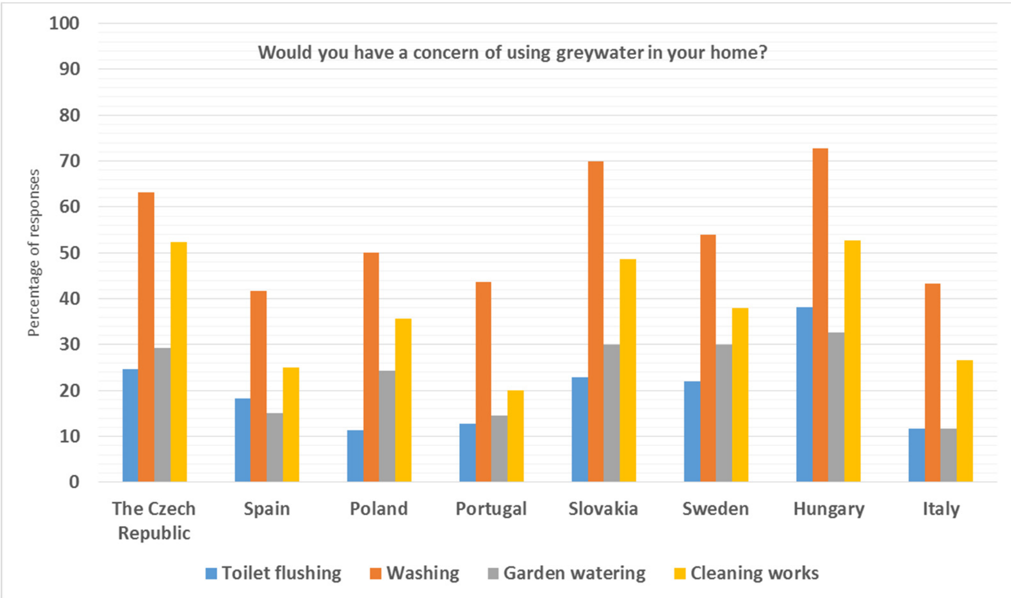

Figure 6. Affirmative answers indicating the respondents' concerns regarding the use of greywater in homes, broken down by particular purposes.

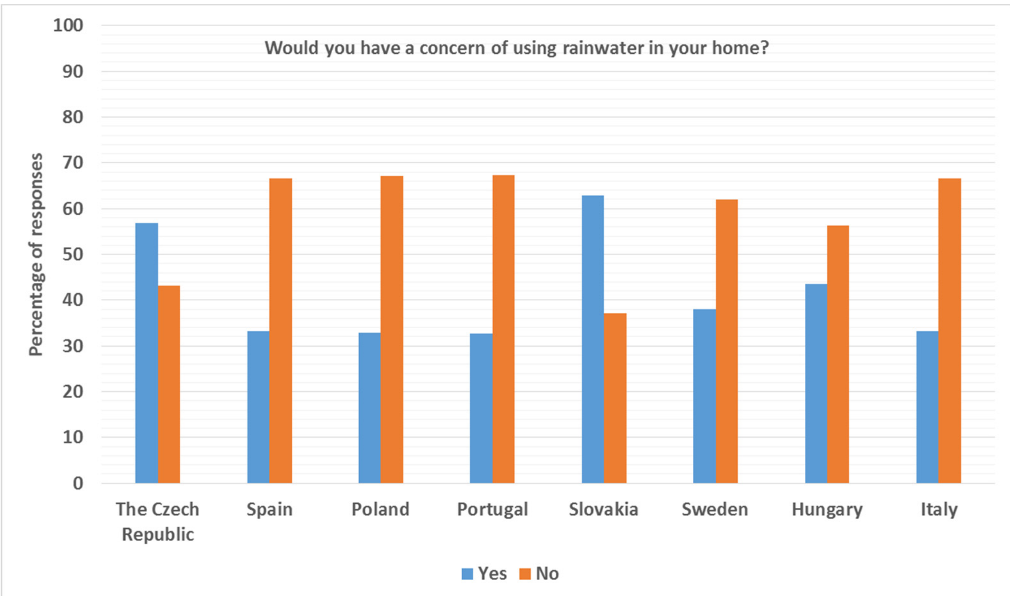

Figure 7. Answers to the question about concerns of using rainwater in respondent's house.

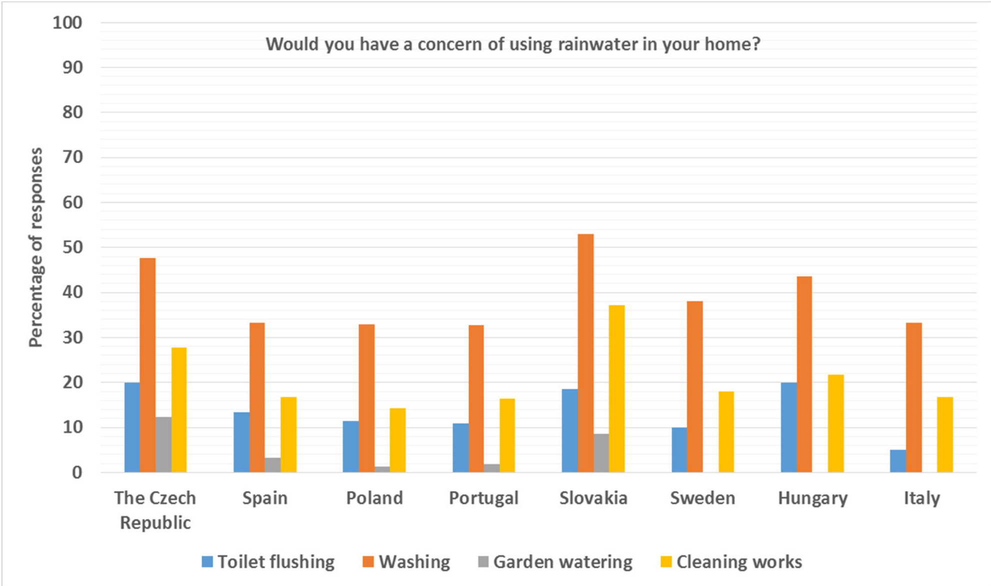

Figure 8. Affirmative answers indicating the respondents' concerns regarding the use of rainwater in homes, broken down by particular purposes.

For the next question, the respondents were asked to express their opinions on their willingness to install a system with rainwater (RWHS) in their homes. It was shown that 67% of respondents would use such a solution. This was most frequently indicated by the Poles and least often by the Hungarians (56%). There were no statistically significant differences in the responses of respondents from different countries ($\chi^2 = 13.40$, $p = 0.063$). Among the total number of respondents who did not want to use RWHS, the same percentages indicated reasons for increased capital expenditure and hygiene considerations.

The final question of the survey was "Would a subsidy for installing these systems encourage you to use them in your home?" Over three-quarters of the respondents said "yes". The chi-squared test showed that the differences are statistically insignificant.

4. Conclusions

For many years, human activity has resulted in overexploitation of natural resources, including water resources. As a result, there are problems with access to water in many regions of the world, both in terms of quantity and quality. Unfortunately, this affects the standard of living of many people and, in extreme cases, results in their death. Increasingly frequent water shortages, caused not by excessive exploitation alone, but also by growing demand, climate change, and intensification of urbanization, also limit economic development. This problem is observed by both scientists and politicians. As a result, water strategies have been implemented in many regions, and their purpose is sustainable management of the available water resources.

Therefore, this study was carried out to determine the cost effectiveness of rainwater harvesting systems and greywater recycling systems in single-family houses located in eight different European countries. In this research, the life cycle cost methodology was used, which allowed establishing the whole costs of six installation variants incurred over a long period of time. In addition, in these countries, questionnaire surveys were also conducted to learn about public opinion regarding the implementation of unconventional water systems.

The results of the financial analysis showed that the LCC methodology was an appropriate tool to evaluate and compare different investment options, and also to support the decision-making process. The obtained financial indicators for each installation variant made it possible to choose the optimal solution that could bring benefits in the long term. The research also confirmed that the adoption of a solution based only on initial investment expenditures may lead to the wrong decisions because, in many cases, these expenditures constitute an insignificant part of the costs resulting from the operation of the facility for several decades. Moreover, it was observed that the amount of LCC costs of the analyzed installation variants, and thus, the selection of the optimal variant was largely influenced by technical parameters and climatic conditions, as well as the prices of tap water and wastewater discharged to the sewer system. It should also be noted that, when comparing the variants of installations with greywater recycling system and rainwater harvesting system, the second performs much better because the capital expenditures for its implementation are much lower than those required for the execution of an installation with recycled greywater.

Survey results have shown that residents of regions where water resources are lower and water shortages appear are more positively inclined toward the implementation of unconventional water systems in buildings. Their greater awareness of the possibilities of saving water and favor of alternative solutions may result from information campaigns conducted in these countries in recent years and law regulations promoting these systems, and sometimes, requiring the use of such solutions. In most of the cases studied, the use of both rainwater and greywater for washing raised the highest levels of concern among the respondents. This was due to hygiene reasons. Overall, it can be concluded that rainwater is more acceptable to society as an alternative water source than greywater.

As this research revealed, for many respondents, apart from hygiene reasons, increased capital expenditures also constitute barriers to implementing these systems. The vast majority (75%) of all respondents indicated co-financing as a good incentive for them to implement these systems in their homes.

This research and, above all, its results are scientific and practical. Despite the fact that they were about case studies, they can be a valuable guide for investors, designers, and leaders who develop water and wastewater strategies. Co-financing could also provide an additional incentive to use unconventional water systems, especially in situations when their implementation is currently not profitable. These solutions would become more common if societies, through appropriate campaigns, were informed about the environmental and financial benefits that can be obtained from the use of rainwater and greywater.

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