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# ANALYSIS OF THE COST OF LEAKS FROM THE WATER SUPPLY SYSTEM, INCLUDING METHODS TO REDUCE WATER CONSUMPTION

## Abstract

The article presents an economic analysis of water leaks from the water suply system on the example of a single-family house, taking into account methods aimed at preventing uncontrolled water losses, including also water consumption reducing methods. The analysis was conducted for selected variants in the economic aspect. The research included measurements of water consumption on the main water meter and specially prepared containers for measuring water leaks. Simple leaks that are not easily visible can generate over 1700 PLN additional costs per year for the household budget. The results of the analyses carried out make it possible to assess which variant of the analysis is the most favourable in economic terms, making it possible to reduce water consumption by up to 60% of the standard consumption. The payback time for the analyzed variants varies from 5 to about 310 days.

**Keywords:** water, sewage, water saving, water leakage, LEED, BREEAM, solenoid valve, water pressure reducer, water batteries, water fittings, economy, ecology

## ANALIZA KOSZTÓW WYCIEKÓW Z INSTALACJI WODOCIĄGOWEJ WRAZ Z METODAMI OGRANICZENIA ZUŻYCIA WODY

## Abstrakt

W artykule przedstawiono analizę ekonomiczną wycieków wody z sieci wodociągowej na przykładzie domu jednorodzinnego, z uwzględnieniem metod mających na celu zapobieganie niekontrolowanym stratom wody, w tym również metod ograniczających zużycie wody. Analizę przeprowadzono dla wybranych wariantów w aspekcie ekonomicznym. Badania obejmowały pomiary

zużycia wody na wodomierzu głównym oraz specjalnie przygotowane pojemniki do pomiaru wycieków wody. Proste wycieki, które nie są łatwo widoczne, mogą narazić budżet domowy na dodatkowe koszty w wysokości ponad 1700 zł rocznie. Wyniki przeprowadzonych analiz pozwalają ocenić, który wariant jest najkorzystniejszy pod względem ekonomicznym, umożliwiając zmniejszenie zużycia wody nawet o 60% zużycia standardowego. Czas zwrotu nakładów dla analizowanych wariantów waha się od 5 do około 310 dni.

**Słowa kluczowe:** woda, ścieki, oszczędność wody, wyciek wody, LEED, BREEAM, elektrozawór, reduktor ciśnienia wody, baterie wodne, armatura wodna, ekonomia, ekologia

# 1. Introduction

Water is a valuable resource. According to a report [1,2] of the World Health Organization (WHO) and UNICEF, 1 in 3 people (i.e. 2.1 billion people) have no access to drinking water at home, and 6 in 10 (i.e. 4.4 billion people) are deprived of appropriate sanitary conditions.

Scarcity as well as the high processing and distribution costs are constantly increasing the water and sewage bills. In developed countries, the average water consumption per capita has increased almost 10-fold in the last 100 years and more than 2-fold in the last 30 years[3].

In public utility buildings, the average water consumption is around 50% higher than that measured in residential buildings, approx. 200 litres per day and per person. In special buildings such as a hospital, water consumption can exceed 500 liters per day and per person [3].

A user who is not directly charged for water tends to behave differently than when at home. Breakdowns or leaks are less frequently reported and repaired in public utility buildings than in residential houses, although leakage problems are ignored here as well. Support in optimizing the amount of water flow is the use of in design process LEED or BREEAM certification [4, 5].

The aim of this article is to present the problem and the scale of water leakage from the system and to present the associated costs. In the first part of the article, the amount of water leaking from the water supply system in a single-family building was measured. This part also identifies potential sources of water leaks. The second part focuses on methods of preventing water leakage and ways to reduce water consumption, starting from the simplest to the more complex solutions. In the third and last part of the article, an economic analysis of the proposed solutions was carried out, along with the determination of the time of the expected return on investment.

## 2. Materials and methods

### 2.1. Analysis of water consumption (leakage) in a single-family building

The average rate for a cubic meter of cold water in Poland is 4.40 PLN [6]. Closely related to the consumption of water are costs of sewage disposal. In Poland, the average cost of sewage disposal is 6.60 PLN per cubic meter, which gives a total cost of 11 PLN per cubic meter of water.

The analysed single-family house is used as a weekend house. It is not used from Monday to Friday. The water supply was not shut off for leak analysis (1 toilet and 1 leaking tap). Water consumption results were measured over the next five weeks on Sunday afternoons and Saturday mornings. The measurement results based on the water meter readings (water consumption) are presented in Fig. 1. On the basis of the obtained measurements, the average result was 2.15 m³/5 days, which is 0.43 m³/day when converted into a 24-hour period. The results summarized on Fig. 1 are reduced by the amount of water leaking from the wash basin faucet.

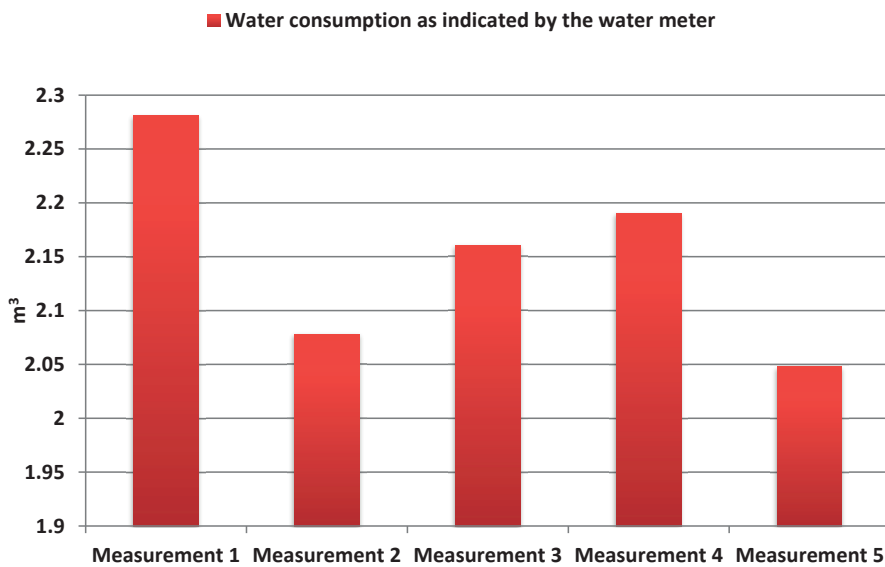**■ Water consumption as indicated by the water meter**



Fig. 1 Summary of the amount of water leaking from the toilet according to the water meter indications on a weekly basis

Source: own study

The volume of water leaking from the tap was measured using a graduated vessel. The results are presented in the Table 1.

Table 1. An overview of the amount of water leaking from the washbasin faucet

| Amount of water leaking from the washbasin faucet [dm³] | |
|---|---|
| Measurement 1 | 5.1 |
| Measurement 2 | 6.05 |
| Measurement 3 | 6 |
| Measurement 4 | 7 |
| Measurement 5 | 8.1 |

Source: own study

Another potential source of water leakage in the domestic system may be the safety valve at the hot water tank. The safety valve is an element that secures the tank when the water temperature increases, and volume of water. The expansion vessel compensates for these changes occurring in the domestic hot water tank at the time when water is being heated. In domestic hot water systems, the expansion vessel at the hot water tank is often omitted [7]. The correct diagram of the water tank connection is presented on Fig. 2.



1 - water supply installation
2 - cut-off valve
3 - check valve
4 - expansion vessel - water installation
5 - safety valve for water installation
6 - drain to the sewage system
7 - water tank
8 - domestic hot water installation
9 - installation of water circulation
10 - return from the coil pipe
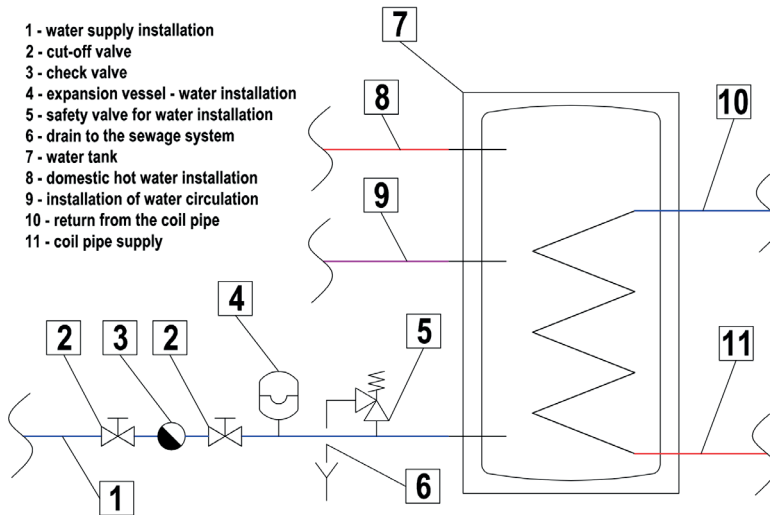11 - coil pipe supply

Fig. 2. Connection diagram of the hot water tank on the water connection side with a safety valve and an expansion vessel

Source: own study

As a result of heating, water increases in volume with rising temperature. As the hot water system is a closed one, the increase in water volume arising from thermal expansion leads to an increase in pressure in the system [7]. If we assume that in

the first phase, with rising pressure, the tank is not deformable, then the increase in pressure occurring the tank can be calculated from the formula (1) and (2):

$$\Delta p = -\frac{V_1 - V_2}{\xi \cdot V_1} \tag{1}$$

$$V_2 = V_1 + V_1 \cdot \beta \cdot \Delta T \tag{2}$$

where:
$V_1$ – initial water volume [m³]
$V_2$ – water volume after heating [m³]
$\beta$ – thermal expansion coefficient of water [K⁻¹]
$\xi$ – water compressibility coefficient [m²/N]
$\Delta T$ – temperature difference between initial and heated water [K]

The amount of leakage depends on the temperature of water in the tank. In the case of a natural gas heat source, this temperature fluctuates around 60°C, while in the case of a solid fuel such as coal, this temperature can even reach 80°C in the case of excess heat.

In many cases, it is the lack of an expansion vessel, its installation in the wrong place or failure to adjust its parameters after installation in the system that causes the "dripping" effect of the safety valve.



Fig. 3. Water leakage through the hot water tank safety valve
(system without expansion vessel)
Source: own study

The permissible tolerance for the safety valves is + 10% and -20%. This means that the valve with a set pressure of 6 bar will open fully at 6.6 bar and will close at the latest when the system pressure has dropped to 4.8 bar. Therefore, to ensure proper operation of the system, the maximum pressure in this installation must be at least 20% lower than the set pressure of the safety valve, which is intended to to prevent the open valve from not closing completely and causing water leakage from the installation through the safety valve.

For 5 consecutive weekends, when the water in the tank was heated, the volume of water leaking from the safety valve was controlled with the help of a prepared water tank. The results are presented Table. 2.

Table 2. An overview of the amount of water leaking through the safety valve

| Amount of water leaking through the safety valve [dm³] | |
|---|---|
| Measurement 1 | 4.5 |
| Measurement 2 | 4 |
| Measurement 3 | 4.05 |
| Measurement 4 | 5.5 |
| Measurement 5 | 6 |

Source: own study

During two days of water heating, an average of 4.8 dm³ of water leaked through the safety valve for 2 days, which comes up to 2.4 dm³/day.

On average, 2.15 cubic meters of water per week are wasted by leaks in the building under analysis. In annual terms, this is a loss of 157 m³/year, which leads to approximately 1728 PLN of additional annual costs in water and sewage bills. Leakage problems in residential and public buildings are ignored and often unnoticed - an invisible stream of water in the toilet or an occasional drop from a tap. The most common cause of toilet leakage is scale build-up (Fig. 4 and Fig. 5), and in the case of the faucet, a worn rubber seal (Fig. 6 and Fig. 7).

One of the indirect consequences of leaks is the drop of water pressure in the system. In order to maintain the correct pressure, on a larger scale, pumps need to be run to raise the pressure to the correct level, but this involves additional electricity consumption to drive the pressure-raising pumps [8, 9].

Fig. 4. Water tank with the mechanism covered with limescale
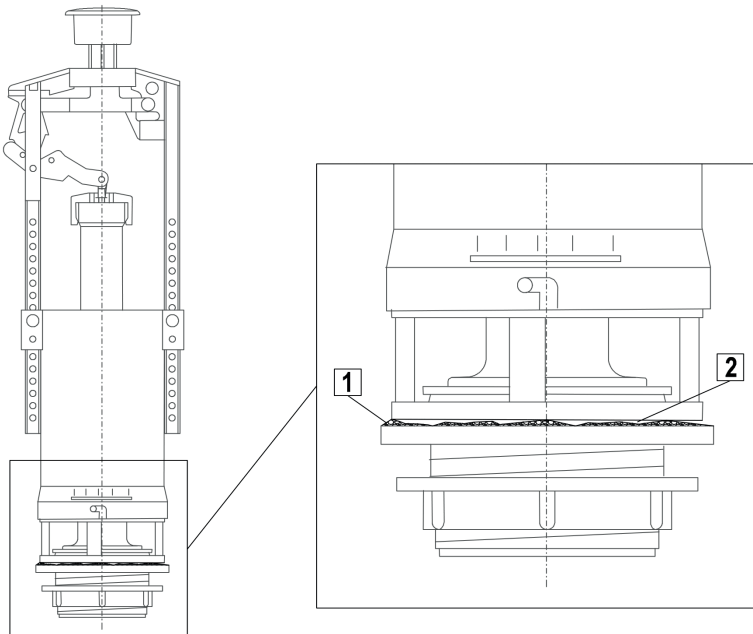
Source: own study



Fig. 5. Toilet drain valve covered with limescale. 1 - a layer of limescale, 2 – leaks

Source: own study

Fig. 6. Damaged rubber seal on a wash basin faucet, causing water leaks
Source: own study



Fig. 7. Water leakage from the sink faucet due to damaged rubber seal
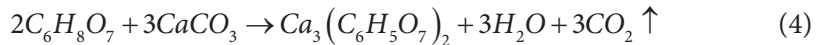Source: own study

## 2.2. Methods of preventing water leaks along with with solutions limiting water consumption

There are many ways of reducing water consumption and preventing leakage [10–15], and water consumption figures were recorded between June and August of that year. In Study 1 (n = 264, from the simplest one, i.e., constant maintenance of existing water facilities, through education, to more complex active systems.

One of the simplest methods is regular maintenance, which includes replacing a damaged drain valve, or by using simple chemical products (for example, acetic acid or citric acid, which are readily available and sufficient for home conditions), where the reaction produces neutral salt, water and carbon dioxide. Examples of chemical reactions are marked as (3) and (4).

$$2CH_3COOH + CaCO_3 \rightarrow \left(CH_3COO\right)_2 Ca + H_2O + CO_2 \uparrow \qquad (3)$$

$$2C_6H_8O_7 + 3CaCO_3 \rightarrow Ca_3\left(C_6H_5O_7\right)_2 + 3H_2O + 3CO_2 \uparrow \qquad (4)$$

The BREEAM or LEED certification system [4, 16–21] is a process that contributes to reducing water consumption (in buildings with a greater number of water receivers, but not only). One of the criteria for assessing these systems is to reduce water consumption thanks to the use of water-saving fixtures and household appliances of the appropriate class. In modern construction engineering, such solutions have already become a standard option in many buildings. An additional element that allows limiting the water outflow is the use of a leak detection system. In most cases they are implemented as an appropriate algorithm in the building management system (BMS) and are activated when the water flow through the meter exceeds the programmed maximum level at the given time. Importantly – they are programmed in accordance with the water consumption criteria set by the owner or user of the building. Smaller devices intended to prevent excessive water consumption are flood detectors or solenoid valves in the toilet inlets. An illustrative solution is presented on Fig. 8.

The first active system intended to minimise water leaks is the use of a solenoid valve (Fig. 9). This solution is not complicated. A system fitted with a solenoid valve works on the basis of a lighting control system, based on motion sensors. As soon as a person enters, the sensor can switch on the lighting and simultaneously open the shut-off valves for hot and cold water supply to all water users in the bathroom. After people leave the room and a set time delay lapses, the water supply to the sanitary facility is automatically cut off, which eliminates the potential negative effects of dripping taps and "suspended" toilet flushing tanks.

The use of solenoid valves in buildings with multiple sanitary facilities, assuming their equipping with only a sink, shower and toilet, creates hundreds of hazardous locations that could potentially lead to significant amounts of wasted
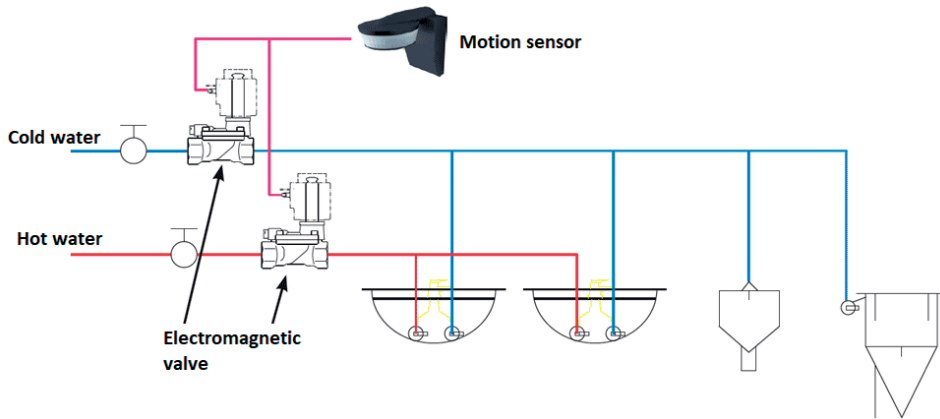
Fig. 8. Sanitary connection diagram with solenoid valve

Source: [22]



Fig. 9. Danfoss EV 220B and 250B water saving solenoid valves

Source: [23]

water and effluent. Examples of the use of such valves are hotel rooms or sanitary facilities in office buildings. In hotel rooms, the system works by cutting off the electricity after the person leaves and takes the key - a magnetic card from the reader. After a power failure, the valve closes and cuts off the water supply to the sanitary facility. In office buildings, the system works on the same principle, but with the use of a motion sensor.

Another way to reduce water consumption is to use special fixtures [3] (Fig. 10 and Fig. 11) that limit the outflow of water. The flow rate for a washbasin is 3 dm$^3$ / min and for showers it is 6 dm$^3$ / min. The split-flow function and automatic shut-off reduce water consumption and operating errors. Time of water flow to the wash basins is limited to 7 seconds. For the toilet, there is a double button that allows flushing in two modes of 3 or 6 liters, and a 3-second flush of urinals.

Fig. 10. Electronic basin faucet DELABIE
Source: [24]

Fig. 11. Shower faucet – with a limited
water flow time
Source: [25]

In order to reduce water consumption in washbasin taps, an automatic shut-off system for the water flow can be usage after removing your hands from the faucet detection area (active pulse infrared). Water is not wasted if the drain is not closed due to negligence or bad habits. The water flowing time out of the washbasin faucet is reduced to a minimum, i.e., hand washing and rinsing without soaping time. The basin taps have a flow rate of 3 dm³/min. Water savings can be up to 90% as compared to traditional washbasin faucets (Table 3).

Table 3. Comparison of the water flow from a traditional wash basin faucet
with a DELABIE faucet

|  | Outflow | Soaking | Soaping | Rinsing | Water consumption |
|---|---|---|---|---|---|
| Traditional bathroom faucets and fixtures | 9 dm³ | 5 s | 20 s | 7 s | 4.8 dm³/32 s |
| DELABIE bathroom faucets and fixtures | 3 dm³ | 5 s | - | 7 s | 0.6 dm³/12s |

Source: [3]

In the case of shower fittings, the flow can be stopped by the user at any time. If the user does not do this, the flow automatically stops after 60 seconds, which also reduces water consumption. Electronic shower panels have a flow rate of 6 dm³/min. Water savings in the case of showers reach up to 80% as compared to traditional showers (Table 4).

Table 4. Comparison of the water flow from a traditional shower faucet system
with a DELABIE electronic shower faucet

|  | Outflow | Soaking | Soaping | Rinsing | Water consumption |
|---|---|---|---|---|---|
| Traditional shower faucet system | 15 dm³ | 60 s | 120 s | 60 s | 60 dm³/4 min |
| DELABIE shower faucet system | 6 dm³ | 60 s | - | 60 s | 12 dm³/2 min |

Source: [3]

Another water fitting (Fig. 13) in which we can reduce water consumption are urinals. One way of reducing water consumption is to reduce the size of the bowl, which can contribte to even a 6-fold reduction in water consumption. With the use of appropriate valves, the time of water flow can be shortened to 3 seconds (standard time is 7 seconds), which leads to about 60% water savings as compared to the base state. Reducing water consumption is also possible through the adaptive mode (Fig. 12), which detects periods of intense use and adapts its flush. The principle of this valve is that during intensive use (for example, during a break at school), the amount of water is limited to rinsing the urinal. After the lapse of this intensive period of use, the urinal bowl is additionally rinsed, cleaned and the water in the siphon is renewed, which prevents the release of unpleasant odors.
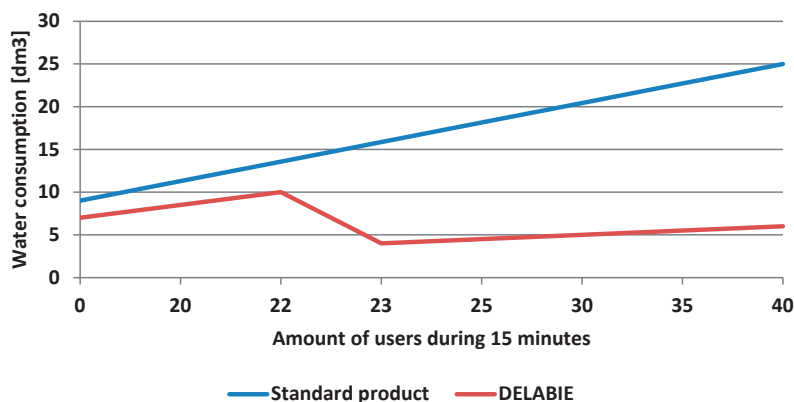


Fig. 12. Comparison of water usage of a standard manufacturer's urinal valve
and a DELABIE valve

Source: [3]

In the case of a toilet (Fig. 14), the way to limit leakage and reduce water consumption is to connect the water supply directly (without a tank). This solution is based on pressure prevailing in the system. Flushing is always possible (there is

no waiting time to fill the tank, which is especially useful in busy places such as schools during breaks). Flushing the toilet directly means that the water does not stagnate, so there are no conditions for limescale build-up and leakage, as is the case with water tanks.



Fig. 13. Urinal drain valve DELABIE
Source: [26]

Fig. 14. WC direct flush valve DELABIE
Source: [27]

An alternative method of saving water is to use a water pressure reducer [28]. The use of a reducer and lowering the pressure in the system contribute to water savings, i.e., it prevents excessive water flows. The lower the pressure, the less water will appear at the tapping point. Reduction of water outflow, and at the same time savings are calculated according to the formula (5):

$$Vk = Vp \cdot \sqrt{\frac{p_1}{p_2}} \qquad (5)$$

where:
Vk– final flow [m³]
Vp– initial flow [m³]
$p_1$ – initial pressure [bar]
$p_2$ – final pressure[bar]

For example, reducing the water pressure from 6 to 3 bar allows reducing the water leakage and water usage in the installation by 29%.

### 2.3. Application areas for devices to prevent water leakage
### and to reduce water consumption

Solenoid valves in combination with a motion sensor that shuts off the water supply to the sanitary facility are widely used in public buildings such as schools - during breaks, water consumption increases when toilets are being used. For example, the valves are an additional protection against leaks and malicious behavior of students who turn on the water.

Valves are used in a similar way in hotels and retirement homes. In the case of hotels, these valves, similarly as in the case of schools, protect against malicious behavior of people accommodated there who endeavour to extort compensation, for example, for a flooded bathroom.

In the case of retirement homes, it is a form of protection against actions of the elderly, who, due to their diseases or infirmity, often tend to forget to turn off the water.

In public buildings such as offices, stations, airports, shopping centers or gas stations, solenoid valves are also intended to protect against water leaks and ensure water savings by cutting off the flow when people using sanitary facilities forget to turn off the water or do it in a malicious way.

In old buildings and existing ones, solenoid valves are also used. They cut off the water when the user is not at home, protecting from potential flooding (for example, against the breakage of a water hose connected to the toilet) and the consequences of theoretical flooding (payment of compensation).

Fittings limiting water consumption are also used in all the above-mentioned facilities, shortening water consumption time and minimising its usage. The set time of outflow from the fittings reduces the number of users who contribute to unbalanced water consumption.

## 3. Results and discussion

### 3.1. Economic analysis of individual solutions to reduce leakage
### and water consumption

For the purposes of the economic analysis, a period of one year of operation of a given solution was assumed (Table 5) for devices intended to prevent leakage and reduce water consumption. The analysis was based on the collected data (Fig. 1, Table 1, Table 2). Discounts provided by producers were not taken into account. On the approximate costs of a given device have been presented.

Table 5. List of solutions preventing water leakage and limiting its consumption together with unit prices in [PLN]

| Solution | Cost [PLN] |
|---|---|
| Drain valve for WC | 30 [29] |
| Chemical products | 26 [30] |
| Water pressure reducer | 310 [31] |
| Solenoid valve Danfoss EV 220B DN25 | 767 [32] |
| Expansion vessel (for water installation) | 117 [33] |
| Electronic basin faucet and set for DELABIE direct rinsing WC | 1274.03 + 848.19 [24,27] |

Source: own study

Assuming the average cost of water consumption amounting to 11 PLN/m$^3$ (payment for water and sewage) and the average amount of water leaking from the toilet water tank, amounting to 0.43 m$^3$/day, the return on investment was calculated based on formula (6):

$$T = \frac{P}{K} \cdot \frac{1}{V} \qquad (6)$$

where:
T – payback time [days]
P – financial expenditure [PLN]
K – payment for water and sewage [PLN/m$^3$]
V – unit consumption of water [m$^3$/day]

As regards water leaks through the safety valve, when there is no expansion vessel installed, the water outflow depends on the setting of domestic hot water temperature (thermal expansion of water). In the analyzed case it was 60°C. The average amount of water leaking through the safety valve is 2.4 dm$^3$/day. Based on the formula (5), the payback time of the expansion vessel will be approximately 12 years.

The use of a water pressure reducer and lowering the pressure in the installation from 6 to 3 bar saves water up to 29% of the baseline. Taking into account only the leakage from the toilet itself, the pressure reducer payback time will be approximately 225 days. If the installation for the entire facility is included, the refund will be achieved earlier.

The use of the Danfoss EV 220B DN25 solenoid valve for the bathroom node in the analyzed case (leakage from the toilet and washbasin amounting to 0.435 m3/day) will reduce the uncontrolled water outflow to a minimum level. Water will flow out only when you use the bathroom. The valve payback time amounts 161 days.

The use of DELABIE fittings helps save water to a greater extent than it prevents uncontrolled leakage. Therefore, the analysis for DELABIE's fittings was carried out in comparison to standard faucets and flush kits for one sanitary facility (bathroom), similar to the solenoid valve presented in the analysis.

Taking into account only the water leakage from the toilet and washbasin (0.435 m³/h), the cost of DELABIE faucets and valves for one bathroom would be recovered after 449 days. It should also be mentioned that the return may turn out to be faster owing to a lower water consumption as compared to standard batteries.

Let us assume a 4-person family with a daily water consumption of 140 dm³/(day*person), which gives us approximately 204 m³ of water per year. If 45% of this water flows from the sink and toilet and the remaining part of the flowing water is the bathtub or shower, this is not included in this analysis. On this basis, we can establish that approximately 92 m³ of water flows out through the toilet and washbasin. DELABIE as a manufacturer of a washbasin faucet provides 3-fold less outflow than for a traditional faucet. For a direct flush as compared to a toilet with a water tank, the outflow of water is also ca. 3 times smaller. By using water-saving faucets and fittings, we are able to reduce water consumption by ca. 60 m³/year for the entire 4-person family. This leads to approximately 660 PLN/year lower bills for water and sewage. Taking these data into account, the investment payback time is 310 days instead of 449 days.

The results of individual solutions are presented on Table 6.

Table 6. Overview of leakage prevention solutions and payback times for the investment

| Solution | Payback time [days] |
|---|---|
| Drain Valve for WC | 7 |
| Chemical products | 6 |
| Water pressure reducer | 225 |
| Solenoid valve | 161 |
| Electronic basin faucet and set for direct rinsing WC | 310 |

Source: own study

## 4. Conclusions

The article presents the results of an analysis of water leakages in a single-family building. Water leaks from the toilet, washbasin and the safety valve at the domestic hot water tank. The analysis allows making an estimation of the expected costs of uncontrolled water leaks, which can generate significant losses to the household budget. As a result of such simple leaks that remain invisible, over 1700 PLN additional costs per year can be generated for the household budget.

The use of the analyzed solutions contributes to minimising water consumption and also reduces operating costs of the installation in the building.

These results refer to the scale of one bathroom in a single family house. For facilities with multiple sanitary facilities such as hospitals, offices, hotels - water leaks can cause very high additional costs for water and sewage (larger water installation scale).

The analysis established that the most cost-effective methods of preventing leaks, which are the quickest to achieve and also the simplest, is to respond quickly by replacing faulty equipment or using appropriate chemicals. Bathroom fixtures will become covered by limescale if water is hard. Such fixtures require regular maintenance as it is a recurring problem. The replacement of devices and assuring a quick response means that the cost of such a procedure pays off after a few days. An important aspect is raising the awareness and responding to the leakage problem. Fast response minimizes unnecessary costs in the household budget.

In the further part of analysis, the issue of the expansion vessel was omitted due to the fact that the payback time was long (117 days) and the amounts of leaked water were insignificant (max 6 dm$^3$ per 2 days). The issue of valves for urinals and showers was also not analyzed due to the lack of comparative data.

In the case of the other variants, the Danfoss solenoid valve coupled with a motion detector is most cost-effective. Installation of such a valve in the sanitary facility in the event of a water leak allows achieving a return after 161 days. This valve can also be widely used in other types of buildings, such as schools, hotels, guesthouses, offices, retirement homes, railway stations, shopping malls or gas stations; in combination with a motion detector, they significantly reduce water consumption and help prevent various forms of vandalism that could lead to waste of water due to its irresponsible discharge. This system also assures protection of existing buildings against unexpected water leakage from the water supply hose to the gas boiler or toilet.

Another example of an analysis aimed at reducing water consumption and reducing water leakage is the use of a pressure reducer on the water connection and reducing this pressure. Depending on the starting pressure and that after reduction, it is possible to reduce the water flow by approximately 29% when reducing the pressure from 6 bar to 3 bar. In such a case it should be borne in mind that excessive pressure reduction may cause the system to malfunction. The consequence of an excessive reduction in water pressure may be a lack of water flow from the most distant water draw point (insufficient pressure). The return on such investment in the event of a leak from the toilet and washbasin takes 225 days for the analyzed case.

For DELABIE's faucet, the return period for a washbasin faucet and a direct flush toilet valve, including leakage prevention only, is 449 days. However, considering the fact that these devices mainly contribute to saving water by reducing the runoff,

reaching up to a 60% reduction in water consumption, the payback time is reduced to 310 days. In the following years, the user is able to save up to 60% of the bills forwater and sewage.

Similarly as Danfoss solenoid valves, DELABIE's fixtures are widely used, especially in public buildings, where the time of water outflow is significantly reduced, and that reduces water consumption and also prevents acts of ecological vandalism. It is worth noting, however, that the analysis does not take into account discounts from producers and, moreover, the scale of leaks in a given facility may vary, from those imperceptible drops of water to a visible stream of water in the toilet.

The final choice of a method intended to prevent leaks and save water depends on the user (sanitary design) who is guided mainly by economic aspects and the comfort of use. The lowest costs generate good habits, frequent maintenance and fast response to emerging system failures.

## References

[1] *Progress on Drinking Water, Sanitation and Hygiene Update and SDG Baselines*, UNI-CEF 2017, Available at: https://data.unicef.org/resources/progress-drinking-water--sanitation-hygiene-2017-update-sdg-baselines/ (Accessed: 29th April 2022).

[2] *Water, Sanitation and Hygiene (WASH) | UNICEF*. Available at: https://www.unicef.org/wash (Accessed: 29th April 2022).

[3] *Armatura_sanitarna_budynków_użyteczności_publicznej*. Available at: https://www.delabie.pl/ftp/documents/pol-PL/centrum-obsługi/katalogi/Armatura-sanitarna/mobile/index.html (Accessed: 29th April 2022).

[4] Knapik M., *Analysis of influence of LEED certification process to achieve the passive house standard*, "Tech. Trans." 2017, 9, 137–150.

[5] Scofield J.H., *Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings*, "Energy Build." 2013, 67, 517–524.

[6] *CENY WODY W POLSCE MIASTA ALFABETYCZNIE I MALEJĄCO*. Available at: http://www.cena-pradu.pl/woda.html (Accessed: 29th April 2022).

[7] *Thermal expansion rate of water: Hot Water Expansion Rate & Hot Water Pressure Increase in Hot Water Tanks or Boilers*. Available at: https://inspectapedia.com/plumbing/Hot_Water_Expansion.php (Accessed: 29th April 2022).

[8] Knapik M., *The influence of pipe diameter selection on operating costs of heating installation in the context of the anticipated increase in electricity prices*, E3S Web of Conferences 2019.

[9] Knapik M. *Analysis of the possibility to cover energy demand from renewable sources on the motive power of the heat pump in low-energy building*, E3S Web Conf. 2017.

[10] Aitken C.K., Mcmahon T.A., Wearing A.J. & Finlayson B.L., *Residential Water Use: Predicting and Reducing Consumption 1*, "J. Appl. Soc. Psychol." 1994, 2, 136–158 (1994).

[11] Halilch G. & Stephenson K., *Effectiveness of Residential Water-Use Restrictions under Varying Levels of Municipal Effort*, "Land Econ." 2009, 4, 614–626.

[12] St. Hilaire R. et al., *Efficient Water Use in Residential Urban Landscapes*, "HortScience" 2008, 7, 2081–2092.

[13] Ferrara I., *Residential Water Use*, "OECD J. Gen. Pap." 2008, 2, 153–180.

[14] Lee M., Tansel B. & Balbin M., *Influence of residential water use efficiency measures on household water demand: A four year longitudinal study*, "Resour. Conserv. Recycl." 2011, 1, 1–6.

[15] Kanakoudis V.K. & Tolikas D.K., *The role of leaks and breaks in water networks: technical and economical solutions*, "J. Water Supply Res. Technol." 2001, 5, 301–311.

[16] Knapik M., *Budownictwo proekologiczne – zrównoważony rozwój,* I Ogólnopolska Konf. Nauk. OSA – Odpad. Środowisko, "Atmos." [5–6 June 2014], Mater. Conf. Ref. presentations 87–92.

[17] Lee Y.S., *Comparisons of Indoor Air Quality and Thermal Comfort Quality between Certification Levels of LEED-Certified Buildings in USA*, "Indoor Built Environ." 2011, 5, 564–576.

[18] Newsham G.R., Mancini S. & Birt B.J., *Do LEED-certified buildings save energy? Yes, but…*, "Energy Build." 2009, 8, 897–905.

[19] Cole R.J. & Jose Valdebenito M., *The importation of building environmental certification systems: international usages of BREEAM and LEED*, "Build. Res. Inf." 2013, 6, 662–676.

[20] Seinre E., Kurnitski J. & Voll H., *Building sustainability objective assessment in Estonian context and a comparative evaluation with LEED and BREEAM*, "Build. Environ." 2014, 110–120.

[21] Reposa J.H., *Comparison of USGBC LEED for Homes and the NAHB National Green Building Program*, "Int. J. Constr. Educ. Res." 2009, 2, 108–120.

[22] *OSZCZĘDZANIE WODY. ŁATWO POWIEDZIEĆ – I ŁATWO WYKONAĆ*, Available at: https://wentylacja.com.pl/news/oszczedzanie-wody-latwo-powiedziec-latwo--wykonac-66802.html (Accessed: 29th April 2022).

[23] *EV220B – uniwersalne zawory elektromagnetyczne 2/2-drożne z serwosterowaniem | Danfoss*. Available at: https://www.danfoss.com/pl-pl/products/sen/valves/solenoid--valves/industrial-solenoid-valves/ev220b/#tab-overview (Accessed: 29th April 2022).

[24] *Umywalki*. Available at: https://www.delabie.pl/produkty/armatura-sanitarna-do-budynkow-uzytecznosci-publicznej/umywalki (Accessed: 29th April 2022).

[25] *Natryski*. Available at: https://www.delabie.pl/produkty/armatura-sanitarna-do-budynkow-uzytecznosci-publicznej/natryski (Accessed: 29th April 2022).

[26] *Pisuary*. Available at: https://www.delabie.pl/produkty/armatura-sanitarna-do-budynkow-uzytecznosci-publicznej/pisuary (Accessed: 29th April 2022).

[27] *WC*. Available at: https://www.delabie.pl/produkty/armatura-sanitarna-do-budynkow-uzytecznosci-publicznej/wc (Accessed: 29th April 2022).

[28] *Reduktor ciśnienia - po co, kiedy, gdzie i jakie stosować?* Available at: http://www.husty.pl/index.php?option=com_content&view=article&id=164:reduktor-cisnienia-po-co--kiedy-gdzie-i-jakie-stosowac&catid=108&Itemid=498 (Accessed: 29th April 2022).

[29] *Zawór spłukujący*. Available at: https://ehydrogaz.pl/zawory-wc-zawor-spustowy-do--spluczki-z-funkcja-stop,c104,p609,492a1685fd857b55a,pl.html?gclid=CjwKCAj-w9qiTBhBbEiwAp-GE0b7K93K-3oonFJLFTZD4oGy39iac4Ox5k1Xihb6xc8qsag-3doGpTzRoCeD0QAvD_BwE (Accessed: 29th April 2022).

[30] *Faren F200 płyn do odkamieniania spłuczek w WC 1L - Higiena Kompleks*. Available at: https://hurtowniasrodkowczystosci.pl/product-pol-1670-Faren-F200-plyn-do-odka-mieniania-spluczek-w-WC-1L.html?utm_source=iai_ads&utm_medium=google_shopping&curr=PLN (Accessed: 29th April 2022).

[31] *Herz Membranowy reduktor ciśnienia DN25*. Available at: https://www.techni-ka-grzewcza-sklep.pl/sklep/produkt/herz-membranowy-reduktor-cisnienia-dn-25-kod-1268213.html?srsltid=AWLEVJzKVM-I2Bx3nmZt3cU5FN37Jw7tIGHjiqk-bYh6UyjfrktVzVM61oMQ#/ (Accessed: 29th April 2022).

[32] *Danfoss Zawór elektromagnetyczny bez cewki EV220B 25B G 1N*. Available at: https://www.technika-grzewcza-sklep.pl/sklep/produkt/danfoss-zawor-elektromagnetycz-ny-25dn-kod-032u7172.html?srsltid=AWLEVJyJ8UF-4_-TDkCGuCUTxMyXISQC-w4JObiymz8HY42bwQOwJA_rkZlA#/ (Accessed: 29th April 2022).

[33] *Naczynie przeponowe 8 L wzbiorcze C.W.U. 8 bar*. Available at: https://hurtinstal.pl/na-czynie-przeponowe-5-l-wzbiorcze-cwu-8-bar-p-318.html (Accessed: 29th April 2022).