ORIGINAL ARTICLE

Profitability analysis of dual installations in selected European countries

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Abstract

The most important goal of every water distribution system is to deliver water to the consumers in the demand and time determined by its users. However, not all water usages require the potable water quality. One of the technical solutions enabling water recycling and its reuse is a dual installation system. Dual installations recycle rain wastewater or grey water from bathtubs, showers and sinks and further reuse it for irrigation or toilet flushing. The profitability of a dual installation system is highly dependent on the water price, which tends to vary significantly according to the location. The purpose of this paper is to evaluate the profitability of dual installation systems in exemplary hotel building hypothetically located in 10 different European countries. The profitability was determined on the basis of multi-criteria decision analysis performed for two installation variants. The investment was evaluated in terms of technical, economic and environmental aspects. As a result, the selected countries were ranked in order of the most profitable location for dual installation system's investment.

Introduction

The most important goal of every water distribution system is to deliver water to the consumers in the demand and time determined by its users. However, not all water purposes require the potable water quality. According to EN12056-5 (2000), only 44% of daily water demand should be satisfied by drinking water quality—water used for drinking, cooking, dish washing and hygiene purposes. Other purposes (e.g. toilet flushing, cleaning, irrigation) can be satisfied by recycled water. One of the technical solutions enabling water recycling and its reuse is a dual installation system. Dual installations recycle rain wastewater or grey wastewater from bathtubs, showers and sinks and further reuse it for irrigation or toilet flushing (World Health Organization 2006). The dual installation system requires additional sewage installation

design—black wastewater and grey wastewater should be drained separately. Black wastewater (from toilets or urinals) should be outflowed directly to a sewage network, while grey wastewater should be filtered, pre-treated, stored and reused (Stadnik 2015). The operation of a dual installation system is technically reasonable, when the grey wastewater inflow is higher than greywater demand. However, even when the water balance is positive, there should be also a technical possibility to supply greywater installation with potable water—therefore there is always a necessity to guarantee an additional water supply connection to the dual installation system (Grzelak and Fiałkiewicz-Kozieł 2017).

Considering the growing interest in dual installations, many countries and organizations state their position to water reuse. It can be noticed that there is a significant diversity of legal regulations according to dual installation systems application. In several regions, the water reuse is forbidden, while other countries encourage to it. The different approaches to greywater usage are caused mainly by cultural, economic and social diversity. In Europe, greywater usage is regulated by European Council Directive 91/271/EEC. According to the Directive, the greywater usage is accepted, but with several exceptions. For example, Germany, leader of rain- and greywater reuse in Europe, among several technical requirements, allows the dual installation

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system operation only if it does not need high energy usage and also if the dual installation system payback time is acceptable (Nolde 2005).

The main advantage of dual installation system is water saving by its recycling and reuse. Except for the greatest dual installation benefits, there are also several other advantages: less energy consumption by pumps in order to deliver water, less wastewater at water treatment plant, possibility of eco-certificate for the building (Alexander and Clark 2016). As a result, there are also economic advantages—dual installation may became profitable even after 3–5 years of operation. However, the profitability of a dual installation system should be calculated for each case individually—the profitability is highly dependent on the water price, which tends to vary significantly according to the location. On the other hand, some advantages of dual installation system may be also claimed as disadvantages: less wastewater causes worse hydraulic flow conditions in sewage networks. Additionally, each investment causes an environmental effect on natural resources, human health, global warming, etc. (Hoekstral 2016), and it should be included in overall investment evaluation. Increased consumption of resources at the stage of building a dual installation inclines towards subjecting them to the additional analyses in this area. Currently, there are several tools supporting the evaluation of environmental impact of the investment: Water Footprint (Hoekstra et al 2011), Virtual Water Trade (Chapagain and Hoekstra 2004) or Life Cycle Assessment (Góralczyk et al 2001).

The multiplicity of aspects, which should be taken into account during dual installation investment evaluation, makes this issue a difficult task. The purpose of this paper is to evaluate the profitability of dual installation systems in an exemplary hotel building hypothetically located in 10 different European countries by the application of an advanced decision-making supporting tool, including technical, economic and environmental aspects.

Materials and methods

Object description

The profitability analysis of dual installations was performed for a new designed hotel building (Nakonieczna 2019). The analysis included two variants of a dual installation. In the Variant I, the greywater storage tank (7 m^3) is located inside the building, while in Variant II the tank (6.5 m^3) is located outside the building. In the Variant I, there are 30 bedrooms in the hotel building, while in Variant II 32 bedrooms. In both variants, the sanitary equipment in each bedroom includes sink, shower or bathtub and toilet. In the Variant I, the total number of showers is 30 and the total number of sinks is 32. Analogically, there are 32 showers

and 34 sinks in Variant II. The greywater is designed to be reused for flushing in 33 and 35 toilets, respectively, in Variants I and II. Cleaning warehouses are equipped with sinks and showers; there are also sinks in kitchen and lobby bar. The hotel building was hypothetically located in 10 different European countries: the Netherlands (NL), Poland (PL), Germany (DE), the United Kingdom (UK), Denmark (DK), the Czech Republic (CZ), Belgium (BE), Greece (GR), Switzerland (CH) and Italy (IT).

Multi-criteria analysis

The profitability analysis of dual installations in selected 10 European countries was determined on the basis of multi-criteria decision analysis (*MCDA*) performed for two installation variants. The investment was evaluated in terms of three main criteria: technical, economic and environmental. The main criteria were further divided into sub-criteria. Each sub-criterion was marked from 1 to 5, where 5 was the highest possible mark. The main and sub-criteria and their weights were assigned as follows:

1. Technical main criterion (weight: 25%)		
1.1	Water balance	(25%, mark 1—unfavourable, 5—very favourable)
1.2	Material availability	(15%, 1—hard available, 5—easy available)
1.3	Necessary work	(20%, 1—a lot of work, 5—little work)
1.4	Installation difficulty	(20%, 1—difficult assembly, 5—easy assembly)
1.5	Maintenance	(20%, 1—difficult, 5—easy)
2. Economic main criterion (weight: 55%)		
2.1	Investment costs	(45%, 1—high, 5—low)
2.2	*SPBT* payback time	(30%, 1—long, 5—short)
2.3	*NPV* indicator	(25%, 1—low profitability, 5—high profitability)
3. Environmental main criterion (weight: 20%)		
3.1	Human health impact	(25%, 1—high, 5—low)
3.2	Ecosystem quality impact	(25%, 1—high, 5—low)
3.3	Climate change impact	(25%, 1—high, 5—low)
3.4	Natural resource impact	(25%, 1—high, 5—low)

The technical criterion rates the possibility of the installation application, investment difficulty level and operation and service complication of the installation. As both variants of dual installations are relatively easy to implement in a new design hotel building, the weight of this criterion was assumed as 25%. The technical criterion was divided into five different sub-criteria: water balance analysis results, building materials availability, necessary installation work, installation difficulty and maintenance. The water balance was calculated in accordance with British Norm BS 8525 (2010-1). The detailed water balance enables to evaluate

the amount of grey wastewater and demand of grey water in relation to dual system users. The water balance is positive when the amount of grey wastewater is higher than the greywater demand. As a positive result of water balance is the basis for dual system application, this sub-criterion was weighted as 25%. The other sub-criteria were weighted with 15–20%, as there are no significant difficulties in building material availability, installation or maintenance of dual installations.

The economic criterion was established as the most important (weight: 55%) due to the fact that profitability of dual installation is highly dependent on the investment costs and the water prices, which tends to vary significantly according to the location (Suchorab et al 2018). The economic criterion was further divided into, respectively, weighted three sub-criteria: investment cost, simple payback time (SPBT) and net present value (NPV) analysis. The first sub-criterion (investment costs) was weighted as 45% and was calculated with distinction of 1 man-hour costs for each of the selected countries. The second economic sub-criterion was the SPBT indicator (weight: 30%), which shows a moment when the investment starts to be economically profitable, including also incurred investment costs (Pastusiak 2010). The SPBT indicator value can be calculated in accordance with the formula (1) (Jodłowski and Dobrzański 2016). The third economic sub-criterion was NPV indicator (weight: 25%), which can be used in investment planning to analyse the profitability of a projected investment. The investment is profitable when NPV value is positive. The negative NPV value means that the investment is unprofitable, and NPV equalled to 0 means that the investment is susceptible to external factors (Jodłowski and Dobrzański 2016). The NPV indicator can be calculated in accordance with the formula (2) (Tarapata 2003).

$$SPBT = \frac{N}{Q - O} \tag{1}$$

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1 + i)^t} \tag{2}$$

where SPBT—simple payback time [years]; N—initial investment costs [€]; Q—economic profit [€/year]; O—maintenance costs [€/year]; R_t—net cash inflow-outflows during a single period t [€/year]; i—discount rate [%]; t—time of the cash flow [year].

To calculate both SPBT and NPV indicators, the annual cost of operation of dual installation systems was needed to be calculated. For that reason, for each country, the actual water prices for 1 m^3 water in the years 2014–2019 were adopted (Nakonieczna 2019). For the next 5 years, the water prices were forecasted on the basis of actual

data from the previous period and regression analysis. For each country, a water prices trendline was determined by linear, power, logarithmic or exponential function. The function characterized by the highest value of a coefficient of determination R^2 was chosen as a trendline for each country. If R^2 occurred lower than 0.5 for all functions in question, indicating the lack of the fitting calculated data to the actual, the arithmetical mean of actual water prices (2014–2019) was taken as a constant price for the years 2020–2024.

The main environmental criterion was weighted as 20%—making it the least important criterion due to the fact that time-consuming environmental analyses are still rare during the investment process. Both variants of dual installation systems can be perceived as environmentally friendly, as they limit the usage of drinking quality water. On the other hand, additional resources and energy are used during the construction and operation of dual installation system. Therefore, Life Cycle Assessment (LCA) method was used in this study in order to evaluate the possible environmental burdens connected with all these stages. LCA allows to estimate the materials and energy used as well as emissions and wastes generated during the life cycle of certain product and enables the presentation of the results in the form of an easy to interpret environmental impact indicator, which is a criterion in this study. Since dual installations can have a wide range of influence on environment and natural resources, the environmental criterion was further divided into 4 sub-criteria, in order to evaluate the impact on human health, ecosystem quality, climate change and natural resources. The environmental burden of the dual installation system was calculated via SimaPro v. 8.1 software, including IMPACT 2002+ as the Life Cycle Impact Assessment method, where the four sub-criteria corresponded to the four damage categories. The sub-criteria were evenly weighted (25%) according to the methodology guidelines (Jolliet et al 2003). IMPACT2002+ is a combined midpoint/damage approach, and allows to aggregate all the used resources and emissions to the environment into 14 impact categories (midpoint categories with 14 different units expressing the certain effect) into 4 basic damage categories with 4 respective units. During the next step of the calculation, transformation of the results into single score expressed in Points is possible, which allows to compare the certain results by the use of common unit (Jolliet et al 2003). The life cycle inventory was based on the authors' calculations, detailed list of materials and devices (Nakonieczna 2019) in addition to Ecoinvent database (2020), and included construction of dual installation and 30-year operation time, in particular energy used for pumping and drinking quality water consumption.

Results

The technical criterion is independent of the hotel building's location; therefore, the received marks are equal for all analysed countries. In both variants, the water balance was positive; therefore, both marks were 5 (very favourable). The greywater demand equalled 902.28 dm^3/d and 489.10 dm^3/d, respectively, for Variants I and II. The building material availability was also marked with 5, as the required material (or equivalents) is easy accessible in all analysed countries. The main difference between dual installation variants is the location of greywater storage tank: inside or outside the hotel building. Variant I (storage tank inside the hotel building) requires 99 man-hours and 6 moto-hour of necessary work. In Variant II, the 168 man-hour and 8 moto-hour of work are required. Therefore, the higher mark (4) was received by Variant I, while Variant II was marked with 2. The installation difficulty is quite nearing between variants, except storage tank installation. Therefore, Variant I was marked with 4 and Variant II with 2. Both installation variants require periodic maintenance and service, but in Variant I it can be more difficult due to the worse access to the storage tank inside building (mark 3) in comparison with Variant II (mark 4). The overall marks for the technical criterion for Variant I and II were calculated as 4.20 and 3.60, respectively.

The second main criterion (economic) was mostly based on the investment and operational costs of dual systems.

To evaluate the savings (profits) generated by the recycled water, it was necessary to analyse water prices in all 10 countries. The summary graph of water prices trendlines for each country is presented in Fig. 1. The actual unitary prices for 1 m^3 of drinking quality water in the years 2014–2019 as well as the detailed water prices forecasted for the years 2020–2024 are presented in Table 1. Water prices for 1 m^3 of drinking water tend to vary significantly in reference to the location. It is mainly caused by domestic water policy, water resources availability, water distribution systems and society awareness. In the analysed 10 exemplary European Countries, water is the most expensive in Belgium, Switzerland and Germany, and the cheapest in Greece. Only in 3 of the analysed countries the water price trendline is growing (Poland, Denmark, the Czech Republic). In 2 cases (Greece and Switzerland), the coefficient of determination R^2 was unacceptable for any of linear, power, logarithmic or exponential function, and therefore, the water prices were forecasted in accordance with the average water price in years 2014–2019.

The investment cost of the dual installation system was calculated as a sum of materials' costs and working costs. In Variant I, materials were valued as 2383.00 € and in Variant II as 1876.47 €. The working hours included 99 man-hours and 6 moto-hours of necessary work in Variant I and 168 man-hour and 8 moto-hour in Variant II. During the calculation, the minimal working wages in each country were taken into account. The detailed results of investment costs are presented in Table 2. Generally, Variant II was
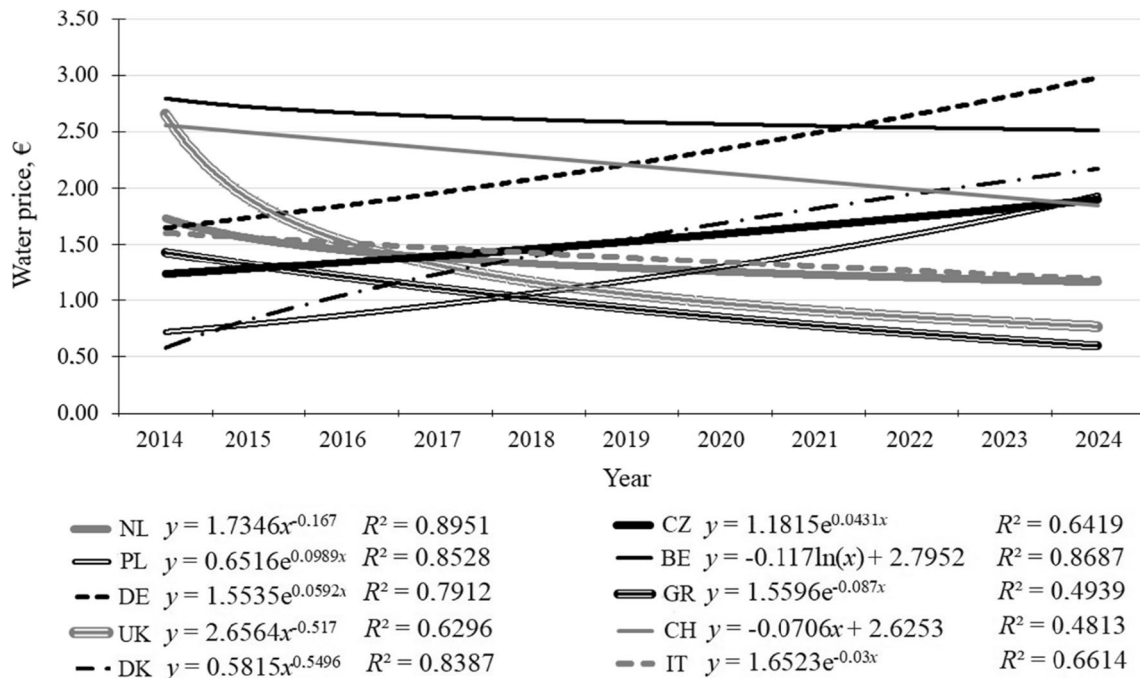

NL $y = 1.7346x^{-0.167}$ $R^2 = 0.8951$

PL $y = 0.6516e^{0.0989x}$ $R^2 = 0.8528$

DE $y = 1.5535e^{0.0592x}$ $R^2 = 0.7912$

UK $y = 2.6564x^{-0.517}$ $R^2 = 0.6296$

DK $y = 0.5815x^{0.5496}$ $R^2 = 0.8387$

CZ $y = 1.1815e^{0.0431x}$ $R^2 = 0.6419$

BE $y = -0.117\ln(x) + 2.7952$ $R^2 = 0.8687$

GR $y = 1.5596e^{-0.087x}$ $R^2 = 0.4939$

CH $y = -0.0706x + 2.6253$ $R^2 = 0.4813$

IT $y = 1.6523e^{-0.03x}$ $R^2 = 0.6614$

Fig.1 Water price trendlines (2014÷2024)

Table 1 Water prices (2014 ÷ 2019) and forecast water prices (2020 ÷ 2024) (in €)

Year	Country									
	NL	PL	DE	UK	DK	CZ	BE	GR	CH	IT
	€									
2014	1.80	0.72	1.69	2.25	0.54	1.24	2.80	1.35	2.50	1.52
2015	1.51	0.74	1.71	3.00	0.81	1.27	2.71	1.18	2.55	1.62
2016	1.37	0.94	1.72	1.16	1.30	1.33	2.68	1.40	2.57	1.55
2017	1.36	0.95	2.16	1.16	1.34	1.37	2.63	1.38	2.10	1.52
2018	1.33	1.19	2.10	1.13	1.56	1.64	2.61	0.71	2.30	1.37
2019	1.35	1.08	2.16	1.14	1.21	1.43	2.59	0.92	2.25	1.37
2020	1.25	1,30	2.35	0.97	1.69	1.60	2.57	1.17	2.38	1.34
2021	1.23	1,44	2.49	0.91	1.82	1.67	2.55	1.17	2.38	1.30
2022	1.20	1,59	2.64	0.85	1.95	1.74	2.54	1.17	2.38	1.26
2023	1.18	1,75	2.81	0.81	2.06	1.82	2.53	1.17	2.38	1.22
2024	1.16	1,93	2.98	0.77	2.17	1.90	2.51	1.17	2.38	1.19

Table 2 Investment costs and SPBT and NPV indicators

Country	Investment cost		SPBT					NPV	
	Variant I	Variant II	Variant I			Variant II		Variant I	Variant II
	(€)	(€)	Annual saving(€)	Payback time(years)		Annual saving(€)	Payback time(years)		
NL	6059.95	10,251.16	1103.39	5.49		598.12	17.14	5624.34	−4345.53
PL	4120.38	7312.46	1123.16	3.67		608.83	12.01	9750.99	−221.26
DE	6034.01	10,186.98	2391.30	2.52		1296.25	7.86	15,616.59	1121.12
UK	6024.27	10,026.05	789.13	7.63		427.76	23.44	2647.68	−5753.31
DK	5992.62	10,084.65	1746.02	3.43		946.47	10.66	17,509.99	2227.36
CZ	4068.03	7427.21	1572.05	2.59		852.16	8.72	10,714.94	158.14
BE	6096.44	10,340.23	2311.73	2.64		1253.12	8.25	17,068.82	1788.91
GR	4891.07	7376.74	1055.67	4.63		572.25	12.89	8333.43	−636.20
CH	6096.44	10,634.19	2147.43	2.84		1164.06	9.14	15,020.19	384.45
IT	5540.36	8986.05	1138.89	4.86		617.36	14.56	4162.38	−4154.55

more expensive (averagely by 68.98%) than Variant I due to the greater workload required. The highest investment costs were in Switzerland, Belgium and Denmark, while the lowest in Poland, the Czech Republic and Greece. The differences are generated by higher minimal working wages.

The first economic indicator estimated in the analysis was simple payback time. Generally, the higher the investment cost, the longer the investment payback time, but in the analysed cases of dual installation systems, also the greywater demand and water prices should be taken into account. Considering all components, the calculated *SPBT* values are presented in Table 2. The payback time of the dual installation in Variant I is relatively low in all analysed countries. In this analysis, it was assumed that the profitability limit of the dual installation is 10 years. Therefore, in Variant I, the investment is profitable in all analysed countries. There are four countries (Germany,

the Czech Republic, Belgium and Switzerland) where SPBT indicator is lower than 3 years. On the other hand, the Variant II of the dual installation is profitable (SPBT lower than 10 years) only in four locations (for which SPBT < 3 years in the Variant I).

In accordance with calculated net present value indicators with 4.5% discount rate (presented in Table 2), the dual system installations are profitable in all analysed countries (Variant I). On the other hand, in Variant II the NPV value was positive only in five countries (Germany, Denmark, the Czech Republic, Belgium, Switzerland). Moreover, the NPV value in the Czech Republic and Switzerland was only slightly above zero, and in these countries, the installation of a dual system in Variant II should be carefully considered. On the basis of calculated investment costs and economic indicators, countries were further evaluated with a suitable mark.

Similarly to the economical criterion, the environmental impact of the designed systems was estimated by the use of LCA method (see p. 2.2) and then assigned to the corresponding marks. As a part of environmental criterion, the impact on human health, ecosystem quality, climate change and natural resources was analysed. The calculation of IMPACT2002 + indicator in 30-year perspective of dual system lifetime allowed to compare two variants of installation in the analysed locations in accordance with the mentioned damage categories, as presented in Table 3. The results of environmental analysis show that in most of the locations, Variant II of the dual system is represented by higher values of indicators, expressing the more intensive environmental impact in the categories: human health, ecosystem quality and resources. The diverse situation in climate change category was connected with the higher electricity consumption by the water pump as a result of the higher volume of grey water reused in Variant I.

The detailed environmental criteria and the corresponding marks are presented in Table 4. The base of mark assignment was, as previously, the difference between the maximum and minimum values of the indicator in selected damage category divided into five sectors (marks 1–5) equal in range. The Variant I of the dual installation system revealed to be the most influential on climate change (mark 2.3—average impact for all 10 locations). The impact on natural resources and ecosystem quality was comparatively low with the same average mark equal 4.9, while for human health category it was only a little bit worse (average mark 4.8). Variant II was assessed as potentially worse for the environment, with categories: ecosystem quality and resources assigned the average mark 1 and human health assigned average mark 1.5. The impact on climate change was relatively small (average mark 4) since less energy was predicted to be used for pumping in this variant. Due to the fact that Variant I of

Table 3 Results of IMPACT2002 + calculation in the four damage categories

Country	Human health		Ecosystem quality		Climate change		Resources	
	Variant I	Variant II	Variant I	Variant II	Variant I	Variant II	Variant I	Variant II
	(Pt)	(Pt)	(Pt)	(Pt)	(Pt)	(Pt)	(Pt)	(Pt)
NL	0.4697	1.0385	0.0430	0.1051	0.9360	0.8039	0.6879	1.1986
PL	0.6503	1.1408	0.0465	0.1071	1.0596	0.8739	0.7336	1.2245
DE	0.4654	1.0360	0.0436	0.1054	0.9391	0.8057	0.6866	1.1978
UK	0.5226	1.0684	0.0464	0.1070	0.9450	0.8090	0.6906	1.2001
DK	0.4706	1.0389	0.0466	0.1071	0.9037	0.7856	0.6210	1.1607
CZ	0.5205	1.0673	0.0436	0.1054	0.9821	0.8300	0.6977	1.2041
BE	0.4604	1.0332	0.0433	0.1053	0.8529	0.7568	0.6974	1.2039
GR	0.7368	1.1898	0.0470	0.1073	1.0474	0.8671	0.7824	1.2521
CH	0.4444	1.0241	0.0431	0.1052	0.8094	0.7322	0.6573	1.1812
IT	0.5318	1.0737	0.0465	0.1071	0.9292	0.8001	0.6714	1.1892

Table 4 Environmental criteria and sub-criteria with marks

Country	3.1 Human health impact		3.2 Ecosystem impact		3.3 Climate change impact		3.4 Natural resources impact		3. Environmental (overall mark)	
	I	II	I	II	I	II	I	II	I	II
NL	5	2	5	1	2	4	5	1	4.25	2
PL	4	1	4	1	1	3	5	1	3.5	1.5
DE	5	2	5	1	2	3	5	1	4.25	1.75
UK	5	1	5	1	2	4	5	1	4.25	1.75
DK	5	2	5	1	3	5	5	1	4.5	2.25
CZ	5	1	5	1	2	4	5	1	4.25	1.75
BE	5	2	5	1	4	5	5	1	4.75	2.25
GR	4	1	5	1	1	3	4	1	3.5	1.5
CH	5	2	5	1	4	5	5	1	4.75	2.25
IT	5	1	5	1	2	4	5	1	4.25	1.75

the dual installation is designed inside the hotel building and therefore the less building material is required, as well as that it allows to reuse more grey water, this variant was assessed as better for the environment. The overall mark (average) for environmental criterion was 4.23 for Variant I and 1.88 for Variant II. It is worth mentioning that the distinction between the countries is strongly correlated with their energy mixes, and conventional energy markets, characteristic for some of them (PL, GR), result in lower marks in the ranking.

The overall mark for the dual installation systems was calculated as a weighted arithmetic mean of all main and sub-criteria marks. The detailed results of a multi-criteria analysis are presented in Table 5 (Variant I and Variant II). Taking into account only the economic criterion, Variant I of the analysed dual system is much more profitable than Variant II. Enough to say, that the lowest mark of the Variant I (3.50—the UK) is still higher than the best mark for the Variant II (2.75—Poland and the Czech Republic). The results obtained for the economic criterion are one of the varying between different countries with the highest weight (55%); therefore, it translates into the overall marks.

The overall lowest-rated location for the Variant I has also a mark higher than the best mark for the Variant II, and the country sequences in order of both economic and overall marks are the same. For the Variant I, the sequence in descending order is in the following: the Czech Republic, Belgium and Switzerland, next Denmark, Germany, Poland, next successively Greece, the Netherlands and Italy with the same mark, and the latter—the United Kingdom. For the Variant II, similarly the Czech Republic is on the top, next Poland, followed by Greece and Belgium, next Germany, Denmark and Switzerland, Italy, the Netherlands and the latter the United Kingdom. The economic criterion was considered as the most important, so it was the most strongly weighted. However, it is worth to underline that an increase or a decrease in its weight influences the values of the overall marks and differences in the marks between the variants, but does not influence the country sequence. The differences increase if the weight is higher. Generally, the Variant I of the analysed dual installation system is much more profitable, regardless of the location.

Conclusions

A dual installation system enables to reuse grey water, so it is an effective way to diminish both drinking water consumption and the amount of sewage produced by the consumers. This issue is particularly important for regions experiencing seasonal drought or long-term water shortages, where the reuse of grey water can improve the water balance. It translates into financial and ecological profits; however, they can vary in different countries, especially in the economic aspect. The multi-criteria analysis of two variants of dual installation systems in 10 European countries showed that in the case in question, the best possible location for the dual installation system is the Czech Republic for the both variants. The most unprofitable locations occurred in the UK, for both variants. It is worth to underline that this sequence is caused mostly by economic criterion weighted as 55%, where the price of work was the most meaningful element. The consideration of environmental aspects would move the best location of the system to the countries with higher shares of renewable energy, where the long-term operation of system would cause lower emission of greenhouse gases. The clear differences were visible between the variants in marks of all countries in question. For the Variant I, the marks occurred 1.5–2.0 times higher than for the Variant II. Thus, it can be supposed that locating a greywater storage tank inside a hotel building is more profitable than outside, regardless of the country.

It should be underlined that the obtained results of the analysis are the approximate only, because the weights influencing the results were assumed theoretically as the same for all countries in question. The assumption of weights is always problematic in a multi-criteria analysis, mainly because of its subjective character, and should be discussed

Table 5 Multi-criteria analysis results for dual installation system—variants I and II

Country		NL	PL	DE	UK	DK	CZ	BE	GR	CH	IT
1. Technical		Variant I = 4.20/Variant II = 3.60									
2. Economic	I	3.75	4.75	4.55	3.50	4.55	4.75	4.55	4.45	4.55	3.75
	II	1.00	2.75	2.15	1.00	1.85	2.75	2.15	2.45	1.85	1.75
2.1	I	4/1	5/3	4/1	4/1	4/1	5/3	4/1	5/3	4/1	4/2
2.2	/	4/1	5/3	5/4	4/1	5/3	5/3	5/4	4/2	5/3	4/2
2.3	II	3/1	4/2	5/2	2/1	5/2	4/2	5/2	4/2	5/2	3/1
3. Environmental	I	4.25	3.5	4.25	4.25	4.5	4.25	4.75	3.5	4.75	4.25
	II	2.0	1.5	1.75	1.75	2.25	1.75	2.25	1.50	2.25	1.75
Overall mark	I	3.96	4.36	4.40	3.83	4.45	4.51	4.50	4.20	4.50	3.96
	II	1.85	2.71	2.43	1.80	2.37	2.76	2.53	2.55	2.37	2.21

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among construction process participants, with the final decision of an investor. Ultimately, weighting should be conducted taking into account local conditions of each country. However, the obtained results based on a multi-criteria analysis with theoretical weights are sufficient to indicate the most profitable locations and better variant of a dual installation system for furthermore detailed analysis, supporting the decision stage of a construction process.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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