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Costs-benefit Analysis for the use of Shallow Groundwater as non-conventional Water Resource

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Abstract

Encouraging the implementation of non-conventional water resources (NCWR) is a fundamental strategy to face the future challenges due to urban population growth and resource scarcity. The implementation of a systematic process of Cost Benefit Analysis (CBA) offers reliable economic indicators to support decision makers in taking actions shifting towards NCWR. While infrastructure costs are directly estimated, while the benefits depend upon the considered stakeholders and require a tough estimation of the achieved ecosystem services. This research provides a framework for CBA analysis adopting NCWR at municipal level. The framework has been then applied to two case studies in Milan focused on the exploitation of shallow groundwater, where the obtained economic indicators has stressed out the importance of considering a complete benefits analysis that could support incentive policies on shifting part of the financial benefits to direct users leading to benefits for the whole community.

Keywords Water reuse · Alternative water reuse · Ircular economy · Sustainability

List of abbreviations

CBA	Cost Benefit Analysis
CSS	Combined Sewer Systems
GW	Grey Water
IRR	Internal Rate of Return
NCWR	Non-Conventional Water Resources
NPV	Net Present Value
PBP	Pay Back Period
SGW	Shallow Ground Water
SW	StormWater
TAV	Total Economic Value

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WWTP Wastewater treatment plant

1 Introduction

Supplying water needs for a growing population in urban areas under climate change scenarios requires to rethink water resources management, as water withdrawals continue to grow and, in parallel, resources become less available (Thomas and Durham 2003; Salgot et al. 2012; Strzepek et al. 2010; UN 2018; Cook et al. 2018;. Mukherjee et al. 2018; Boretti and Rosa 2019; Ferrasso et al. 2021; Heidari et al. 2021; Oral et al. 2021). Commonly freshwaters are still consumed to satisfy non-potable water uses, although it is estimated that the systematic exploitation of alternative resources could reduce the domestic water consumption up to 50% (Cureau and Ghisi 2019). A new approach for water supply is essential to cope with the upcoming scenarios, combining an optimization of water resources allocation and natural water cycle restoration in urban areas (Becciu et al. 2018; Raimondi and Becciu 2014; Penn et al. 2012; Ricart et al. 2021; Tortajada 2021; Cotruvo 2016; Madonsela et al. 2019). Water consumption optimization strategies include saving freshwater for strictly potable uses and encouraging the use of non-conventional water resources (NCWR) to meet the non-potable water supply demand (Qadir et al. 2007; Asano 2007; Lazarova 2013). In practice, NCWR such as reclaimed water, rainwater, stormwater, greywater and shallow groundwater (SGW) can be potentially used for toilet flushing, crops and landscaping irrigation and for many industrial uses (Silva and Naik 2010; Schuetze 2013; Oron et al. 2014; Campisano et al. 2017; Son et al. 2020; Pronk et al. 2021).

Strategies for encouraging the use of NCWR should consider the identification of resource availability, optimal uses and a correct socio-cultural awareness, especially among end-users, and improving cost-benefit ratio (Marks and Zadoroznyj 2005; Bixio et al. 2006; WRA 2009; Alcon et al. 2010; Fielding et al. 2019, Nemeroff et al. 2020).

Reaching the economic sustainability is an indispensable part of the process, making cost-benefit analysis (CBA) essential (Aulong et al. 2009; Bianchini and Hewage 2012; Redwood et al. 2014; Kihila et al. 2014; Kim et al. 2016; Rosasco et al. 2018, van Dijk et al. 2020; Arena et al. 2020). The financial benefits achievable adopting NCWR differ according to the perspective of the different involved actors. Local and federal government can reduce costs of infrastructure, construction, renovations and operation when freshwater demand decreases; another key issue is the reduction of the the volumes of waste waters to be treated, thanks to the lower amount of used waters delivered to the sewer systems. It also fundamental that end-users can save money in terms of their drinking water costs (Matos et al. 2015). Specific benefits can be gained from different NCWR, such as reclaimed water in agriculture that leads to fertilization reduction costs, by means of the reuse of nitrogen and/or phosphorus (WHO 2006; Kihila et al. 2014; Chen and Chen; 2014). Actually, the end-users may often be encouraged to use NCWR by incentives or constrained by regulations and policies (Gabe et al. 2012; Claus and Rousseau 2012; Molinos-Senante et al. 2011, 2013; Ab Rahman et al. 2013; Redwood et al. 2014, Kim et al. 2016; da Costa Pacheco et al. 2017).

In principle, the use of NCWR leads to environmental benefits not easily quantifiable and monetizable, but that can be estimated as ecosystem services, where natural resources are evaluated from an economic point of view (Costanza 2020; Knüppe and Pahl-Wostl 2011:

Zhang et al. 2022; Ekins 2003; Chenoweth et al. 2018; Lv et al. 2021). Some examples can be the reduction of pollution loads discharged in watercourses, the reduction of greenhouse emissions and lower operational costs, that can be accounted as an increase of the "natural capital" (Chenoweth et al. 2018), and the improvement of ecosystem services (Ekins 2003; Bichai et al. 2015). At a first glance, NCWR may be perceived as no added value (Hurlimann and Dolnicar 2016; Smith et al. 2018). However, environmental benefits - especially for future generations - can be considered as an intrinsic value of changing ways of using water resources. Estimating the value of shifting environmental ways must also consider society's willingness to pay for this change. This is an established concept for understanding the monetary value of a particular change and for assessing whether the society would be willing to pay for that change, if undertaken.

As an instrument to aid the shift towards a sustainable supply system not based only on freshwater, this study proposes a framework to evaluate the economic and environmental sustainability of implementing and operating infrastructures with NCWR, including an estimation of the delivered ecosystem services. The proposed framework has been applied to two case studies in Italy using SGW. These two case studies show how the purely economic evaluation, understood as investment and management costs compared with savings, does not allow for the full determination of the benefits obtained, which must also keep into account all the other environmental and social benefits.

2 Methodology

The application of CBA as a decision tool for adopting NCWR begins by identifying locally available resources and selecting the most suitable ones for each scenario. Economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Back Period (PBP) are used to assess the project financial viability and to help decision-makers.

Infrastructures for NCWR have the same main elements of a traditional supply system: collection, temporary storage, treatment and distribution. In particular, reclaimed water is collected directly from the treatment plant and reaches the end-user via a specific network, or simply through a water truck. On the contrary, greywater collection and distribution via a specific network and storage is not recommended, while treatment is required depending on the kind of end-use (Boano et al. 2020); so, this treatment can be filtration, membrane filtration or biofiltration (Kim et al. 2005; Liu et al. 2021). Moreover, rainwater is collected from roofs from impermeable surfaces in general including parking lots, although with a higher contamination risk in comparison with roofs. In both cases, a filter retains gross materials and a first flush device diverts the initial runoff with higher pollution concentration, further treatment may be required depending on the end-use (Jeffrey et al. 2022). Due to the stochastic nature of the rainfall process, an equalization storage tank should be included to function as a buffer storing water for periods where demand is higher than availability. SGW pumped from wells is roughly constant in time and requires a storage tank for operational reasons (Yuan et al. 2016).

When a specific distribution network for NCWR conveyance is present, the drinking water network must remain active to let the system work also in dry periods. The costs include pipelines and, if necessary, pumping system building, operation and maintenance.

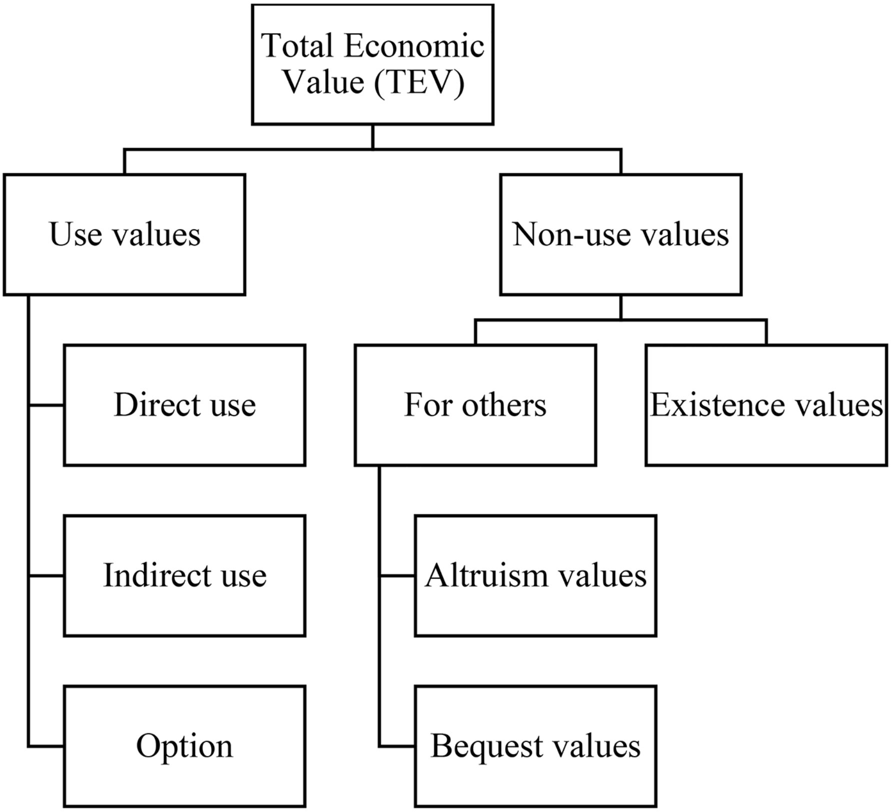

Fig. 1 - Total Economic Value (TEV) diagram (ISO, 2019)

2.1 Benefits Assessment

The TEV method (Total Economic Value), resumed in Fig. 1) can be used to estimate parametric benefits (Randall 1987; ISO 2019; Maechler and Graz 2020). This approach combines the evaluation of values related to the direct use of water resources (use values) and values not related to direct use (non-use values). When NCWR is used for toilet flushing or landscape irrigation, drinking water savings are considered as direct use for an end-user, whereas they are considered indirect for commercial, industrial, or public uses and treatment reduction costs. For both cases, the benefit economic value is easily obtained knowing the drinking water or treatment cost by cubic meter.

Uncertainty exists about the options for the future use of the water resource available for reuse, but not yet used. The evaluation of these options requires the definition of an evolution scenario of ecosystem services and water resources availability, their costs and total water needs by categories of use.

Non-use values include indirect benefits related to the general improvement of the environment and water ecosystems and are more complex to estimate. This improvement certainly has a direct impact on the water resources future availability and therefore an estimated value within the previously highlighted scenarios of the ecosystem services evolution, but also an indirect landscape / recreational value (Bianchini and Hewage 2012; Alcon et al. 2013).

2.1.1 Water Withdrawals Reduction

Use-values benefits from water withdrawals depend on the considered stakeholder. Water withdrawals costs are transferred from utilities providers to end-users and benefits on reduction directly come from the tariff, although consumption reduction reduces profits for the formers. Reducing withdrawals impacts the terms of future use options, both for water utilities and community, in terms of greater resilience of the water supply system before the possible reduction of current water availability. Considering a scenario with 2-8% reduction on precipitation in Italy for the last 50 years (Brunetti et al. 2006), this benefit can be evaluated on average and is precautionarily equal to 10% of the current use value.

2.1.2 Energy Reduction from Pumping Stations

Withdrawals reduction also entails the corresponding reduction of required energy. The benefit is primarily economic and can be assessed parametrically, considering the average energy cost for pumping. Moreover, the reduction of energy consumption is associated with an environmental benefit, mainly in terms of greenhouse gases emissions reduction, although quite complex to estimate. One possibility is to refer to the higher cost of energy from "green" sources compared to the one from traditional sources, as an index of the choice value in favour of the environment. All over the world, the cost of producing energy from "green" sources has steadily decreased in recent years, with a growing reduction in the cost gap compared to traditional sources. Nowadays, a reasonable estimation of the cost percentage gap can be about 10%. So, the overall benefit, including the environmental benefit, can therefore be estimated at 110% of the direct economic benefit (energy saving).

2.1.3 Treatment Costs Reduction

NCWR (such as SGW, rainwater and stormwater discharged directly into the CSS) represents an additional and sometimes substantial component in the Wastewater Treatment Plant (WWTP). The benefit deriving from their reuse can be evaluated as savings on treatment costs, so the parametric evaluation of this benefit derives directly from the average treatment costs.

2.1.4 Lower Hydraulic risk for Urban Drainage Networks

In general, SGW volumes drained by the sewer system increase the flood risk, because they permanently fills part of the conduit, reducing its conveyance capacity during storm events. By using SGW, it is possible to restore the hydraulic risk defined during the design phase of the sewer network, when SGW where not considered. The relative benefit can be assessed by considering the cost saving related to avoiding the adaptation of that sewer network.

2.1.5 Withdrawals Reduction from Surface Water Bodies

NCWR can be introduced directly into systems by dedicated canals or pipelines, such as irrigation networks or industrial aqueducts, or into systems that can be used for other kinds of withdrawals, including drinking. In the first case, the benefit is mainly associated with the increase in water availability and therefore in obtainable production (use value). The evaluation of this benefit thus derives from the economic value (added value) of the goods produced per m^3 of water used. In Italy, for example, this water value is on average equal to about 2 EUR/m^3 in the agricultural sector and to 100 EUR/m^3 in the industrial sector (ISTAT 2022).

In the second case, the benefit is still linked to the increased water availability, but this must be evaluated considering the priorities established by local laws and regulations. Also the "non-use values" have to be included. The latter can be assessed considering to the willingness of the consumer to pay more for the water service in exchange for interventions to improve the environmental quality of water resources. Being the average annual expenses of an Italian family for the water utilities about 400 EUR, such a willingness is conservatively estimated in terms of 10% higher costs.

2.1.6 Improving the Quality of Natural Water Systems

The environmental benefit of NCWR consists essentially in reducing the discharge into surface water bodies. Of course, discharges are higher in strongly anthropized watercourses, and this allows on one hand to more easily reach the minimum ecological outflows even during drought periods. On the other hand, it allows the dilution of pollutants of urban, industrial and agricultural origin, thanks to the general better quality of groundwater (Brewer 2008). Reducing discharge in the combined sewer system (CSS) impacts on the overflows and by-pass activation and consequently polluting loads on watercourses and improves the WWTP purification processes. The economic value of both these benefits is once again associated with "non-use values" and therefore complex to be assessed. It seems reasonable to refer to 10% of the cost of water distributed by the water utilities.

2.1.7 Impact Analysis

The impacts related to NCWR include the diversification of the type of water used to meet different water needs, highlighting the value of the water distributed by the aqueduct and suggesting the need to use it wisely and not to waste it (Manasvini et al. 2018). This diversification shows that water resources in general, and valuable water resources used for drinking purposes in particular, must be protected as they are vulnerable and limited. Anyway, an improved awareness of stakeholders about the different types of NCWR can become a strategic element for spreading a greater environmental sensitivity also in wider sections of the population.

3 Case Studies

The proposed framework for NCWR CBA analysis has been applied to two case studies in Milano, Italy. For both cases the chosen NCWR has been SGW, a resource with a volumetric availability considered infinite due to the alpine and subalpine areas contribution and subject to small extend extraction, normally done through wells subordinate to concessions and therefore with a known flow rate. Furthermore, in recent years there has been a decrease in these extractions with a consequent growth in the resource availability (Gattinoni and Scesi 2017). The presence of an aquifer with a water table close to the ground surface, indeed, demands a constant pumping to protect underground lines stations and underground floors of the surrounding buildings from flooding, discharging continously into the CSS. In both cases, chemical-physical analysis meets local regulations for non-potable uses.

The case studies have been chosen to implement the interventions in a stable and highly dense urban context, being the possibility of using existent infrastructures an enhancement to use the project as a best practices example. Based on these criteria, two case studies have been considered, one in the Rho municipality, which is a medium-density, predominantly residential urban context, and the other in Milan, which is a high density, mainly residential and commercial urban context characterized by large public spaces.

Three benefit scenarios have been considered: B1 considers the total economic value (TEV), B2 uses just the values and B3 only use values from drinking water savings (water tariff). The considered costs are from pumping SGW and conveying through a non-potable distribution network.

The benefits associated with the reuse of SGW in the two case studies are mainly the following: reduction of water withdrawals from deep aquifers, reduction of energy used for pumping, reduction of treatment costs, reduction of hydraulic risk for urban drainage networks, reduction of withdrawals from surface water bodies, improvement of the quality of natural water systems. The benefit of the hydraulic risk reduction for urban drainage networks has not been considered.

The average costs associated with deep aquifers pumping are about 0.025 EUR/m^3 for both case studies, considering the prevalence of three atmospheres (30 m of piezometric height), 70% average pumping efficiency and energy required equal to 0.12 kWh / m^3.

Since SGW also requires pumping to reach surface, this cost should be deducted from the economic benefits related to energy saving. In unit terms, this cost is lower due to the lower withdrawal depth. Furthermore, this cost is already borne by the operator of the pumping or geothermal installations. Thus, from a collective benefit perspective, this cost may not be considered as a deduction in the calculation of benefits.

Treatment costs are equal to 0.58 EUR/m^3 in the case of Rho and 0.35 EUR/m^3 in the case of Milan. Both in case study 1 (Rho) and in case study 2 (Milan) deep artesian aquifers are the main source of drinking water, requiring pumping systems with medium-high prevalence.

3.1 Rho case Study

The city of Rho (45°32′N 9°02′E) is located north of Milano and has a population of about 50,000 inhabitants with a density of about 2,230 inhabitants/km^2. Due to the local high-water table, seven wells have been identified (A-G, a map is available on SI) pumping water to protect underground levels from flooding, discharging directly into the CSS increasing CSO discharges into the Olona river. The project has proposed to implement a new underground open-channel network to discharge SGW that can be used for non-potable uses. Small pressure networks would serve end-users, fed by storage tanks connected to the open-channel network. The network would discharge the excess SGW downstream into an existing network used for agricultural irrigation purposes. The well A is the only one with a known flow rate, therefore the Rho case study has considered two scenarios: Rho-Scenario 1 considers that the existing wells from A to G could supply the requested non-potable uses, while Rho-Scenario 2 considers only well A with users downstream. The pumping system A (serving a municipal underground car park and a local Civic Theatre's geothermal plant) discharges approximately 110 l/s to the CSS.

First, defining benefits scenarios implies defining main stakeholders: for the CBA analysis of this study, the main stakeholder is the utilities management agency. But the indirect use considers another stakeholder, that is the end-user and water utilities provider, while non-use values consider benefits for the entire community.

3.1.1 Potential SGW uses

The supply volume has been estimated considering water consumption per year. A total of 34 schools have been identified in the area with an average annual total water consumption of 95,650 m^3 (average turnover value between 2017 and 2019). The Italian standard UNI-11,445 (regulating systems for the collection and use of rainwater for uses other than human consumption) has been used as a reference to estimate the consumption for school toilet flushing, leading to a value of 20 l/day. The estimation considered three schools and the number of students enrolled for the school year 2020/2021, increased by 10% to take into account also the school staff. A total of 205 school days per year have been considered and the water consumption for toilet flushing has been estimated and compared with the total annual consumption for three schools with toilet flushing, representing from 37 to 72% of annual consumption. The water consumption from the school year 2020–2021 has not been considered due to the pandemic that brought to closing the schools for some months.

An estimate of 50% of total annual consumption has been considered as non-potable use for toilet flushing. An average annual water consumption for toilet flushing for the 34 schools has been estimated to be approximately equal to 47,825 m^3, with an average value of 1,406 m^3 and a median value of 969 m^3.

As for irrigation water consumption, data supplied by the water utilities company suggest that 85 end-users are irrigation users with a total annual consumption of 124,139 m^3 (average value in the years 2017–2019). In particular, 76 of those users have an annual consumption of less than 500 m^3, while only 9 have a consumption of more than 1,000 m^3/year. A relevant case is the one of sport centre with a soccer field, which has a consumption of almost 98,000 m^3/year (average in the years 2017–2018), corresponding to approximately 79% of the total irrigation consumption of the 85 users. SI gathers a list with the water consumption by user.

3.1.2 Cost Analysis

The open-channel network connecting all the ten wells represented by letters A to J has a length of approximately 5 km. A network with roughly 3.5 km will convey waters coming from wells from A to F. Other four independent channels will convey waters coming from wells G, H, I, J, each with lengths of less than 1 km. The parametric cost expected for the construction of these channels is estimated in 250 EUR/m with a total cost of 1,159,500,00 EUR for Rho-Scenario 2 and 302,500 EUR for Rho-Scenario 1. For Rho-Scenario 1, the project includes channels N1-F (Length = 988 m) and A-N1 (Length = 222 m), discharging the excess pumped water from well A. Lengths and costs information from the open channels are reported on Table 1 – SI.

To estimate the costs of the pressure pipeline networks a flow rate of 1.5 l/s for flushing each WC has been considered. In each school, the presence of 1 toilet per 20 students and a simultaneous use coefficient of 1/4 have been considered. Assuming that, in the planned pressure network, each pipe serves a maximum of two schools for which 800 is the estimated overall average number of pupils and staff, the maximum flow rate required is in the order of 15 l/s.

To estimate the flow rates required for irrigation, it is considered that the irrigation of gardens and green areas normally takes place according to a fix pre-scheduled temporal sequence. In particular, in the case of large areas like the soccer field, irrigation takes place section after section. Considering sprinklers with a discharge of about 0.25 l/s, capable of covering an area of about 50 m^2, the discharge of 15 l/s previously identified for sanitary needs is sufficient to cover the requests of an area of about 3,000 m^2, which is a safe-side estimation of the area served by each pipe. In addition, irrigation is normally carried out in the evening, not overlapping with the hours of school activity and insulation. A maximum flow rate of 15 l/s can therefore be considered a precautionary value for the sizing of the pressure networks in the Rho case study. A diameter of 150 mm, corresponding to a flow velocity of about 0.85 m/s, appears adequate.

Nine distribution networks (RP1-RP9) with pressure pipelines near the open-flow channel sand wells would distribute water to the end-user. For the Scenario 1 only networks RP6 and RP8 have been considered.

Using the parametric costs of 358 EUR/m for a 150 mm diameter, and applying the other parametric costs shown in the previous paragraphs, the initial and maintenance costs for the Rho-Scenario 1 are 116,000 EUR and 6,000 EUR/year respectively and for Rho-Scenario 969,000 EUR and 54,200 EUR/year. Costs do not include interventions within the buildings using the SGW but only the municipal network that functions as a non-potable water supply system. Details on the pressure networks costs can be found on Table 2.

For the open flow channels, operational costs represent periodic maintenance costs, whereas the energy costs for the pumping and maintenance of the pressure distribution networks has been considered as 10% of the initial cost per year.

3.1.3 Benefits Assessments

Estimations are performed only for the three most significant benefits and from an economic point of view, i.e. those relating to the reduction in supply and energy costs due to extractions from deep aquifers for drinking purposes and those relating to the reduction in treatment costs.

The use of NCWR is expected to reduce the consumption of drinking water by about 139,000 m^3/year. Considering a tariff of 1.00 EUR/m^3, which is quite low in comparison to most of the other European Countries, this reduction corresponds to saving 139,000 EUR/year (Ferasso et al. 2021).

The indirect benefits related to the reduction in high-quality water use from deep aquifers are estimated as 10% of the current use value, resulting in an additional benefit of 14,000 EUR/year.

Considering an energy cost for pumping water from the deep aquifer of 0.05 EUR/m^3, the energy savings are approximately 7,000 EUR/year. To this, an additional 10% for indirect environmental benefit must be added, equal to 700 EUR/year.

Considering a treatment cost of 0.58 EUR/m^3, the reuse of SGW corresponding to about 3,153,600 m^3/year will amount to approximately 1,639,872 EUR/year savings. The possible future reuse of water from other pumping systems would allow this feature to be significantly increased. This benefit has been considered solely for the well A, since the flow rate is unknown for the remaining wells.

3.2 Milan case Study

The area chosen for the case study in Milan (45°27′40.68″N 9°09′34.20″E) includes two university campuses and several residential buildings. The pumping system from the underground station of Piola discharges continuously 52.8 l/s in the CSS.

3.2.1 Potential SGW uses

The project proposes to redirect these SGW pumped towards an ancient underground channel, which is part of a broader network of underground open-flow channels functioning (like in the Rho case) as a distribution system for non-potable water. In a first phase, this channel would supply for the irrigation in the nearby squares and non-potable uses for both the Leonardo Campus of Politecnico di Milano and an elementary school in the area. In the future, other users could connect to this network. The requirement for the irrigation use is estimated about 5 l/day/m^2 in the vegetative period. The non-potable uses can be estimated as 50% of the total consumption for both the Politecnico di Milano and the elementary school. The total consumption invoiced between 2019 and 2020 is equal to 89,514 m^3, considering non-potable use (78,203 m^3) irrigation (11,311 m^3).

3.2.2 Cost Analysis

Part of the pumped water will directly feed the irrigation system for the closest square to the pumping station through an under-pressure derivation, without the need for reservoirs and other pumps. The SGW not used directly will be conveyed by the same pipe into a currently unused channel. Unlike the water supply network, this free surface channel can only be used as a transport infrastructure requiring a pressure distribution system to supply the users.

The costs are related to building the tank, the pumping system and the distribution network. For the tank, a volume of 4 m^3 is considered appropriate, with a cost of approximately

Table 1 – Initial, operation and benefits for interventions at Rho and Milano

	Unit	Rho	Rho - phase 1	Milano
Initial Cost	EUR	-2'128'500	-418'500	-505'000
Operational costs	EUR/year	-160'625	-26'925	-43'153
B1	EUR/year	2'072'411	2'012'455	664'903
B2	EUR/year	1'877'650	1'829'456	601'405
B3	EUR/year	115'625	877	46'694

B1: total economic value (use and non-use values)
B2: indirect use values
B3: indirect use values: only drinking water savings

10,000 EUR. The cost of the pumps, considering a total power of 12 kW and a parametric cost of 4,000 EUR/kW, is approximately 48,000 EUR. The cost of an autoclave of about 4 m^3, equal to about 8,000 EUR, is also added.

Considering a diameter of 200 mm, the cost of the pressure distribution network, which is about 1 km long, is estimated to be around 435,000 EUR, with a total plant cost of around 500,000 EUR.

As for operating costs, considering an energy cost of approximately 0.5 EUR/kWh and a pump head of 30 m, the energy cost to pump approximately 90,000 m^3/year is approximately 5,250 EUR/year. Considering also the other operating costs, estimated at about 5% of the mentioned amount per year of the plant costs, the total is about 30,000 EUR/year.

3.2.3 Benefits Assessments

The use of NCWR of non-potable water for toilet flushing and irrigation purposes will reduce the consumption of drinking water by about 90,000 m^3/year. This reduction, considering the declared tariff of approximately 0.77 EUR/m^3, corresponds to saving 69,300 EUR/year.

The indirect benefits related to the reduction of high-quality water withdrawals from deep aquifers are estimated as 10% of the current value in use, so an additional benefit of about 7,000 EUR/year can be added.

Considering an energy cost associated with pumping water from the deep aquifer used by the water supply network of 0.05 EUR/m^3, the reduction in drinking water consumption corresponds to energy savings of approximately 4,500 EUR/year. An additional 10% for indirect environmental benefit, equal to another 450 EUR/year, is added to this benefit.

3.3 Cost-benefit Analysis

The economic indicators used for CBA analysis have been estimated with the cost and benefits obtained, a discount rate of 2%, normally used for public developments, and a 50-year life use. The major benefit is represented by the indirect values (Scenario B2), coming mainly from water treatment costs. SGW discharges into CSS are conveyed to the WWTP with costs, considered indirect costs for end-users. For both cases, avoiding the SGW discharge into the CSS provides significant economic benefits, justifying the financing by the local utilities managing Agency. The benefits achievable solely from water tariffs (Scenario B3) are substantially smaller (Table 1; Fig. 2).

While the economic indicators show the abundant positive cost-benefit analysis in scenario B1 for both cases, when shifting to scenario B3 with only end-user savings on drink-

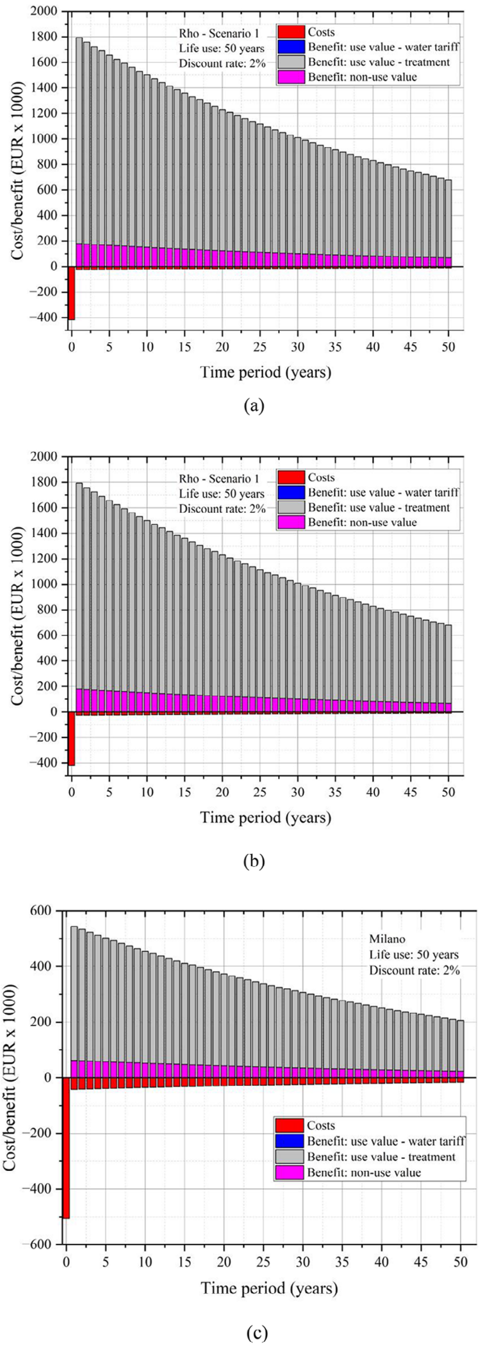

Fig. 2 Cost and benefit considering different stakeholders. a – Rho – scenario 1, b – Rho – scenario 2, c – Milan.

ing water then the NCWR becomes economically unsustainable with PBP abundantly above the life use for the Milan case and actual operational costs higher than benefits for Rho case (Table 2). The main motivation for this project is to avoid SGW discharge on the CSS, that is considered an indirect use value.

4 Conclusion

Protecting water resources is a fundamental factor towards resilient cities referred to SDG's 6, 11 and 14 (ONU Agenda 2030). Supply system strategies should focus on optimizing water use and reducing potable water use for non-potable needs. Encouraging the use of non-conventional water resources (NCWR) can help to meet this goal with other benefits, as for example reducing water discharge into the sewer system, with consequent benefits in terms of flood risk reduction, overflow volume and frequency reduction, and improvement in the efficiency of the waste water treatment plants. To disseminate the use of NCWR, a careful CBA considering all the involved stakeholders (including local population) becomes an essential tool for decision makers and especially for public policies developers that intend to consolidate these practices. The first step is to identify local NCWR availability,constraints and possible uses. Then it must be carried out an objective CBA considering different scenarios. While estimating costs can be straightforward and mostly dependent on local prices, the benefits estimation is more complicated. To do this, the TEV criteria allow to define benefits scenarios for use and non-use values that can range from the benefits for direct use value, represented by the end-user potable water saving costs, to community benefits that can be achieved protecting water resources. As shown with the CBA carried out for both the case studies presented in this research, this broad analysis is fundamental. The key point, that has come out from both the case studies, is that CBA results, when considering only direct use-value, could lead to the decision of not using the NCWR, mostly driven for the low local potable water costs, while a broader analysis including all the actual benefits has been abundantly positive. This feature can be used to support local incentive public policies and subsidies for NCWR use transferring part of the financial incentives to the end-users, to encourage the NCWR implementation which will provide large benefits to the whole community.

Table 2 – Cost Benefits Analysis (CBA)

	Rho-Scenario1			Rho – Scenario2			Milano		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
NPV (EUR)	5,794,669	5,182,662	-354,257	6,197,401	5,622,353	-123,702	19,032,620	17,037,306	-39,372
PBP (Years)	2	2	NA	1	1	NA	1	1	> 50
IRR	90	81	NA	474	431	NA	123	111	< 0

B1: total economic value
B2: direct and indirect use values
B3: direct use values
NA: not applicable
Discount rate: 2%

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Declarations

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