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# Environmental Benefits and Economical Sustainability of Urban Wastewater Reuse for Irrigation—A Cost-Benefit Analysis of an Existing Reuse Project in Puglia, Italy

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**Abstract:** Besides benefits associated to increased water availability for irrigation, reuse projects of urban water can also provide positive environmental impacts, as they contribute to improve water quality of the receiving bodies by diverting wastewater from their outlet. This represents a typical win-win situation where significant synergies can be achieved between urban and agricultural sector, and the environment. These favorable conditions, however, do not necessarily imply that water reuse is either feasible from an economic perspective nor that the underlying supply chain is going to be triggered, if certain conditions are not met. Cost-Benefit Analysis (CBA) is considered a sound, theoretically well-grounded tool to analyze the financial and economical sustainability of an investment. The paper presents the CBA of an existing reuse scheme in Puglia, in southern Italy, reclaiming wastewater for irrigation from a coastal area with growing recreational, beach-related activities. Supported by operational data, official statistics and sector documents, the CBA reveals that in almost all scenarios the existence of environmental benefits must be invoked in order to consider the project economically sustainable. Coherent screening of the different impacts, isolating the ones that are applicable to the specific case-study, shows that these benefits are mainly non-use benefits related to the aesthetic enjoyment of clean water in the reclaimed stretch of coastline where wastewater discharge may no longer take place or take place in a way that significantly reduce seawater pollution.

**Keywords:** wastewater reuse; cost-benefit analysis; environmental benefits; recreational benefits; coastal area

## 1. Introduction

Water reuse is a growing practice worldwide, especially where scarcity issues concretely limit the development of economic activities such as agriculture and manufacturing. Beside long-term improvements of the water supply-demand balance, water reuse also allows avoiding treated wastewater discharge in water bodies, thus providing an alternative to other investments aimed at protecting water quality of sea, rivers and lakes.

In the first decade of this century most of the research work in this field has focused on issues such as the hazards associated to the practice of reuse [1,2] and its social acceptability [3,4]. This body of work has brought to the definition of standards and assessment of risks of wastewater reuse that have eventually been used in current national legislation. Much less effort has been spent on the economic analysis of this type of plants: in fact, compared to ordinary secondary treatment, wastewater reuse

also entails additional investment and operation costs that must exceed or, at least, be comparable to the benefits from using reclaimed water.

In defining a general least-cost model for a regional supply system that includes wastewater reuse as additional source, Spulberg and Sabbaghi [5] observe that first-order equilibrium conditions imply that marginal cost be the same across the different types of supply sources, including reuse. They thereby provide grounds for suggesting that water reuse should be developed only where the marginal cost of conventional resources is itself high, as is common in arid or semiarid areas. In the same least-cost analysis vein, Hochstrat et al. [6] analyze the financial sustainability of reuse projects under given scenarios of water pricing by developing least-cost analyses of reuse alternatives.

In a broader context, where environmental impacts are considered in addition to implications for water supply, the analysis must be broadened as to encompass benefits from the project. Some authors suggest that wastewater treatment can be seen as a production process that gives rise to both a desirable output (clean water) and to a series of pollutants (i.e., organic matter, phosphorus, etc.) [7,8], so that avoiding uncontrolled disposal of these pollutants can produce environmental benefits that can increase the financial sustainability of water reuse plans [9]. More in general, if viewed from the standpoint of the environment and not only of water supply, water reuse can produce additional benefits, compared to those deriving from wastewater treatment, that go beyond the mere increase of water availability and that can contribute to the economical sustainability of the project.

The idea of benefits implies, however, the existence of a certain demand level for the services that reuse can provide and some connection with their value. The supply—demand concept is particularly relevant in the evaluation of reuse projects and makes them an ideal application field of cost—benefit analysis (hereafter CBA), so that CBA is now recognized as the most suitable appraisal tool of reuse projects [10,11], although the literature on CBAs of actually planned or specific, existing reuse plants is rather sparse. Among the few examples, a CBA for centralized wastewater reuse in Beijing [12] a reuse plant in Italy [13], a reuse scheme in Israel [14] and the examples contained in guidelines [10,11].

A feature of reuse projects is that most benefits are both site and context—specific: if, for instance, local legislation prescribes low levels of nutrients concentration, the benefits of avoided fertilizer cost is not likely to occur. On the other hand, costs related to permanent health risks are considered unacceptable in developed countries so that they do not need to be accounted for in a classic, deterministic framework. Finally, although environmental benefits are often invoked in the literature as a component of the overall benefits from reuse, they are seldom quantified.

In studying the potential for water reuse in wide areas, many authors point out the need to integrate region-wide economic modelling and assessment with the knowledge of the specific technologies, and of their costs. For instance, in studying the economical sustainability using a large input-output model, Lopez-Morales and Rodríguez-Tapia [15] observe that the extent to which outputs from economic models can support the design of a strategy for water sustainability with empirical relevance depends on accurate representations of treatment technologies and conveyance infrastructure. Overall, there emerges the need for an in-depth, plant-scale analysis [16] to understand the opportunities that each different reuse scheme can offer. At a regional scale, the possibility to increase the general welfare through wastewater reuse seems to stem from the aggregation of individual, well thought-out, site-specific opportunities that must be carefully gauged under the different aspects of technical feasibility, financial and economical sustainability, and complexity of the supply chain.

All these are hot issues since the opportunities of concretely developing reuse projects ultimately relies on the possibility to increase overall social welfare through the plants. If social welfare is actually increased, then forms of compensations/incentives/subsidies may be devised to support the plants, otherwise they will be doomed to failure. The paper hence aims at contributing to close this gap and support the developing practice of CBA of specific reuse projects by providing a CBA of an existing reuse scheme, located in Puglia, in southern Italy. The plant can be considered paradigmatic of a whole class of urban wastewater reuse facilities that are planned to be connected to irrigation throughout the region [17]. The work provides a somewhat novel contribution to the practice of CBA on water

reuse from at least two standpoints: in the first place, it attempts to analyze and quantify the different claimed benefits of this type of projects by considering the multi-sectorial spectrum of impacts that range from agriculture to recreation, including possible implications on municipal water supply. In the second place, while CBA analysis is typically an *ex-ante* exercise, as its aim is to direct decision-making on future investments through a preliminary assessment of costs and benefits, this work is closer to an *ex-post* CBA. *Ex-post* CBAs are used in policy assessment to understand the real costs of the investment and if the expected benefits have materialized: in this study, starting from an existing reuse plant and from the observed investment and operational parameters, our evaluation exercise seeks to establish under which conditions the project is sustainable. This, in turn, will allow understanding the gaps to be closed for future planning for similar investments. At a more general level, the paper attempts to establish a methodological path to shape other CBAs on similar schemes, to identify the types and sources of information needed for the analysis and to reduce uncertainties.

## 2. Materials and Methods

### 2.1. Cost-Benefit Analysis

CBA is to be regarded as a partial or general equilibrium exercise [18] where the ability of a project or of a policy to increase general welfare is analyzed with reference to a contra-factual situation characterized by the existing equilibrium between supply and demand of a certain good or service. The policy or project shifts the equilibrium by increasing supply or reducing demand and can thus enhance welfare. Analysis of supply and demand is hence understandably a fundamental step of CBA. Impacts are all expressed in monetary terms either as costs (negative impacts) or as benefits (positive impacts). As the impacts of the project are likely to last  $n$  years, it is necessary to homogenize the flow of net benefits (benefits less costs). This is achieved through the discount factor  $(1 + i)^{-t}$ . Overall, results of the analysis can be condensed in two indicators, net present value (NPV) and internal rate of return (IRR):

$$NPV = \sum_{t=0}^n \frac{B_t - C_t}{(1 + i)^t} \quad (1)$$

$$0 = \sum_{t=0}^n \frac{B_t - C_t}{(1 + i)^t} \quad (2)$$

In Equations (1) and (2) the definition of  $B_t$  and  $C_t$  varies according to the type of analysis (financial or economic) that is being performed. In financial analysis,  $C_t$  are investment, operation and replacement costs borne to run the project in year  $t$  and  $B_t$  are revenues directly paid by users in year  $t$  for the goods or services provided by project's operation.  $B_t$  also include the residual value of the investment at the end of the period of analysis ( $t = n$ ).

In the economic analysis, the scope is broadened to society as a whole and includes indirect or external impacts, i.e., effects of the project not directly captured by charges paid by users. In the economic analysis, all inputs and outputs should be assessed at their shadow price, whence the need to use conversion factors (CF's) and shadow wages, whereas external impacts are to be inferred by eliciting stakeholders' willingness to pay. Therefore, the economic analysis is developed starting from the financial one. In addition, in the financial analysis, "i" is the discount rate, reflecting the opportunity cost of money, while in economic analysis "i" represents the social discount rate (e.g., [19]).

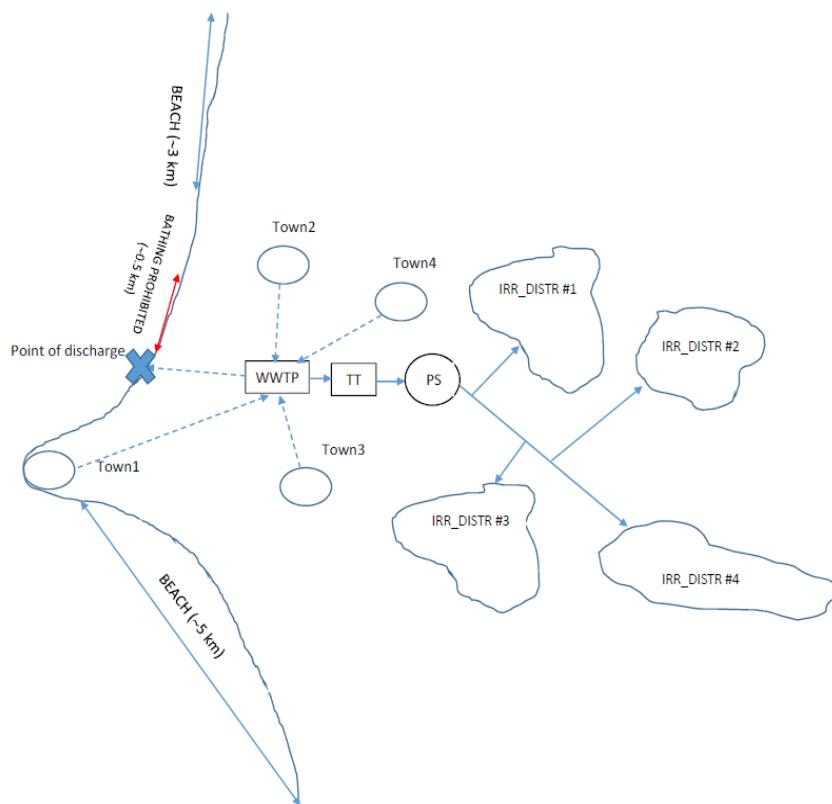
The methodological path indicated by the EU guide to CBA of investments [19] includes seven steps: (i) Description of the context, (ii) definition of objectives, (iii) project identification, (iv), technical feasibility (demand analysis and option analysis), (v) Financial analysis, (vi) Economic analysis, (vii) Risk assessment (sensitivity analysis). In this paper, for concision's sake and for reasons that will become apparent further on, we shall focus on points (i), (ii)–(iv) and (vi). Financial analysis is skipped as it is self-evident that reuse for irrigation is not sustainable financially and risk assessment has been carried out considering different scenarios focusing on the occurrence of some class of impacts.

## 2.2. Materials

Certified investment costs from project construction, re-evaluated as of end of 2019, were used to carry out the analysis, as well as Operation and Maintenance (O&M) costs from operation of the reuse scheme in the first years of operation, provided by the utility managing the plant. For the analysis of demand, data from a number of different site-specific statistics, studies and reports on the sectors affected by the project (agriculture, tourism and municipal water service) were used. Assessment of benefits other than external ones is based on computations based on models, while the analysis of environmental benefits takes advantage of a literature review, although, as will be seen, in the development of the analysis this literature has been used to benchmark the level of external (environmental) benefits that would make the project economically sustainable.

## 3. The Case Study: The Gallipoli Wastewater Treatment Plant

The case study is illustrated in Figure 1. The Gallipoli wastewater plant (WWTP) is a secondary treatment plant that treats wastewater of four municipalities (indicated as town 1, town 2 . . . town 4 in Figure 1), having overall a population ranging from 37,000 in winter to averagely over 70,000 in August. In 2010 the plant was upgraded with a scheme for water reuse, denoted as “the project” hereafter, consisting of a tertiary treatment module (TT) and of a facility that includes a pumping station (PS) and a pipeline. The TT is needed to bring water to the quality standards prescribed by the Italian legislation on reuse (Decree 185/2003 of the Ministry of Environment) while the PS with the pipeline is necessary to convey water to four irrigation districts of a nearby reclamation consortium for irrigation by farmers. Thus, the TT with the pumping station and the treated water transportation pipeline constitute the self-sufficient unit of analysis, subject to CBA.



**Figure 1.** Schematic of the study area.

### 3.1. Description of the Context: The Institutional Framework

The regional administration of Puglia (also termed the Region hereafter) is the body in charge to plan the investments to implement the European Water Framework Directive 60/2000 (WFD in the following) in the region. The water planning instrument of the Region is the Water Protection Plan (Piano di Tutela delle Acque—PTA) that is draft according to national guidelines adopting the WFD.

With a regional act (27/08), the Region has included tertiary wastewater treatment within the domain of municipal water service (supply, sewerage and wastewater treatment) “where necessary to achieve the quality objectives of the PTA”. This implies that co-financing of investments, as well as operation costs of water reuse, are now charged together with municipal water service. There is a single tariff structure valid for all Apulian municipalities: the tariff is collected by AQP, the regional water company, as reward for managing municipal water service throughout the region. As a consequence, the cost of reuse is charged to all customers in the region. Favorable institutional conditions for water reuse investments are also provided by national legislation on reuse, prescribing that reclaimed urban wastewater be supplied to final users at no additional cost for them. In order to foster the implementation of reuse throughout the region, in 2012 the Region has prepared ad hoc technical specifications requiring that an analysis be performed on the reuse projects included in the master plan prior to implementation, showing their technical—economic feasibility.

### 3.2. Description of the Context: Organisation and Characteristics of Water Services in Puglia

Puglia is a water-scarce region with limited surface water. Most of the local water resources consist of groundwater, as a good portion of the region sits over a karstic aquifer. For this reason, at the beginning of the twentieth century, a large open-channel aqueduct was built (now called Canale Principale—the Main Canal), to convey spring water located in the neighboring region of Campania to all Apulian municipalities. Together with this infrastructure, a national body (Acquedotto Pugliese, AQP) was created to implement the development of municipal water service in the region. In more recent years, the main canal has been sided by other water supply schemes, all supplied by extra-regional, multipurpose surface resources. AQP is now a region-owned joint-stock company that also provides sanitation services (sewerage and wastewater treatment) to all Apulian municipalities. As far as irrigation is concerned, service is entitled to six reclamation consortia that are now regional bodies in charge to operate resources and distribution networks.

Presently, the water balance for municipal use sees most of the water withdrawn from surface water resources, including springs (~460 Mm<sup>3</sup>/year) and 60 Mm<sup>3</sup> from wells, 50 Mm<sup>3</sup> of which in Salento, the peninsula forming the heel of the Italian boot, where Gallipoli is located. Water losses in distribution networks are still around 40%, but have decreased and are bound to decrease further in the next years, thanks to investments on urban distribution networks. In the Salento area, where the case study is located, irrigation water comes almost exclusively from groundwater, as networks are not yet connected to the interregional reservoir schemes.

### 3.3. Description of the Context: Socio—Economic Information

Gallipoli is a municipality of around 20,000 inhabitants in the province of Lecce. In 2016, the average household income in Gallipoli was 23,775 € [20]. More socio-economical information for the area is available only at the more aggregated scale of the Lecce province and of the Region as a whole: in the province, agriculture covers around 3.5% of the value added, with decreasing perspectives, while touristic activities make up in the whole region around 13.6% of the value added. These last figures are certainly magnified in the case of the Gallipoli area, where tourism is likely to make up a greater part of the municipality’s value added. According to the last census of agriculture [21] farms have an average area of 2.3 ha, are for the most part (99.3%) run by individuals and their average standard output (6222 €/farm) is the lowest among the 110 Italian provinces ([21], p. 109).

North and South of town there are beaches with good economical perspectives, so that there is now a growing attention towards environmental values and beaches are viewed as important assets to protect against pollution. The WWTP discharges near the town, in a stretch of coast, approximately 500 m long, that is partly rocky and where bathing is currently prohibited, due to the risk of microbiological pollution of the effluent. Gallipoli's coastal area is a site of community importance (SCI). The area included in the SCI (92/43/EEC) is however south of the WWTP outflow and is not affected by it: the monograph on this SCI does not mention sea pollution as one of the vulnerability factors for this site.

### 3.4. Identification of the Project: Objectives

The project was set out by Gallipoli's municipality and its object is to convey reclaimed water to some irrigation districts operated by the local irrigation consortium. By doing this, the project is intended to reduce pressure on the aquifer by substituting the groundwater resources presently used by the consortium for irrigation with reclaimed water.

### 3.5. Identification of the Project: Technical Description of the Project, Investment Costs and O&M Costs

Currently, the Gallipoli secondary wastewater treatment plant is designed to treat 79,000 PE. The tertiary treatment consists of clariflocculation, filtration and disinfection by UV-rays. The total treatment capacity is 500 m<sup>3</sup>/h, shared between two modules of 250 m<sup>3</sup>/h each. The pumping station consists of two pumps in parallel plus one reserve, to convey a maximum flow of 0.14 m<sup>3</sup>/s of reclaimed water from a tank downstream the outlet of the plant to the highest delivery point, with an overall gross head of 47 m, through a 1230 m long, Φ 350 HDPE pipeline.

Information on investment costs is reported in Table 1. Conversion factors have been applied to account for the shadow prices of inputs (labor, energy, materials) that need to be considered to determine the economic investment costs when performing the socio-economic cost-benefit analysis of the project [19].

**Table 1.** Investment costs of the Gallipoli tertiary treatment plant and estimated Conversion Factors (CF) for the economic analysis.

Item	Cost (2019 €) *	Incidence (%)	CF	Notes on CF Assessment
Feasibility study, design, project management etc.	520,189	18%	1.00	100% Skilled labor (CF = 1)
Yard Labour	303,252	11%	0.61	10% skilled labor + 90% unskilled labor. Shadow wage for unskilled labor = FW (1 - u) (1 - t); FW: financial wage, u = male unemployment rate in the Lecce province (16.0% average 2005–2019); t = rate of the social security and relevant taxes (0.32)
Materials (Civil works)	689,794	24%	0.82	EU Guide to cost-benefit analysis of investment projects, 2008 p. 175
Rental + transports	95,623	3%	0.68	EU Guide to cost-benefit analysis of investment projects, 2008 p. 176
Electro-mechanical components and equipment	1,221,544	43%	0.85	EU Guide to cost-benefit analysis of investment projects, 2008 p. 177
Total/Average	2,830,403	100%	0.839	

\* Source: re-evaluated (2019) project costs.

The system is presently devoid of a suitable storage capacity such as a tank to store reclaimed water during the night, when the consortium provides no irrigation service. The tank can have two

roles: (i) increase the degree of utilization of reclaimed water for irrigation, (ii) allow permanent diversion of wastewater discharge into the sea.

Although the built project does not presently include any such tank, for the sake of completeness we deem useful to include in the CBA a scenario where a tank is in place. Sizing of this tank can be performed assuming a peak flow equal to plant's treatment capacity ( $500 \text{ m}^3/\text{h}$ ), so that tank capacity necessary to store water for 11 h (from 8 PM to 7 AM) is  $5500 \text{ m}^3$ . Assuming a square tank  $27 \times 27 \text{ m}$  and 8 m deep, with waterproofed earth slopes, a cost of  $0.83 \text{ M}\text{\euro}$  can be estimated. This figure stems from an analytical model of costs of the tank [22]. Assuming a 20% of overhead expenses also for this new infrastructure, total tank cost would rise to  $1.00 \text{ M}\text{\euro}$ .

Information on O&M costs is contained in Table 2. They have been reconstructed via data from the first three years of operation (2012–2014) for which AQP has provided an accurate cost breakdown. As Table 2 shows, water production has rapidly increased over the years, possibly showing increasing acceptance of reclaimed water by farmers, and costs have decreased. However, present data of delivery to the irrigation consortium do not yet fully reflect the potential of the plant. To assess it, data from Table 3 were used to obtain a reference maximum production MP (fourth item from the bottom, Table 3), of  $1.5 \text{ Mm}^3/\text{year}$  of reclaimed water potentially available for irrigation.

**Table 2.** O&M costs of the Gallipoli tertiary treatment plant and estimated Conversion Factors (CF) for the economic analysis.

Item	2012 *	2013 *	2014 *	Incidence (%) **	CF	Notes
Labour	12,621	17,799	12,154	16%	0.79	50% Skilled labour (CF = 1) + 50% unskilled labour (CF = 0.57)
Reagents (€)	27,441	31,858	14,737	19%	0.80	EU Guide to cost-benefit analysis, 2008 p. 175
Maintenance (€)	14,872	23,038	6879	9%	0.71	EU Guide to cost-benefit analysis, 2008 p. 175
Energy to run the TT (€)	13,894	14,440	21,216	28%	0.96	EU Guide to cost-benefit analysis, 2008 p. 175
Energy to run the PS (€)	4207	8598	21,095	28%	0.96	EU Guide to cost-benefit analysis, 2008 p. 175
Reclaimed water produced ( $\text{Mm}^3$ )	0.09	0.18	0.45			
Unit TT cost ( $\text{\euro}/\text{m}^3$ )	0.78	0.48	0.12		0.85	
Unit variable TT cost (reagents + energy) ( $\text{\euro}/\text{m}^3$ )	0.47	0.25	0.08		0.89	
Total/Average	73,035	95,733	76,081	100%	0.879	

\* Operation data from AQP; \*\* For year 2014.

In 2014 unit operation costs were  $0.12 \text{ \euro}/\text{m}^3$ . Variable operation costs (consumable reagents plus energy) in 2014 have converged to  $0.08 \text{ \euro}/\text{m}^3$ . As far as maintenance costs are concerned, operation data must be considered carefully: in 2014 they were around 0.3% of the investment costs and the average 2012–2014 was  $14,900 \text{ \euro}$ , approximately the 0.56% of overall project cost. This may not reflect the average expenditure that will be born during the whole life of the project as the plant is still new. According to [23], maintenance cost should vary in the range of  $0.5 \div 1.0\%$  of the investment cost for civil works and in the range  $1.0 \div 2.5\%$  of the investment cost for electromechanical equipment. Considering data in Table 1, this corresponds to upper and lower bounds for maintenance costs of around  $41,600 \text{ \euro}/\text{year}$  and  $17,700 \text{ \euro}/\text{year}$  respectively. For this reason, maintenance costs in the CBA will be assumed to have the average value of  $29,600 \text{ \euro}/\text{year}$ . Maintenance costs of the tank are set equal to  $5000 \text{ \euro}/\text{year}$  (0.5% of the investment cost).

**Table 3.** Technical parameters used throughout the analysis.

Parameter	Symbol	Value	Unit	Comments/References/Source
Inhabitants	I	36,771		<a href="http://demo.istat.it/bil2019/index.html">http://demo.istat.it/bil2019/index.html</a>
Visitor overnights per year:	V	487,573		<a href="http://www3.provincia.le.it/statistica/economia/tabc13.htm">http://www3.provincia.le.it/statistica/economia/tabc13.htm</a>
Alezio		2416		
Gallipoli		466,349		
Sannicola		9642		
Tuglie		9166		
Magnifying coefficient to allow for non-accounted visitors	M	5.3		<a href="http://www.agenziaapugliapromozione.it/portal/documents/10180/24526/Il%20turismo%20che%20non%20appare">http://www.agenziaapugliapromozione.it/portal/documents/10180/24526/Il%20turismo%20che%20non%20appare</a>
Average daily per-capita water consumption	WC	200	l/d	<a href="https://www.istat.it/it/archivio/240016">https://www.istat.it/it/archivio/240016</a>
Dispersion coefficient	DC	0.8		
Length of irrigation season	L	184	days	From 1st May until 31st October <a href="http://www3.provincia.le.it/statistica/economia/tabc14.htm">http://www3.provincia.le.it/statistica/economia/tabc14.htm</a>
Visitors ratio over the irrigation season	VRI	91	%	
Maximum estimated production of reclaimed water for irrigation	MP	1,485,078	m <sup>3</sup> /year	MP = DC × (I × L + VRI/100 × V × M) * WC/1000
Production of reclaimed water for irrigation with the current rules (7/7, 13/24)	CP	804,417	m <sup>3</sup> /year	CP = MP × 13/24
Opportunity cost of electrical power	C <sub>kWh</sub>	0.15	€/kWh	
Efficiency of the pumping system	η	0.60		

### 3.6. Demand Analysis

Given the context outlined above, the consumption levels of four types of goods or services may be considered to be affected by the project: water for irrigation, water for municipal supply (given the possible substitution effect of groundwater), better quality for irrigation water and, finally, beach and recreational services. The project also affects the latter because avoiding discharge into the sea or enhancing the quality of the water discharged can improve water quality in a stretch of coast that can become attractive for beach activities and generate aesthetic values.

#### 3.6.1. Demand for Irrigation Water

CREA (the National Council for agriculture research and economics), formerly INEA, provides information on irrigated agriculture in all Italian regions, and specifically Puglia, through periodical reports, the last of which dates back to 2010, with data from 2005 and 2006. The INEA report contains economic performance indices of irrigated land, estimated on a sample of farms in each of the six Apulian reclamation consortia, and comparison is made with the same indicators for farms that do not perform irrigation ([24], Table 3, p. 57). Data show quite clearly that in the regional context of Puglia, the consortium where the plant is located, is the one where irrigation is in the average the least productive, in terms of gross production and value added.

Another revealing indicator is the ratio between actually irrigated areas and potentially irrigable areas in the consortium. According to the consortium's last classification plan (2012), potentially irrigable areas amount to 10,386 ha while irrigated areas oscillate around 2000 ha, so that no more than 20% of the areas that are potentially irrigable are actually irrigated. This confirms that, although infrastructure was built more than thirty-five years ago, public irrigation has not taken off in these districts. One of the explanations is that drilling technologies have improved over time so that farmers find it easier to drill their own well (drawing from the same aquifer from where consortium extracts water) than depending on consortium delivery times and that they probably also find it economically more advantageous.

Overall, the irrigable area in the five districts that can be supplied by reclaimed water is 1647 ha. Given the above, the actually irrigated land can be estimated as 20% × 1647 = 330 ha. We will assume that these areas can be supplied only by consortium resources as the aquifer is not easily accessible in these specific places.

Gross water requirements of the five districts have been extrapolated from information on the whole consortium, with some uncertainty: according to INEA average requirement is 2260 m<sup>3</sup>/ha, while other sources report higher estimates, with an average requirement of around 2700 m<sup>3</sup>/ha

(see Table S1 in the Supplementary Materials section contains more details on the distribution of crop types and unit water requirements).

Considering the uncertainty on water requirements of crops, we can estimate that water demand for these districts may range from  $330 \times 2260 = 0.75 \text{ Mm}^3/\text{year}$  to  $330 \times 2700 = 0.89 \text{ Mm}^3/\text{year}$ . Comparing these values with the amount of reclaimed water that the plant is able to supply ( $1.5 \text{ Mm}^3$  in one season), we can conclude that: (1) reclaimed water has certainly a potential to substitute groundwater in the districts completely; (2) it can allow irrigation of areas that are irrigable with consortium resources, but are presently supplied by farmer's wells. This is only possible, however, if selling prices of consortium water are less than the cost of pumping from private wells or if benefits from the project exceed costs, so that part of them can be used to incentive farmers to use reclaimed water. This aspect is important to trigger the reuse mechanism and will be dealt with in the discussion section.

### 3.6.2. Demand for Municipal Water

While reused wastewater cannot be used directly for municipal supply, it may be exchanged with better quality water, thus having an impact also on municipal supply. In this specific case, exchange would imply that groundwater spared for irrigation could be used for municipal supply. However, with non-revenue water accounting around 50% still in 2008, AQP has decided to direct investments toward reducing losses through an extensive program of network metering and rehabilitation through a two-step plan implying investments for over 160 M€. Of these, 93 M€ have already been spent in 143 municipalities and the other 57 M€ are being currently spent. This is meant to decrease withdrawals from supply sources, especially groundwater that is growingly unsuitable for municipal use due to quality issues. In addition, alternatives are being analyzed to increase municipal water supply to Salento from surface water in order to reduce the dependence on groundwater resources and the availability of new extra-regional water resources are further reducing the share of groundwater in the resources mix used by AQP to supply the region. This short overview on the current actions of the regional water utility should convince that reuse is not considered strategic for the water utility and that overall the interactions between water reuse and municipal supply, via a possible displacement effect of groundwater use, are rather weak.

### 3.6.3. Demand for Better Quality of Irrigation Water

A much-lamented problem of water resources in Apulia that enjoys wide attention in sector documents (e.g., PTA; [25]) is the progressive deterioration of water quality in the karst aquifers over which most of the region is located. It is claimed it can have serious consequences for both water supply and irrigation, and the decrease of fresh water is seen as a threat for the whole region. As analyzed above, however, only 10% of water supply for municipal use now comes from groundwater, with a further decreasing trend, while groundwater continues to be a major, if not the only, supply source for irrigation in the area. Urban water reuse can hence contribute in three ways to improve the issue of reduced groundwater quality: (i) indirectly, by substituting groundwater as a supply source and thereby avoiding extraction, thus increasing the recharge/withdrawal ratio, (ii) directly, by substituting water for irrigation with less saline water, and (iii) by managed aquifer recharge.

Considering the water volumes at stake in this project, it is unlikely that impacts (i) and (iii) will be detectable so we concentrate on impact (ii). High salinity is known to have detrimental effects on both soils and crops: although the importance of this issue is stressed by sector documents, available data on saline concentration in the Salento aquifer date back to mid-90s [25,26], so that building an updated picture of the situation is not easy. In addition, the impact of salinity on crop production depends on a quantity of factors including soils and crop type, irrigation strategies and techniques and, of course, on saline concentration in groundwater. All these difficulties and uncertainties notwithstanding, we will endeavor to assess this type of benefits further in the paper.

### 3.6.4. Demand for Better Water Quality for Beach Services

The other service that reuse can provide is to reduce or avoid discharge into the sea of wastewater, thereby allowing using stretches of coastline where bathing would be otherwise forbidden for recreational purposes. In this case, basic questions to answer are (i) whether there is an actual demand for these services, and (ii) if the coastal stretch where the wastewater outlet is located is able to provide them.

Gallipoli is one of the fastest growing summer destinations for beach-related activities in Puglia, which in turn ranks seventh among the twenty Italian regions by increase in visitor overnights in the 2010–2019 decade [27]. In 2019, based on data from Puglia Regional Administration, the tourism density indicator of the municipality of Gallipoli (number of overnights per square kilometer) ranked second in the 213 Apulian municipalities with a distance of only 2% from the first. In 2018, among the first ten Apulian municipalities for visitor overnights, Gallipoli rates first in the indicator expressing accommodation density (number of beds per square kilometer).

In the Gallipoli area, most visitors are interested in beach activities. The municipality of Gallipoli has 32 km of coastline, 8 km of which are beaches that are presently used for recreational activities. In 2019, 509,586 visitors overnights have been officially spent in Gallipoli, but a magnifying coefficient of 5.30 must be applied to allow for not accounted overnights revealed by selling data of sold newspapers and solid waste production [28]. This implies that overnights in 2019 can be estimated in 2,701,000 units and are concentrated in the summer season, with a peak in August of around the 38% of total annual visitors, resulting in an average of circa 33,100 visitors/day in August. As around 65% of them visits the beach during the day [29], Gallipoli beaches can be assumed to receive around 21,500 visitors/day in August. This figure is relevant because it can provide some information on how close these beaches are to their carrying capacity [30,31], that is, to the density of beach occupants beyond which visitors feel no longer comfortable and seek alternative locations.

From satellite images the average depth of Gallipoli's usable beaches can be estimated in 30 m, so that the available area for visitors would be  $30 \times 8000 = 240,000 \text{ m}^2$ , corresponding to a peak available room for occupant of  $11.2 \text{ m}^2/\text{visitor}$ . Assuming instead that all the estimated 33,000 tourists/day visit the beach, the available room for occupant would decrease to  $7.3 \text{ m}^2$  per visitor. These figures are certainly affected by uncertainties related to the actual available extension of the beach and to the number of visitors, yet they are not far, if not included, in the range of capacity thresholds available in the literature (ranging from 3.0 to 10.0  $\text{m}^2$  per occupant). They point out that there may exist a demand for additional space for beach activities, so that the availability of further stretches of beach with good water quality may produce economic benefits, besides those associated to aesthetic values, that must be quantified separately.

From a survey in the area, this stretch of coastline can be schematized as a  $35 \times 500 \text{ m}$  rectangle. Rather than being a sandy beach as elsewhere in the surroundings, this is a rather rocky stretch of coast. We consider that a stripe 5 m—wide from the sea-line must be left free of concessions, and further assume that a stripe of 10 m is left empty between two adjacent concessions. Considering that the average dimension of a concession in the municipality of Gallipoli is  $1700 \text{ m}^2$  [32] we obtain that eight beach concessions may be established in this area. A study of the Italian Revenue Service [33] provides a statistical sample of beach concessions nationwide, clusters them in ten groups, each with different characteristics in terms of average area, average length, fraction of sheltered areas, number of sunbeds and bed-chairs etc. Further, an analysis of the existing concessions in Gallipoli shows that 60% of these can be assumed to belong to cluster 3 (concessions with bar and restaurant), 20% to cluster 1 (concessions with bar) and 20% to cluster 3 (concessions with beach services only). From the number of sunbeds and beach-chairs inferable from [33] and assuming an average rate of occupation of 70%, in line with the hotel room occupation rate, a number of visitors during the peak season (August) can be estimated: the number of visitors in this stretch of coast would be of around 4000 visitors/km/day. The figures from the previous section (33,000 beach-visitors/day for 8.0 km of beaches) would yield a number of 4125 visitors/km/day for this stretch of coast, thereby pointing out that the number of

visitors estimated through the beach concession data [33] is consistent with the same figure obtained from visitor overnights data. A summary of the information used in this section, that is also relevant for the estimation of benefits further in the paper, can be found in the Supplementary Materials section at Table S2.

### 3.6.5. Demand Analysis—Concluding Remarks

The above sections have shown that in the reclamation consortium demand for irrigation water is not growing and that irrigated areas with consortium resources are decreasing with time, probably because farmers can use water extracted from their own wells. Overall, the percentage of areas irrigated by consortium resources is quite low, compared to the potentially irrigable area and it can be assumed that areas irrigated by resources from the consortium are those where farmers have no other option because in their property access to the aquifer is locally difficult or impossible.

In this context, it can be excluded that the availability of reclaimed water will lead to increase the extension of irrigated areas, but it will rather substitute groundwater resources for irrigating the existing districts. However, the displacement effect on groundwater resources, if any, is likely to impact only the agricultural sector: in the municipal sector, there exist other alternatives to improve the water balance. AQP is attempting to decrease the share of groundwater by both reducing gross demand to the supply sources via programs of loss reduction and by increasing the share of surface resources supplying the region.

Further, data on tourism indicate a potential issue of beach congestion, thereby pointing out the opportunity to look at further stretches of beach where recreational activities may be carried out.

Finally, sector documents lament increasing saline concentration in groundwater. While for the municipal sector this will tend to be less worrying in the future thanks to the above-mentioned strategy of reducing groundwater use, it may provide grounds to farmers to resort to less saline water (the treated effluent) thereby generating a demand for irrigation water of better quality than the one they can extract from the aquifer.

## 3.7. Identifying and Monetizing Benefits

Figure 2 reports a list of the socio-economic effects that may potentially be activated and those that are actually likely to be generated in this specific situation, according to the outcomes of the above demand analysis. These effects result in the following socio-economic benefits:

- (1) Reduced costs for the irrigation consortium (avoided costs)
- (2) Improved water quality for farmers
- (3) Avoided discharge into the sea of effluents from secondary treatment, improving bathing water quality and aesthetic values of the affected area.

### 3.7.1. Reduced Costs for the Irrigation Consortium

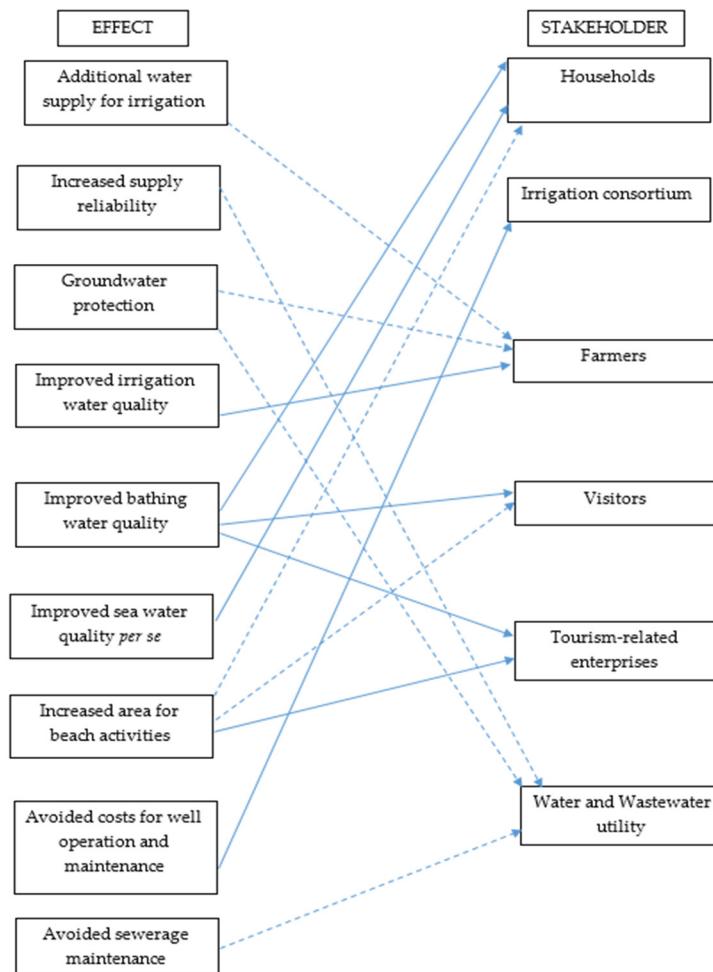
These benefits stem from the fact that (1) the irrigation consortium presently extracts water from wells averagely 100 m deep, while with the project water will be pumped with a head, gross of head losses, of 47 m and (2) that the consortium may give up using some well, thereby reducing maintenance costs.

Unit benefits ( $\text{€}/\text{m}^3$ ) can hence be estimated through:

$$B_1 = C_{\text{kWh}} \frac{9.81 \times (H_{\text{with}} - H_{\text{without}})}{\eta \times 3600} \quad (3)$$

where  $C_{\text{kWh}}$  indicates the opportunity cost of energy (Euro/kWh),  $H_{\text{with}}$  (47 m) and  $H_{\text{without}}$  (100 m) the head with and without the project and  $\eta$  is the pumping efficiency of the system. The other relevant parameters to assess Equation (3) are contained in Table 2. With this information, one obtains a saving of 0.036  $\text{€}/\text{m}^3$ . Reduced maintenance costs can be estimated indirectly from well data. Well number,

well average depth and average flow depth lead to an estimate of savings of 7000 €/year in well and pump maintenance.



**Figure 2.** Potential effects generated by the project and affected stakeholders. Dotted lines indicate potential effects that are not activated, given the specific conditions in terms of supply and demand.

### 3.7.2. Improved Water Quality for Farmers

To analyze this aspect, we consider the difference in crop production using reclaimed water and water with its current quality characteristics. A methodological issue arises here, as we are looking at benefits generated in a “third market”, namely that of the crops produced in the irrigated areas, a method that is generally not recommended, due to the difficulty of associating project’s impacts to transactions in that market. We have to follow this path because raising of demand for less saline water is a potential, not yet in place, impact of the project, so that there is no existing system, say a treatment plant to reduce salinity, that reclaimed water may substitute at a lower cost. This also implies that this impact (and the related benefits) is exceedingly uncertain, so that in the discussion appropriate scenarios shall be considered that do not include this effect.

It should be highlighted that reclaimed water does have itself a non-negligible saline concentration because of seawater intrusion in sewerage, occurring because Gallipoli is a coastal town, so that reclaimed water for irrigation is currently being used waiving the limits on chloride concentration. According to a set of measurements, average conductivity of reclaimed water is in the range 1.4–1.9 dS/m,

while groundwater extracted from the aquifer has a salinity that can be assumed between 1.7 dS/m and 2.0 dS/m. Benefits from reduced water salinity,  $B_{\text{salinity}}$ , are assessed as follows:

$$B_{\text{salinity}} = \sum_{i=1}^{\text{Ncrops}} SO_i \times A_i \times b_i \times \Delta CE \times I_i / 100 \quad (4)$$

where  $SO_i$  is the standard output of the  $i$ -th crop-type (€/ha),  $A_i$  is the area invested in the  $i$ -th crop,  $\Delta CE = CE_{\text{groundwater}} - CE_{\text{reclaimed}}$ , being  $CE$  the saline concentration in groundwater/reclaimed water (in dS/m).  $I_i = 1$  if  $CE > a_i$  (water salinity exceeds  $a_i$ , the salinity tolerance threshold of the  $i$ -th crop) and  $I_i = 0$ , if  $CE < a_i$ .  $b_i$  (%) dS/m) is the rate of reduction of production beyond the salinity threshold. The standard output of an agricultural product is the Eurostat metrics for the average monetary value of the agricultural output at farm price. Equation (4) is derived from the Maas-Hoffmann relationship [34] expressing crop yield in saline conditions in percent of production when water salinity is not constraining production. In principle, in a CBA value added of crop production should be used; however, as CBA performs incremental analyses, standard outputs can be legitimately be used instead of value added.

Table 4 reports information on the sensitivity of crops to water salinity, together with the parameters needed to apply Equation (4) for a given salinity of treated wastewater and groundwater. To highlight the percentage of estimated production gain when reclaimed water is used instead of groundwater, Table 4 also contains the production percentages with the two types of water for a specific salinity difference (0.3 dS/m).

**Table 4.** Economic and salt tolerance parameters to assess benefits due to reduced saline concentration in irrigation water. MT, MS and S respectively indicate medium tolerance, medium sensitivity and sensitivity to salt concentration. Values in the third and second last column are obtained from the Maas-Hoffmann relationship for saline concentrations of 2.0 and 1.7 dS/m respectively. Benefits in the last column are obtained multiplying the standard output (second column) by the difference between second last and third last column.

Crop Type	2013 S.O. (€/ha)*	Salt Tolerance Parameters			Production with Saline Groundwater	Production with Reclaimed Groundwater (in% of Reference Production with Non-Saline Water)	Benefit (€/ha)
		Threshold a (dS/m)	Slope b (%/dS/m)	Rating			
Tobacco	7064	-	-	MT	100.0	100.0	0
Sunflower	559	-	-	MT	100.0	100.0	0
Melon	13,555	0.7	12.7	MS	83.5	87.3	516
Tomato	13,555	1.7	15	MS	95.5	100.0	610
Eggplant	13,555	0.7	10.3	MS	86.6	89.7	419
Pepper	13,555	1	21	MS	79.0	85.3	854
Fennel	13,555	1.1	18	MS	83.8	89.2	732
Cauliflower	13,555	1.2	18	MS	85.6	91.0	732
Lettuce	13,555	0.9	19.5	MS	78.6	84.4	793
Potato	10,622	1.1	18	MS	83.8	89.2	574
Grape	9885	1	14.4	MS	85.6	89.9	427
Orchard	7724	1.1	25	S	77.5	85.0	579
Olive	2300	-	-	MT	100	100	0

\* <https://rica.crea.gov.it/produzioni-standard-ps-210.php>.

### 3.7.3. Benefits from Avoided Effluent Discharge into the Sea

Three different types of benefits may in principle apply in this specific situation: (i) avoided costs of managing the outlet point, (ii) benefits related to the provision of non-consumptive coastal ecosystem services such as recreational activities and (iii) aesthetic (and, more in general, non-use) services. Concerning the first type of benefit, no maintenance costs can be assumed to be avoided, as effluent discharge will continue to take place into the sea off the irrigation season, so that maintenance will continue to be necessary. As far as the provision of recreational and aesthetic services, we shall provide separate discussions, based on the available literature and on own considerations.

### 3.7.4. Recreational Values of the Area

If the area where effluent discharge presently takes place is no longer affected by it, recreational (beach) services may be activated. There is in principle an extensive body of literature available, based on revealed preference methods such as travel costs [35–39] and hedonic prices [40–42]. In addition, two recent important meta-analyses of coastal recreation values are now available both at global [43] and European scale [44]. Benefit transfer [45] is now developing as a discipline attempting to take advantage of the thousands of studies available worldwide on environmental services to provide estimates on environmental values in areas where no studies are available. However, several issues arise when attempting to transfer values to the specific case and are likely to seriously bias results of the transfer. In the first place, most of these studies are regional analyses to estimate the environmental value on large-scale areas such as gulfs or natural parks.

The issue of scale is relevant in these studies as the availability of substitute sites strongly limits the validity, or even hinders the applicability, of this type of methods (e.g., [46]). Lew and Larson [47] observed for instance that, while a day on the beach has a value between 28 and 44 USD for the residents in the San Diego area in California, damage associated to the non-availability of a specific beach is around 1–2 USD/person/day if an alternative site is at hand. In addition, the available studies differ by methodology, objectives, interest groups involved and socio-economic context. Different methodologies can lead to include different values in the consumer surplus estimate [48]. Johnston et al. [45] warn that any type of scaling (by area, income and so on) may lead to significant inconsistencies.

Another issue is the valuation attribute used in a study that may be inappropriate for the area where results are to be transferred. A number of studies available for improvement of seawater quality for beach activities, for instance, was produced in the United Kingdom in response to the introduction of EU bathing Directive [49,50]. In investigating the willingness to pay (WTP) for improved seawater quality, the authors identify this attribute with a reduction of the risk of experiencing gastroenteritis: this would be probably considered an inappropriate or even unacceptable trade-off elsewhere.

From this standpoint, the study by Machado and Mourato [51] is more transferable in that, besides the gastroenteritis metrics, it also uses more neutral attributes for water quality, such as “good”, “average” and “bad”. Mean WTP for improving water quality from bad to average is 11.0 USD/person/year, and the mean WTP for a further increase of water quality from average to good is valued 7.94 USD/person/year. In addition, with the exception of [50] and, partly, [49], all these studies implicitly identify beach visitors with local residents. This is however not the case in Puglia, where there is a wide prevalence of extra-regional visitors. This issue is not trivial, as the groups of respondents in environmental assessment studies should ultimately reflect the attitudes of who will be actually paying for the improved environmental services they receive.

Considering that in Apulia over 85% of visitors come from outside the regional borders, it is reasonable to assume that extra-regional, seasonal, visitors are the main direct beneficiaries of improved water quality for beach activities, while residents are the main beneficiaries of aesthetic, non-use values. In this assumption, an increase in seawater quality should produce an increase of visits to the site [49]. However, given the reduced dimensions of the coastal stretch to be reclaimed and the substitution effect of the other available beaches, it is very unlikely that its availability for recreational activities will be able to increase the number of trips to Gallipoli: more likely, it will rather produce a displacement of visitors and reduce beach congestion. While there exists a certain body of literature devoted to assessing the role of congestion in valuing environmental goods [52,53] there are very few studies available on the specific value of reducing beach congestion. McConnell [54] provides a consumer surplus ranging from 1.42 to 6.43 USD per activity day. However, as shown by the above demand analysis, the fact that Gallipoli beaches are congested is all but certain and specific studies should be carried out to isolate this effect.

In these conditions, with no demand increase realistically imaginable and no benefits from reduced congestions demonstrable, the only estimate of a proxy of the increased value for this stretch of beach is the fee for beach concessions. It can be assessed from the number of estimated beach concessions

at 3.6.4 and data available in Table S2 of the Supplementary Materials section, using values from current Italian legislation, that distinguishes between non-sheltered areas ( $2.64 \text{ €}/\text{m}^2$ ) and sheltered areas ( $5.87 \text{ €}/\text{m}^2$ ), thereby obtaining an estimate of 41,232 €/year.

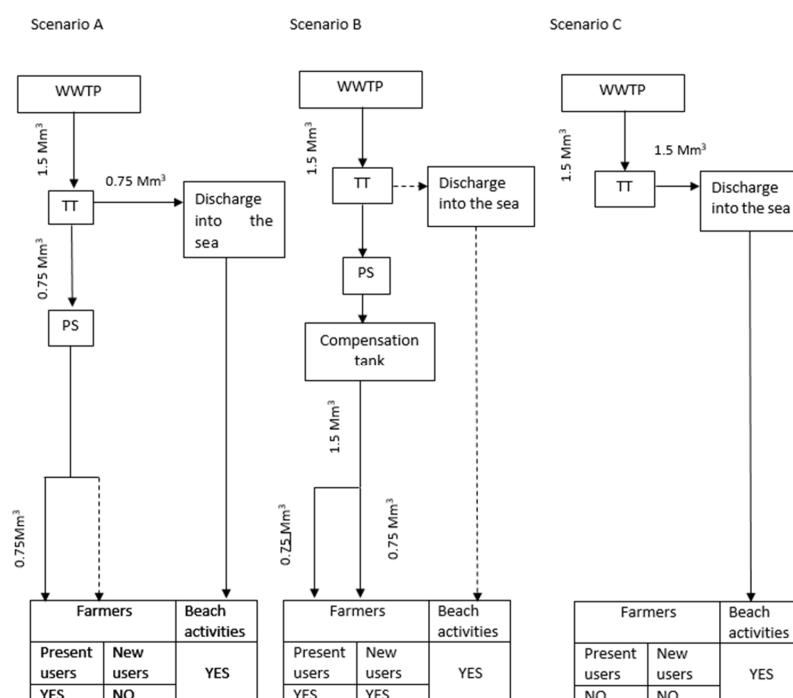
### 3.7.5. Aesthetical Values of the Area

Few studies are available that focus prevailingly on non-use values of improved seawater quality. Among these, the studies of Silbermann et al. [55] on New Jersey beaches and Kontogianni et al. [56] on Thermaikos bay, near Thessaloniki in Greece.

Through a contingent valuation (CV) study, Silbermann et al. [55] found a una-tantum willingness to pay of 19 USD/person (1985 USD) for a restoration program from residents. Also through a CV study, Kontogianni et al. [56], examined the willingness to pay of individuals to ensure the full operation of wastewater treatment plants, leading to significant improvements in the water quality of Thermaikos Bay, a gulf several tenths of kilometres long, which is adjacent to Thessaloniki, Greece, with a population of around 870,000. The average amount pledged was of €15.23, due every four months as an incremental increase in water rates (~60 €/year in 2002 Euros). A complex combination of consumer and citizen modes of cognition, linked to self-identity and pride in the city as well as moral and ethical concerns, was found to determine individuals' commitment to the water quality improvement scheme.

### 3.8. Three Scenarios for the Cost-Benefit Analysis

Although effects generated by the project are mutually independent, their occurrence depends upon certain conditions in the reuse supply chain, according to the interaction scheme depicted in Figure 3. It illustrates the three different scenarios considered for the discussion. Scenario A assumes that delivery of reclaimed water to the irrigation consortium is not performed during the night, as occurs to date, given the absence of storage capacity, so that reclaimed water production for irrigation is no higher than  $CP = 0.80 \text{ Mm}^3/\text{season}$ . All the wastewater flowing out of the WWTP undergoes tertiary treatment, so that recreational benefits may be activated, as seawater quality allows eliminating the bathing prohibition.



**Figure 3.** Schematic of three scenarios examined. Dotted lines indicate flows that do not occur in the specific scenario. Water amounts to irrigation ( $0.75 \text{ Mm}^3$ ) are those evaluated at Section 3.6.1.

Scenario B assumes instead that storage capacity is built, implying an additional investment and maintenance cost, but allowing reclaimed water production for irrigation to grow up to plant's capacity of 1.50 Mm<sup>3</sup>/season. Clearly, also in this case, recreational benefits may be activated. Finally, scenario C mimics the situation in which only the tertiary treatment plant is built, so that no reuse actually takes place, but water is discharged in the sea, at a quality level that makes it to suitable to remove the present bathing prohibition in the coast stretch of 500 m.

#### 4. Results

Table 5 summarizes costs for the reuse plant relevant for the analysis, Table 6 reports the quantification of benefits and Table 7 contains the corresponding economic performance indicators NPV and IRR. NPV and IRR have been calculated by (1) and (2) assuming a social discount rate of 3.5%, a planning horizon of 30 years, and a useful life for electromechanical equipment of both TT and PS of 15 years. This implies substitution at year 15 and 0 residual value at year 30. At year 30 also electrical equipment is assumed to have zero salvage value.

**Table 5.** Project costs (re-evaluated in 2019 €). All items are adjusted with Conversion Factors. Replacement costs include electro-mechanic devices in the TT plant in all scenarios and pumps to boost reclaimed water to irrigation districts in scenarios A and B.

Costs	Investment Costs (M€)	O&M Costs (M€/year)	Replacement Costs (15th Year—M€)	Residual Value (M€)
Scenario A	2.384	0.140	0.765	0.755
Scenario B	3.385	0.145	0.765	1.332
Scenario C	2.231	0.139	0.650	0.672

For civil works a useful life of 70 years is assumed and a linear depreciation rate, implying a 4/7 residual value of civil works at the end of the 30 years period. Table 6 is based on average water requirements for crops of 2260 m<sup>3</sup>/ha, the lower end of the uncertainty interval described in the previous sections. This implies that benefits related to crop production will be the highest, a favorable condition that, as will be seen shortly, does not suffice to make the reuse project sustainable in most cases merely looking at irrigation benefits.

**Table 6.** Benefits for the three scenarios A, B and C and for various possible ΔCE's. ΔCE indicates the difference in saline concentration between groundwater and reclaimed water. Unit benefits from improved irrigation are obtained from the values of last column of Table 4 multiplying them by the invested areas and dividing by water requirements. Only salt-sensitive crops are considered in their evaluation, so that actual benefits are obtained from the fraction of reclaimed water used to irrigate salt-sensitive crops (81% of total water).

Scenario	ΔCE (dS/m)	Unit Benefits from Improved Irrigation Water (€/m <sup>3</sup> )	Reclaimed Water Delivered (Mm <sup>3</sup> )		Reduced Costs for the Consortium * (M€/Year)	Improved Quality of Irrigation Water (M€/Year)	Recreational Benefits (M€/Year)
			To Present Users	To New Users			
<b>Scenario A</b>							
	0.0	0.000	0.75	0.00	0.034	0.000	0.041
	0.2	0.135	0.75	0.00	0.034	0.081	0.041
	0.4	0.270	0.75	0.00	0.034	0.163	0.041
	0.8	0.540	0.75	0.00	0.034	0.325	0.041
	1.0	0.675	0.75	0.00	0.034	0.407	0.041

**Table 6.** Cont.

Scenario	$\Delta CE$ (dS/m)	Unit Benefits from Improved Irrigation Water (€/m <sup>3</sup> )	Reclaimed Water Delivered (Mm <sup>3</sup> )		Reduced Costs for the Consortium * (M€/Year)	Improved Quality of Irrigation Water (M€/Year)	Recreational Benefits (M€/Year)
			To Present Users	To New Users			
<b>Scenario B</b>							
$p_w = 0.1 \text{ €/m}^3$	0.0	0.000	0.75	0.00	0.034	0.000	0.041
	0.2	0.135	0.75	0.75	0.061	0.165	0.041
	0.4	0.270	0.75	0.75	0.061	0.330	0.041
	0.8	0.540	0.75	0.75	0.061	0.659	0.041
	1.0	0.675	0.75	0.75	0.061	0.825	0.041
$p_w = 0.3 \text{ €/m}^3$	0.0	0.000	0.75	0.00	0.034	0.000	0.041
	0.2	0.135	0.75	0.00	0.034	0.081	0.041
	0.4	0.270	0.75	0.00	0.034	0.163	0.041
	0.8	0.540	0.75	0.75	0.061	0.659	0.041
	1.0	0.675	0.75	0.75	0.061	0.825	0.041
$p_w = 0.6 \text{ €/m}^3$	0.0	0.000	0.75	0.00	0.034	0.000	0.041
	0.2	0.135	0.75	0.00	0.034	0.081	0.041
	0.4	0.270	0.75	0.00	0.034	0.163	0.041
	0.8	0.540	0.75	0.00	0.034	0.325	0.041
	1.0	0.675	0.75	0.75	0.061	0.825	0.041
<b>Scenario C</b>	-	-	-	-	-	-	0.041

\* includes estimated 7000 €/year savings for reduced wells maintenance.

**Table 7.** Cost-Benefit Indicators (NPV and IRR) for the three scenarios described in the Results section and various. The table also contains the estimated minimum additional benefits necessary to make the project sustainable ( $NPV \geq 0$ ).

Scenario	$\Delta CE$ (dS/m)	NPV (M€)	IRR	Minimum Aesthetic Benefits that Make NPV = 0 (M€/Year)	Minimum Aesthetic Benefits that Make NPV = 0 (% of Total Benefits)
Scenario A					
	0.0	-3.70	—	0.206	73.0%
	0.2	-2.23	-4.3%	0.124	44.0%
	0.4	-0.76	1.1%	0.043	15.0%
	0.8	2.09	9.5%	0	0
	1.0	3.64	13.5%	0	0
Scenario B					
$p_w = 0.1 \text{ €/m}^3$	0.0	-4.625	-7.9%	0.257	77.0%
	0.2	-1.164	1.0%	0.065	20.0%
	0.4	1.809	7.1%	0	-
	0.8	7.755	17.7%	0	-
	1.0	10.729	22.8%	0	-
$p_w = 0.3 \text{ €/m}^3$	0.0	-4.625	-7.9%	0.257	77.0%
	0.2	-3.158	-3.8%	0.176	53.0%
	0.4	-1.690	-0.2%	0.094	28.0%
	0.8	7.756	17.7%	0	-
	1.0	10.729	22.8%	0	-
$p_w = 0.5 \text{ €/m}^3$	0.0	-4.625	-7.9%	0.257	77.0%
	0.2	-3.158	-3.8%	0.176	53.0%
	0.4	-1.690	-0.2%	0.094	28.0%
	0.8	1.245	6.0%	0	-
	1.0	10.729	22.8%	0	-
<b>Scenario C</b>		-4.145	-	0.230	85%

## 5. Discussion

From the demand analysis for irrigation water, since the 330 hectares of land that have no alternative water resource to those supplied by the consortium have a water demand of  $0.75 \text{ Mm}^3/\text{season}$ , we can conclude that in scenario A all reclaimed water will be absorbed by these farmers. On the other hand, in scenario B, the additional available quantity of  $1.5 - 0.75 = 0.75 \text{ Mm}^3/\text{season}$  should be used by those farmers, denoted as “new users” in Table 6, who currently use their own wells, but may be interested in shifting to reclaimed water. Let  $p_w$  be the price charged by the consortium, net of avoided costs from individual pumping: new users have already potentially access to reclaimed water as they are connected to the consortium’s distribution network, but they will use reclaimed water only when  $p_w$  allows crop production to be remunerative in the appropriate market, leaving all other inputs unchanged.

This can occur thanks to potential gains related to increased crop production thanks to better water quality, so that in Table 6 no water is delivered to new users if  $p_w$  is greater than the unit income from the increased production ( $\text{€}/\text{m}^3$ ). In this scheme, the trade-off between consortium charges and the increased income (*ceteris paribus* a function of the different salinity of reclaimed water and groundwater) hence becomes a key factor for triggering the reuse mechanism, as shown by the economic indicators of Table 7.

This also has consequences for households and beach visitors, who have standing to support the investment, if needed, to generate the recreational and aesthetic benefits they expect. From this standpoint, it makes a difference whether the goal of removing the bathing prohibition requires permanent diversion of wastewater discharge from the sea or if tertiary treatment is able to guarantee the microbial standards required by the bathing directive, as assumed here. In this second assumption it makes sense considering scenario C, where only a tertiary treatment is implemented, but no reuse. Then the project should not include the pumping stations and the related costs. Scenario C mimics the situation where the reuse project collapses into a project for mere aesthetic and recreational purposes.

The results of Table 7 prove in the first place that, if no positive impact can be associated to improved water quality for irrigation (corresponding to  $\Delta CE = 0$ ), in no case can investment and operation costs of reuse be sustained by savings of the reclamation consortium and by the increased value of the beach stretch.

In the case of  $\Delta CE = 0$ , the willingness to pay of non-farmers to make the project economically sustainable ( $NPV = 0$ ) should be at least 206,000  $\text{€}/\text{year}$ , as in scenario A, accounting for the 73% of the total benefits required to make the project economically sustainable.

From the discussion on recreational/non-use values, we can conclude that the interest group who should show a similar willingness to pay is Gallipoli’s citizen. Considering that there are around 8400 households in Gallipoli, this would imply a willingness to pay of around 25  $\text{€}/\text{household per year}$ . While it is difficult to compare this value with those from Silbermann et al. and from Kontogianni et al., we can affirm that if this extra money were to be paid through water rates by the citizens of Gallipoli, this would imply an increase of around 8% of the current average water rate per household. The latter is presently around 300  $\text{€}/\text{year}$ , as assessed from data of Table 1, and from the rate structure of AQP.

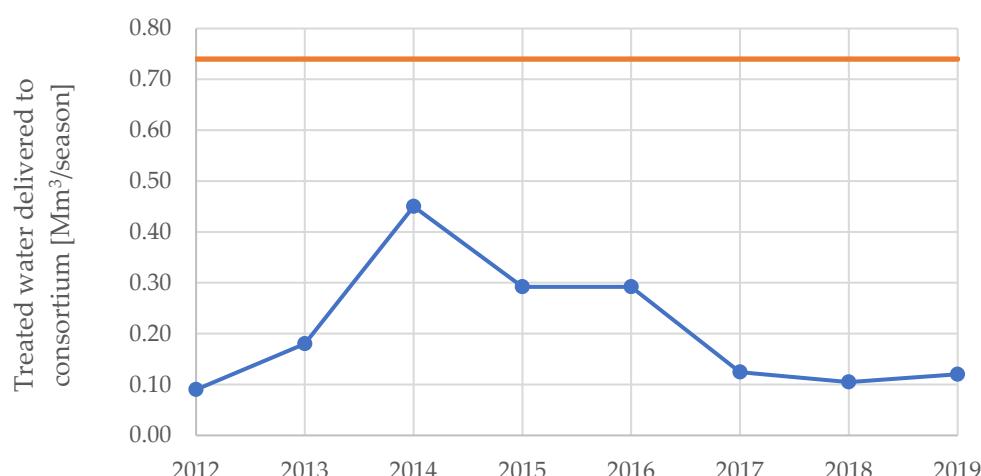
Even if no benefits from improved water quality can be generated, reuse should be preferred to the option of a mere tertiary treatment with no reuse, as the latter would entail a stronger willingness to pay of non-farmers (230,000  $\text{€}/\text{year}$  in scenario C).

Recreational and non-use value decrease their role in making the project economically sustainable if the, indeed uncertain, benefits from improved water quality could actually be generated ( $\Delta CE > 0$ ). These benefits accrue to “present users” and can also accrue to “new users” if the selling price of reclaimed water is less than the increased unit revenues farmers can gain from water of better quality.

There are situations in which better quality of irrigation water could make the difference in supporting the economical feasibility of the project even when reclaimed water is enough only for present users, as in scenario A. This occurs however when the quality difference between reclaimed

and groundwater is significant ( $\Delta CE \geq 0.8 \text{ dSm}^{-1}$ ). When also new users find it convenient to use reclaimed water, in some instances ( $p_w \leq 0.1 \text{ €}/\text{m}^3$ ) quality differences can be less marked.

It should be highlighted that the general results of this analysis are corroborated by the present state of the project: Figure 4 shows a comparison between actual and expected volumes absorbed by farmers. The figure shows that after a peak in 2014, volumes have gradually decreased. Volumes actually used by farmers have systematically kept lower than expected.



**Figure 4.** Comparison of actual (blue) and expected (orange) amounts of treated wastewater delivered to the irrigation consortium from 2012 to 2019.

As water quality analyses do not show particular criticalities, this supports the idea that the demand for irrigation water is weak in the districts. On the other hand, although the quality of effluent wastewater from the TT would be adequate to allow discharge even in a sensitive area, the option commonly viewed as safer to protect coastal environments is a marine outfall system. As such, they are often supported by municipal administrations regardless of the increased investment and operational costs, resulting in long debates and difficulties in implementation with water service contractors.

All these controversial aspects support the idea that a reuse project for irrigation should be ultimately carried out when demand for reused water is certain and at a level adequate to potential supply; if this condition is not met, other ancillary benefits are not likely to make the project sustainable. Non-use benefits can always be invoked, but they must be gauged by directly asking the appropriate interest groups. It is also interesting to observe that the outcomes of this analysis are also confirmed on a regional scale: out of around 80 identified feasible potential reuse sites in the Water Protection Plan, only five have been operational in the last five years and most of them are working at lower levels than the expected ones.

## 6. Conclusions

The paper has presented a cost-benefit analysis of an existing reuse project in Apulia, Southern Italy. The case study is paradigmatic of a whole class of reuse projects where a multitude of different effects are generated to a range of different beneficiaries, so that both need to be identified and quantified in order to define a correct evaluation framework. By stressing the role of demand analysis in this type of assessment, the paper has shown that these effects can potentially be quite different from those conventionally invoked for this type of projects, typically increase of water resources availability or substitution of freshwater resources for higher-value uses such as households, and hence require careful understanding and investigation. In addition, the paper has confirmed that economic benefits to farmers are able to cover investment and operation costs of this type of plants only in a limited number of cases, subject to the occurrence of rather uncertain conditions, and that other types of

benefits, such as recreational and even non-use benefits, need to be considered in order to consider the project economically justifiable.

In this specific case study, once it has been made clear that by no means farmers would benefit from an increase of water quantity, benefits to farmers take the somewhat elusive (and, as said, extremely uncertain) form of increased crop production thanks to improved water quality. From this standpoint, the paper has provided a stylized framework for the assessment of this type of benefits and an as much stylized way to incorporate them into the cost-benefit analysis. To this end, a rather stiff rule is introduced, attempting to mimic the slow, complex process of farmers actually perceiving this increase in crop production and decide to switch to reclaimed water, also based on the price that the supplier charges them.

If this type of benefits cannot be generated, most of the positive impacts of the project should be attributed to generic “environmental benefits” that the project should be able to provide. Through a coherent demand analysis supported by plans, sector documents and official statistics, the paper has revealed that no actual recreational benefits can be associated to the project except those deriving from the mere availability of a further beach stretch. They have been quantified through current fees for beach concession, so that aesthetic and non-use impacts can be considered the only suitable class of environmental effects generated by the project. By analyzing the features of the stakeholders and their involvement, the analysis has also led to support the idea that citizen of Gallipoli, the municipality where the WWTP outlet point is located, are those benefitting from such non-use services.

The weight of these non-use benefits in making the project economically sustainable (i.e., with a NPV = 0) can be up to around 75%, corresponding to circa 25 €/household, as savings for the irrigation consortium only counts for a 10% and benefits deriving from the fee for beach availability for around 15%.

Isolating the relevant environmental impacts among all the likely ones and identifying the affected stakeholders can be crucial to design effective surveys for assessing willingness to pay through stated preference methods: the paper has illustrated a methodological path to do so. Such a survey shall then be in charge to understand whether citizen’s willingness to pay for improving water quality in the presently prohibited coast stretch is comparable to the value required to make the reuse project economically sustainable in the quite likely case that benefits related to decreased salinity in irrigation water do not materialize.

**Supplementary Materials:** The following are available online at <http://www.mdpi.com/2073-4441/12/10/2926/s1>, Table S1: Crop types, distribution, and water requirements in the study area, Table S2: Relevant information to assess demand for beach services in Gallipoli and the related benefits.

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