Blue Plan Papers 11

TREATED WASTEWATER REUSE IN THE MEDITERRANEAN: LESSONS LEARNED AND TOOLS FOR PROJECT DEVELOPMENT

Nicolas Condom, Marianne Lefebvre, Laurent Vandome

PLAN BLEU
UNEP/MAP Regional Activity Centre
October 2012

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Plan Bleu
UNEP/MAP Regional Activity Centre
15, rue Beethoven, Sophia Antipolis
06560 Valbonne
France
www.planbleu.org

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Authors

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Steering Committee of the Project

The study was conducted within the framework of the "Environment and Water" program of the Center for Mediterranean Integration (CMI) with the participation of CMI partners:

- French Development Agency (AFD), Frédéric Maurel and Alain Rotbardt
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- Plan Bleu, Gaëlle Thivet

Reading Committee

Gaëlle Thivet and Dominique Legros (Plan Bleu)

Production

Maps and Charts: The authors and Jean-Pierre Giraud (Plan Bleu)

Bibliography and Documentation: Hélène Rousseaux

Graphic Design and Layout: Isabelle Jöhr

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Executive summary

Context, Objectives and Methodology of the Study

Wastewater reuse consists in using wastewater that has undergone different levels of treatment for beneficial purposes.

Projects for treated wastewater reuse (TWWR) contribute to an integrated management approach of water resources and to the protection of the environment. TWWR projects are particularly strategic in arid and semi-arid countries in the Mediterranean region where there is a strong pressure on water resources, as well as competition for water between the different uses in a climate change context.

Although TWWR is simple in principle, its effective implementation is nevertheless quite complex as illustrated by the difficulties encountered in the realization of projects. Combining cross-sector issues relating to water resources management, sanitation, the environment, agriculture and public health, TWWR requires an integrated, multi-disciplinary approach that should be specifically adapted to each situation.

The main objective of this report, conducted within the framework of the Environment and Water Program of the Marseille Center for Mediterranean Integration, is to capitalize on lessons learned in the Mediterranean region and to propose an analytical framework for projects, as well as methodological tools for decision-making.

This document is the result of a synoptic review of some twenty recent studies and reports of different nature (reports prepared or sponsored by international organizations, national reports by Mediterranean countries, prospective studies, etc.) to which a number of bibliographical references have been added.

It contains:

- A methodology and an analytical framework to identify and classify technical and economic criteria adapted to TWWR problems and issues;
- A descriptive analysis of experiences conducted in the Mediterranean region highlighting, among others, the negative and positive impact of projects;
- A decision-making tool suggesting a checklist that may be used by sponsors or donors in the initial stages of TWWR projects.

A number of figures and examples from situations observed in Mediterranean countries are used to illustrate these different elements.

Treated Wastewater Reuse in the Mediterranean: A Variety of Resources and Uses

In the Mediterranean, the predominant use of TWWR is agricultural irrigation, and it is quickly expanding because the agriculture sector withdraws a significant share of conventional water resources (an average 65% all Mediterranean countries considered, and over 80% in southern and eastern Mediterranean countries), and also, because in relation to the total volume of potentially reusable water only a minimal share of wastewater is currently treated in most Mediterranean countries. Moreover, in countries with limited sewerage facilities, irrigation with raw wastewater is an established practice, hence a lower risk of rejection or “yuk factor” concerning TWWR that provides safer water with less health risks. Lastly, TWWR has a significant fertilization potential.

Treated wastewater reuse for green areas and golf courses is rapidly increasing. Few regulations exist on TWWR for aquifer recharge, but it is in quick progression in countries with substantial experience and expertise in treated wastewater reuse like Spain, Israel or Tunisia.

Urban and industrial uses are localized, and there is no mention of domestic uses (greywater recycling) or purification of treated wastewater for drinking water.

Drivers, Context and Strategic Objectives of TWWR Projects

Together, the drivers, the context, and the objectives identified by actors lead to the definition of strategies and to the development of TWWR projects.

Drivers are associated to major structural changes—for example, increased water scarcity, stronger urban development or the expansion of irrigated agriculture, which may be observed in all Mediterranean countries.

Context related factors that explain the emergence or absence of TWWR projects are specific to each country or local situation. They concern the political, economic, regulatory, and health conditions, the type of agriculture, the available volume of water resources and sanitation coverage.

Objectives identified by actors (policymakers, users, special interest groups, etc.) in a given context and taking into account existing drivers include: improving health conditions, conservation of drinking water resources, environmental protection, and economic development of agriculture and tourism.

Obstacles and Success Factors of TWWR Strategies

Strategies for the development of TWWR projects will be more or less effective depending on the context.

The main obstacles identified are:

- Actors are faced with difficulties to fully apprehend the complexity of TWWR (dealing with cross-sector issues that concern water, food, health and the environment);
- Regulations are not adapted to local contexts;
- Competition for water resources (mainly conventional water);
- Difficulty to combine supply (resource) and demand (uses) planning over time and space;
- Inadequate or incomplete sanitation coverage;
- Risks of soil salinization and water pollution;
- Lack of monitoring procedures or analytical capacity;
- Inadequate tariff policy (heavily subsidized conventional water resources) and limited financial capacity;
- Inadequate technical knowledge and skills;
- Depending on the context, the public's perception could be highly negative, and the project may be eventually rejected.

On the contrary, success factors include:

- An integrated, multi-disciplinary and multi-sectoral approach, concerted among stakeholders and coordinated with the relevant institutions;
- Taking into account from the initial stages of project planning, the potential uses of TWW in relation to the quantity and quality of the wastewater resource;
- Incorporating TWWR into an integrated water resources management (IWRM) policy.

Economic and Financial Analysis

Cost-Benefit Analysis

By comparing the costs and benefits of a TWWR project, the economic analysis helps decide whether or not a project should be carried out; whereas the financial analysis will determine if the project may be financed and how. This report will focus on the economic analysis through the cost-benefit analysis (CBA) method.

Indicators for the valuation of the costs and benefits for the different actors involved in TWWR (during supply, treatment, storage, distribution, as well as end users) are presented. These indicators are useful in private cost-benefit analyses to determine if a project will be profitable enough for a private investor. Private costs include initial investment costs (costs for construction or upgrading of the treatment plant and network) and operating and maintenance (O&M) costs. The potential benefits for the investor are greater volumes of water sold and lower costs for wastewater disposal (not being reused). In addition, the end user (irrigation users, for example) can benefit from increased crop yield through organic fertilization and a more reliable water supply. These elements are likely to have a positive impact on the user's willingness to pay for water.

The social CBA will measure the social utility of a project by including all the negative and positive externalities, that is, the costs and benefits borne by agents outside the project during its implementation. Positive and negative externalities may concern health and environmental issues, as well as social aspects related to a TWWR project, for example: the impact on soil and groundwater pollution, water flows, periurban agriculture and landscapes, drinking water supply, long-term benefits for soil management and crop production associated to organic fertilization, greenhouse gas emissions due to wastewater treatment and the visual and odor pollution generated by settling ponds.

These externalities are rarely evaluated for projects developed in the Mediterranean and as a result the economic evaluation is distorted. This paper describes various methods to estimate a project's externalities and its qualitative impact.

TWWR Projects and Alternative Scenarios

A typology of the different scenarios for the development of TWWR is suggested. It includes all the different components of TWWR from source to use: (i) unplanned reuse, (ii) sanitation, (iii) TWWR for irrigation, (iv) TWWR for irrigation and aquifer recharge, (v) wide-ranging TWWR including domestic uses and drinking water, and (vi) desalination. Through this classification, it is possible to: analyze wastewater reuse in the different countries; identify potential models for efficient reuse; and compare wastewater reuse scenarios to conduct a cost-benefit analysis.

The typology will also be useful to identify a "without project" (or counterfactual) situation for comparison with a development scenario over 25 to 30 years (lifespan of the investment). The evolution of risks if the project is not undertaken should also be analyzed: health risks, competition among the different uses for conventional water, environmental risks (salinization of groundwater, lower aquifer levels, degradation of aquatic systems), social risks related to conflicts over downstream water uses, agricultural risks due to untreated wastewater reuse or to diminished water resources, and the risks for the tourism sector from the pollution generated by discharged effluents.

Based on the situations observed, six comparisons of development scenarios of TWWR are presented[1]. For each of these comparisons, a detailed analytical framework lists the different types of private and social costs and benefits that should be taken into consideration, as well as appropriate indicators for quantitative and qualitative evaluations.

Looking forward to a Paradigm Shift

Based on successful and unsuccessful situations observed, different recommendations aimed at removing obstacles and planning sustainable TWWR projects may be proposed:

- Adopting a holistic and multidisciplinary approach associating the resource-use (top-down) approach to the use-resource (bottom-up) approach.
- Choosing a wastewater treatment model that will be specifically adapted to the use by planning a system with separate flows—particularly for upstream domestic and industrial flows—and by taking account of sludge management.
- Considering the irrigation system (water-soil-plant-people) as an integral part of the wastewater treatment and reuse process. It should be adapted accordingly by modifying, whenever possible, soil management and crop production practices (using different farming techniques, irrigation equipment and quantities, etc.).
- Adopting measures to reduce and control health and environmental risks, as well as public rejection of the project.
- Taking into account every economic aspect by evaluating all externalities through private and social cost-benefit analyses, and adopting an appropriate tariff policy.
- Organizing specific training and awareness programs for each group of actors in order to develop their understanding, skills, and ultimately, gain acceptance of the projects.
- Following an adapted, phased "project approach" so as to clarify the context, evaluate the water situation, identify possible scenarios, and evaluate project feasibility and its viability, before planning and organizing the project.

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[1] i) Sanitation vs. No Sanitation, (ii) TWWR for irrigation vs. Irrigation with raw wastewater, (iii) TWWR for irrigation vs. Sanitation without irrigation, (iv) TWWR for irrigation vs. Traditional irrigation with conventional water resources,

(v) All TWWR applications (including domestic and drinking water) vs. TWWR for Irrigation + Aquifer recharge + Industrial and Urban uses (vi) TWWR vs. Desalination and Water transfers

Introduction

Context: Challenges for Developing TWWR in the Mediterranean

Wastewater reuse (WWR) consists in using wastewater that has undergone different levels of treatment for beneficial purposes.

Projects for treated wastewater reuse (TWWR) contribute to an integrated management approach of water resources and to the protection of the environment. TWWR projects are particularly strategic in arid and semi-arid countries in the Mediterranean region where there is a strong pressure on water resources, as well as competition for water between the different uses in a climate change context.

By developing an alternative use for treated wastewater, these projects reduce the pressure on water resources and may "release" significant quantities of conventional water for other uses or for the conservation of the environment and preservation of groundwater and surface water.

There is a wide range of treated wastewater applications, which vary according to the level of treatment: agricultural land irrigation, irrigation of parks and green urban areas, industrial and urban uses, environmental and recreational uses and aquifer recharge.

Issues at stake in the development of TWWR are linked to:

- Increasing water needs for agriculture, mainly due to climate change;
- Growing urbanization that results in rising volumes of effluents and the expansion of water supply and sanitation networks;
- New market opportunities for periurban farmlands that may benefit from the advantages of treated wastewater and its nutrients content.

Although TWWR is simple in principle, its effective implementation is nevertheless quite complex as highlighted by the obstacles encountered in the realization of many projects. Combining cross-sector issues related to water resources management, sanitation, environment, agriculture and public health, TWWR requires an integrated, multi-disciplinary and multi-sectoral approach, specifically adapted to each situation.

Objectives of the Study

The main purpose of this synoptic review, carried out within the framework of the Environment and Water Program of the Marseille Center for Mediterranean Integration (CMI), was to capitalize on lessons learned from TWWR experiences in the Mediterranean region and to propose an analytical framework for projects, as well as methodological tools for decision-making.

It also aimed to:

- Propose a typology of TWWR scenarios observed at regional, national and local levels;
- Identify and analyze the obstacles to the development of TWWR projects and formulate recommendations to remove such obstacles;
- Prepare operational methodological guidelines with equal emphasis on technical, organizational, and economic aspects.

Scope and Methodology

Methodology

This document is based on the analysis of some twenty studies and reports of different nature (reports prepared or sponsored by international organizations, national reports, prospective studies, etc.). Further information is provided in complementary bibliographical references, chiefly on economic aspects. The documents used to prepare this paper are also listed in the bibliography.

The study consists of:

- A methodology and an analytical framework to identify and classify technical and economic criteria adapted to TWWR problems and issues, which are generic and not limited to situations in Mediterranean countries. These criteria are assembled in various tables throughout the document;
- A descriptive analysis of experiences conducted in the Mediterranean region so as to understand the dynamics of TWWR projects;
- A "project approach", a decision-making tool, in the form of a checklist that may be used by sponsors or donors in the initial stages of the projects. The checklist appears in *Table 15*.

The document may be thus approached from different angles.

Structure of the Document

The first section presents the different water resources and uses in the Mediterranean so as to clearly show the nature of TWWR and the issues at stake (*Wastewater Reuse in the Mediterranean: a Variety of Resources and Uses*). Drivers and contexts leading to the development of projects are analyzed and compared in an effort to understand how they will determine the objectives and strategies with respect to risks and benefits (*Drivers, Context, and Strategic Objectives for TWWR Projects*). Follows a detailed economic assessment, through social and private cost-benefit analyses, complemented by a review of the financial aspects (*Economic and Financial Analysis*). As a conclusion and summary, the last section analyzes the levers that could remove obstacles and proposes an operational framework for the early phases of projects (from the initial idea to the feasibility study) including two tools: a step-by-step project methodology and a checklist. (*Moving Forward: Learning from Existing Experiences for a Paradigm Shift*).

Limits of the Study

The aspects below are presented succinctly in this report, reflecting the content of the documents analyzed.

- Activated sludge management (wastewater treatment plants, lagooning): it is an essential component of the TWWR approach, which consists in transferring matter from wastewater to sludge. However, this aspect is not developed in the documents on Mediterranean countries included in our analysis.
- Unplanned use of raw wastewater (for irrigation): a preponderant and traditional practice, it may represent the base scenario (counterfactual situation) for TWWR project development. It would be useful to analyze these practices (risks and benefits) that are rarely discussed in the documents studied. This report presents unplanned use at Mediterranean scale (*Raw Wastewater and Effluent Reuse*) and it is integrated as one of the scenarios in the economic analysis *(TWWR Project and Alternative Scenarios*).
- Other TWWR models: TWWR is often implicitly planned for domestic wastewater in a centralized treatment system (combined sewer network and treatment plant). But there are other forms of sustainable and planned wastewater reuse that can be complementary such as reuse in decentralized (on-site or near source) treatment locations and reuse through land application of raw agro-industrial effluents (land treatment).
- Energy–TWWR linkages: the energy approach is relevant to optimize TWWR projects economically and environmentally (CO_2 emissions), as well as for their comparison in economic terms with other non conventional resources, mainly desalinated water. This information was not available in the documents studied.

Treated Wastewater Reuse in the Mediterranean: A Variety of Resources and Uses

A Typology of Resources and Uses

Table 1 shows the variety diversity of water resources and uses in the Mediterranean, as well as possible uses according to the type of water resources. Untreated domestic wastewater is essentially used for crop irrigation and for environmental uses like low-water level support and the conservation of wetlands. Treated wastewater is used for irrigation of green areas and golf courses, aquifer recharge, industrial or urban uses.

Table 1 Types of water resources and uses in the Mediterranean region

WATER RESOURCES	CONVENTIONAL		NON CONVENTIONAL						
	Aquifers	Surface Water (rivers, lakes)	Drainage Water	Brackish Water	Raw Domestic Wastewater	Treated Wastewater	Desalinated Seawater	Desalinated Brackish Water	Raw Industrial Effluents
USES									
Crop irrigation	●	●	●	●	●	●	●	●	●
Irrigation of green areas and golf courses	●	●				●			
Aquifer recharge		●				●			
Environmental (low-water level support, wetlands, etc.)		●	●	●	●	●			
Industrial	●	●				●	●		Partial (recycling)
Urban	●	●				●			
Domestic	●	●					●		
Drinking water	●	●					●		

Raw Wastewater and Effluents Reuse

Untreated Domestic Wastewater for Irrigation (Unplanned WWR)

It should be noted that due to the lack of suitable reclamation facilities, the most common use of raw wastewater is irrigation (untreated and uncontrolled).

In places where a collection network exists (including rustic networks), wastewater is discharged at different points of periurban areas in canals used by farmers as alternative resources. Because of the proximity to markets combined with the absence of a cold chain, periurban agriculture is developing in contact with wastewater. Worldwide, an estimated 20 million hectares of farmlands are concerned by wastewater irrigation (UN, 2003). Likewise, it is estimated that 10% of the world population consumes produce grown in land irrigated with untreated wastewater (80% in Hanoi, 70% in Dakar, 25% in Pakistan) (FAO, 2010 and Bahri, 2009). In addition, the volume of wastewater produced is increasing rapidly.

In areas with few wastewater treatment plants, this is often the "without project" scenario (existing conditions) to be taken into consideration—with its negative and positive impacts—in the economic analysis of TWWR options.

Land Treatment of Agro-industrial Effluents

In land treatment, an irrigated soil-plant system is adapted for waste purification to exploit its wastewater treatment capacity. Pretreatment of effluents (through filtration, for example) may be required and storage capacity is necessary. Land treatment involves the repeated application of wastewater to the soil. The system requires strict monitoring of changes in the chemical properties of the soil and wastewater and thorough risk assessment (Bahri, 2009).

Beneficial Use of Wastewater Sludge

The beneficial use of wastewater sludge follows the same principle as land treatment. Actually, all treated wastewater reuse inevitably implies producing sludge (in treatment plants or through lagooning), since wastewater treatment consists mainly in transfers of matter from wastewater to sludge.

Sludge management is closely related to TWWR, but this aspect is often neglected in studies on TWWR in the Mediterranean.

Treated Wastewater Reuse in the Mediterranean: Paradigm and Uses

Treated Wastewater Reuse (TWWR) Paradigm

Wastewater reuse consists in using wastewater that has undergone different levels of treatment for beneficial purposes. A distinction should be made between:

- *Planned reuse* of treated wastewater that entails continuous water quality monitoring from source to use; and
- *Unplanned wastewater reuse*.

Treated wastewater reuse (TWWR) is the link between water resources and sanitation and agricultural water demand—and even fertilizers demand. (Urban and industrial uses are currently less developed.)

Treated wastewater reuse is consistent with an integrated water resources management (IWRM) approach, which is defined as follows: “Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment” (Global Water Partnership, 2000).

Typology of Treated Wastewater Reuse Applications

Figure 1 presents possible uses of treated wastewater, with the related detailed data in *Table 2*.

TWWR and Irrigation

Throughout the world and in the Mediterranean, TWW is predominantly used for irrigation of agricultural land. This application is expanding quickly for the following reasons:

- In the Mediterranean, irrigated agriculture accounts for almost 65% of conventional water withdrawals and over 80% in southern and eastern Mediterranean countries: treated wastewater therefore appears as an alternative that would enable saving conventional resources.
- The share of TWW in water for irrigation is still very low in most countries: 1% worldwide (IWA, 2008). In Syria, wastewater (treated and untreated) supplies 6% of the water demand for irrigation. There is clearly a strong development potential for wastewater use.
- Wastewater’s potential as fertilizer is significant: compared to a water input of 800 mm/year[2], the quantities of nitrogen and phosphorus in treated wastewater (activated sludge without denitrification)[3] are 150 kg and 50 kg respectively, which would represent more than half of fertilization needs.
- In countries with limited sewerage facilities, the use of raw wastewater for irrigation is a firmly established practice; therefore, there is a lower risk of rejection or “yuk factor” with respect to TWWR that guarantees more reliable water with less health risks. This is true in rural areas but not in urban centers due to differences in rural and urban population perceptions of treated wastewater reuse).

TWWR for green areas and golf courses is quickly increasing (Kramer & al., 2007).

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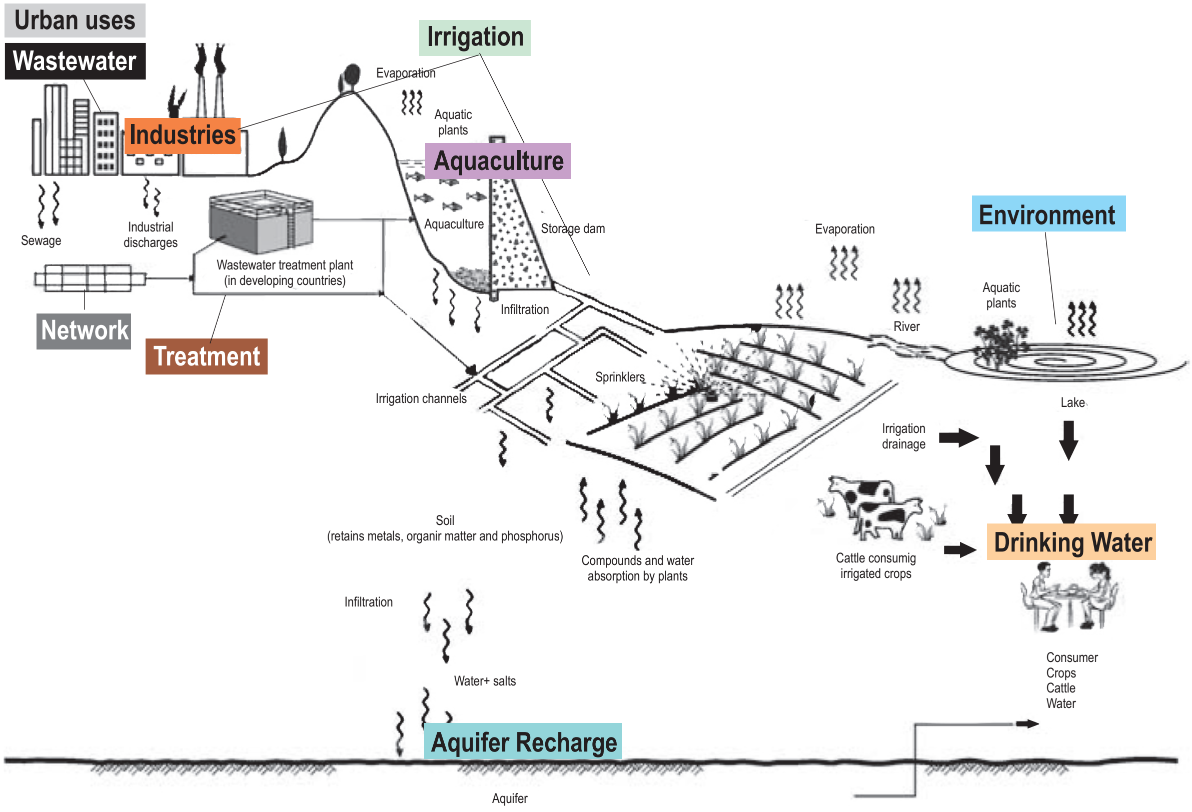
[2] Mean value for Syria (Source: BEI and AHT Group AG, 2009).

[3] Values used: Total Nitrogen: 15 to 35 mg/l; Phosphorus: 4 to 10 mg/l (Source: Asano; 2007).

Figure 1 Treated Wastewater Reuse (TWWR)



Source : Adapted from WHO, 2006

Table 2 Treated Wastewater Reuse (TWWR) applications and examples in the Mediterranean (and Asia)

Irrigation	Irrigation of food and non-food crops Landscape irrigation: parks, golf courses, residential areas, etc. Forest irrigation Land treatment
	Ex.: Crops and/or forest irrigation (Spain, France, Israel, Italy, Jordan) *Ex.: Landscape irrigation of golf courses, green or urban areas (Hammamet, Tunisia)*
Preservation of the Environment	Aquifer recharge Augmentation of surface water Fight against salt intrusion Recreational and environmental uses (lakes, etc.)
Industrial Uses	Recycling (cooling water, process water, etc.) Construction
	Ex.: Industrial use (Morocco, mining site of the Office Chérifien des Phosphates) (see Box 2)
Urban Uses excluding irrigation (separate distribution system)	Toilet flushing (on-site reuse) Cooling water for air conditioning Firefighting Ornamental use Street and road maintenance Car washing
	Ex.: Greywater recycling (Cyprus, Japan)
Drinking Water	Indirect reuse through augmentation of surface water Direct reuse (combined with conventional drinking water)
	Ex.: Drinking water supplies (Singapore)
Other Uses	Firefighting, artificial snow, etc.

TWWR and Aquifer Recharge

The main objectives of aquifer recharge through TWWR are:

- Maintaining the piezometric levels so that irrigation users may remobilize filtered water;
- Fighting against salted effluent intrusion (Barcelona in Spain and Korba in Tunisia);
- Using land treatment capacity for advanced treatment of TWW (mainly for immobilization of phosphorus).

The reports analyzed for the study only mention or briefly describe this use, which in a way translates the reality in the field. Aquifer recharge is less developed and is given less priority than TWWR for irrigation, except in Spain (project in Barcelona), Israel or Tunisia (project for Greater Tunis) that are leaders in TWWR. This application requires particularly efficient water quality control of treated wastewater and sound knowledge of the hydrogeological context.

Box 1 Aquifer recharge with treated wastewater in the Mediterranaen

In the Mediterranean, aquifer recharge is secondary to TWWR for irrigation. Marked differences are observed in TWWR for groundwater recharge, specifically, there are:

- Countries like Spain (leader in aquifer recharge) or Israel that have operational applications;
- Countries in which large-scale pilot projects have been developed that have regulations on aquifer recharge (Tunisia);
- Countries that are not currently concerned by this use that is prohibited or unregulated: Cyprus, Egypt, (experimental sites), France, Italy, Lebanon, and Syria.

Lessons learned from experience show positive results from technical and scientific points of view, for example, Shafdan in Israel or Nabeul and Korba in Tunisia (AFD and BRLi, 2011). The efficiency of measures against saltwater intrusion is currently being evaluated in Spain.

TWWR in Industries

Industrial reuse of treated wastewater allows increasing the productivity of factories while saving water resources and reducing the volume of residual water. There are two possibilities.

- An industrial site reuses the wastewater produced and treated on-site, which is referred to as recycling. Confirmed expertise in wastewater treatment is essential to maintain water quality without risks to the industrial process (machines). It is therefore necessary to identify specific treatment solutions adapted to each context taking into account the quality of water and the intended use (cooling, internal process, cleaning). An additional positive impact is that industrial water does not pollute domestic wastewater, and it becomes easier to reuse the latter.
- Treated domestic wastewater may be reused for cooling and cleaning (the energy sector, car washing, paper industry, steel and textile production, etc.).

Box 2 Industrial reuse of wastewater for phosphate washing in Morocco (Khouribga)

In Morocco, the wastewater treatment plant (WWTP) of Khouribga (activated sludge) is the largest project for the industrial reuse of wastewater for phosphate washing. The Office Chérifien des Phosphates (OCP) that exploits the mine of Khouribga (80% of phosphate extraction in Morocco) co-financed the WWTP that will have a 15,700 m^3/day treatment capacity by 2020. The OCP is planning to reuse all the wastewater treated throughout the year for phosphate washing. Since washing involves spraying, it is necessary to use water free of pathogens, colorless and odorless after tertiary treatment. This project has a strong positive impact on the protection of underground water in the region and is less expensive compared to other alternative sources of water like seawater desalination (BEI and AHT Group AG, 2009).

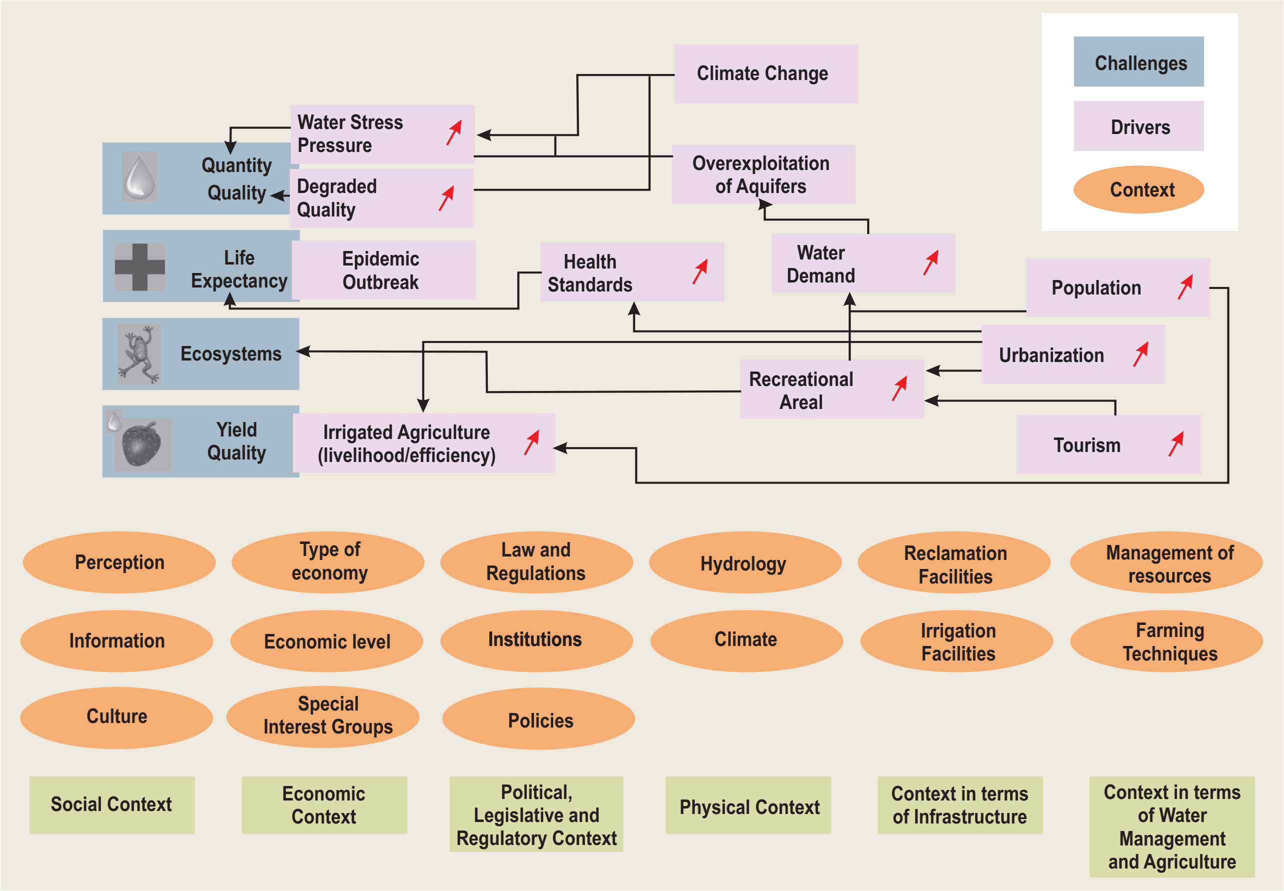
In view of the policies implemented for separate treatment of industrial water (in Morocco, for instance), TWWR for industrial applications is likely to increase in the future.

Drivers, Context and Strategic Objectives of TWWR Projects

Together, the drivers, context, and objectives identified by actors lead to the formulation of strategies and to the development of TWWR projects.

Figure 2 presents the drivers and context indicators associated to four challenges: water, health, environment and agriculture/food.

Figure 2 Drivers and context indicators of a TWWR project



Drivers

Typology of Drivers

Drivers are associated to major structural changes that are mostly unrelated to any specific choice or policy, for example, increased water scarcity, growing urban development or the expansion of periurban agriculture. These changes become drivers when they reach critical thresholds or are in the process of becoming critical.

Table 3 presents a typology of drivers based on information from the Mediterranean projects analyzed.

These drivers will become increasingly powerful if no action is taken.

Inter-related Drivers

It is difficult to isolate drivers: most of them are linked by cause and effect relationships.

For example, the **degradation of the quality of groundwater** is associated to the following drivers:

- Climate change – Accounting for lower precipitation levels in some countries, it aggravates water scarcity and reduces the water supplied to rivers, resulting in concentrations of pollutants and diffuse pollution from transfers to aquifers.

Table 3 Typology of drivers for the development of TWWR strategies in the Mediterranean

Sector of Application	Drivers
Water resources and demand	Pressure on water resources, overexploitation of groundwater (withdrawals >recharge) Deterioration of the quality of surface water and groundwater (pollution by wastewater, diffuse pollution from agriculture, local industrial pollution, salinization by saltwater intrusion) Increased demand of drinking water (population, tourism) Other uses increasing rapidly (industries, tourism activities) Climate change (higher water stress)
Wastewater discharges	Increased wastewater discharges Recycling of nutrients in treated wastewater
Environment	Degradation of aquatic ecosystems Disappearance of wetlands
Irrigated agriculture	Development of periurban agriculture Increasing demand of food produce Development of a more profitable irrigated agriculture Degradation of soil fertility (unplanned reuse)
Landscape	Development of recreational and green areas
Health conditions	Infections, diseases, epidemics
Socioeconomic	New livelihood opportunities Stricter health requirements (water, environment, food products, particularly for export) Unacceptability of unplanned practices (irrigation with raw wastewater)

Climate change has intensified the frequency of droughts and extreme climate events and has diminished water resources. In Spain, inflows of water to basins have been reduced from 30% to 50%. In Syria, annual rainfall dropped by 30% during the last century (BEI and AHT Group, 2009).

- Infiltration of untreated wastewater due to the lack of reclamation facilities.
- Overextraction of groundwater leading to saltwater intrusions that increase salt levels in aquifers (World Bank, 2010).
  This is the case in Israel (coastal aquifer) where the salt concentration has doubled in a few decades (>250mg CL/l) resulting in the abandonment of 60% of wells used for drinking water supplies.
- Tourism development in coastal regions has limited the possibility of discharging TWW into the sea, which has led actors to consider more efficient solutions for effluent treatment and TWWR in order to increase water quality (eutrophication control). On the contrary, seasonal population peaks contribute to increase the volumes of wastewater to be treated.
- Increased development of agriculture and industries that affect the quality of groundwater.
  In Israel's coastal aquifer, concentrations of heavy metals, microbial pollutants and toxic compounds have increased. Doubled levels of nitrate content have rendered 15% of the pumped water unfit for consumption according to Israeli water quality standards.
- Urbanization and the accompanying soil sealing are the cause of reduced aquifer recharge in heavily populated areas (In Israel: current deficit of 70 million cubic meters, and 150 million cubic meters by 2020).

The **disappearance of aquatic ecosystems** is associated to the following drivers:

- Overexploitation of groundwater resulting in lower piezometric levels. In Spain, 60% of wetlands have disappeared over the last 40 years (EVREN, 2011).
- Human activity in general that tends to withdraw the share of resources needed for the survival of ecosystems.
  The Dead Sea level drops by one meter every year, as the Jordan's waters are diverted to supply water to Israel, Jordan and Syria (Feitelson & Laster, 2011).

The Context: Typology and Examples

The context (national, regional or local) will determine the ranking of these drivers and their relative importance in decision-making. The context is characterized by indicators (for example, GDP population, rainfall, etc.), or variables, likely to change with time (due to economic growth, climate change impact, etc.).

A typology of context indicators and the related changes is presented in *Table 4*. Concrete cases are used to illustrate these factors in the following sections.

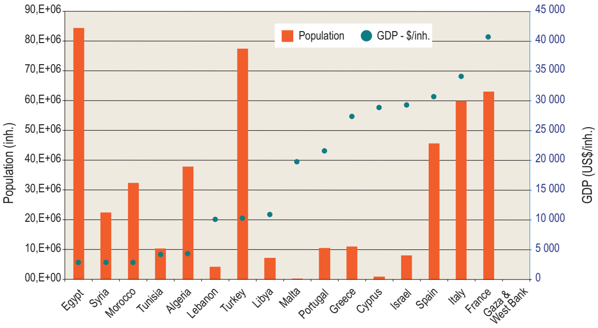
Socioeconomic Context

- **Level of Economic Development**

  The order of drivers or motivations and their relative importance varies according to the level of economic development of countries (FAO 2010). Concerning agriculture, the main objective of developing countries—providing food for the population and a source of income—has changed in developed countries where leading objectives include improved public health and the development of recreational areas.

  Population and economic development data for Mediterranean countries is provided in *Figure 3* below.

Figure 3 Population and GDP in Mediterranean countries in 2009



Sources: GDP 2009 (IMF) - Population (INED))

- **Development of Urban Centers**

  The population of southern and eastern Mediterranean countries is increasing rapidly (annual population growth rates: 1.5% in Israel, 2.5% in Syria and 1% in Tunisia). But the most significant change is the population influx to urban centers: by way of example, the proportion of the urban population in Israel is 92%, and 33% in Syria (50% by 2050), and it will reach 75% in Tunisia by 2050. This urban concentration not only increases the production of wastewater, but it also reinforces the potential role of periurban agriculture in the consumption of TWW.

- **The Agriculture Sector** in Syria, Tunisia, Spain and Israel

  In Syria, agriculture is a major economic sector. It accounts for 22% of GDP and occupies 31% (5.8 million hectares) of the country's land. 25% of cultivated land is irrigated (2004) almost entirely (97%) by submersion/flood and gravity irrigation systems, with low efficiency levels (approx. 60%). Crop yields from irrigated land (mainly cereals, cotton, and vegetables) are clearly higher than those grown on rainfed agriculture (five times more for wheat and citrus fruit). Sprinkler and drip irrigation methods are not common (190,000 hectares or 3% of irrigated land) but are developing quickly. Drainage is employed in 62% of irrigated land to avoid salinization.

  In Tunisia, agriculture is a developing sector that contributes 11% to GDP and employs 23% of the active population. There are 4.9 million hectares of arable land of which only 8% (405,000 hectares) is irrigated. There is limited irrigation potential (approx. 500,000 hectares) in view of the water resources allocated to the sector. 60% of irrigated land uses sprinklers (111,000 hectares) and drip irrigation (24,500 hectares). Significant efforts are already being made to modernize Tunisia's irrigation systems.

  In Spain, agriculture accounts for 3% of GDP. 3.5 million hectares are irrigated and highly efficient techniques (drip and sprinkler irrigation) are used on 66% of irrigated land. There is a complex network of multi-purpose dams and reservoirs where water is stored for agriculture, restoration of minimum flows, hydroelectricity, etc.

  In Israel, agriculture contributes 2% to GDP. Of the 355,000 hectares of arable land, 51% is irrigated and upgraded mainly through high value-added crops (50% fruits, 25% vegetables). Water quality requirements are variable.

- **Tourism and Industry sectors** in Syria and Tunisia

  In Syria, industrial water demand appears to be the same as domestic water demand (8.5% of the total water demand in 2025).

  In Tunisia, industries contribute 26% to GDP. Tourism is an important sector accounting for 7% of GDP.

Water Situation: Increasing Pressure on Water Resources

Water resources are quite unequally distributed in the Mediterranean both in time and space. Frequent droughts and water scarcity affect particularly southern and eastern Mediterranean countries. It is estimated that "water scarcity", that is, when the renewable water supply falls under 1,000 m^3 per capita per year, could affect a population of 250 million in the Mediterranean by 2025, of which 80 million would be in a situation of "absolute scarcity" with less than 500 m^3 per capita per year.

In the last half of the 20th century, the total water demand of all Mediterranean countries doubled, reaching 280 km^3 per capita per year in 2007. It could

Table 4 Context indicators related to decision drivers for TWWR projects

Variable	Indicators and changes
Socio-economic	
Level of economic development	GDP (or GNI) Change: Growth rate
Demography	Population density Change: Population growth
Urbanization	Distribution urban/rural area Change: urbanization, migration flows to cities
Role and Type of Agriculture	Arable crops, vegetable growing, etc. Role of irrigated agriculture Type of irrigation, efficiency, methods Economic role Types of market: export/domestic/livelihood
Tourism, Industry	Number of tourists, industrial development
Special interest groups	Special interest groups (agriculture/tourism, environmentalists, consumers)
Culture, Religion	Perception of wastewater reuse
Water resources, uses and water deficit	
Water resources	Potential of renewable water resources Conventional resources (groundwater, rivers) and non conventional (treated wastewater, desalinated brackish water, desalinated seawater, drainage water) Groundwater and surface water exploitation index
Water demand, particularly irrigation and domestic water demand	
Quality of groundwater and surface water (pollutants, salinity, nitrogen)	
Water deficit	Water stress index Use of renewable supply of water index Droughts
Experience in wastewater reuse	Existing raw wastewater irrigation (YES/NO) Existing TWWR (YES/NO)
Irrigation with raw wastewater (unplanned)	Volume of raw wastewater reused Surface irrigated with raw wastewater
Irrigation with treated wastewater	
TWWR Applications	
Physical	
Climate	Precipitation, potential evapotranspiration Droughts (frequency, duration)
Physical and hydrological characteristics	Watershed characteristics Nature of soils Transboundary watersheds
Reclamation facilities	
Wastewater collection system	YES/NO Number of wastewater treatment plants
Wastewater treatment	YES/NO Method
Policies and regulations	
(Geo) politics	Policy incentives International agreements Autonomy in water resource management
Type of laws, regulations and recommendations	
At international, national, regional or local levels	Guidelines (Recommendations) (WHO, EPA, etc.) Laws and regulations on the preservation of surface water and groundwater, wastewater treatment and irrigation Specific laws and regulations applicable to TWWR

increase even more by almost 20% by 2025, mostly in southern and eastern Mediterranean countries.

In some countries (Egypt, Israel, Jordan, Libya, Malta, Palestinian territories, Syria), water withdrawals are close to or already exceed the threshold of renewable water resources (*Figure 4*).

An increasing proportion of water demand is met through the production of unsustainable water based on withdrawals of fossil water or overdrafts of renewable resources (which is mainly the case in the coastal aquifers of Spain, Israel and Tunisia).

To address this water stress situation, Mediterranean countries increasingly resort to non conventional water sources, such as desalination of seawater or brackish water and treated wastewater reuse. Figure 5 presents the volumes of conventional and non conventional water resources available for some Mediterranean countries.

Additionally, the quality of groundwater and surface water has degraded in many Mediterranean regions due to overexploitation of aquifers and the resulting seawater intrusions (salinity); discharges of untreated urban water (microbial pollutants, nitrogen, phosphorus, emergent pollutants); industrial discharges (toxic compounds) and agricultural pollution (drainage water, pesticides, herbicides, nitrogen, phosphorus).

Wastewater Treatment and Reuse

Percentages of volumes of raw, treated or reused wastewater for several Mediterranean countries are shown in *Figure 6*. The graph compiles only available data to date from reference studies.

Legislative and Regulatory Framework

Table 5 summarizes the legislative and regulatory framework applicable to TWWR (regulated / non regulated uses, and whether or not TWWR is authorized when regulations exist)[4] in different Mediterranean countries .

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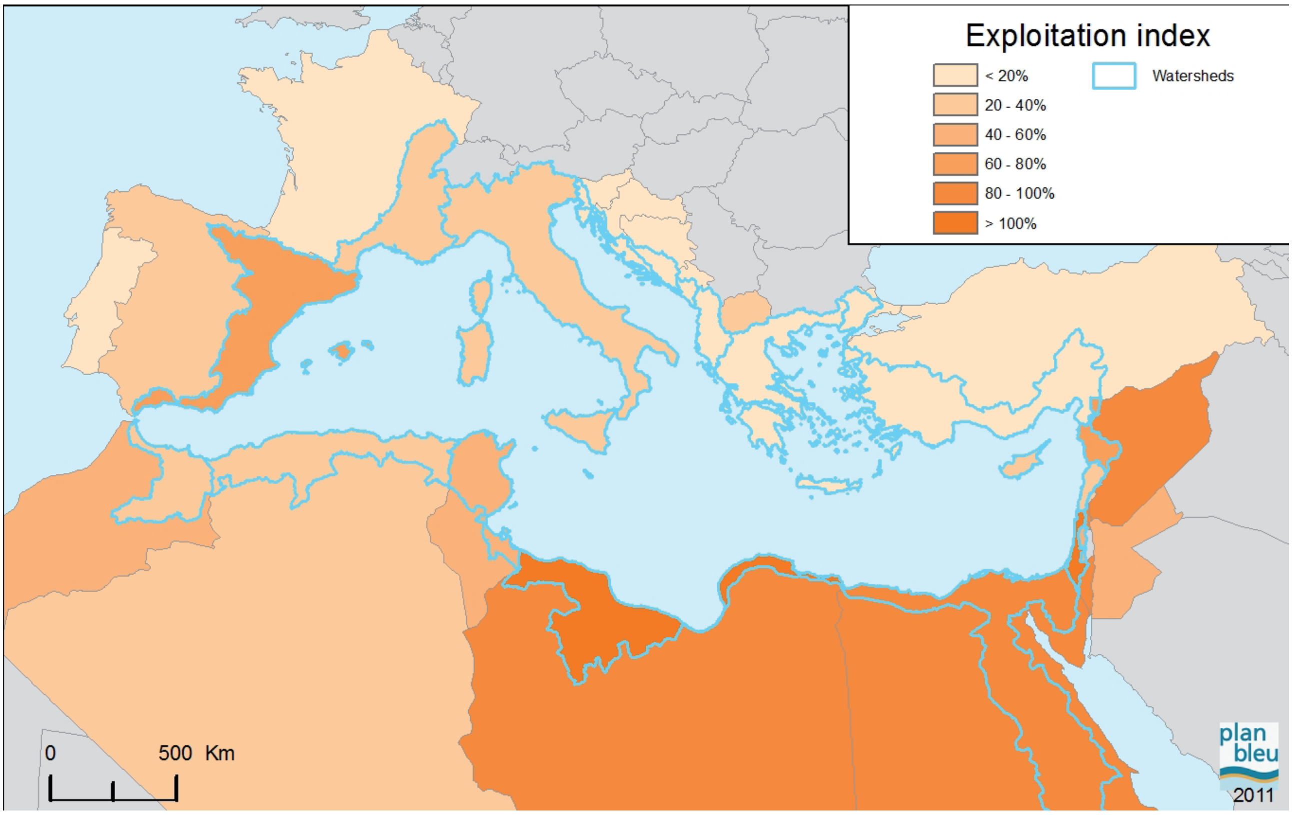
[4] This is not an exhaustive compilation and should be completed for some countries where regulations and laws have changed recently.

Figure 4 Renewable water exploitation index in the Mediterranean, by country and by watershed (2005-2010)



Source: Plan Bleu, 2011

Note: An index close to or higher than 80% indicates severe water stress; and index ranging from 60 to 80% indicates high risks of structural stress over the medium term; countries with an index between 20 to 60% may experience local or occasional water stress.

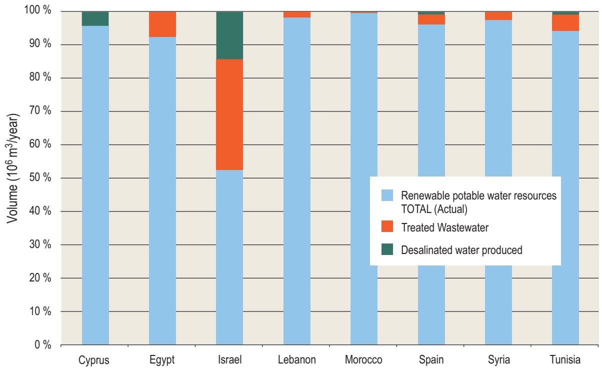
Table 5 Authorized use of TWWR by country

	Cyprus	Egypt	France	Greece	Israel	Italy	Jordan	Lebanon	Morocco	Portugal	Spain	Syria	Tunisia	West Bank	(Saudi Arabia)	(Koweit)	(Oman)
Agricultural Irrigation	🟩	🟥 C+F+E 🟩	🟩	🟩	🟩	🟩	🟩	▨	🟩	🟩	🟩	🟥 C+P	🟥 C 🟩	🟥 C 🟩	🟥 C 🟩	🟥 C 🟩	🟩
Ladscape Irrigation/ golf courses	🟩	🟩 **	🟩	🟩	🟩	🟩	🟩	▨	🟩	🟩	🟩						🟩
Aquifer Recharge	▨		▨	🟩	🟩	▨	🟩	▨	🟩	🟩	🟩	🟥 *					
Environment	▨		▨	🟩		▨	🟩	▨		🟩	🟩						
Industrial Recycling	▨		▨	🟩		🟩		▨		🟩	🟩						
Urban Use	🟩		🟩	🟩		🟩		▨		🟩	🟩						
Domestic Use	▨		▨	🟩		▨		▨		▨	🟩						
Potable Water	▨		▨	▨		▨		▨		▨	▨						
	(1)		(1)			(1)		(2)		(1)	(1)			(1)	(2)	(2)	(2)

C: Products eaten raw - F: Fruit withour pericarp - E: Crops for export - P: Pasture
* Aquifers exploited for drinking water
** Excluding green areas in schools
Source: Compiled by the author - Data sources: (1): Eureau - (2): Xanthoulis (2010)

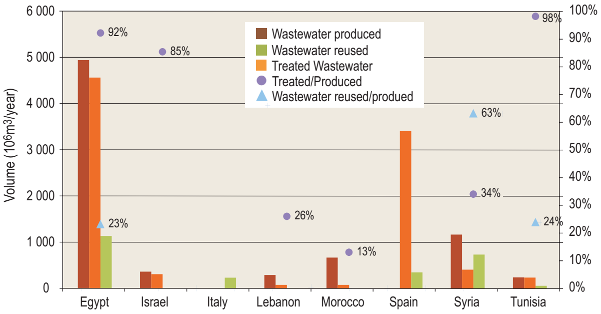
🟥 **Regulated / Banned**
🟩 **Regulated / Authorized**
▨ **No regulations**

Figure 5 Relative share of conventional and non conventional water resources in some Mediterranen countries (2008-2010 data depending on the country)



Sources: Reports included in the bibliography, international databases (Aquarec, Aquastat, IMF, World Bank,WHO, INED) and different authors (Boyer, 2008).

Figure 6 Wastewater Treatment and Reuse in Mediterranean countries (2009-2010)



Sources: Reports included in the bibliography, international databases (Aquarec, Aquastat, IMF, World Bank,WHO, INED) and different authors.

Risks and Benefits of TWWR

The implementation of TWWR projects is only taken into consideration if they are expected to produce benefits (production of additional water resources, reduced pollution, increased crop yield, etc.). These benefits must be evaluated against perceived or possible risks (soil pollution in case of inefficient treatments, rejection by users or consumers, financial profitability risks, etc.).

Table 6 and *Table 7* present a typology of risks and benefits associated to TWWR projects.

Note: It is useful to bear in mind that a risk is the probability of a hazard interacting with a sensitivity (or exposure). Mitigating risks implies developing strategies to minimize the hazard and/or the sensitivity. Example: health measures whose objective is to reduce the concentration of pathogens in the water (reducing the hazard) and to propose protection measures to reduce exposure (reducing the sensitivity).

Table 6 Typology of risks associated to TWWR

Sector or element concerned	Risks	Hazards	Sensitivity (Exposure)
Health	Microbial risks: cholera, infections, diarrhea, allergies Chemical risk: intoxication, cancer Poor quality of food products	Pathogens Toxic compounds Emerging pollutants, endocrine disrupters	Exposure (public, users, consumers)
Environment	Eutrophication, groundwater pollution Odors Impact of treatment by-products (membrane concentrates, sludge) CO_2 emissions (energy consumption for treatment)	Nitrogen, phosphorus toxic compounds, heavy metals	Depth of aquifer, environmental sensitivity (coastal areas)
Soil and plants	Plant toxicity (salts) Salinization and land degradation (salt water) Accumulation of pollutants in the soil	Salinity, heavy metals	Crop sensitivity, soil fragility
Perception	Visual impact (storage) Odors Social rejection (lack of knowledge, fears) Tensions in case of expropriations	Nuisance	Level of perception, tendency to change
Distribution, equipment	Algae growth Corrosion, biofilms, clogging	Organic matter, nitrogen, phosphorus, suspended solids	Type of irrigation system

Table 7 Typology of benefits associated to TWWR

Sector or element concerned	Benefits
Water resources	Lower pressure on drinking water supply, improved allocation, volumes of conventional water are released for drinking water supply Diversified resources, TWWR is incorporated into an integrated water resources management (IWRM) approach TWWR (production and transport) is less expensive than other non conventional resources (for example: desalinated water) Preservation of piezometric levels through aquifer recharge Better quality groundwater Adaptation to population density
Environment	Safer sanitation services (soil/plant buffer), and even energy savings Reduced nutrients in surface water, seawater and groundwater Less eutrophication Restoration of aquatic life Protection against saltwater intrusions Preservation of minimum flows, recreational water supply (fountains, lakes, etc.) Lower energy consumption in wastewater treatment plants and for water conveyance Less greenhouse gas emissions Fight against desertification through water supplies for green belts
Agriculture and recreational areas	Increased soil fertility due to the nutrients found in TWW and increased crop yield Reduced need for traditional fertilization (savings in fertilizers) Secure water supply (particularly during droughts) Diversification to crops with high added value Agronomic value of by-products of wastewater treatment installations Food security, development, periurban agriculture
Social	Improved quality of life (green areas) and health conditions Agriculture contributes to wastewater treatment Participatory approach involving local actors Preservation and creation of jobs (periurban agriculture)

Box 3 TWWR in Israel, Syria and Tunisia: Relationships between drivers, context and objectives

Israel

In the 1950s, the increasing lack of water due to the imbalance between limited water resources (essentially located in the north) and an increasing demand (in the center and south, generated by population growth and irrigation water needs for cotton fields) led Israeli authorities to implement a twofold program to modernize irrigation systems and to identify new water resources (desalinated water and treated wastewater).

Concerning desalination, pilot studies were carried out on desalination of brackish water, followed by seawater in the 1980s. The severe droughts of 1998-1999 created awareness on the strategic importance of desalination to secure quality water supply.

As for wastewater reuse, during the 1970s, the competition over water resources between growing domestic uses and irrigation needs, as well as a cholera outbreak caused by the consumption of vegetables irrigated with raw wastewater resulted in:

- the creation of sanitation programs that combined treatment and reuse, as in the Shafdan project for a treatment system consisting of activated sludge and infiltrations in the aquifer, and the Kishon project. The water initially used in peripheries is today conveyed through a system of dams and canals to the agricultural land in the South; and
- the formulation of an ad hoc legislative framework.

In the 1990s, water quality requirements became stricter and the perception of TWWR changed:

- due to more modern irrigation methods and the cotton crisis, an agriculture reoriented to high value-added crops became more demanding in terms of water quality;
- irrigation restrictions due to droughts changed the farmers' mentality who saw TWWR as a possibility to have a secure water supply;
- irrigation with raw wastewater is no longer accepted by the increasing number of urban dwellers who are better educated and trained;
- massive migration flows from former USSR countries compelled authorities to expand sanitation coverage.

Strategies were formulated to expand sanitation services and TWWR integrating its technical, regulatory (new regulations) and social aspects. Today, Israel is among the Mediterranean's leaders in TWWR.

Syria

Agriculture is a major sector in the Syrian economy. Irrigation with (raw) wastewater is an old and culturally accepted practice. One of the key drivers for TWWR is producing additional water resources for the expansion of irrigated agriculture—five times more productive than rainfed agriculture—taking into consideration the impact of climate change (30% less rainfall during the last century) and the strong population growth.

In 1971, water quality standards are published (based on WHO, FAO and EPA standards) and the Polluter Pays principle is put into practice. In 2002, standards applicable to irrigation through TWWR become even more restrictive than WHO standards (TWWR is forbidden for crops that are consumed raw).

Efforts to find new sources of water lead to transboundary agreements.

Practically all treated wastewater is consumed by the agriculture sector that accounts for 87% of total water demand.

The deterioration of the quality of groundwater (nitrates, salinity, and pollution from oil industry) justifies developing aquifer recharge (after denitrification of treated wastewater) for wastewater dilution and against saltwater intrusions in coastal aquifers. Aquifer recharge is currently prohibited.

Tunisia

Facing increasing water pressure, Tunisia implemented during the 1980s a program for wastewater treatment and reuse for irrigation (Medjerda basin), and facilities were installed in 11 major Tunisian cities. A managing body, the National Sanitation Utility (*Office National de l'Assainissement,* ONAS) was created. Since then, its status has changed and the utility's responsibilities now cover the entire TWWR cycle.

Irrigation with untreated wastewater was forbidden in 1975, and TWWR standards were formulated in 1989.

At the same time, programs were developed to mobilize conventional resources leading to the creation of a system consisting of dams (20), mountain reservoirs (220) and lakes, as well as 50,000 wells and 20,000 bore wells. Efficient sprinklers systems were installed through programs to modernize irrigation practices, which also included cultivating crops requiring less water, with direct benefits for the agriculture sector.

In the 1980-90s, overextraction of groundwater and the deteriorated quality of coastal aquifers (shallow and sensitive to seawater intrusions) led to the implementation of pilot sites for aquifer recharge by TWWR (in the Nabeul Region in 1985, and later in 2007) and to the development of sanitation and TWWR programs.

The development of tourism and its consequences in terms of water quality standards and new recreational areas is also a strong and more recent driver for TWWR in landscape applications, such as golf courses and green areas.

Aware of the importance of wetlands preservation, two projects were developed, in the Sahel region and the Cap Bon Region, with positive impacts.

In the 1990s, desalination of brackish water was developed, and not long ago seawater desalination.

Moreover, more recent actions closely related to TWWR include programs for the management of drinking water supply (network maintenance, training for personnel, tariffs, etc.) and for sludge management (Decree of 2007).

Strategic Objectives in relation to Drivers and Context

Historical Evolution in Three Countries

Objectives are defined by actors (policymakers, professional representatives, users, etc.) in a given context and in view of the drivers that lead to observed or future critical situations. Some examples include environmental protection, improving public health, developing agriculture or the preservation of drinking water supply. In some studies, these objectives are referred to as "motivations".

A strategy consists of a group of objectives and the method designed to reach those objectives.

Box 3 summarizes the historical evolution of TWWR in three Mediterranean countries and illustrates the relationship between drivers, context and objectives

Main Objectives of TWWR Applications

The main objectives of decision-makers in Mediterranean countries who choose to launch TWWR projects are to:

1. Improve health, environmental and social conditions:
   - New source of water supply,
   - Agricultural production and food security,
   - Safer health conditions: no more irrigation with raw wastewater and better wastewater treatment,
   - Improved environmental conditions: protection and restoration of sensitive environments such as wetlands and coastal areas, maintaining minimum flows and piezometric levels through aquifer recharge, conservation of aquatic systems, control of brackish and seawater intrusions, benefits of nutrients recycling, etc.
2. Anticipate the future:
   - Adapting to climate, population and economic changes,
   - Developing new uses: greywater recycling, TWWR for drinking water.
3. Promote economic efficiency: TWWR is less expensive than other non conventional resources (for example, desalination), selling water to private actors (urban irrigation, golf courses, industries).
4. Enable and support economic development:
   - Participatory local development of agricultural, recreational, urban and industrial activities,
   - Support to the development of an economic sector: for example, agriculture in Syria and tourism in Tunisia with new recreational areas.
5. Undertake a sustainable development policy and communicate on this topic.

Traditional and Sometimes Competing Strategies

In the absence of an integrated approach in which all aspects of TWWR are taken into consideration (water, health, environment, food and social issues), TWWR is often treated as a component attached to more traditional lines of reasoning within programs for sanitation or modern irrigation practices.

A strategy centered on TWWR can be confronted to other courses of action against which it will be evaluated.

TWWR and Sanitation

Wastewater is at the same time:

- A "problem": 90% of urban zones throughout the world do not have adequate sanitation (Bahri, 2009) resulting in major health (users in contact with wastewater, contaminated food) and environmental (pollution of aquatic environments, water pollution) problems.
- An important economic resource: both in terms of food production and as source of employment in the agriculture sector. Throughout the world, 20 million hectares of land are irrigated with raw wastewater (UN estimate, 2003).

Wastewater contains 27 million tons of nitrogen and 3 million tons of phosphorus or the equivalent, respectively, of one third and one fourth of fertilizers sold worldwide (theoretical equivalence) (WHO, 2006).

Ideally, sanitation strategies include actions associated to (i) the water resource, (ii) the collection of wastewater and solid waste and (iii) the treatment and reuse of wastewater and waste. Reuse is therefore a component of a more comprehensive strategy. For local governments, considering institutional and financial aspects, it is important to determine if these actions may be carried out simultaneously. If it is not possible, priorities should be established. The analysis of the situation could be conducted by comparing different scenarios (see *TWWR Projects and Alternative Scenarios*).

In line with the country's level of development (in relation to the gross national income – GNI), the following trends have been observed (World Bank, 2010).

- For low-income countries (GNI < US$975 per capita): lack of regulatory framework, health standards or collection network, limited or no wastewater treatment, and irrigation with raw wastewater;
- For middle-income countries (GNI per capita ranging from US$975 to US$3,855): regulations are being developed, larger coverage of sanitation services, implementation of a sanitation network, limited or no treatment and irrigation with raw wastewater;
- For high-income countries (GNI > US$3,855 per capita): regulations exist as well as a wastewater collection network with primary, secondary and sometimes tertiary[5] treatment, and treated wastewater reuse.

In a traditional sanitation approach, implementing TWWR applications is done once a system for wastewater treatment is already in place. It is a top-down approach (upstream ➔ downstream) according to a time-phased plan.

Many TWWR projects are launched on account of projects for the rehabilitation or expansion of wastewater treatment plants. This is a more integrated approach (uses are taken into consideration with respect to the resources), but TWWR options are contingent on the existence of a sanitation system.

Finally, in more recent approaches, TWWR is considered an integral element of a sanitation project (including a wastewater network and a treatment plant). In this case, it is part of a bottom-up approach (downstream ➔ upstream) that allows iterations between the needs for each use (varying in time) and the collection system (separate domestic/industrial wastewater flows, separate-sewer networks) and treatment levels (see Looking forward: Learning from Existing Experiences for a Paradigm Shift).

TWWR and Modern Irrigation Methods

Depending on the water stress level, irrigation is either a *sine qua non* for agriculture or a way of increasing crop yield from 100% to 400% (FAO, 2010) and therefore a highly attractive option. In Syria, for example, yields for wheat and citrus fruit crops quadrupled with irrigation (BEI and AHT Group AG, 2009). Water consumption for irrigation (an average 65% of withdrawals in the Mediterranean) is still strong, but it tends nevertheless to become stable due to programs for the modernization of irrigation techniques.

Treated wastewater is presented as a non conventional, alternative water resource for domestic uses or for the tourism sector, depending on priorities.

In a water saving approach, it may be necessary to determine whether or not a strategy to modernize irrigation (equipment, practices) without any TWWR projects will be more efficient than TWWR applications. Two situations may be observed:

- When low efficiency irrigation systems (40% to 60% for gravity irrigation systems) are preponderant, a policy to modernize equipment and to provide training for irrigation users seems to be more efficient than TWWR.
  In Morocco, an increase in efficiency of 20 points (for instance, by replacing gravity irrigation with sprinklers) could reduce losses by half and water withdrawals by almost 25%, the equivalent of 2 billion m^3/year, or 15% or the total water demand. Subsidizing more modern equipment for irrigation is a more efficient method of saving water, and TWWR projects hence appear as less attractive.
  In Syria, gravity irrigation is used in 88% of irrigated land. Based on mean values, if all treated wastewater were to be used in irrigation, an additional 11,000 hectares could be irrigated compared to 730,000 additional hectares that could be irrigated with more efficient irrigation systems (saving 50% of water resources) (BEI and AHT Group AG, 2009).
- If highly efficient irrigation systems are already in place (80% with sprinklers and even higher with drip irrigation), there is less margin for optimization, and TWWR becomes a powerful lever for the preservation of conventional resources.
  Early in the 1950s and 60s, Israel implemented policies to modernize irrigation systems and currently has substantial expertise in drip irrigation.

Potential Obstacles, Constraints and Failure Factors

This section presents and illustrates possible obstacles to the development of a TWWR project and the constraints observed in ongoing projects that may sometimes become failure factors. The nature and ranking of constraints will vary depending on the context of the project.

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[5] Tertiary or advanced treatment: wastewater treatment following the traditional secondary treatment, which consists in removing chemically and physically non biodegradable pollutants and mineral nutrients

Based on data collected from Mediterranean countries in which TWWR for irrigation is preponderant, *Table 8*[6] presents a typology of the main obstacles encountered, illustrated with examples in the Mediterranean region. *Box 4* highlights the assets and limitations of laws and regulations in the implementation of TWWR projects in the West Bank, Morocco and Syria.

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[6] This table should be completed for aquifer recharge, industrial, urban and domestic uses or drinking water supply.

Box 4 Assets and limitations of laws and regulations for TWWR project development in the West Bank, Morocco and Syria

The strict discharge standards in the West Bank are difficult to enforce.

In Morocco, the legal and regulatory framework lacks coherence and is incomplete, particularly with respect to: obligations of local governments and users; tariff and operation regulations; monitoring of discharges and sanctions for non-compliance with standards (including industrial discharges); sludge management and wastewater reuse. (Source: National liquid sanitation program, adopted in 2005 with objectives for 2020.) As for TWWR applications, the legal framework is incomplete and there is the problem of effectively enforcing regulations. This could also be related to the fact that among the many existing legal texts, some are conflicting and not many of them were drafted with an integrated management of resources in mind.

In Syria, it is forbidden to use treated wastewater for irrigation of crops that will be eaten raw (contrary to WHO recommendations) therefore excluding TWWR for vegetable growing and motivating some users to go back to unplanned reuse practices. For combined sewer effluents, crop rotation requires the application of the most restrictive standard. The number of chemical parameters to be controlled (38) requires analytical capacity that is not always available in Syria (heavy metals, etc.). FAO standards—maximum salinity level—are not enforceable in a local context in which the water's geochemical salinity is naturally high and where farming practices are adapted to high salinity levels. The ban on aquifer recharge by TWW is a constraint on TWWR for irrigation, since it does not allow for a complementary use outside of irrigation periods. Regulations are inadequate, particularly regarding health protection measures; there is no monitoring (no planned water quality controls), and additional means are required to enforce regulations.

Table 8 Potential obstacles, constraints and failure factors for TWWR projects for irrigation

Obstacles related to:	Types of obstacles encountered	Examples in the Mediterranean
Complexity of TWWR	It is difficult to develop customized solutions: difficulty to integrate the entire chain, from source to application; the great number and variety of parameters involved (most are context specific). Ineffective top-down approach: traditional approach to sanitation network dimensioning based on the wastewater (upstream) without taking into account downstream use.	
Institutional and organizational context	No common authority and lack of coordination between scattered institutions. Lack of a TWWR strategy within and Integrated Water Resources Management approach. Inexistent master plan. Lack of combined strategies with sludge management. Limited involvement of concerned actors not adequately organized (users, consumers, etc.).	In Morocco, the interministerial coordination committee for wastewater reuse management that was created in 2004 is still not operational. In Syria, five ministries are involved in TWWR management. In Tunisia, a national utility (ONAS) exists but does not have financial autonomy. Lack of shared awareness of the challenges of TWWR has been observed in several countries, particularly in Morocco and in Syria. There is frequently no master plan (Lebanon, Morocco).
Legislative and regulatory framework	Inexistent or incomplete legislation and regulations Inadequate standards	Sometimes regulations do not exist (Lebanon), others are very recent (France), are not adapted to uses, or are not flexible enough because they are exact copies of international standards. This is the case in countries where raw wastewater reuse is a strong tradition that will be favored if stringent standards are adopted for TWWR (For example: banning TWWR for crops eaten raw in the West Bank, Egypt, Syria and Tunisia.)
Competition between TWW and conventional water	When there is a choice, conventional water resources are favored because they: (i) appear as safer and less restrictive, (ii) are less expensive because often subsidized, (iii) saving them may be more effective than developing an alternative water supply. There is also competition with irrigation practices that use raw wastewater.	Today in Morocco and Syria, policies for water resources mobilization for agriculture and for the modernization of irrigation methods are still more efficient than TWWR in terms of water savings. In Tunisia, farmers prefer conventional water sources, when they exist, to TWW that entails constraints (protection, restriction on crops) and risks. Concerning groundwater pumping, and all the more if it is saline groundwater, the economic competitiveness of TWW is genuine.
Difficulties to combine supply and demand planning	Distance between wastewater production and reuse locations (spatial variability) Regular supply vs. Seasonal demand (time variability)	In Syria and in Tunisia, wastewater treatment plants are concentrated in urbanized coastal areas where there are less opportunities to use TWW (since these zones receive adequate rainfall). On the contrary, arid regions inland with low urbanization levels are in great need of water. Concerning TWWR for irrigation, the greatest needs are from April to October, remaining low the rest of the year. As for tourist areas, the rise in wastewater production is better synchronized with the increase in water demand for irrigation (Spain, Morocco, Tunisia, etc.).
Inadequate storage capacity	Inadequate storage capacity (need 4 to 6 months of storage in large reservoirs, lakes, underground reservoirs, etc.) Silting up of reservoirs	
Wastewater collection and sanitation systems	Inadequate sanitation capacity Poor treatment level /quality of TWW Sanitation not a priority/other infrastructures (energy, drinking water supply) Inadequate technical expertise Industrial effluents combined with domestic effluents	The lack of treatment capacity limits the possibility of TWWR (For example: 20% of TWW reuse in Syria). As a result, the untreated wastewater is directly discharged into the sea on coastal zones: large volumes of water resources lost that could have been reused (Morocco, Lebanon). In Lebanon, a particular situation due to the post-war reconstruction process, human and financial means are mobilized on infrastructure for drinking water and energy supply to the detriment of sanitation. Because of the average performance observed for wastewater treatment plants, the lack of treatment for toxic compounds (heavy metals, emerging pollutants, medicine residues) and inexistent desalination procedures, it is not possible to meet the quality levels required by TWWR standards. All of these factors contribute to discredit treated wastewater reuse. Inadequate skills in treatment systems have been pointed out in Spain. In Morocco, Syria and Tunisia, contamination of domestic wastewater has resulted from the lack of a separate collection and treatment system for industrial effluents.
Soil management and crop production	Restricted choice of crops according to regulations (in particular, those that prohibit TWWR for irrigation of crops eaten raw). Deterioration of soil fertility: reduced infiltration (accumulation of suspended matter), soil salinization and excessive sodicity. Inadequate drainage resulting in soil salinization and reduced yields.	Salt concentrations in treated wastewater are sometimes higher than in conventional water and may cause soil degradation—affecting physical and chemical fertility—in the absence of drainage systems. In Tunisia, land salinization observed in many projects has become an obstacle. Two projects (Mornag and Morknine) have been abandoned for this reason.
Financial arrangements and tariff policy	Lack of financial capacity and structures Inappropriate tariffs for TWW (low profitability), conventional water for irrigation is provided free of charge or subsidized.	In many cases, conventional water tariffs do not integrate the “water scarcity” factor and fees are inadequate to ensure profitability of TWWR projects. In Morocco, water fees only cover 25% of sanitation costs.
Negative perception and unacceptability	A negative perception of TWWR by farmers, consumers and policymakers: (i) fears of potential risks involved, (ii) due to negative experiences in uncontrolled conditions or badly planned. Cultural and/or religious barriers	In France, irrigation with wastewater downstream from the Acheres treatment plant that collects wastewater from Paris and the pollution it generated impacted the public opinion and may explain in part the belated regulations that followed particularly focused on protection measures against health risks (see Decree on TWWR for irrigation of August 2010).
Lack of a “project methodology”, of training and of communication	Absence of an economic analysis method for projects Lack of expertise Lack of training Not enough information campaigns on the benefits	In Syria, knowledge and expertise are inadequate at all levels: decision-makers, managers, and operators. In Morocco, farmers are not correctly informed.
Inadequate monitoring, controls and evaluation	No monitoring procedures No controls due to the lack of available and qualified personnel Limited analytical capacity	

Economic and Financial Analysis

Economic and Financial Evaluation: The Principle

The economic and the financial analyses are two different analytical stages in a TWWR (treated wastewater reuse) project.

Economic Analysis

The economic analysis will be used to decide if a project should be implemented and to determine if it is economically justified, that is, if the benefits exceed the costs.

There is a twofold difficulty in this stage since on the one hand, all costs and benefits must be identified and evaluated and it is a fact that some cannot be easily monetized, and on the other, projects should be compared using common indicators. The economic cost-benefit analysis may be complemented by a cost-effectiveness analysis to verify that the project concerned minimizes costs for a given objective. To do so, it is necessary to compare the costs of different projects that produce the same benefits.

In addition, in the economic cost-benefit analysis, the actors of a project bear the financial costs (investments, operating and maintenance) and their benefits are revalued in economic terms, in other words, in terms of the costs or benefits they represent for the country. Financial (market) prices are adjusted, excluding taxes, charges and subsidies that are a country's internal transfer or redistribution mechanisms, and the price of goods is estimated at their border value (excluding domestic value transfers). The most commonly used method worldwide to evaluate these market costs is based on reference prices and is used by most international financing institutions[7].

The analysis of social costs and benefits (social CBA) takes into account the impact of the project on society as a whole: consumer surplus, externalities and valuation of non market costs and advantages, including on the environment, and on the health of the population affected by the project. Applicable methods are described in detail in the section on the *Analysis of Social Costs and Benefits* and in *Annex 1*.

Financial Analysis

The purpose of a financial analysis is to determine if a project can be financed and how (Mills & Asano, 1986). The financial analysis will look into funding structures.

Financial Analysis of a Project

The financial analysis of a project verifies the overall financial balance of a project and seeks to identify adequate financing arrangements for the different project components. It provides information about the project's viability through criteria relative to the return of capital and investments: the Financial Internal Rate of Return (FIRR) and financial Net Present Value (NPV), of creditworthiness in case of indebtedness, and of liquidity. For the lender, the financial analysis of a project is useful to establish the debt-service capacity through the debt service coverage ratio[8]and to set up the financing plan of the investment program.

A financial analysis estimates the incremental costs and benefits of the project, based on financial market prices, and compares them to a "without project" scenario. It determines the annual financial flows for the entire project and for the analysis period. An annual cash flow table compares annual uses and resources (financial costs and advantages) at project scale:

- **Investment flows**: acquisitions of fixed assets. For a TWWR project, the financial analysis takes into consideration direct additional investments required for TWW collection, treatment, storage and distribution infrastructures. Investment flows should include all necessary investments concerning health protection, environmental protection, or measures against nuisances.
- **Operating flows**: income and operating costs of operators. Operation expenses related to health monitoring and protection measures, environmental controls and mitigation measures should be included in the analysis.
- **Financial flows**: (including debt servicing or repayment of capital and interests payments). Using the financial flows, it is possible to identify financing needs in the form of equity investments, subsidies or debts, and financing mechanisms may be defined to assure the financial stability of the project.

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[7] See AFD 2004: *Guide d'analyse économique des projets de Développement. Analyse coûts-avantages et coûts-efficacité.* WB, 1991 - The Economics of Project Analysis: A practitioner's guide. W.A. Bard et al. 1991. P.Belli et al.: Handbook on economic analysis of investment operations, 1998

[8] Debt Service Coverage Ratio: operating flows/ debt servicing—Interests and capital.

Note: A financial analysis will include financing modalities in calculations of financial flows. Whereas, an economic analysis excludes financing modalities of investments: financing charges and depreciation are not taken into account.

Analysis of the Financial Viability of the Sector or the Operator

Through the financial analysis of a sector or operator, the 3Ts (Tariffs, Taxes and Transfers) typology is useful to distinguish what can be financed by the users through water *tariffs*, by the State through *taxes* and subsidies and what remains to be financed mainly by private investors and international donors (*transfers*).

Economic and financial analyses do not necessarily coincide. An economic analysis may conclude that a project is economically justified, but it will not necessarily be financed for different reasons.

- The information on the capital market is incomplete: all benefits and costs are not known to donors.
- Some benefits and costs will concern society as a whole but are not integrated in the financial transactions, i.e. absence of mechanisms to internalize externalities. The project sponsor, who has a purely financial objective, will not take into account these external elements that could nevertheless “tip the balance”, that is, lead to conclude that benefits exceed costs and that the project is economically justified.

Methodology notes for a financial analysis are presented in *Annex 2*.

Cost-Benefit Analysis (CBA): Objectives and Methodology

Objectives of CBA

A **cost-benefit analysis (CBA)** seeks to maximize the net present value of all the expected benefits of a project discounting all the costs, sustained by or beneficial to all parties involved throughout the project’s lifespan, taking into account certain external constraints. It may focus on either private or social costs and benefits:

- **Private Costs and Benefits Analysis**: A Private CBA is conducted by an investor who seeks to determine the profitability of a project. It is not necessarily a private company or firm. A local government may want to carry out a profitability analysis, irrespective of whether there are the costs and benefits for society or not. A private CBA will take into account all the costs sustained and the benefits received by actors involved in wastewater treatment and reuse.
- **Social Costs and Benefits Analysis**: The Social CBA is conducted by a regulating authority (central or local government) that seeks to measure the “social utility” of a project by comparing all the costs and benefits involved for society. It includes costs and benefits for water users, for public health and for the environment. This approach takes into consideration positive and negative externalities, avoided costs and opportunity costs.

Importance of social cost-benefit analyses for TWWR

According to Faruqui, “[…] the reality is that proponents usually only present vague economic estimates on the benefits and costs of wastewater use [...], leaving donors and policy-makers unaware of the significance of effluent irrigation to the economy.” (World Bank 2010) Once studies are correctly carried out, TWWR should become a priority in countries affected by water scarcity. “Wastewater use projects are often undervalued when compared to other water projects because benefits such as watershed protection, local economic development, and improvement of public health are not properly quantified.” (World Bank, 2010).

Methodology for a Cost-Benefit Analysis

This section reviews the key elements to be included in a cost-benefit analysis.

- **Identification of project drivers and context** (*see the typology of drivers in Table 3 and context indicators in Table 4*). It is particularly important to verify if a political will truly exists to implement a public policy for TWWR and to remove institutional, health and financial constraints. Likewise, there must be an effective demand for water reuse, in other words, the needs should be identified and the existence of a long-term and solvent demand over a 25-30 year period should be confirmed. Finally, the social and cultural perception and acceptability of the TWWR project should be analyzed.
- **Definition of objectives**. Benefits should be measured against the objectives defined for the project. For example, if the main objective is aquifer recharge, it is important to have reliable estimates of environmental benefits. If the main objective is to provide water for irrigation, more time should be dedicated to evaluate the benefits for farmers.
- **Identification of alternative scenarios and the “without project” (or counterfactual) scenario** (present conditions and over time). *Table 12* presents a typology of TWWR scenarios

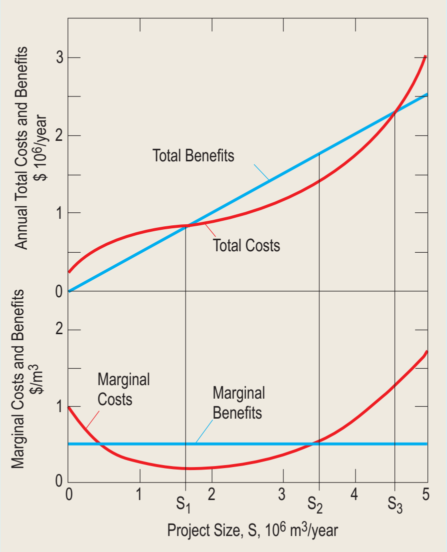
analyzed in detail in the section on Comparison of Alternative Scenarios.

- **Confirming the presence of a genuine political will** for the project's development.
- **Identification of all externalities** (see *Table 11* for a typology of externalities).
- **Evaluating over the long-term (25 to 30 years) the water resources/uses situation in the project zone**. This analysis will include surface waters and groundwater by watershed and in aquifers. It will be the basis of the economic evaluation and will be used to identify and estimate the positive and negative externalities associated to competing uses of water during the analysis period. Another approach developed by Falkenmark (1995) does not consider the water present in the soil as a loss because from an economic point of view, in rainfed agriculture, it will guarantee the farmers' income and, in irrigated agriculture, it increases irrigation water efficiency by reducing the quantity of irrigation water needed.
- **Considering marginal benefits and costs instead of total and average costs**: Marginal costs will initially drop due to economies of scale: treating a larger volume of water will not be much more expensive because the infrastructure already exists (*Box 5*).
- **Conducting sensitivity analyses**, that is, measuring how a change in a given parameter affects the profitability of a project (Net Present Value or Internal Rate of Return). Switching values—the change in the value of a variable that is needed for the project's NPV to be equal to zero—may also be calculated for some parameters. Usually, sensitivity tests in project evaluations concern:
  - — the impact of an increase in investment, operating and maintenance costs of a project (+10%, +20%, etc.);
  - — the impact of a delay (+1 year or +2 year, etc.) in the investment period;
  - — the impact of a decline in demand or direct benefits expected (less irrigated land, for example);
  - — the impact of the volume of wastewater that may be mobilized for TWWR according to estimates of population growth, increased distribution, consumption and connections to the sanitation network.

Box 5 Why use marginal costs and benefits to evaluate the optimum size of a project

Marginal costs will initially drop due to economies of scale (*Figure 7*); however, once the project has achieved a certain size (S1), it becomes more expensive to increase the volumes treated and reused, for instance, because users are further away and distribution costs vary in proportion to the distance. In Figure 7, benefits exceed costs until S2. Beyond that size, for each additional unit, costs exceed benefits. But if only total costs and benefits are compared, all project sizes from S1 to S3 appear as economically justified. Actually, the project should not go beyond S2 because the costs are higher than the benefits.

Figure 7 Marginal costs and benefits according to optimum project size



Source: Asano & al., 2007

For example, the decision to continue to a tertiary treatment in order to increase water reuse volumes for reuse should be based only on the additional costs: additional costs for further treatment after the secondary treatment (disinfection to remove pathogens, denitrification, removal of phosphates, desalination) + costs to expand the plant's production capacity + costs for the network's development to convey the treated wastewater to new users who did not use this water resource before the tertiary treatment was adopted.

Private Costs and Benefits Analysis

In a private cost-benefit analysis, all costs sustained and benefits received by actors involved in wastewater treatment and reuse will be taken into consideration. A private CBA is carried out for companies and providers of water supply and wastewater treatment services, as well as for direct beneficiaries of TWWR.

Private Costs

Private costs are the costs sustained by all actors involved in the treatment and reuse of wastewater. In general, a distinction is made between initial investment costs (implementation costs and capital costs) and operating and maintenance costs (O&M) (see *Table 10*). Costs may also be classified according to the TWWR sequence or chain (source, treatment, storage, distribution, irrigation) (see *Table 9*).

Note: The investor sponsoring the project does not necessarily bear all the private costs. For example, the farmers themselves will often sustain the costs of adapting irrigation equipment. In some cases, however, the local government or the treatment facility may decide to subsidize the purchase of new equipment to encourage farmers to adopt wastewater reuse for irrigation. It is therefore important to consider all the costs involved (Asano, 2007).

Private Benefits

Wastewater reuse projects will only be developed if they yield net benefits to the different actors involved in TWWR, particularly to water providers and distributors, as well as to those who will use the water.

These net benefits may be measured using the surplus concept.

A surplus is the difference between a benefit and a cost for an economic agent.

Table 9 Private costs in the TWWR chain

Cost Item	TWWR Component concerned	Cost determining factors	Indicator
Network	Source (cost of conveying wastewater to treatment plant) Distribution (cost of conveying treated wastewater to users)	Distance between source and end user Local topography	Amount of investment per m^3 of water provided
Land: cost of reservoirs	Storage	Storage volumes depend on the difference between the statistical distribution of wastewater volumes and that of exploitable water volumes	Required surface area (m^2 of land required/m^3 of water produced) * cost per m^2
Facilities/Equipment: construction or upgrading of treatment plant	Treatment	Treatment standards Whether or not a treatment plant already exists before the reuse project	Amount of investment per m^3 of water provided
Facilities/Equipment: adapting existing equipment for wastewater reuse	Irrigation (filtrating equipment, conversion of network or working with a double network)	Water quality Initial equipment (with or without irrigation)	Amount of investment per m3 of water used
Energy consumption	Source Treatment Storage Distribution Irrigation	Plant size Level of treatment	kWh/m^3 * price of kWh
Labor	Source Treatment Storage Distribution Irrigation	Plant size Level of treatment Automation level	Total wage bill per m^3 of water provided
Chemical products	Source (network cleaning) Treatment Storage (reservoir cleaning) Distribution (network cleaning) Irrigation (network and pump cleaning)	Level of treatment	Amount per m^3 of water treated or used Amount per km of network to be cleaned

For a producer, the surplus is the difference between sales and production costs. The surplus of TWW providers and distributors is equal to:

Water volume sold (m3) x Price billed (/m^3) + Subsidies received (/m3) – Production costs (/m^3)

For a consumer, the surplus will be the difference between what the consumer is willing to pay (WTP) and the price actually paid for the good or service in question.

TWW users' surplus is equal to: **Water volume used (m^3) x [Value of TWW (/m^3) – Net price paid (unsubsidized) (€/m^3)]**

The value of TWW for users is equal to:

Benefits of irrigation (see *Annex 1*) **+ Additional benefits of TWWR over conventional water – Costs generated**

It is often difficult to compile the necessary data to calculate the value of TWW for users. An alternative would be to conduct user surveys on their willingness to pay for TWW (see *Annex 1*).

Note: The impact of the project could be better evaluated through changes in surplus, rather than on surplus values. Economists often recommend calculating the aggregate surplus, or the sum of consumer and producer surplus. However, it is advisable to clearly identify the net gains for each user category so as to have a better idea of public acceptability of the project. Also, the notion of aggregate surplus may be misleading: it is not a social CBA concept because it does not take into account the externalities.

Economic Analysis Framework for TWWR Projects—Private CBA

The economic analysis framework presented in *Table 10*, listing private costs and benefits, was designed to be used during the preliminary stages of project development.

Social Costs and Benefits Analysis

Social Costs and Benefits

A social CBA seeks to measure the "social utility" of a project by comparing the costs and benefits for society as a whole. A social CBA includes costs and benefits for water users, public health and for the environment. This approach takes into consideration positive and negative externalities, avoided costs and opportunity costs.

By their very nature, estimating and quantifying a project's externalities and qualitative impact is difficult or quite expensive. Some of the methods chosen, even if the approach is simplified, allow time and costs savings during project preparation.

Social Costs

Social costs are the costs sustained by agents outside the project due to the project's implementation. They are also called negative externalities. They fall into three categories: externalities related to public health, to the environment, and social externalities.

The evaluation of externalities of treated wastewater reuse projects is still in its incipient stages. A list is proposed in *Table 11*.

Note: *Annex 1* contains:

- Methodology notes the evaluation of positive and negative externalities of TWWR projects.
- Specific methods for evaluating environmental risks and benefits.
- The principal factors that will determine acceptability of TWWR projects by different actors.

Social Benefits

Sometimes the benefits for TWW users do not justify carrying out a project for treated wastewater reuse. However, there may be substantial benefits for other stakeholders (drinking water users, industries, environmental protection associations, etc.) who, though not direct TWW users, benefit from positive externalities. It is therefore essential to integrate the benefits for all of society in the analysis of TWWR projects.

For example, wastewater reuse for irrigation in the Llobregat Delta in Spain should enable saving annually 19 million cubic meters of surface water. This water then becomes available for drinking water supply, and it is possible to limit the use of more expensive solutions like conveying water from the Ter River or desalination (FAO, 2010).

Social CBA: Measuring the Impact on Public Health

Depending on the initial situation before the project, a TWWR project may generate:

- A positive impact on public health when as a consequence of the TWWR project (i) water of higher quality is used instead of untreated or partially treated wastewater and (ii) additional health protection measures are implemented;
- Potential health risks when TWW replaces an available and unpolluted conventional water

Table 10 Economic Analysis Framework for Treated Wastewater Reuse Projects—Private CBA

Parameter Analyzed	Type of Cost/ Benefit	Cost/Benefit Item	Indicator	Example
Private Costs	Implementation costs	Engineering studies and monitoring	% of total cost of project	
	Capital costs	Additional tertiary treatment	Amount of investment per m^3 of water provided	
		Wastewater conveyance network	Amount of investment per m^3 of water provided	Israel, Becker (2004; 2010): wastewater conveyance and distribution costs for irrigated agriculture, excluding avoided costs for wastewater discharge into the sea or a river (approx. €0.21/m^3).
		Treated wastewater distribution network	Amount of investment per m^3 of water provided	
		Equipment	Amount of investment per m^3 of water provided	
		Land	m^2 of land surface required per m^3 of wastewater treated * cost per m^2	Activated sludge treatment and tertiary treatment (filtration) require from 0.15 to 0.30 m2/inh. Technologies using basins require additional surface area (from 3 to 5 m^2/inh.) (WHO, 2006). In Shafdan, in Israel, basins for wastewater filtration cover a total surface area of 120 hectares with a capacity of 380,000 m3/day. The estimated land value is €7,600 per hectare (highly urbanized zone).
		On-site conversion costs	Amount of additional investment per m^3 of water used	
			Amount of additional investment per irrigated hectare	
	Maintenance costs	Labor	Number of employees required * labor costs	
			Cost/m^3 of water provided	
		Equipment and Consumables	Cost/m^3 of water provided	
		Equipment depreciation	Lifespan of capital goods (years)	In general the average depreciation rate applied is 4% (for a lifespan of 25 years). Based on DWS rates, the annual rates by type of equipment are as follows (FNDAE/OIE 2004):
			Capital depreciation rate	Civil engineering: 1% Channels and dikes: 3% Hydro mechanical equipment: 5% Electrical equipment: 5% Piping: from 0.25% to 1% depending on the type
	Operating costs	Energy for treatment, conveyance and distribution	kW/m^3 of treated wastewater	0.3-0.6 kWh/m^3 for treatment with activated sludge + 0.4-0.5 kWh/m^3 for desalination through reverse osmosis (Israel)
			kW/m^3 of water distributed	Energy for conveyance and transport of treated wastewater for agricultural irrigation = 0.5 kWh/m^3 (Israel)
		Labor	Number of employees needed * cost of labor	
			Cost/m^3 of water provided	
		Monitoring/Analyses	Cost/m^3 of water provided	
		Consumables	Cost/m^3 of water provided	
Private Benefits	Gains for the wastewater producer and reused water distributor	Sales linked to reuse	Sale price by m^3 * volume of wastewater treated and distributed	
		Avoided costs	Savings on avoided alternative investment	Savings on transport investments for sea outfall or discharge into rivers (Israel)
		Image/Communication	Difficult to monetize	
	Gains for the irrigation user	Increased crop yield due to organic fertilizers	Increased yield per hectare * sale price of crop	Increased gross margins per hectare of 81% for fodder crops, 66% for cereals, and between 3% and 6% for tree crops (Tunisia, AHT, 2009).
			Savings in Euros in purchases of artificial fertilizers	The fertilization value is estimated at 350 Euros per hectare in Castell Platja d'Aro (Spain). In Tunisia, estimates in savings for fertilizers range from €23/ha to €102/ha (DEI, 2003 in AHT 2010).
			Difference between the price of land with access to TWW and the price of land with access to surface water (not rich in fertilizers)	In Pakistan, the lease price of land with access to wastewater is 2.5 times higher than the price of land with access to surface water, which gives an idea of the value of nutrients.
		Impact on the water bill	Cost variation = (price of reused water * volume of water applied) – (price before project * volume before project)	
			Avoided costs if before project: water used = groundwater or surface water	Pumping costs avoided—pumping groundwater is no longer necessary due to access to wastewater: €0.11/m^3 (Spain)
		Increased water supply security	Changes in volumes of water applied / crops and yields / profits	The increase in water supply reliability according to the Israeli Water Authority (IWA) is equal to €0.0085/m3. This is the value of water when applied to the least productive crops (€0.085/m3) times the probability of water restrictions that would result in stopping the production of these crops (once every 10 years).
			Crop yield lost in case of water scarcity * sale price of crops * frequency of water scarcity	

supply. Health related aspects are the leading concern of authorities when considering the development of a TWWR project. Estimates of health costs and benefits associated to a TWWR project should take into account health protection equipment and measures that will be required to meet WHO recommendations (2006).

The health impact assessment of treated wastewater reuse involves the evaluation of:

- TWWR impact on mortality: a DALY (disability-adjusted life year) measures life years lost due to disease in relation to an ideal situation of leading a healthy life. DALYs are used to quantify (i) years lost due to a premature death, and (ii) years lived with a disability. WHO has set a risk threshold target of a DALY loss of ≤10-6 per person per year, for treated wastewater reuse in direct irrigation.
- TWWR impact on quality of life (morbidity): a QALY (quality-adjusted life year) measures the loss of quality of life due to disease.
- TWWR impact on health expenses: the measurement of the evolution of health expenses includes both medicine and hospitalization expenses required by patients.

Social CBA: Measuring Environmental Impact

In the same way as health aspects, the costs and benefits of the environmental impact of TWWR projects are critical factors the will help determine if the project is economically justified. Since they are difficult to evaluate and quantify, until now, environmental costs and benefits have been rarely included in the economic analysis of TWWR projects.

Table 11 presents different sources of benefits of a wastewater reuse project for the environment, for society and for soil management and food production, and suggests indicators to evaluate project externalities.

The assessment of environmental benefits may be based on the same methods presented in Annex 1 for the evaluation of negative environmental externalities (*Box 7*). An important aspect of the assessment of environmental benefits of wastewater reuse is the valuation of use and non-use values of water

One of the leading causes of environmental degradation is that the value of environmental goods is underestimated during the planning stage of major projects. In general, there is no institutional mechanism to assign a value to these environmental goods for which a market price rarely exists. Economists have developed valuation methods to determine the value of these externalities in order to include them in a cost-benefit analysis.

Box 6 Health risk assessment in TWWR in the city of Santiago, Chile

In 1991, Chile was faced with endemic typhus and epidemic cholera; two diseases associated to crop irrigation with untreated wastewater. The emergency program set up included (i) intercepting wastewater discharges in the most polluted rivers used for irrigation, (ii) chlorination of other discharges, (iii) financial incentives for farmers for the use of well water for irrigation, (iv) a ban on the sale of farm products irrigated with untreated wastewater, (v) education and information campaigns. Typhoid cases dropped from an annual average of 3,558 to 454 cases/year in 1992. Typhoid incidence declined from 50 cases per 100,000 population to 12 cases per 100,000 population in 1993, and 2.2 cases per 100,000 population in 2006.

A second program focused on the construction of two major interceptors of untreated wastewater and of a wastewater treatment plant for Santiago de Chile. Costs of additional treatment were estimated at US\$78 million/year or US\$0.14/m^3.

A cost-benefit analysis was carried out for a complete treatment of wastewater. The study concluded that added together the combined annual benefits of reduced mortality and morbidity from typhoid and cholera, avoided losses in export revenues and increased farm output ranged between US\$23.7 and US\$76.6 million annually. These benefits alone could cover the annual cost of wastewater treatment estimated at US\$78 million annually. Additional benefits associated to reduced mortality and morbidity from hepatitis and diarrheal diseases (not including typhoid and cholera) were estimated between US\$33.4 and US\$166 million annually. Environmental benefits and water use cost were not taken into consideration.

Source: World Bank, 2010, from Bartone 1994, Ferrecio 1995, Laval & Ferrecio 2007, Bitran & Arellano 2005, Larrain 2009, Yayur 2009.

Box 7 Environmental impact of TWWR projects in Spain and Israel

Reduced pressure on water resources in Spain (El Prat & San Feliu Project)

Through the development of TWWR projects, conventional surface water may be released for alternate uses, thus creating benefits. By estimating the value of the water released for urban drinking water supply at the price of drinking water (€1.11/m^3), these volumes of water released account for 64% to 98% of the benefits/externalities considered in the economic analysis of the project. Moreover, opportunity costs of water during a drought period have also been recently estimated in Spain at €7.38/m^3, further confirming the benefits associated to a lower pressure on water resources (International Water Association, 2011).

Nitrogen-related environmental damages and cost of greenhouse gas emissions in Israel

In Israel, the environmental damage caused by nitrogen leaching from wastewater has been estimated at €0.072/m^3 by Haruvy et al. 1997. Further estimates suggest €0.02133/m^3 (price of carbon/kWh * consumption in kW/m^3) as the cost of greenhouse gas emissions associated to energy consumption for wastewater treatment.

Economic Analysis Framework for TWWR Projects—Social CBA

Table 11 Economic Analysis Framework for Treated Wastewater Reuse Projects—Social CBA (Externalities)

Parameter Analyzed	Type of Cost/Benefit	Cost/Benefit Item	Indicator	Valuation Method	Example
Negative Externalities/Social costs	Health costs	Incidence and prevalence of waterborne diseases	Rates of incidence and prevalence of waterborne diseases associated to pathogenic microorganisms (bacteria, viruses, protozoa, helminths) per person per year	Loss in DALYs for populations concerned	Epidemiological study over a three-year period carried out for the Clermont-Ferrand project to assess the impact on field workers (particularly those assigned to corn detasseling) and on neighboring populations. At the end of the study, it was recommended as a preventive measure to discontinue manual corn detasseling and to use machines instead (AFD/BRL, 2011). Cost of information (cost of the study that mobilized 15 doctors and 7 pharmacists) and costs associated to preventive measures are not available.
		Information and prevention campaigns	Cost of information and preventive measures	Cost of information and prevention campaigns	
				Cost of additional health controls (For example: increased frequency of medical examinations * cost of medical examination)	
		Tolerable risk level in DALYs and QALYs (WHO)	WHO Standards, 2006: Loss of 10^{-6} DALY per person per year (=1 death per 1,000,000 population or one diarrheal disease per 10,000 population per year)	DALYs * 10-6 pppy * population affected (calculation of DALYs according to WHO Guidelines) and cost of health protection measures required to meet WHO standards (10-6 DALYs / pppy)	
		Health security / Product quality	WHO standards (2006) and risk management plan for health security and product quality	Cost of health security measures and restrictions on irrigation to meet WHO standards and Losses in value added in agriculture due to restrictions on the types of culture and the additional investments costs required in restricted irrigation.	
	Environment costs	Soil contamination	Use and non-use values of soil	Use value: (i) direct use value = PNV of agricultural production + (ii) indirect use value: environmental services provided by the soil + (iii) option value: benefit of using the soil in the future. Non-use value: (i) existence value: WTP for soil protection, (ii) bequest value	Haruvy et al. (1997) estimate the environmental damage caused by nitrogen leaching from wastewater in Israel to €0.072/m³. This result is obtained using a linear programming model. The damage is evaluated at the implicit price associated to the leaching constraint. The implicit price is understood as the decline in profits due to additional restrictions on nitrogen leaching of 1 kg/ha.
			OR: yield loss/contaminated hectare	Loss of agricultural PNV/ha/year * analysis period	
			Water salinity (Na+, K+, alkalinity)	Yield loss/ha from soil salinity * sale price of farm products	
		Odor pollution	Depreciation of homes	Real estate market	
			Defensive expenditure	Cost of protection and deodorization measures	
		GHG emissions	Value of GHG emissions	Price of ton of carbon * GHG emissions/kW * kW/m³	The cost of emissions of greenhouse gases associated to the energy used in wastewater treatment is €0.02/m³ (Israel). This value is obtained by multiplying the value of the externality (price of carbon)/kWh by the consumption of kWh/m³.
		Contamination of groundwater	Use and non-use values of groundwater	For contaminated groundwater that cannot be used: Use value: Direct use value, indirect use value and option value. Non-use value: existence value, hedonic values and bequest values.	
		Eutrophication of water surface	Use and non-use values of surface water		
		Negative impact on river flows, wetlands and biodiversity	Use and non-use values of surface water		
	Social costs	Conflicts of use	Conflicts on land use	Land market price * surface used	
				OR: benefits lost because the land is used for another activity	
			Conflicts for water use	Value of water in Euros/m³ associated to another use	
		Acceptability problems	Perception: Attendance rate to information meetings	Communication budget of the project	The Clermont-Ferrand project had a communication budget of €0.05 million (excluding VAT) for an annual reuse volume of 0.8 Mm³/year.
			Culture/Religion		

Table 11 Economic Analysis Framework for Treated Wastewater Reuse Projects-Social CBA (Externalities) (Cntd)

Parameter Analyzed	Type of Cost/Benefit	Cost/Benefit Item	Indicator	Valuation Method	Example
Positive Externalities/Social Benefits	Environmental Benefits	Better quality surface water and groundwater (wastewater is not discharged into rivers)	Use and non-use values of water	Water volumes that have become usable * direct use value + indirect use values + non-use values	Pareto (2003) estimates aquifer treatment costs in Israel against excessive nitrogen leached out by poor quality wastewater to €0.08//m^3.
			Avoided costs for ecosystems recovery	Costs for ecosystems recovery if "without project" situation	
			Reduction in the rate of mortality of aquatic species and riparian vegetation	Use value and non-use value of species * change in mortality rate	
		Improved sanitation	Avoided costs for improved sanitation	Investment and O&M costs of alternative sanitation required if no TWWR project	
		Lower pressure on surface water and groundwater	Use and non-value of surface water and groundwater	Price of drinking water * volumes released through reuse (this water will be sold at least at this price to urban users) + indirect use value + non-use value of released water volumes	The positive externality on the exploitation of water resources is estimated at €1.11/m^3 for El Prat and San Feliu in Spain, or equal to the price of drinking water (FAO 2010).
		Better conservation	Avoided costs (through the water released) for augmentation of water supply	Investment and O&M costs avoided through better water security for cities (for example, desalination, transfers between regions, etc.) in the analysis period	
		Contribution to urban Integrated Water Resources Management	Qualitative assessment of the level of integration		
		Positive carbon balance	Lower emissions compared to an alternative water supply	Price of ton of carbon * savings in GHG emissions/kW *kW/m^3	
			Less distance between the source of the water supply and the users (local benefit)		
	Social Benefits	Preservation of periurban agriculture	Direct and indirect income of jobs safeguarded and new jobs	Average annual net income * number of direct or indirect jobs created or safeguarded	170 direct jobs result from the reuse of wastewater treated in the Hammamet plant (Tunisia) for irrigation of golf courses in Citrus and Yasmine (AFD/BRL).
					The increase in irrigated surfaces and associated industries can create 5 jobs per 1,000 m3 of water used per year in the West Bank and Gaza (World Bank, 2004).
		Contribution to food security by increasing agricultural production	Changes in the import/export ratio of agricultural products	CIF value of variation in imports of farm products	
		Greening landscapes	Changes in real estate prices	Difference in changes of real estate prices/m^2 in relation to changes in average local prices * constructed surface directly impacted by project	
		Protection or creation of social linkages between urban and rural communities	Difficult to monetize		
	Benefits for soil management and food production	Reduced consumption of mineral fertilizers	Avoided damages associated to artificial fertilizers	Evaluation of damages due to the presence of artificial fertilizers in the soil * amount of fertilizers that are not used on account of the fertilizer content in wastewater	
		Increased soil fertility (recycling of organic matter)	Amount of organic fertilizers in treated wastewater	Valuation of benefits from the presence of wastewater's fertilizer content in the soil * fertilizer content/m3 of water * m^3 of water applied per hectare	
		Desertification control (by installing irrigated zones)	Avoided costs of desertification	Land value of agricultural land that would be lost without the project and avoided costs of desertification control	

TWWR Project and Alternative Scenarios

The economic analysis of a TWWR project is only relevant if it compares the project concerned with at least two alternative scenarios.

Identifying Scenarios

Based on the situations studied, a typology of scenarios that include all the different components of TWWR, from source to use, is presented in *Table 12*. This typology is useful to:

- Group countries according to the reuse situations observed (from raw wastewater for irrigation to treated wastewater reuse for drinking water);
- Identify possible successive changes to reach more advanced and higher expertise levels in wastewater reuse (from unplanned to planned reuse) and to determine the order of appearance of TWWR applications (from irrigation to greywater recycling in the same facilities they are produced);
- Compare, if appropriate, the different scenarios in order to carry out the project's cost-benefit analyses by identifying the "without project" or counterfactual situation (*Comparisons of Alternative Scenarios*).
- Consider, beyond the TWWR alternative, other possible and competing options like desalination or irrigation with conventional water.

Note on the Methodology

- First, if the reference scenario is a without project situation, it is important not to associate to the project those costs and benefits that would have been present without the project anyway. For example, if a project consists in adding a tertiary treatment to improve the quality of water already in use even though it has only been treated to a secondary level, all the benefits associated with water reuse should not be attributed to the project (Asano et al., 2007).
- Second, different projects may have different production capacity. Consequently, costs should be compared by unit of water treated or reused, or one same volume of water output should be determined for all costs and benefits estimates.

Counterfactual Situation

The counterfactual or "without project" situation is the reference or benchmark used to evaluate the impact of the TWWR project. The without project situation is drawn up from the analysis of the current status and anticipates the changes that would most likely take place during the analysis period (25 to 30 years) if the project were not carried out.

In a TWWR project, the evolution of the without project situation may draw attention to:

- Health hazards for the population in contact with or using untreated effluents for irrigation, as well as for consumers of agricultural products;
- New or growing competition for water use, conventional groundwater and/or surface water, in a context of water scarcity. A situation that has already been observed in many Mediterranean countries. Estimates on its evolution over a 25-30 year period may highlight important externalities that would justify a TWWR project;
- Significant environmental risks in the absence of treated wastewater reuse (saltwater intrusions, lower aquifer levels, degradation of aquatic systems, etc.);
- Social risks associated to conflicts between water users downstream, due to the pollution from effluents in a without project scenario;
- An agricultural risk related to the use of untreated or partially treated wastewater (pollution and soil contamination, quality of agricultural products), and to the disappearance of periurban agriculture in the absence of a TWWR project (diminished water resources);
- Risks for the tourism industry due to the pollution caused by effluents discharged into rivers downstream or into the sea in tourist areas.

Comparison of Alternative Scenarios

Each project should be compared to one or several alternative scenarios (S). In reference to *Table 12*, we suggest below possible and realistic comparisons between the different scenarios.

Comparison n°1: Sanitation (S2) vs. No Sanitation (S1)

Note: The S2 scenario is only relevant in TWWR when the implementation of sanitation services is planned as a preliminary to TWWR.

Comparison n°2: TWWR for irrigation (S3) vs. Irrigation with raw wastewater (S1)

Example: In Israel, water used for irrigation is usually of poor quality. The objective of projects for upgrading treatment plants is to install tertiary treatment facilities. With these projects it should be possible to diversify the crops that may be irrigated with treated wastewater and to reduce health and environmental hazards (Feitelson & Laster, 2011).

Table 12 Typology of scenarios for wastewater reuse from source to use

Scenario N°	Wastewater Collection	Treatment		Uses								Examples	Obstacles
		Primary/ Secondary	Additional	Agricultural Irrigation	Landscape Irrigation	Aquifer Recharge	Environment	Industries	Urban	Domestic	Drinking water		
1	Unplanned reuse: domestic and industrial effluents are inadequately collected and discharged (without proper treatment) in the periphery of cities in natural environments and agricultural zones.												
1a	🟥 -	🟥 -	🟥 -	+	-	-	+	-	-	-	-	Gaza, *Mexico*	Lack of financing for infrastructure
1b	🟧 +/-	🟧 +/-	🟥 -	+	-	-	+	-	-	-	-	Gaza, *Mexico*	Lack of financing for infrastructure
2	Sanitation: domestic and industrial effluents are collected and treated before being discharged in natural environments.												
	🟩 +	🟩 +	🟧 +/-	-	-	-	+	-	-	-	-	France (before the Decree of August 2, 2010)	Regulation
3	TWWR for irrigation: domestic and industrial effluents are collected and treated to advanced levels in order to be reused for irrigation of agricultural land and recreational areas.												
	🟩 +	🟩 +	🟩 +	+	+	-	+	-	-	-	-	France	
4	TWWR for irrigation, aquifer recharge and urban and industrial uses: domestic and industrial effluents are collected and treated to advanced levels for reuse.												
4a	🟩 +	🟩 +	🟩 +	+	+	+	+	+	-	-	-	Spain	
4b	🟩 +	🟩 +	🟩 +	+	+	+	+	+	+	-	-	Spain	
5	TWWR for all applications: TWWR includes all uses including domestic applications and drinking water.												
5a	🟩 +	🟩 +	🟩 +	+	+	+	+	+	+	+	-	Tunisia, Israel	
5b	🟩 +	🟩 +	🟩 +	+	+	+	+	+	+	+	+	*Singapore*	
6	Desalination of brackish or sea water												
7	Traditional Irrigation: conventional water (water from rivers or groundwater) is used for irrigation; TWWR covers all other applications, including domestic use and drinking water.												
8	No irrigation												
9	Water transfers between regions												

🟥 Unplanned

🟧 Partially planned

🟩 Planned

Comparison n°3: TWWR for irrigation (S3) vs. Sanitation without irrigation (S2)

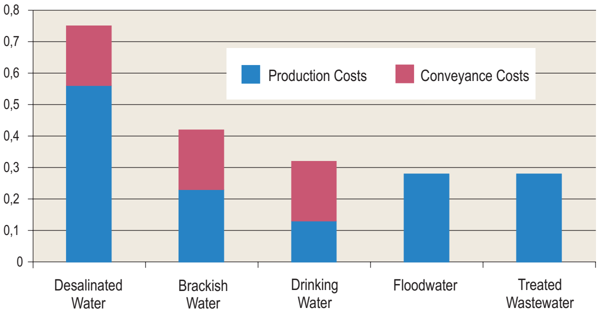
Example: The project for agricultural land irrigation in Black Limagne downstream from an activated sludge treatment plant in Clermont-Ferrand (France) was developed in a context where no other less expensive alternatives were available to secure a water supply: lack of groundwater on the one hand; and on the other, the high cost of pumping surface water from the Allier River (at a distance of more than 20 km from the site). Finding a water supply to reduce the exposure of crops to climatic hazards was quickly seen as a necessity in order to honor contracts (cereals and sugar beet) (AFD & BRLi, 2011).

Comparison n°4: TWWR for irrigation (S3) vs. Traditional irrigation with conventional water (S7)

Example 1: In Blanes (Spain), most farmers use groundwater for irrigation. Treated wastewater reuse would enable protecting aquifers from over-exploitation and pollution (FAO, 2011).

Example 2: In Israel, a comparison of production and distribution costs of irrigation water from different sources (desalinated water, brackish water, drinking water, floodwater and TWW) clearly shows that TWWR is the least expensive option (*Figure 8*).

Figure 8 Production and conveyance costs for different sources of irrigation water (Feitelson & Laster, 2011)



Source: Feitelson & Laster; 2011

Comparison n°5: All TWWR applications (S5) vs. TWWR for irrigation, Aquifer recharge, Industrial and Urban uses (S4)

Example: No Mediterranean country has yet authorized TWWR for all applications, particularly the most delicate and advanced such as reuse for drinking water.

Examples for this scenario may be found in Asia (Singapore, for example).

Comparison n°6: TWWR vs. Desalination (S6) and Water transfers (S9)

Even though wastewater treatment and desalination are often compared, the issues at stake in the utilization of these two non conventional resources are different. Desalinated water is in general of very good quality and its production costs are much higher than the production costs of wastewater treatment. Most desalinated water is used by industries or for the drinking water supply of cities. On the contrary, TWW is used for lower water value applications, i.e. mainly for irrigation of agricultural land, golf courses and public parks, as well as for street cleaning. Moreover, environmental externali-ties are also different: desalination is likely to have a highly negative environmental impact, chiefly due to brine discharges into the sea. Whereas the environmental impact of wastewater reuse is rather positive (improved quality of surface water and reduced pressure on water resources). Even so, wastewater reuse could result in lower effluent discharge into rivers that could cause environmental damages.

For example, the TWWR development project in Platja d'Aro on the Costa Brava (Spain) was compared to a project for the installation of a desalination plant and to the construction of a pipeline to bring water from the Ter River. Estimated costs suggested were €0.33/m^3 for reuse, from €0.45 to €1/m^3 for desalination, and €0,82/m^3 for water transfer (FAO, 2010).

Choosing Costs and Benefits for the Economic Analysis

Depending on the comparison chosen, the list of externalities to be considered for the economic analysis will vary. Tables 13 and 14 present an evaluation of costs and benefits of TWWR project scenarios for four types of comparisons. It identifies the externalities to be considered along with a qualitative (+, ++, =) analysis.

Table 13 Comparisons of costs and benefits of TWWR project scenarios: Private Costs and Benefits Analysis

Parameter Analyzed	Type of Cost/ Benefit	Cost/Benefit Item	Indicator	Evolution of TWWR Scenarios			
				From Scenario 1a to Scenario 2	From Scenario 2 to Scenario 3	From Scenario 3 to Scenario 4	From Scenario 5 to Scenario 6
				Wastewater Treatment	Irrigation	Irrigation + Aquifer recharge	All applications including domestic use & DWS
Private Costs	Implementation costs	Engineering studies and monitoring	% of total cost of project	+	+	+	+
	Capital costs	Additional tertiary treatment	Amount of investment per m^3 of water provided	+/-	+	+	++
		Wastewater conveyance network	Amount of investment per m^3 of water provided	+	if expansion	if expansion	if expansion
		Treated wastewater distribution network	Amount of investment per m^3 of water provided	-	+	++	++
		Equipment	Amount of investment per m^3 of water provided	+	+	++	++
		Land	m^2 of land surface required per m^3 wastewater treated * cost per m^2	+/-	+	+	++
		On-site conversion costs	Amount of additional investment per m^3 of water used	0	+	+	0
			Amount of additional investment per irrigated hectare	0	+	+	0
	Maintenance costs	Labor	Number of employees * cost of labor	+	+	+	+
			Cost/m^3 of water provided	+	+	+	+
		Equipment and consumables	Cost/m^3 of water provided	+	+	+	+
		Equipment depreciation	Lifespan of capital goods in years	+	+	+	+
			Capital depreciation rate	+	+	+	+
	Operating costs	Energy for treatment, conveyance and distribution	kW/m^3 of treated wastewater	+	+	+	+
			kW/m^3 of water distributed	0	+	+	+
		Labor	Number of employees needed * cost of labor	+	+	+	+
			Cost/m^3 of water provided	+	+	+	+
		Monitoring/Analyses	Cost/m^3 of water provided	+	+	+	+
		Consumables	Cost/m^3 of water provided	+	+	+	+
Private Benefits	Gains for the wastewater producer and reused water distributor	Sales linked to reuse	Sale price per m^3 * volume of wastewater treated and distributed	sanitation tax	+	+	+
		Avoided costs	Savings on avoided alternative investment	+ if sea outfall avoided	+ irrigation/ green areas	+ to be estimated for all uses	+ to be estimated for all uses
		Image/Communication	Difficult to monetize	+	+	+	+
	Gains for the irrigation user	Increased crop yield due to organic fertilizers	Increased yield per hectare * price of crops	0	+	+	0
			Savings in Euros in purchases of artificial fertilizer	0	+	+	0
			Difference between the price of land with access to TWW and the price of land with access to surface water (not rich in fertilizers)	0	+	+	0
		Impact on the water bill	Cost variation = (price of reused water * volume of water applied) - (price before project * volume before project)	0	+	+	0
			Avoided costs if before project: water	0	+	+	0
		Increased water supply security	Changes in volumes of water applied / crops and yields / profits	0	+	+	0
			Crop yield lost in case of water scarcity * sale price of crops * frequency of water scarcity	0	+	+	0

Table 14 Comparisons of costs and benefits of TWWR project scenarios: Social Costs and Benefits Analysis

Parameter Analyzed	Type of Cost/ Benefit	Cost/Benefit Item	Indicator	Evolution of TWWR Scenarios			
				From Scenario 1a to Scenario 2	From Scenario 2 to Scenario 3	From Scenario 3 to Scenario 4	From Scenario 5 to Scenario 6
				Wastewater Treatment	Irrigation	Irrigation + Aquifer recharge	All applications including domestic use & DWS
Negative Externalities/Social Costs	Health	Infection rate * cost of treatment		Lower risk	Higher risk	=	risk for domestic use and DWS
		Incidence and prevalence rates	WHO standards	-	Higher risk	=	risk for domestic use and DWS
		Cost of information / prevention		Lower risk	+	=	+
		Cost of health controls (For example: increased frequency of medical examinations)		Lower risk	+	=	risk for domestic use and DWS
		Tolerable risk level in DALYs and QALYs (WHO)	WHO Standards, 2006: Loss of 10-6 DALYs pppy	Lower risk	Cost for 10-^{6} DALYs pppy	=	risk for domestic use and DWS
		Pathogenic microorganisms	Bacteria, viruses, protozoa, helminths (WHO standards, 2006)	Lower risk	Higher risk	=	risk for domestic use and DWS
		Health security / Product quality		0 if there is no irrigation in the “without project” scenario	+ on new irrigated land;- on land already irrigated in the “without project” scenario	=	risk for domestic use and DWS

Looking forward: Learning from Existing Experiences for a Paradigm Shift

After a brief discussion of the success factors identified for projects in the Mediterranean region, this section presents recommendations to remove the obstacles listed in *Table 8* followed by a methodological framework—consisting of a phased plan and a checklist—that will be instrumental to successfully complete a TWWR project stage by stage.

Identifying Success Factors

The success factors identified for projects are the positive counterparts of the obstacles observed. Success factors include:

- Operational institutions working together in a coordinated approach on TWWR;
- Appropriate and progressive regulations that take into account the constraints of irrigation users (balancing health and food production/soil management concerns);
- An integrated water resources management (IWRM) policy, a health and environmental policy;
- Adequate and efficient treatment systems;
- Public acceptance;
- Economic and financial viability of projects.

Box 8 Success factors of TWWR projects in Israel

- Early recognition of the strong pressure on water resources
- Regulations adapted to promote the development of TWWR
- Rapid conversion to more profitable farming practices with reduced water consumption
- A combination of water savings programs (modernization of irrigation methods) and research on non conventional water resources (TWW and desalinated water)
- Developing engineering and technological skills that allow efficient TWWR capacities.

Removing Obstacles

The following recommendations are proposed to remove the obstacles for successful TWWR projects.

Establishing a Coherent Institutional and Regulatory Framework

In order to remove the obstacles associated to fragmented authority among institutions and to the numerous regulations, it is recommended to:

- Create an organization that will enable a dialogue between the institutions concerned;
- Develop specific policies, laws and regulations on TWWR.

Adopting an Integrated Approach to Address the Complexity of TWWR

In a context characterized by the variety of resources and uses, it is essential to adopt an integrated water resources management approach of regional scope, from source to use. In particular, it is crucial to:

- Consider wastewater as a resource (non conventional) and not as waste: wastewater becomes an element to be included in the integrated management scheme of water resources;
- Adopt a "regional" approach, from a watershed point of view, which not only integrates management of drinking water, wastewater, pollution and reuse but that will also evaluate socio-economic components and trends, particularly, the relationships between urban centers and periurban agricultural zones;
- Transcend the top-down approach to adopt a bottom-up approach: the top-down approach traditionally adopted in sanitation systems, which consists in collecting and treating wastewater without planning for its reuse, should be replaced by a bottom-up approach in which the needs (uses) are analyzed in relation to the resources (different flows of wastewater and effluents) that will be treated according to the intended application;
- Adopt an integrated multi-sectoral approach that combines health, food, environmental, economic and social issues.

The Right Choice in Sanitation

There is no one unique solution. It is recommended to:

- **Choose a sanitation model that is adapted to the use and at the same time adapted to the nature** and quality of available resources (wastewater);
- **Identify simple solutions that may be replicated and which are specific to local conditions** (level of expertise, physical and climate conditions, financial capacity);
- **Consider the type of sewer system** (centralized or decentralized). The principle of a combined sewer system should be analyzed in terms of efficiency and costs, and the country's economic

development level. If necessary, the combined sewer system should be abandoned to adopt a more eco-friendly alternative that retains valuable organic matter (nutrients), consumes less energy, is simpler and requires less maintenance;

- **Consider separating wastewater flows**: preferring the use of a separate sewer system for industrial wastewater that is essential to obtain better quality treated wastewater;
- **Choose flexible treatments** to be able to adjust water quality (nitrogen and phosphorus content) according to seasonal demand (agricultural water/aquifer recharge);
- **Integrate sludge management** as an integral element of TWWR projects. This aspect should not be neglected because, for proximity reasons, sludge may be applied to agricultural land irrigated with TWW.

"Use" as the Determining Factor of TWWR

The entire TWWR chain from production to storage, including treatment, should benefit the intended water use. If it is irrigation, it should be carefully analyzed with regard to its technical aspects, farming and irrigation techniques, risks, benefits and constraints. It is particularly recommended to:

- **Choose reuse sites that are as close as possible to the water resources;**
- **Consider the irrigated water-soil-plant system (traditional agriculture, green areas) as an integral component of wastewater treatment (land treatment)**. The water-soil-plant system is a powerful "reactor" that decomposes organic matter, absorbs and holds nutrients and adsorbs salts. Its role is to be considered in TWWR for safe wastewater treatment (reduced environ-mental impact). The potential reuse of the different residues (wastewater, waste) should be evaluated according to the climate, soil, health and safety level and the social, economic and political context;
- **Assess over time and space the differences** between water demand (changes associated to crop seasonality, the impact of crop rotation and farming techniques) and available water supply (in quality and quantity) so as to plan for storage capacity and complementary applications (aquifer recharge, for example);
- **Rethink irrigation practices and methods with respect to TWWR** (constant water resources, perception of treated wastewater as source of higher health risks).

Mitigating Risks

Risk reduction is a vital objective that may be achieved through a combination of actions aimed at mitigating hazards and sensitivity (for example by combining treatment and protection measures to lower health risks) (see *Table 6*). When risks are not managed or assessed correctly fears surface, as well as obstacles to acceptability.

Economic and Financial Dimensions

A project may seem viable or not viable depending on the degree of precision of the figures in the economic analysis. It is essential to:

- **Valuate costs**, but also and particularly the externalities (private and social CBA) that may weigh heavily in terms of the project's justification;
- (in cases where competition exists for conventional water resources) **Take into account the use value of water** and the avoided costs when conventional water resources may be released for other uses by carrying out the TWWR project;
- **Introduce a balanced water tariff policy** that will establish, among others, how polluters and/or users will bear the costs of wastewater treatment;
- **Determine if the financial return is not guaranteed** by the tariff policy, in which case, positive externalities of the TWWR project (for the environment or public health, or for the preservation of conventional water sources) may justify setting up a system of public subsidies.

Changing Mentalities and Developing Skills

In order to change the public's perception of TWW and to enable actors to lead, manage and optimize TWWR, all of which are essential, it is recommended to:

- **Conduct information campaigns** to explain TWWR and inform users, consumers and decision-makers;
- **Set up training programs for the different actors** (plant manager, irrigation user, policymaker) with specific objectives and based on their needs, skills and learning capacity. Training for instructors (or "ambassadors") and developing electronically accessible modules are some of the options that could have a stronger impact;
- **Establish linkages between wastewater treatment and farmers**, which come together within the TWWR framework although, theoretically, everything seems to set them apart. Wastewater treatment is a rather continuous, linear, technical and controlled process (data collection, a set of indicators). Agriculture involves land

specific (soil, climate), discontinued (irrigation is used only during growing periods) processes in a changing context that requires knowledge often passed on through oral tradition from one generation to another (few data available or centralized).

An Appropriate Approach to Assess Project Potential

A meticulous approach adapted to the specificity of TWWR projects is necessary to evaluate potentialities. The main questions to be considered stage by stage are presented in *Figure 9*. They are presented in the form of a checklist in *Table 17* that also specifies relevant indicators for each question and references corresponding to other tables in this report.

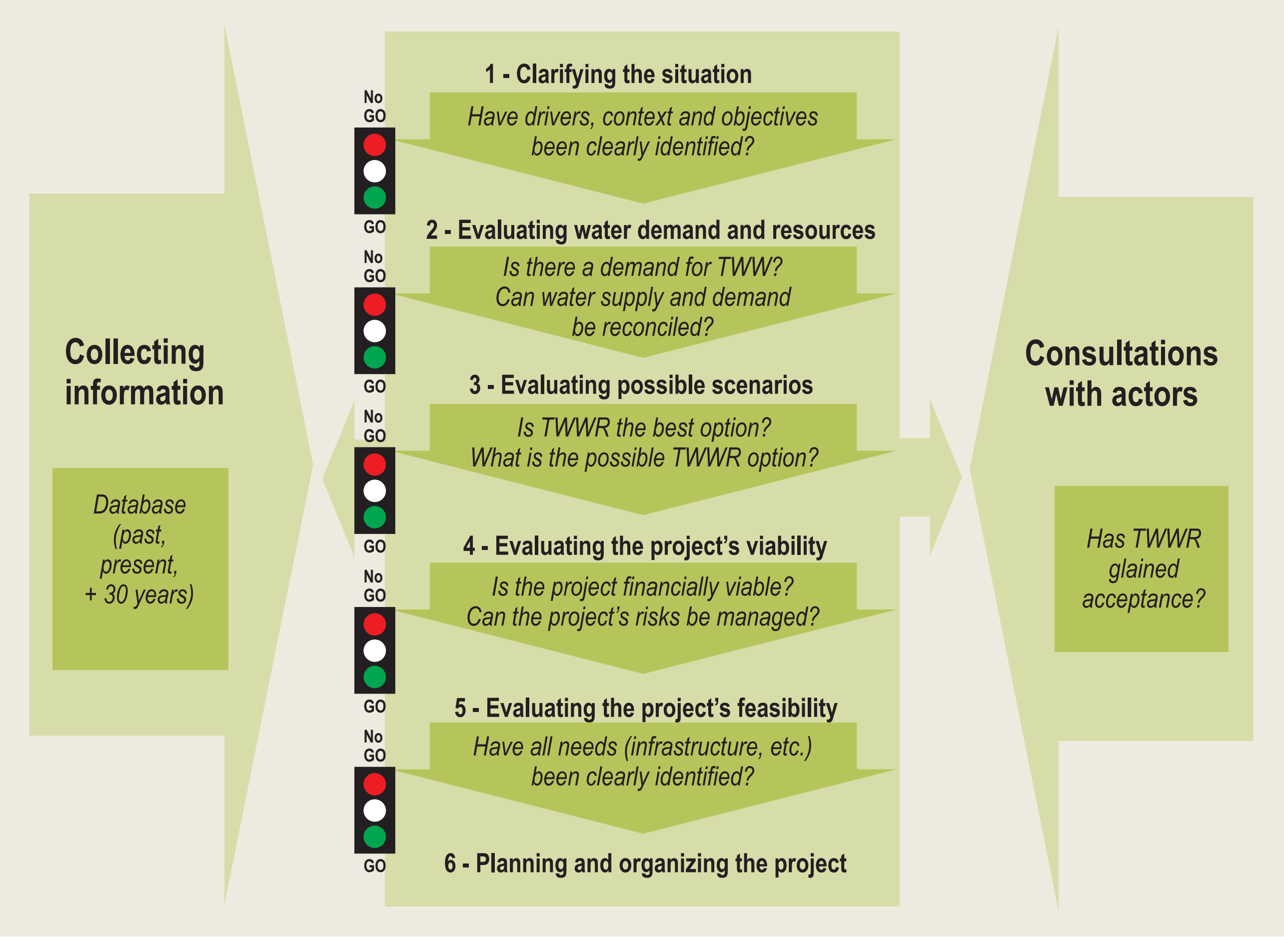
Stages for Project Evaluation

There are six sequential stages: (i) **clarifying the situation**, (ii) **evaluating water demand and supply conditions**, (iii) **identifying possible scenarios,** (iv) **evaluating the project's viability**, (v) **evaluating the project's feasibility**, and (vi) **planning and organizing the project**. It is essential to validate the current stage before moving on to the next one.

A successful project evaluation depends equally on the capacity to collect relevant information and to include all the actors concerned throughout the entire process.

The information that should be collected throughout the decision making process is listed in *Table 17* in *Annex 3*.

Figure 9 Outline for the evaluation of a TWWR project



Checklist for Project Evaluation

This checklist will help sponsors or donors compile the necessary information to answer key questions. Once the questions have been answered, the checklist becomes a tool for decision-making and sharing information. It is also a support for the joint work of all the actors involved in the project.

Table 15 Evaluating a TWWR project: Questions to be asked stage by stage

Stage 1: A clear definition of the problem: drivers, contexts and objectives	
What are the project's drivers? (see *Table 3*)	Types of drivers (population density, water scarcity, etc.)? Ranking of drivers? How are the drivers interconnected?
What is the context of the project? (see *Table 4*)	Type of context factors (economic level, culture, etc.) What are the leading factors that spur the drivers?
What are the project's objectives?	Are they clearly identified? Are they clearly associated to the project's drivers or context?
Transversal stage: Collecting basic information: to date and evolution over a 30-year period	
Institutions, legislation and regulations, policies	Are the institutions already organized? Is TWWR authorized? Are there any policies that offer incentives to TWWR?
Socio-economic	What is the social, economic and cultural context?
Water and climate conditions and ecosystems	What is the climate and water context? Are there any sensitive ecosystems?
Agriculture and irrigation	What are the intended uses (agricultural and landscape irrigation)?
Water supply and demand	What are the intended uses with respect to the resources? How do available water resources relate to possible uses?
Infrastructures	Is there efficient infrastructure for wastewater collection, treatment, distribution and irrigation?
Financing and Economy	What are the revenues and costs? What is the applicable tariff policy?
Reuse Practices	Is there a tradition of wastewater reuse? What type?
Stage 2: Evaluating water supply and demand	
Water resources [9]	Describe the quality and quantity of water resources: • Conventional (groundwater, surface water) • Non conventional (untreated wastewater, TWW, desalinated water, brackish water, drainage water)
What is the water demand? **Is there a demand for TWWR applications?** [10]	What quantity for what use (drinking water, domestic, industrial, public use, agricultural or landscape irrigation, hydroelectricity, etc.) What would be the minimum environmental flows to maintain groundwater and surface water levels? Location of water demand in relation to the water resources: (distance between irrigated land and wastewater production areas, for example) Is there a demand from the private sector?
Water Resources/Demand (25 to 30 years)	Is it possible to combine supply and demand planning? Are there needs that have not been satisfied (water stress conditions)? Are there water use conflicts (in terms of volume, location)? Can TWW meet the needs?

Sources :

[9] Master plans for water resources, watershed studies, hydrology and hydrogeology maps and studies, water laws, water quality standards, databases for water quality monitoring.

[10] Master plans for water resources, watershed studies, master plans for water supply, urban development master plans, sectoral development plans (irrigation, hydroelectricity, etc.), water use quota allowed for each use, population census and projections, water quality laws and regulations, laws on environmental flows.

Table 15 Evaluating a TWWR project: Questions to be asked stage by stage (Cntd)

Stage 3: Evaluating possible solutions (scenarios) in relation to objectives and context	
What are the possible options? (see *Table 12*)	How would the "without project" (counterfactual) situation evolve? What are the options using conventional resources? What are the options using other non conventional resources? What are the options with TWWR? Is it a simple scenario: one resource, one use? Is it a complex scenario: multi-use, multi-source, changing uses over time (for example: TWWR for irrigation coupled with TWWR for aquifer recharge at the end of the growing season?
Stage 3: Evaluating possible solutions (scenarios) in relation to objectives and context (Cntd)	
Is the TWWR project economically viable? (see *Tables 10 and 11*)	Private costs and benefits (Private CBA): What are the investment, operating and maintenance costs for infrastructures for the collection, treatment, storage and distribution of wastewater? What are the costs and benefits for the wastewater producer and distributor of treated wastewater, for the irrigation user and for end users? Social costs and benefits (Social CBA): What are the costs and benefits for public health? What are the costs and benefits for the environment? What are the costs and benefits for society?
Is the TWWR application the best option? (see *Tables 13 and 14*)	Is TWWR better than other available options? Is it complementary? What is the optimum TWWR scenario?
Transversal stage: Evaluating public perception	
Has TWWR gained acceptance? (information sources: surveys)	Have actors been identified and are they involved in the project? Is there a tradition of WW reuse? To what extent do users and end users accept TWWR?
Stage 4: Evaluating the project's viability (financial analysis and risks)	
Is the project financially feasible?	Clearly state who will pay and how: what is the financing plan (tariff, taxes, own funds, loans, grants)? Are water tariffs adequate? Is the project financially viable for the water operator/distributor? Is the project financially viable for the irrigation user or the end user? Are technical, health and environmental monitoring programs financed? How? What are the financial consequences for the State or the local government?
What are the risks of the project?	Is the solvent demand for TWWR sustainable and does it correspond to the available wastewater and the investments planned? What is the sensitivity of the project's profitability to a change in usable TWW volume? What is the sensitivity of the project's financial profitability to an increase in investment costs?
Stage 5: Planning the project and launching feasibility studies	
Evaluating infrastructure needs	Is additional infrastructure needed for wastewater collection and treatment (collection network and types of treatment)? Specify. Identify the needs in adapted and efficient irrigation systems and methods (agricultural and landscape irrigation). Identify the needs associated to greywater reuse in buildings. Identify the needs for treatment of industrial effluents.
Environmental and health impact study	
Organizing the project	
Defining monitoring modalities	
Establishing a business plan	

Annexes

Annex 1: Methodology Notes for the Economic Analysis

1. Evaluating Externalities

- All the elements that cannot be quantified should nevertheless be clearly presented in the results of a cost-benefit analysis (CBA). They may motivate the decision to carry out or to abandon a project (FAO, 2010).
- It is sometimes difficult to valuate certain externalities. However, economists have developed "contingent valuation methods" based on surveys that are used to associate a value in monetary terms to situation changes, for instance, changes in environmental or health conditions.
- Some criticize economic valuation of externalities arguing it "privatizes" the environment because it assigns a monetary value to what are normally non-market goods or services. These concerns should not be disregarded but monetary valuation should be seen as a mere tool for comparing costs and benefits. Money is a standard measure well known to all and easy to use.
- Concerning water resources, externalities should be evaluated at watershed level for an integrated management of water resources approach (FAO, 2010).
- Since the externalities valuation method is still not stable, specific sensitivity analysis are necessary to measure the impact of uncertainties on the valuation of externalities on the project's profitability.

For example, to evaluate the externality "less pressure on water resources" by calculating the value of water made available for other uses, several indicators may be used: sale price of drinking water, real cost of drinking water, cost of increasing the amount of drinking water available through other means, etc. These different indicators are used to calculate the project's net present value to verify the sensitivity of the final result to the value chosen.

2. Evaluating Environmental Risks and Benefits

One of the leading causes of environmental degradation is that the value of environmental goods is underestimated in the planning stage of large-scale projects. Most of the time, there is no institutional mechanism that will allow associating values to these environmental goods, and particularly, market prices rarely exist. Economists have developed valuation methods to determine the value of these externalities in order to include them in a cost-benefit analysis.

Valuation methods are usually classified in two categories: indirect methods based on observed behaviors that reveal preferences, and direct methods in which individuals answer questionnaires regarding their preferences. The elements discussed below are taken from the work published by Bontems and Rotillon (2007) and from OECD analyses (2006).

Revealed Preferences through Indirect Valuation

A difference is made here between the economic damage function approach that evaluates first the damages (or damage reduction) to which it will then assign a monetary value, from other approaches that use monetary data compiled through the observation of markets indirectly related to the environmental good under consideration.

- **Damage functions**: Firstly, a quantitative causal link needs to be established between wastewater reuse (or variations in wastewater quality) and its consequences. After that, a monetary value is associated to the causal link identified in the first step.

Example: Using wastewater to irrigate a one-hectare field of crops increases soil salinity. Crop yield losses per hectare due to increased salinity may be evaluated. The environmental cost of increased salinity (in euros/hectare) may then be calculated using the sale price (known) of the cultivated crop.

- **Defensive expenditure:** households incur in expenses to protect themselves against environmental degradation. Valuating this expenditure provides a measurement—which is admittedly not perfect yet relatively easy to calculate—of the benefit associated to the environmental improvement. This method provides a minimum estimate of the value since it is not possible to protect oneself from all nuisances.

Examples: Defensive expenditures by households living close to storage tanks to protect themselves against the visual nuisance generated by the tanks; additional costs paid to buy products non-irrigated with wastewater (imported products, for instance).

- **Hedonic price:** this method is based on the hypothesis that there is a relationship between the price of a good and its different characteristics. For similar housing located in different environments, the difference in price should reflect the value of the environmental damage or quality. The validity of this method is limited by the imperfect property market (imperfect information on buyers and the characteristics of the good purchased, credit constraints, etc.).

Example: Wastewater sedimentation basins may be a source of odor pollution. When it is not possible to determine the loss of value of houses located near wastewater treatment plants, the odor nuisance may be estimated with data on the loss of value of houses following the installation of a landfill site or other similar odor nuisance (transfer method).

- **Travel cost**: it is based on the hypothesis that in order to benefit from free environmental services, it is necessary to consume other complementary market goods, among others, to incur in travel costs. A visitors' survey will reveal the travel costs of visitors, which will then be used to estimate the value of a natural site. This method is applied only to recreational environmental goods.

Example: Secondary treatment of wastewater before discharge improves the quality of river bathing waters for swimmers. Variations in the number of visitors and in the distance traveled by visitors to a bathing site may be used to determine the value of a positive externality on water quality.

Revealed Preferences through Surveys

- **Contingent Valuation:** this method consists in direct surveys asking people to state their willingness to pay for an environmental improvement or their willingness to accept a compensation for degradation. It is the only method that may be used for non-use values.

  A survey process is composed of four stages:
  - Building a plausible reference scenario that may by easily explained to all survey participants,
  - Revealing Willingness-To-Pay (WTP) and Willingness-To-Accept (WTA) values for a change in the environment with respect to the reference scenario, using a representative sample of the total population,
  - Calculating the mean value of WTP and WTA and identifying explaining variables,
  - Results are aggregated on a total population scale to give an estimate of the value of the environmental change for the entire population concerned.

Birol et al. (2008) measured the farmers' WTA and WTP in Cyprus in relation to a project for sanitation and aquifer recharge with treated wastewater in the Akrotiri area. They observed the majority of farmers in the area are willing to support the project and that their WTP is highest for the most ambitious project (aiming at high quality underground water).

- **Choice modeling**: This method takes into consideration that one project may have several environmental impacts (multidimensional). Through choice modeling, it is possible to quantify the marginal or unit value of every dimension involved in an environmental change.

  The method is based on:
  - The identification of the relevant dimensions of the environmental asset to be valued, assigning levels to these dimensions.
  - Creation of choice cards, each with at least two scenarios, and each scenario is defined by the dimensions and levels of environ-mental attributes. Choice sets or cards should maximize the information collected on preferences with respect to each environmental attribute, yet minimizing the number of choice sets needed. It is the most delicate step in choice-modeling.
  - Collecting decisions of a representative sample of participants, who must choose their preferred scenario for each choice card.
  - Estimating the value of each dimension of the environmental good by correlating the decisions on the different choice cards.

This method was used to evaluate the preferences of Londoners with regards to the quality of the water of the Thames. London's sewage system is no longer capable of absorbing all the rainfall that the city experiences on a regular basis. Untreated effluent is regularly discharged into the river and sewage carries large quantities of litter.

The Thames Water company considered nine different options to reduce these nuisances. Each option has its own cost levels and service variables. Among the attributes chosen were the number of days per year on which it is not advisable to practice water sports due to increased health risks and the amount of potential fish kills per year.

Analyzing each of these options through contingent analysis would be time consuming since each option would require its own scenario. Choice modeling appeared as a useful alternative. Survey respondents were asked to choose among several choice cards that contained the reference scenario plus one or more potential river improvement scenarios. The scenarios were described in relation to characteristics of the restricted practice of water sports, the survival rate of fish and the price of the different options. With the choice modeling method, each of these characteristics may be assigned an implicit price, like the WTP to reduce the amount of days health risks are associated to water sports or the WTP to reduce the number of fish deaths. These unit values can then be aggregated to evaluate the total benefits of a given option (OECD, 2009).

Notes:

There are few references available on the use of these revealed preferences methods to estimate environmental externalities of wastewater reuse projects. Therefore, it seems advisable to carry out surveys in order to evaluate the willingness to accept and the willingness to pay for wastewater reuse and to valuate the associated environmental benefits and risks for the people living in the area or the persons affected by the project.

Surveys to determine the WTP are time-consuming and expensive so it may be tempting to proceed by a transfer method: the WTP that has been determined for a given good in a given place is used for the same good but in another place. Such a procedure, however, is intrinsically random (Desaigues et Point 1993; AFD 2004). A transfer may involve significant error margins because it is impossible to find two identical objects (goods) and to capture all the social, economic and cultural factors that determine the WTP. Consequently, the transfer method should always be completed with a sensitivity analysis.

3. Project Perception and Rejection Risks

Different actors may contribute to undermine the acceptability of a wastewater reuse project: farm products consumers who believe the health risk is too high; farmers concerned with their health and who fear they will not be able to sell their products to reluctant consumers; citizens that refuse to pay taxes to finance these projects; residents living in areas near treatment plants or irrigation areas afraid of related nuisances, etc.

The following factors will determine the degree of acceptability of wastewater reuse projects (WHO, 2006):

- The degree of public awareness (for example, the number of people informed about the procedure),
- Average understanding of sanitation issues,
- Average knowledge of water stress issues,
- Existing alternatives to wastewater reuse,
- The degree of confidence in the wastewater treatment technology,
- The degree of confidence in the sanitary regulations established by the government.

Remarques

1. Public acceptability will become stronger the more the citizens participate in the development of

Evaluation of negative and positive externalities associated to TWWR projects

Negative Externality	Possible Evaluation Options
Soil contamination	May be evaluated through: • The use and non-use value of the soil concerned by the pollution risk; • The loss of crop yield per contaminated hectare; • The impact of water salinity.
Contamination of groundwater	The risk will be valuated according to the use and non-use value of groundwater. The assessment of water resources with respect to needs completed during the preliminary analysis should allow estimating the use values.
Water surface eutrophication and adverse effects on river flows	Risks will be valuated according to the use and non-use values of the surface waters concerned. The assessment of water resources with respect to needs completed during the preliminary analysis should allow estimating the use values.
GHG emissions	Estimated using GHG emissions from additional energy consumption associated with the treatment and distribution of wastewater. Cost evaluation will be based on the price of the ton of carbon.
Odor pollution	Cost evaluation through the appreciation or depreciation of the value of property/houses or through defensive expenditures.
Positive Externality	**Possible Evaluation Options**
Reduced stress on conventional water resources	• Estimate of use value: value of direct or indirect services rendered through the effective, planned or possible use of conventional water "released" or made available by TWWR; • Estimate of non-use value of water: value associated to the existence of water independently from any present or future use (existence value of an aquifer) (difficult to estimate); • Avoided costs to secure additional drinking water supply for cities (new catchment areas, desalination, transfers between basins, etc.); • If water volumes are released for drinking water supply (DWS): valuation of these water volumes at drinking water prices.
Better quality surface water and groundwater	To be estimated in relation to a "without project" situation in which wastewater treated to lower levels is discharged into rivers. In such case, the following are taken into consideration: • Use and non-use values of water, • Avoided costs for ecosystems recovery, • Reduction in the rate of mortality of aquatic species and riparian vegetation.
Better carbon balance	May be estimated using three indicators: • To what extent are emissions lower compared to an alternative water supply, • Reduction of the distance from the source of water supply and users; • Reduction of emissions from transport of farm products to urban centers.

the project. Members of the community who will benefit from the positive aspects or who will be affected by the negative aspects of a project play an important role during project planning. The public may be involved in many different ways such as public meetings, face-to-face interviews, etc.

2. The degree of acceptability and the public's perception of negative externalities may be evaluated indirectly by organizing public meetings to which urban and rural dwellers are invited. Strong mobilization of local populations may be an indicator of the fears triggered by the project. Such meetings may be instrumental in solving some of the problems related to the public's lack of acceptance before the project is set up.
3. Focus groups or surveys may be useful to understand what motivates their fears (degree of understanding of issues at stake, rationale) and to identify the tools that will dissipate them.

Tsagarakis et Georgantzís (2003) studied the willingness to use recycled water and the willingness to pay of farmers in Crete. Among the different versions of their questionnaire some included information on the benefits and limitations of wastewater reuse others did not. Results show farmers were willing to use recycled water and that access to information on benefits increases acceptability. Living standards and the education level increase acceptability and the positive effect of an information session.

4. Value of Irrigation Water

Irrigation generates value, but since the value of irrigation water is a multifaceted concept, its valuation is a delicate matter. Tardieu (1999) distinguishes particularly the strategic from the "tactical" value of water.

The strategic value is equal to the ratio of the differential added value between irrigated and non-irrigated crops to the water allocated to irrigation. This value represents the strategic choices of the farmer at a moment in time when it is still possible to modify crop rotation and crop irrigation. It is affected by the price of products, crop yield, effectiveness of irrigation techniques, etc. In general, irrigation is used when the strategic value exceeds the price of irrigation.

The tactical value of water is defined as the short-term value when there are limited possibilities to adapt to a potential water scarcity. It depends essentially on the vegetation stage (high tactical value after sowing and low at the end of the vegetation season) and on climatic conditions (high tactical value during water stress and low (even null) in case of abundant rainfall). Tactical value often exceeds the strategic value because losses associated to an irrigation water deficit are higher when it is no longer possible to resort to compensation strategies.

The different methods available to calculate the strategic value of irrigation water will give different estimates. Strategic value may be estimated using mathematical programming models: it is the implicit price associated to input consumption. It may be estimated through econometric analysis using data on revenues, costs and water consumption (Schoengold et al., 2006). It is also possible to evaluate the value of water through surveys and the willingness to pay.

By way of example, in the study on tropical fruit growers in southeast Spain, Calatrava Leyva and Sayadi (2005) estimate the average willingness to pay is €0.27/m^3 of water while they estimate at €1.52/m^3 the marginal value of water based on data on productive characteristics and generated income. Rigby et al. (2010) use a choice experiment, a method based on multi-attributes choices, to determine the marginal value of irrigation water in southern Spain. They estimate the average willingness to pay is €0.45/m^3.

5. Use and Non-use Values of Water

A major positive externality of TWWR for irrigation is associated to the availability of additional water for other uses. It is hence possible to valuate this positive externality by estimating the value of water for these other uses. However, market values do not always exist for all water uses. For example, waters flowing in rivers for bathing or for the enjoyment of a view of a waterfall, or groundwater that is not used but will be accessible to future generations do not have a price. And even when a price has been determined, it reflects only partially the true environmental costs and benefits. A complete economic analysis of WWR must take into account the total economic value (TEV) that includes use and non-use values of water (AFD, 2004).

The use value is the value of services provided through the effective, planned or possible use of water. The non-use value is associated to the existence of water itself, regardless of any future or present use. An individual may want to preserve water without actually using it, or planning to use it, or even if it is not possible to use it (OECD, 2006):

- The water that remains in rivers as a result of TWWR and which can be used by industries has a direct use value for the industrial sector;
- Reconstructing wetlands through TWWR enables water filtering and improves water quality for users downstream (ecosystem service with an indirect use value);

- Recharging an aquifer through TWW has a value even though the water will not be used at the present time. It has an option value if a planned future use has been identified for the aquifer. Moreover, groundwater may have an existence value, associated to no particular use (a feeling of concern for a given good), or even a bequest value if future generations could make use of the groundwater.

Annex 2: Methodology Notes for a Financial Feasibility Analysis

1. Financing TWWR Projects

Reaching an adequate balance between financing sources is vital to assure the financial sustainability of a wastewater reuse project. The contribution key for the financing plan, involving national governments, operators, users of TWWR, international fund donors and private funds should be defined according to the characteristics and constraints of each project.

Water supply and service tariffs, public subsidies and assistance grants (the "three Ts": tariffs, taxes and transfers) are the main funding sources for a project. It is advisable to make sure these three sources allow for "sustainable cost recovery", which is more realistic and practical than the "full cost-recovery" principle through water tariffs only.

Public financing may take different forms: investment subsidies, short or long-term loans on concessional terms, bonds, etc. Sources of public funds include central governments but also local governments when they have tax revenues and/or are authorized to incur in debt. Creditworthy municipalities may receive funds from State budget allocations and financial markets to invest in wastewater reuse projects.

Loans, bonds or shares are useful to mobilize additional funds, particularly for the initial capital outlay. However, these funding sources entail reimbursements or payments that must be included in the financing plan. If, until recently, most projects were financed by governments or public agencies with grants or loans of international agencies, the most recent projects include private operators who participate in project financing.

The table below lists possible financing sources according to investment items, as well as the purpose of each type of investment.

2. Treated Wastewater Tariffs

Effective water tariffs should not only cover (entirely or partially) the costs for water and sanitation services, but they should also provide incentives for a rational use of water resources. However, it is not certain that recommendations in favor of tariff incentives aiming for lower water consumption would apply to wastewater. There are large quantities of wastewater available (at least as long as households and industries do not reduce their water consumption) and if a wastewater reuse system is set up it should be cost-effective.

Price of Treated Wastewater

The price of treated wastewater is very different from one project to another. It ranges from "zero" to the price of conventional water.

- Setting a zero price on wastewater for users encourages acceptability of this innovation, hence reducing wastewater discharges into the environment.

For example, wastewater reuse is provided free of charge in Australia to reduce wastewater discharges into sensitive water environments.

- The price of TWW is often lower than the price of drinking or conventional water. One of the reasons for setting a wastewater price per liter that is lower than the price of conventional water is that larger volumes must be applied in order to dilute the higher salt content of wastewater. The price per liter must therefore be lower to maintain a constant budget for irrigation.

A study conducted in California in 2005 on 11 wastewater reuse projects shows prices for TWW range from 45 to 100 percent of the price of drinking water (77% in average) (American Public Works Association, 2005).

In Israel, the price of TWW for irrigation is between €0.151 and €0.205 per cubic meter depending on the quality, or approximately 40% of the price of conventional water that ranges from €0.346 to €0.504/m^3 depending on the total quantity of water used (Feitelson & Laster, 2011).

The price of TWW in Tunisia is €0.0103 /m^3, significantly lower than the price of conventional water (€0.072/m^3) (1 Tunisian Dirham = €0.51 in October 2011) (EIB and AHT Group AG, 2009).

In the Tulkarem district, in the West Bank, the farmer's willingness to pay for TWW amounts to 50% of the cost of access to groundwater, or €0.65/m^3, provided no restrictions apply to irrigation (World Bank, 2004).

- In some cases, the price of conventional water and TWW is the same. This approach is justified by the additional benefits provided by wastewater (fertilization, reliable supply).

Table 16 Financing sources and costs/expenditures of a TWWR project

	Type of Financing	Principal Source of Financing	Purpose of Financing
Investment	Subsidies	State	Positive externalities (environmental protection, adaptation to climate change)
	Self-financing	Wastewater producers, followed by project revenues for reimbursements	Application of the "polluter pays" principle through sanitation tariffs
	Concessional loans	Donors/State	Positive externalities (environmental protection, adaptation to climate change)
	Commercial interest rate loans	Private Sector	Lower factor cost (golf courses, green residential areas, new land values, etc.)
Operations	Self-financing	Project revenues	Financial stability of the activity (agriculture, vegetable farming, golf courses, etc.)
	Commercial interest rate loans		
Maintenance/ Renewal	Same as investments	Same as investments	

Source: Faruqui, 2000

In Cyprus, for instance, farmers pay €0.1/m^3 for TWW and for conventional water. However, the price of conventional water could increase, in which case, wastewater will become relatively less expensive (Hidalgo and Irusta, 2005).

Public subsidies aimed at reducing the price of TWW for users are justified for three reasons:

- TWWR subsidies offset the additional costs induced (restrictions on crops that can be irrigated, material/equipment that needs to be changed, uncertainties as to the long-term impact on the soil, etc.);
- Subsidies may act as incentives when users are reluctant to use TWW;

Tsagarakis and Georgantzis (2003) show that subsidies may contribute to increase use of TWW by increasing the difference in price between conventional water and wastewater. Nevertheless, some farmers showed no interest in economic incentives due to moral barriers. Information campaigns on the benefits and risks of wastewater use are useful to convince these groups of users.

- A subsidy for TWWR corresponds to a payment for environmental services. The environmental service provided by users of TWW corresponds to the environmental benefits previously defined.

In Platja d'Aro in Spain, the subsidy granted to farmers is justified by the environmental service they provide by contributing to preserve the water level of aquifers (by using TWW instead of groundwater) (World Bank, 2010).

Setting a price for TWW will depend on the characteristics of each project, in particular:

- Production costs for water services;
- Flexibility regarding the cost-recovery objective;
- Benefits drawn from TWW use;
- Users' willingness and capacity to pay for TWW, chiefly determined by: scarcity of conventional water resources, cost of irrigation with conventional water, the quality of TWW resources (willingness to pay will increase with higher levels of treatment of wastewater) and service quality (reliable supply with TWW vs. variable access to conventional water).

Sharing Costs between Urban and Rural Dwellers

The problem with setting tariffs for wastewater reuse is related to the presence of a traditionally negative externality (water pollution) that will nonetheless become a positive externality because TWWR is a source of water supply. Tariffs should therefore allow sharing costs among urban dwellers, producers of wastewaters and the users or TWW. Two models coexist: the "Polluter Pays" principle, when urbanites pay all transport and treatment costs, and the "Polluter/User Pays" when urbanites and TWW users share the costs.

Several countries have set up financing mechanisms through taxes based on the "Polluter Pays" principle according to which urbanites and industries pay a volumetric tax on the wastewater discharged[11]. Urban producers of wastewater pay—through the sanitation charges on their water bill—capital depreciation costs and operating costs of the tertiary treatment required for wastewater reuse. Users/ Beneficiaries of TWW do not pay these costs.

This approach has its limits because although it may motivate urban dwellers to reduce the volume of

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[11] A volumetric tax is adequate for households because the quality of wastewater does not vary significantly. However, for industries the tax should reflect the volume of wastewater discharged as well as the pollution load (organic and solid matter, heavy metals, nutrients, etc.) (World Bank, 2010).

wastewater produced, farmers will not be motivated to lower their water consumption. It may reach a point where the wastewater treatment plant is too big for the volumes of recoverable wastewater and where wastewater users develop production plans based on quantities of water that will not be available in the end.

Example: The main purpose for the construction of a wastewater treatment plant built in 2002 in San Rocco, near Milan in Italy, was to remedy the absence of a sanitation system to treat urban effluents. The installation of the treatment plant resulted in high water and sanitation prices for Milan's users (from €0.30/m^3 before the project to €1/m^3 after the project). Farmers, on the other hand, have access to TWW free of charge and hence demand increasingly larger quantities. Their demands, however, are usually not satisfied by the operator due to high energy costs (AFD, 2011).

A more balanced approach consists in sharing costs among polluters and users of TWW (Polluter/User Pays principle). To do so, different costs must be identified:

- Costs associated to water treatment against pollutants that should be paid by wastewater producers; and
- Costs incurred for the additional treatment required for reuse that should be paid by TWW users.

In this approach, each agent is accountable for its water consumption.

Costs that cannot be easily separated (shared costs) may be distributed according to the benefits received by each party. For projects whose main objective is to assure urban water supply while reducing the stress on water resources, the main beneficiaries are urban dwellers, therefore, financing through a tax on wastewater seems justified. On the contrary, if the main objective is to enable the development of agricultural land through irrigation, setting up a volumetric tariff for treated wastewater is justified.

Example: Installations for tertiary treatment of wastewater were built near Clermont-Ferrand in France to provide irrigation water to the Black Limagne region. Since the main purpose of the project was to provide irrigation water, the project was partially financed through agricultural water tariffs (from €0.2 to €0.3/m3). Residents of Clermont-Ferrand did not pay higher sanitation tariffs because of the low cost of the project on account of a contract signed between farmers and the local sugar factory. The sugar factory grants access to its lagoons for wastewater storage (when they are not being used for sugar production) and farmers accept spreading the sugar factory's waters on their lands (when they are not being irrigated) (AFD, 2011).

Annex 3: Evaluating TWWR Projects -Useful Information and Considerations

Table 17 Useful Information and Considerations to Evaluate TWWR Projects

Variable	**Information and Indicators (To date and over 25-30 years)**
Socio-economy	
Demography	Population, population growth, distribution of population
Economy	Economic level, distribution by sectors (agriculture, industry, tourism, etc.)
Values, culture, history	Public perception of fresh water and of wastewater
Institutions, policies, legislative and regulatory frameworks	
Institutions	Institutions involved in health, water, environment and agriculture sectors Role of each institution in TWWR Coordination of different levels: local-regional-national-international Questions to be considered: Is there a coordinated institutional approach to TWWR? Have the leaders been identified? Who are the authorities in charge of TWWR? (health, water environment, agriculture, finances) Are water management institutions operational? Have all the actors of the project been identified?
Legislative and regulatory frameworks	Laws and regulations on water management TWWR guidelines and regulations Agencies/Institutions in charge of water controls/monitoring Questions to be considered: Are there specific regulations for TWWR? (YES, NO) What are the regulated uses for TWWR? Are laws and regulations operational? Are there guidelines without the corresponding regulations?
Public policy	Integrated water resources management (IWRM) policy Health and environmental policy Agricultural policy Questions to be considered: Is TWWR incorporated into an integrated water resources management (IWRM) approach?
Actors	Institutional actors, users, consumers, associations, etc.
Ecosystem and physical context	
Climate	Rainfall, evapotranspiration, drought frequency (climate change impact)
Hydrology and hydrogeology	Characteristics of watershed basins, structure of aquifers
Ecosystems	Type of ecosystems, protected zones, wetlands
Water quality	Physical and chemical characteristics of water
Soil and irrigation uses	
Land use	Agriculture, green spaces, industries, urban centers Land quality
Irrigation	Practices, material/equipment Irrigation needs for recreational areas

Table 17 Useful Information and Considerations to Evaluate TWWR Projects (Contd)

Variable	Information and Indicators (To date and over 25-30 years)
Demand of water resources (including TWW)	
Potential TWW resources	Do they exist?
Water resources [12]	Quality and quantity of water resources: • Conventional (groundwater, surface water) • Non conventional (untreated wastewater, TWW, desalinated water, brackish water, drainage water) Supply and conveyance infrastructure
Water Demand and TWW Demand [13]	Questions to be considered: How much water for each use? (drinking water, industrial water, municipal water, agricultural irrigation, landscape irrigation, hydroelectricity, etc.) What would be the minimum environmental flows to maintain groundwater and surface water levels? What is the quality required for each use (domestic, industrial, irrigation, etc.)? Location of water demand in relation to the water resources (distance between irrigated areas and wastewater production zones, for example) Is there a demand from the private sector?
Water Resources/Demand (over a 25-30 year period)	What would be the situation for each type of use, by periods (one-month, three-month, annual) and quality level? Are there needs that have not been met (water stress conditions)? Are there conflicts for water use (in terms of volume, location)?
Infrastructures	
	Collection networks, treatment systems, distribution and irrigation systems Operational capability, efficiency
Financing and economy	
Tariffs	Questions to be considered: What are the potential sources of revenues for TWW? What is the water tariff policy (drinking water and sanitation) for the different uses (domestic, industrial, public)? What are the current/future tariffs/charges for irrigation water? What are the tariffs or values of other uses for the different types of water sources (surface water, groundwater, treated and untreated wastewater)?
Private costs and benefits	What are the investment, operating and maintenance costs of infrastructure for collection, treatment, storage and distribution? What are the avoided costs for the alternative investments avoided? What are the private benefits for the wastewater producer and for the distributor of reused water? What are the gains for irrigation users?
Social costs and benefits	What is the health impact: costs and benefits of the project on public health? What is the environmental impact: environmental costs and benefits of the project? What is the social impact: social costs and benefits of the project?
Reuse practices	
	Is raw or treated wastewater reused? What are the TWW volumes for each water use? Amount of land irrigated with TWW? Are there any market studies on TWW available?

Sources:

12 Master plans for water resources, watershed studies, hydrology and hydrogeology maps and studies, water laws, water quality standards, databases on water quality monitoring.

13 Master plans for water resources, watershed studies, master plans for water supply, urban development master plans, sectoral development plans (irrigation, hydroelectricity, etc.), water withdrawal quota by use, population census and projections, water quality laws and regulations, laws on environmental flows.

Acronyms and Abbreviations

AFD	French Development Agency
CBA	Cost-Benefit Analysis
CFU	Colony-forming unit
CIF	Cost Insurance Freight (used to designate the evaluation of the cost of a commercial exchange)
CMI	Marseille Center for Mediterranean Integration
DALY	Disability-adjusted life year: measurement of life time lost due to disease/disability compared to an ideal healthy life
DWD	Drinking Water Distribution
DWS	Drinking Water Supply
EC	Electrical Conductivity
EIB	European Investment Bank
ET	Evapotranspiration
FAO	United Nations Food and Agriculture Organization
FIRR	Financial Internal Rate of Return
GDI	Gross Domestic Income
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
IWA	International Water Association
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
NPV	Net Present Value
OCP	*Office Chérifien des Phosphates* (Morocco)
PES	Payment for Environmental Services
pppy	Per person per year
QALY	Quality-adjusted life year: measurement of the quality of life lost due to disease/disability
SAR	Sodium Adsorption Radio
TWW	Treated Wastewater
TWWR	Treated Wastewater Reuse
WB	World Bank
WHO	World Health Organization
WTA	Willingness-To-Accept
WTP	Willingness-To-Pay
WWR	Wastewater Reuse
WWTP	Wastewater Treatment Plant
YLL	Years of Life Lost

Glossary

Remark: there are many English references on the subject of TWWR in international reports. Therefore, to facilitate translation work, major definitions were left in this language.

Term	Definition
Activated sludge	Sludge produced in the aeration basin during biological wastewater treatment or during the biological treatment process. Sludge is separated from water through a sedimentation process. Sludge may be dehydrated and later transformed into solid biofuel.
Advanced or tertiary treatment	Additional treatment stages after secondary treatment to remove specific constituents such as nutrients, suspended solids, organic matter, heavy metals, dissolved solids (salts, for example) or pathogens.
Agricultural water	Water used to irrigate crops and water for livestock.
Avoided cost	Amount of costs that would have been paid if the project did not exist but that will be avoided by carrying out the project. It is advisable to compare this amount to the cost of the best next alternative after the project under study (instead of choosing the most expensive option which would give an artificially high avoided cost).
Depreciation rate/Capital depreciation	Loss of value of sustainable production assets resulting from tear and wear or obsolescence due to changes in technology or to different needs. In accounting, it is the accounting recognition in monetary terms of the depreciation of production assets.
Disability-adjusted life years (DALY)	Amount of life years lost due to premature death or lived with a disease or a disability. The number of years lost due to premature death is estimated for the population concerned by comparing the average age at the time of death to the average age at which death occurs in a similar population group at national or regional level. The number of years lived with a disability is calculated as follows: number of cases of disease * average duration of the disease * disability weight (ranging from 0 (perfect health) to 1 (death)). For example, diarrhea's disability weight may range from 0.09 to 0.12 depending on the age group.
Direct wastewater reuse	Reuse of treated wastewater without its discharge into natural bodies of water. Introduction of highly treated wastewater, directly in the drinking water supply system downstream of the wastewater treatment plant (WWTP) or into the raw water network immediately upstream of the WWTP.
Discount rate	Discounting implies applying to a gain or cost expected to take place in the future a weighting coefficient that is lower than it would be for a present gain or cost. The weighting coefficient w is associated to the discount rate s (%) as follows: wt=1/(1+s)^t. For example, for a discount rate of 4%, the value of a future gain or loss that is expected in 50 years will only represent 14% of the present value (1/(1.04)^50=0.14).
Eutrophication	Alteration or degradation of bodies of water generally associated to excessive contents of nutrients (nitrogen, chiefly from agricultural nitrates and wastewater, and also from traffic pollution; and phosphorus from wastewater phosphates) that favor the development of algae and water species and may also lead to increased turbidity.
Evapotranspiration (ET)	Evapotranspiration is the total amount of water transferred from the soil to the atmosphere through soil water evaporation and plant transpiration. Potential evapotranspiration (PET) is usually defined as the sum of soil water evaporation and plant transpiration of crops whose stomata are fully open, when the soil provides all the water required (theoretical value).
Excreta	Feces and urine.
Exposure (Vulnerability)	The probability for an individual, group, society or system of being physically or emotionally injured or attacked.
Externality	An externality exists when a consumption or production activity of an agent affects the welfare of another agent, and when there is no economic transaction or compensation involved in this interaction. For example, a factory that discharges untreated wastewater into a river may produce negative externalities for the ecosystem or to the users downstream (e.g. farmers who irrigate their corps with the river's waters). This externality will be integrated in the economic calculations of wastewater producers if a tax on untreated wastewater discharges is created.
Greywater	Wastewater produced from kitchens, bathrooms and/or laundry, which normally does not have high concentrations of excreta.
Groundwater recharge	Infiltration or injection of natural water or reclaimed water into an aquifer to replenish underground water resources or to block seawater intrusion.
Hazard	A situation that constitutes a danger or menace to lives, health, property or the environment.
Health risk	The probability that a health hazard adversely affects the health of an individual or a group.
Indirect wastewater reuse	Reuse of treated wastewater after its discharge into natural bodies of water. Planned introduction of treated wastewater in a raw water supply system, such as a drinking water storage system or in an underground aquifer, resulting in mixing and dilution of organic matter and providing a natural buffer.
Individual preferences	Individual preferences are considered a source of value in CBA. Saying that the level of well-being, satisfaction or utility of an individual is higher in situation A than in situation B amounts to saying that that person prefers A over B. Willingness-To-Pay is used to measure preferences for an advantage or benefit while Willingness-To-Accept is used for costs.
Internal rate of return (IRR)	Discount rate for which the net present value (NPV) of cash flows is zero.

Term	Definition
Irrigation water	Water for artificial land irrigation to stimulate growth of crops and pastures or to maintain vegetative growth in recreational areas such as parks and golf courses.
Landscape irrigation	Irrigation of non-agricultural land such as protected natural zones, golf courses, public gardens, recreational areas and sports facilities, forest plantations and traffic islands on roads and highways
Lifespan of capital goods	Number of years over which a unit will produce the expected output, with reasonable maintenance.
Loss of biodiversity	Mortality of indigenous fauna and flora leading to the depletion of ecosystems, species and genetic diversity.
Marginal cost	The additional cost associated to the production of an additional unit.
Marginal cost of public funds	Cost incurred in raising tax revenues to finance a government subsidy. Individuals and companies paying taxes cannot use the money paid in taxes for other more satisfactory purposes.
Monetization	To assign a money value to a non-commercial and non-monetary variable.
Net Present Value (NPV)	The sum of discounted benefit flows from which costs are deducted.
Non-use value	It is related to the existence of the good itself, regardless of any future or present use. People may want to preserve a good without actually using it or planning to use it, or even if it is not possible to use it. According to the OECD (2006) non-use values may be classified as follows: • Existence values (WTP of an individual to safeguard a good that the individual does not and will not actually use and that nobody else will use). It may take the form of an interest on the asset itself or a feeling of concern for the asset. • Altruistic values: the individual wants the good to be available for the benefit of others, • Bequest values: next and future generations should have the possibility of making use of the good.
Opportunity cost	In a world where resources (time, money, etc.) are scarce, all choices entail an opportunity cost associated to the forgone alternative use/project.
Payment for Environmental Services (PES)	Voluntary transaction in which a specific environmental service is “bought” by one or several buyers to one or several providers, if and only the provider(s) guarantee(s) service provision (Karsenty 2011). PES programs do not pay nature but rather the people who through their practices promote ecosystem services.
Planned wastewater reuse	Direct or indirect reuse of treated wastewater, ensuring water quality control during its conveyance through especially designed facilities and systems for treatment, storage and distribution of treated wastewater.
Polluter Pays Principle	Cost internalization principle according to which the polluter pays the difference between the social cost and the private cost (i.e. the negative externality of pollution). The polluter must take into account the social costs when making decisions thus leading to an optimum situation from society’s point of view. It is not a legal equity principle but rather an economic efficiency principle. The polluter is thereby encouraged to reduce the negative externality, which consequently reduces pollution.
Primary treatment	Initial treatment to remove solid organic and inorganic matter by settling and sedimentation and to remove floating matter (scum) by skimming. Primary treatment may consist of primary sedimentation, chemically enhanced primary sedimentation and upflow anaerobic digesters.
Quality-adjusted life year (QALY)	A measurement of the quality of life lost due to disease/disability. This indicator may also be used to evaluate increased life expectancy (following a medical intervention, for instance) based on the quality of life (depending on the health condition after the intervention).
Risk	Coexistence of a hazard and exposure (vulnerability).
Risk assessment	Comprehensive process in which available data are used to estimate the frequency of occurrence of hazards or specific events (probability) as well as the magnitude of their impact.
Sanitary wastewater	Domestic wastewater containing only urine and feces, collected through on-site sanitation systems such as latrines, public toilets not connected to the sewer system, septic tanks and cesspools.
Sanitation	Access to facilities for excreta disposal and wastewater treatment, as well as any related services, which will ensure privacy and protect the dignity of users in a clean and safe environment for all (COHRE et al., 2008).
Secondary treatment	The next wastewater treatment stage after primary treatment. It involves the removal of biodegradable dissolved and colloidal organic matter through biological treatment processes. Examples of secondary treatment include: activated sludge, trickling filters and aerated lagoons.
Spreading/Application	Farming practice that consists in the application or spreading of fertilizers, herbicides or pesticides over the fields. Most of the time, it refers to manure spreading or to the application of sludge from wastewater treatment plants to fertilize fields.
Sustainability	The principle of optimizing the advantages of a current system without undermining the possibility of similar advantages in the future.
Treated wastewater	Wastewater that has been treated to allow totally safe reuse.
Unplanned reuse	Uncontrolled reuse of wastewater after discharge. An example of unplanned reuse of wastewater is when effluents are discharged upstream in a river whose waters are used downstream for water supply of urban networks and/or for irrigation.

Term	Definition
Use value	Value of services provided through the effective, planned or possible use of a given good or asset. AFD (2004) describes three use values: • Direct use value • The indirect use value or functional value resulting from environmental services. The "amounts" of the service provided are more difficult to estimate than for direct use values and there is rarely a specific price. • An option value that reflects the advantage of making use of the goods in the future. It is particularly relevant for global public goods, such as biodiversity and climate.
Wastewater	All water whose quality has been adversely affected by anthropogenic activities: liquid effluents discharged, among others, by households, public or commercial facilities, industries, or produced by agricultural activities.
Wastewater treatment	Treatment or transformation of wastewater to different levels of treatment in order to allow its reuse in accordance with water quality criteria.
Water recycling	Use of captured wastewater or redirecting them back to the water systems where they came from. This is a particularly common technique in the industry sector.
Willingness-To-Accept (WTA)	This concept is used instead of WTP when agents have property rights over certain goods. In which case, they may ask for a compensation to abandon their rights. Willingness-To-Accept is equal to the monetary compensation they wish to receive for the loss of their property rights
Willingness-To-Pay (WTP)	Amount of money a person is willing to pay to change a situation or to possess goods.

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The Center for Mediterranean Integration is a multi-partner Cooperative Arrangement to facilitate access to advanced knowledge and best practices while generating support among public and independent institutions to increase cooperation, enhance sustainable development and integrate policies in the Mediterranean Region. CMI programs strive to provide solid inputs for evidence-based policy choices and, in so doing, help to improve governments strategies and actions, increase the level of innovative activities and investments in the Region, and stimulate cooperation between countries around the Mediterranean.

afd
AGENCE FRANÇAISE DE DÉVELOPPEMENT

Agence Française de Développement (AFD) is a financial institution and the main implementing agency for France's official development assistance to developing countries and overseas territories. It finances projects, programs and studies through grants, loans, guarantee funds and debt reduction-development contracts and provides capacity development support to its partners in developing countries.

European
Investment
Bank

The EIB is the European Union's bank. The largest multilateral borrower and lender by volume, the Bank provides finance and expertise for sound and sustainable investment projects, primarily in the EU but also in numerous other geographical areas. The EIB is owned by the 27 Member States, headquartered in Luxembourg and has a network of local and regional offices in Europe and beyond.

To date, the EIB has been the largest source of loan finance to the water sector globally, compared with other international financial institutions. Between 2007 and 2011 it has provided EUR 16.1 billion of long-term loan finance in varied forms to public and private clients. The EIB seeks to maximise added value through careful project preparation as well as advisory and technical assistance activities, particularly in countries where water security is at risk due to climatic and other conditions. The EIB supports sustainable, efficient and innovative solutions, including the reuse of treated wastewater, as part of an integrated management approach to water resources use, development and protection.

plan
bleu

For over 30 years and within a context of growing international action for the environment, the 21 states bordering on the Mediterranean and the European Union have together been developing an original mechanism for environmental regional cooperation within the framework of the United Nations Environment Programme's Mediterranean Action Plan (UNEP/MAP).

Plan Bleu is one of the stakeholders involved in this cooperation. One of the main tasks with which it is entrusted is to produce information and knowledge in order to alert decision-takers and other stakeholders to environmental risks and sustainable development issues in the Mediterranean, and to shape future scenarios to guide decision-taking processes.

Treated Wastewater Reuse (TWWR) projects are particularly strategic in arid and semi-arid countries of the Mediterranean region, countries in which there is considerable pressure on water resources. Much of this is driven by competition for water among various sectors in a climate change context.

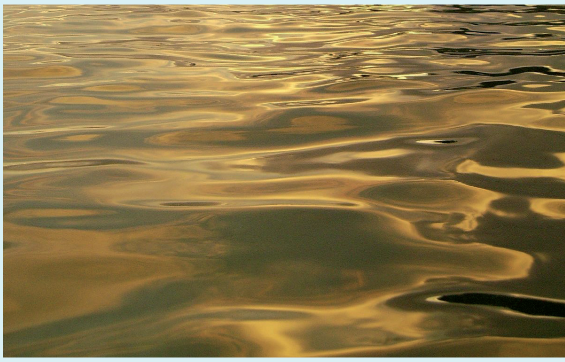
Although TWWR as a concept is straightforward (i.e., using wastewater that has undergone different levels of treatment for beneficial purposes), effective implementation is far less so as illustrated by numerous difficulties encountered in the realization of projects.

This document is the result of a synoptic review of some twenty recent studies (prepared or sponsored by international organizations, national governments, etc.), to which bibliographical references have been added.

It contains:
- a methodology and an analytical framework to identify and classify technical and economic criteria adapted to TWWR problems and issues;
- a descriptive analysis of experiences in the Mediterranean region highlighting, inter alia, negative and positive impacts and obstacles and success factors of projects;
- a decision-making tool that includes a checklist that may be used by sponsors or donors in the initial stages of TWWR projects;
- figures and specific examples from actual project case studies to illustrate various issues highlighted.

Numerous obstacles (poorly aligned regulations, negative public perception, risks, misalignment between water supply and demand) are highlighted within their local context and key success factors are emphasized (e.g., multi-disciplinary approaches, incorporation of TWWR within a broadly integrated water resource management strategy).

Based on successful and unsuccessful situations, the analysis formulates a number of recommendations aimed at removing obstacles and at ensuring more sustainable TWWR projects. Key recommendations include : 1) adopting a holistic, multidisciplinary and bottom-up approach; 2) following an adapted, phased “project approach” considering the irrigation system (water-soil-plant-people) as an integral part of the wastewater treatment and reuse process; 3) adopting measures to reduce and control health and environmental risks; 4) evaluating all externalities through private and social cost-benefit analyses; and 5) organizing specific training and awareness programs for each group of actors in order to develop their understanding and skills, and ultimately, to encourage broad-based support for the project.



Plan Bleu pour l’Environnenement et le Développment en Méditerranée
15 rue Beethoven, Sophia Antipolis, 06560 Valbonne, France
+33 (0)4 92 38 71 30 - www.planbleu.org

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