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ECONOMIC CONSIDERATIONS FOR SUPPLYING WATER THROUGH DESALINATION IN SOUTH MEDITERRANEAN COUNTRIES

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1	ECONOMIC CONSIDERATIONS FOR SUPPLYING WATER THROUGH DESALINATION IN SOUTH MEDITERRANEAN COUNTRIES	Hussein Abazza	Hosny Khordagui, Stavros Damianidis and Vangelis Konstantianos

Acronyms and Abbreviations

AFED	Arab Forum for Environment and Development
BAU	Business as Usual
BOOT	Build own operate transfer
BWRO	Brackish water Reverse Osmosis
CASES	Cost Assessment for Sustainable Energy System
DBOO	Design Build Own Operate
ED	Electro dialysis
EPA	Environmental Protection Agency
EPA	Environmental Protection Act
FAO	Food and Agriculture Organisation
GCC	Gulf Cooperation Countries
GDP	Gross Domestic Product
IDA	International Desalination Association
IPCC	International panel on Climate Change
kW/h	Kilowatt per hour
MDG	Millennium Development Goals
MED	Multiple effect distillation
MENA	Middle East and North Africa
MSF	Multi-stage flash distillation
m^3	Cubic meter
NEI	Nuclear Energy Institute
NPV	Net present Value
OECD	Organisation for Economic Co-operation and Development
PES	Payment for Ecosystem Services
PPP	Polluter Pays Principle
PPP	Public Private Partnerships
R&D	Research and Development
RO	Reverse Osmosis
SMCs	South Mediterranean Countries
SWRO	Seawater Reverse Osmosis
TEEB	The Economics of Ecosystem and Biodiversity
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UPC	Unit product cost
UPP	User pays principle
VC	Vapour compression
WHO	World Health Organisation
WTA	Willingness to Accept
WTP	Willingness to pay

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Preface

This study is prepared to assist the South Mediterranean Countries (SMCs) - Jordan, Syria, Lebanon, Israel, the Occupied Palestinian Territory, Egypt, Tunisia Algeria, and Morocco - examine the costs and benefits of supplying water through desalination as opposed to technical and allocative efficiency. It provides an analysis for the opportunity cost of supplying desalinated water. In doing so it considers the different measures that can be taken to achieve technical and allocative efficiency before resorting to the more expensive option of supplying water through desalination and provides an analysis of the costs and benefits associated with this option. It also provides a set of guidelines and recommendations for performing opportunity cost analysis for supplying water through desalination.

The main target audience for the study is policy and decision makers and practitioners in the SMCs. It aims at providing a guidance tool for policy and decision makers in to enable them take an informed decision with respect to investment in the water sector.

Executive Summary

Water Security is one of the main priorities in South Mediterranean Countries (SMCs) with water consumption per capita being 1000m^3 well below the world average of 6000m^3 and still declining. Water scarcity in SMCs is further exacerbated by population growth, the inefficient use of water in both rural and urban areas, and by climate change. It is therefore essential for countries in this sub region to consider the different options available for addressing current water shortages and future water needs.

Desalination of seawater represents a potential solution for addressing water scarcity and future water needs in SMC's. Since seawater desalination is an expensive alternative for supplying water, it is essential to carefully examine the opportunity cost of desalination versus technical and allocative efficiency.

The main objective of this study is to undertake a socio-economic and environmental cost analysis of supplying water through desalination, and of alternative solutions under technical and allocative efficiency. Based on this analysis, the study examines the opportunity cost of desalination versus technical and allocative efficiency, and provides guidelines for performing opportunity cost analysis for supplying water through desalination. It also concludes by highlighting a set of suggested recommendations to be taken into account in performing such an analysis.

For the purpose of this study it is assumed that the new hypothetical community for which 20,000m^3/day water is to be supplied is located close to a larger community of a population of say 500,000 inhabitants. In order to supply the new community with 20,000m^3 of freshwater, the study proposes the construction of a decentralized wastewater treatment plant to supply water for irrigation thus releasing freshwater originally supplied for agricultural purposes to supply households for the new community with freshwater.

In estimating the stream of costs and benefits for supplying water through desalination a period of 20 years is used applying a social discount rate of 3.5%.

Desalination of seawater and brackish water offers one solution to meet water shortages. Cost of supplying desalinated water is higher than through conventional means, thus representing an increased financial burden on governments and users. Moreover, since in most of the SMCs, water supply is subsidized, with increased cost of desalinated water, subsidies provided by government will considerably increase. While cost of supplying freshwater is about US$ 0.2/m^3, it ranges between US$ 0.5/m^3 and US$ 0.8/m^3 for desalinated water.

In order to calculate the costs of desalination initial capital cost and operating costs are calculated for seawater reverse osmosis (SWRO) and brackish water reverse osmosis (BWRO) and are estimated at US$ 5.1 million and US$ 1.8 million, respectively. Capital cost for building the plant is estimated at US$ 30 million for seawater desalination and US$ 12 million for brackish water desalination plant based on a study by Wittholz providing the costing of desalination water plants worldwide.

Since a large share of the operating cost is attributed to energy, direct costs as well as environmental costs resulting from CO_2 emissions are calculated to derive at the total cost of supplying water through desalination. Other environmental implications aside from the source of energy used, is from the discharge of brine in the sea.

One major factor contributing to the cost of supplying water through desalination is energy. Different costs are calculated for the different sources of energy based on direct costs and environmental damage from the different sources of energy. Not only does this represent a direct fiscal cost, but also an indirect environmental cost represented in increased CO_2 emissions. Apart from the negative impacts of CO_2 emissions on health, it contributes to climate change with its negative impacts on sea level rise, coastal and marine life, impacts on wetlands, mangroves, forests and biodiversity, and desertification. SWRO plants discharge brine into the sea. The high salinity of the brine in calm water with low current has proven to be detrimental to marine biodiversity. Environmental damages resulting from supplying water through desalination are considered in the analysis.

Total cost (NPV using a discount rate of 3.5% over a 20 years period) of supplying 20,000m^3/day of desalinated water for the hypothetical community is estimated at US$ 203.5 million using fuel as the main source of energy and US$ 91 million using coal for SWRO. For BWRO the figures are US$ 167 million and US$ 55 million for fuel and coal respectively. These estimates are calculated on the basis of US prices for energy.

Given the high cost and potential environmental degradation of supplying water through desalination, it is essential to fully exhaust the potential of supplying water through technical and allocative efficiency before resorting to desalination.

Socio-economic costs and benefits of technical and allocative efficiency include a range of measures and policies. Costs and benefits for each policy measure are calculated based on estimates of costs involved and potential benefits using the benefit transfer approach. Measures for achieving technical and allocative efficiency include policies related to good governance, regulatory reforms, and market-based incentives. Physical measures include investing in wastewater treatment, investing in ecosystem conservation, water capture and storage, water conservation programmes, and water saving irrigation techniques.

It is estimated that cost of the plant will range between US$ 4 million – US$ 6 million. Operating cost is estimated to be between US$ 0.10 - US$ 0.19 m^3 depending on the type of technology used. US$ 0.2 is used in the calculations in order to take into account expected increased cost of labour and energy.

Cost of water conservation programmes including installing equipment and systems in buildings (US$ 475 million), as well as irrigation efficient and saving equipment (US$ 311 million) are estimated and captured in the cost. Savings resulting from water conservations in buildings and in agriculture are estimated to result in water savings of between 10%-20% and between 40%-80% respectively. These are estimated to result in annual gains of about US$ 17 million and US$ 66 million respectively. These savings in water are captured as benefits resulting from technical and allocated efficiency.

It is estimated that generally about 15% of total energy consumption is allocated to the water sector. Efficiency in the use of water should result in energy savings. Between 5%-10% per m^3 of water produced goes to energy. A saving of 5% in energy consumption could result in savings of US$ 5.5 million annually.

Other benefits include increased productivity and yields in the agriculture sector of between 20%-30% estimated at US$ 80 million annually. Investment in infrastructure to capture water and recharge natural aquifers, and maintenance of pipelines are estimated and included in the analysis. For the purpose of this study an estimated figure was calculated based on the 20% of the estimated cost of supplying freshwater, which amounts to about US$ 22 million. It is assumed that these measures may result in about 15% increase in water supply and are captured as benefits in the tune of US$ 17 million annually-

Cost of governance and the introduction of regulatory framework are calculated based on human hours required for the development of regulations and the upgrading of institutional and working arrangements. Efficiency in the use and allocation of water resources due to better governance and a regulatory framework is expected to result in 10% savings in water consumption estimated at US$ 11 million annually.

Empirical evidence indicates that improved quality of water and sanitation result in about 2% increase in GDP. This is mainly due to increased productivity of the labour force, more time devoted to productive activity due to less time spent on fetching water, reduced incidence of disease, medical cost, and reduced mortality rate. Using the average GDP for SMCs will yield a benefit of US$ 77 million annually.

Savings in the amount of water allocated for agriculture due to the selection of water saving crops is captured in estimating the benefits from technical and allocative efficiency. This is represented in quantity of water saved in growing the low water content crop and the import of high water content crop estimated at US$ 208 million annually.

Total cost (NPV using a discount rate of 3.5% over a 20 years period) of supplying 20,000m^3/day of water through technical and allocative efficiency for the hypothetical community is estimated at US$ 1.6 38 billion. Total benefits are estimated at US$ 5.760 billion.

The analysis of the opportunity cost of desalination versus technical and allocative efficiency therefore reveals that it is cost effective and yields far more benefits to initially opt for technical and allocative efficiency for supplying water. Supplying water through desalination should only be resorted to after technical and allocative efficiency have been achieved.

The guidelines on performing opportunity cost analysis for desalination section provides an outline of the steps to be taken into account in order to calculate the opportunity cost of supplying water through this option. The guidelines identify and propose means of calculating the cost of foregone benefits and costs of opting for desalination as opposed to technical and allocative efficiency.

The recommendations section highlights factors to be taken into consideration in accounting for costs and benefits on performing opportunity cost analysis for supplying water through desalination. Apart from initial capital and operating cost of supplying water, health and environmental impacts of desalination as well as for technical and allocative efficiency should be estimated and accounted for. Other factors should include costing for storage and recycling facilities, water saving measures in the agriculture and household sector; benefits resulting from the efficient use of water resulting from growing water saving crops and importing high content water crops; jobs created as a result from efficient use of water and its allocation to support economic activities should also be considered as benefits accruing from technical and allocative efficiency.

I. Introduction

South Mediterranean countries (SMC's) fall into an arid zone and are marked by scarce water resources. They can be considered as one of the lowest group of countries in water availability in the world. It is estimated that these countries have less than 1% of the globe's renewable freshwater. Water reserves in the region are declining at a fast pace. It is estimated that it has declined by one third of the 1960's levels and will be halved by 2050 with the current consumption patterns and existing water policies. These estimates though do not take into account potential reduction in rainfall due to climate change. Average annual available water per capita in most of these countries is estimated at about 1000 m^3. This figure is below the United Nations definition of water scarcity. It is expected that by the year 2023 this figure will reach 460 m^3. (Tolba, M. and Saab, N. 2008).

Moreover, a number of these countries such as Egypt, Jordan, the Palestinian Territories, and Syria rely on water beyond their territories (Jägerskog, 2007). The severe water scarcity in these countries and their dependence on water beyond their boundaries would require regional cooperation to better manage this scarce resource.

What is exacerbating the water problem in these countries is the rate of population growth, which is one of the highest in the world. Climate change is also impacting negatively on water resource availability. Moreover, current development models and production and consumption patterns have a negative impact on water resources. Current development models adopted by most of the SMCs are not geared towards the efficient use of resources, particularly water and energy. The main activity in most of these countries is agriculture, which in many instances consumes more than 80% of water and yet is marked by inefficiency in the use of the resource. Moreover, the tourism sector is another sector where water is not being judiciously used (Moustakbal, 2009). Service cost recovery for water in SMCs does not include the full recovery cost of supplying water. The result is the miss allocation and the inefficient use of the resource. It also does not encourage conservation and the provision of efficient water infrastructure projects. Moreover, the water sector in these countries is characterized by having weak institutions, and governance structures (Jägerskog, 2007).

In order to address this shortage in water, alternative means of supplying water are sought. These are either through desalination, or through increased technical and allocative efficiency, and through the tapping of previously unfamiliar sources of water.

These include the following:

- Wastewater resulting from domestic use or what is referred to as grey water can, in some instances, be reused.
- Reclaimed water is wastewater that has been treated from solids and can mainly be used for irrigation. It can also be used for drinking if properly treated and used after being discharged into a water body.

Though reused water is a fast growing market, desalination currently captures a larger market share. Reused water capacity is expected to increase from 19.4 million m^3/d in 2005 to 54.4 million m^3/d in 2015. Seimens estimates that both reused and desalinated water will increase from 48 million m^3/day in 2006 to 158m^3/day million in 2016 (Seimens, 2008).

Efficiency in the use and allocation of water resources due to better governance and regulatory framework is expected to result in more freshwater being made available. These measures involve the use of a strict system of monitoring, compliance and penalties that support this legal framework. Emphasis should be laid on demand side rather than supply side of water. Measures that provide incentives for improved efficiency and reduction in wastage of water should be promoted. Emphasis should be laid on the efficient use of water in the agriculture sector since more than 75% of water available in SMCs is used by this sector. Use of water saving irrigation systems and growing low water content crops can effectively contribute to the efficient use of water by the agriculture sector and significantly result in water saving.

Desalination is growing in the region. Algeria, Egypt and Israel are one of the largest users of desalinated water from the SMCs selected in this review. Over the next decade desalinated water in the region is expected to represent an increasing share of supplied water. The construction of sixteen mega-plants that vary in capacity from 100,000m^3/day to 500,000m^3/day have made the desalination in Algeria one of the world's fastest growing markets. Algeria aims to have a total of 2,570,000 m^3/day in the production of fresh water from SWRO.

In general the costs for operating either a SWRO or BWRO plants are predominantly in the electrical power. It is estimated that 44 % of the costs for a RO plant are in energy (Semiat, 2001), since desalinated water is energy intensive, the carbon footprint is the main concern associated with this industry. Desalination plants are therefore energy intensive resulting in a high level of emission. Depending on the type of energy used to power a desalination plant so too does the environmental damage. Also, for SWRO plants one main concern is the negative impacts on marine biodiversity due to the release of brine in seawater, especially in waters with low currents.

It should be emphasized that supplying water through desalination should only be considered if all other means for supplying water are exhausted. Reason being, desalination is costly and of potential negative impacts to the environment.

Desalination is an old concept and has been used for nearly a century; its importance however has never been graver. It is important though that if this option is finally resorted to that it is considered with a long-term goal in mind. That is to cut costs, reduce heavy reliance on fossil fuels as the main source of energy, and avoid any potential environmental damage resulting from desalination. These factors should, therefore, be seriously considered, designed and costed before resorting to the more expensive alternative of providing water through desalination.
In order to decide on the most cost effective and viable solution for supplying water, an opportunity cost analysis covering the socio-economic and environment implications of supplying water through desalination should be performed. To conduct this analysis, the socio-economic and environmental costs of supplying water through technical and allocative efficiency will need to be undertaken and examined against the first option. Based on an extensive review of literature and experience of countries throughout the world, factors to be considered in the analysis were enumerated and costed.

The guidelines on performing opportunity cost analysis for desalination provides policy and decision makers as well as practitioners with a tool to perform opportunity cost analysis and accordingly make an informed decision of the best option to select.

II: Identification and analysis of socio-economic and environmental costs of supplying water through desalination

Globally, desalinated water represents a very small percentage of the total water supply. It is however, becoming increasingly recognized as an important means of supplying water, especially for countries relying mainly on rainfall as is the case for most of the SMCs. Changes in climatic conditions have led to unprecedented droughts and created the need for innovative means of supplying water. Over 15,000 desalination plants exist globally to date and are supplying fresh drinking water for urban centres as well as the rural sector.

This section is intended to identify the potential socio-economic and environmental costs of supplying water through desalination based on available data, previous studies, and country experiences. Information derived in this section will be used to estimate socio-economic and environmental costs for supplying 20,000 m^3/day for a hypothetical community being considered in this study in section IV.

There are several factors that contribute to the cost of a desalination plant. The first part of this section will highlight the capital and operational costs of a desalination plant, as well as maintenance through the use of a cost database of previous plants, which will take into consideration location and labour costs. The next part will examine energy costs and environmental externalities associated with the use of fossil fuels for the powering of desalination plants as opposed to renewable energies such as solar and nuclear. The last part of the section will provide a brief review of country experiences with desalination.

Capital and operating costs

In order to estimate costs associated with the construction and operation of a desalination plant a database extending over a 35 year period covering capital and operating costs, preliminary and feasibility design and tenders from around the world was considered. Data include information on plant location, technology used, plant capacity, and type of water being treated. Capital costs include the plant and land costs, civil works as well as amortization. Operating costs include costs of chemicals, energy requirements, spare parts and maintenance, and labour. The database includes 331 plants of varying technologies and a harmonized cost analysis especially from plants that reported different costs by different researchers. Also, considering that the database covers the period from 1970 to 2005, present value calculations were made and the currencies adjusted to match the 2005 US$ value.

The unit product cost for a desalination plant (UPC) can be calculated using the formula below. Assuming a twenty-year longevity the equation is as follows:

$$\frac{\frac{Capital\ cost}{Plant\ life} + Annual\ operating\ cost}{Plant\ capacity \times Plant\ Availability}$$

Empirical data indicates that cost of desalination has been decreasing during the last three decades. In 1980 UPC was between $4.5 and $1.5, whereas in 2005 it was between $2.0 and $0.5 per m^3. This trend has continued where current unit prices are now between $1 and $0.5. If we assume an average UPC of US$ 0.7/m^3 then for our hypothetical community, the initial capital cost should be US$ 5.1 million. However, in most instances this may not be the case. Capital costs vary widely regardless of the operating costs. Plants using the same technology, feed water type and size can still have different capital costs ranging from US$72 million to US$307 million (Wittholz, 2007).

To help determine which technology is the cheapest to use, several studies were undertaken that factored the average costs for fixed and operating costs of a plant. Operating costs for both BWRO and SWRO were slightly higher than for thermal processes in desalination. On the other hand though, energy costs for Multi-stage Flash Distillation (MSF) and Multiple Effect Distillation (MED) were significantly higher. For RO, studies have shown that out of the entire cost factors, 63 % were operating costs of which at most 44% were for energy cost. Research indicates that the cheapest seawater process was SWRO and for inland BWRO (Wittholz 2007).

Table 1: Summary of costs for different technologies for 4 different capacities

	Capacity (m^3/d)	Capital cost (US$×$10^6$)	UPC (US$)
SWRO	10,000	20.1	0.95
	50,000	74.0	0.70
	275,000	293.0	0.50
	500,000	476.7	0.45
BWRO	10,000	8.1	0.38
	50,000	26.5	0.25
Source	275,000	93.5	0.16
(Wittholz, 2007)	500,000	145.4	0.14
MSF	10,000	48.0	1.97
	50,000	149.5	1.23
	275,000	498.1	0.74
	500,000	759.6	0.62
MED	10,000	28.5	1.17
	50,000	108.4	0.89
	275,000	446.7	0.67
	500,000	734.0	0.60

??Capital and UPC for the varying capacities of plants with differing technologies is highlighted in table 1. These were calculated using the correlations and cost breakdown for each plant.

The cost of replacing existing water supply with desalinated water is approximately US$ 0.45 ± US$ 0.23 (Wittholz, 2007). One of the main concerns regarding supplying water through desalination is the high-energy requirement associated with it. An increase in the cost of electricity for example from US$ 0.10/kWh to US$ 0.15/kWh could potentially increase the UPC by 17.5%.

The following part of the section examines the different energy sources used for desalination plants and their environmental and social impacts.

In general the costs for operating either SWRO or BWRO plants are predominantly in the electrical power. As earlier indicated, it is estimated that 44 % of the costs for a RO plant are in energy (Semiat, 2001), other estimates go as far as 87% (Zhou, 2004). Cost breakdown are largely dependent on the features of each individual plant making it difficult to develop a generic model. The percentage share of energy costs related to the overall costs of production is examined in a study done by Wilf, where he estimates the UPC of energy in RO plants. Doubling the cost of electricity could increase the UPC by up to 50 % for an RO plant, whereas another could show a different UPC altogether. This simply means that even if the energy needed for operating two different desalination plants are the same, different energy costs will change the UPC of each plant only highlighting the difficulty in determining a clear generic model (Wilf, 2001).

Another factor that should be considered for the initial costing of a desalination plant is its location. Not only does vicinity with both the water source and the destination zone for the water, be it a city or an industrial area, matter but so do land and labour costs. A country where both land and labour are cheap should produce significantly cheaper water as opposed to a country where the factors of production are higher. However a study conducted by Park et al. shows that plant location had very little observable effect on the cost of water. This implies that cost data from around the world can be applied to any location without a huge variance in the outcome (Wittholz, 2007). This is due to the relative costs and weights attributed to energy and capital as opposed to land and labour.

Another cost implication associated with supplying water through desalination is the increased amount of subsidies that governments would have to pay if it were to maintain the same level of water charges. Average cost of supplying water for the SMCs goes as low as US$ 0.1/m^3 rendering the US$ 0.7/m^3 from desalination very expensive.

Environmental Impacts of desalination plants

Apart from high initial capital and operating cost represented in the high share of energy consumption in the desalination process, one main concern is the excessive levels of CO_2 emissions resulting from the burning of fossil fuel. Costs involved in increased CO_2 emissions include negative impacts on the climate represented in global warming and variations in climatic conditions, causing sea level rise, affecting coastal areas of most of the SMCs, and the inundation of low level areas such as the Delta in Egypt. Apart from damage to the environment, social implications include the resettlement of communities, loss of jobs, and negative health impacts. Economic implications include impacts on economic activities such as agricultural crops, fisheries, and tourism.

Since desalinated water is energy intensive, the carbon footprint is the main concern associated with this industry. The carbon footprint for cogeneration plants for MSF plants is between 10-20 kg CO_2/m^3 and for MED is between 11.2-19.6 kg CO_2/m^3. For single purpose thermal plants, the footprint is much higher if waste heat is not properly managed. For power generation plants, the footprint is between 0.5-0.8kg CO_2/kwh depending on the kind of fuel used (Sommariva, 2010).

The high-energy needs for desalination plants make the choice of source of energy used important. If fossil fuels are used as the primary energy source then both greenhouse gases such as CO_2 and acid rain gases such as NO_x and SO_x are emitted into the atmosphere. Table 2 shows estimated CO_2 emissions and cost of energy by source calculated on the basis of average energy needs of 6.09 kWh/m^3 for a desalination plant. This figure was derived from a database containing energy requirements of around 330 desalination plants. Energy consumptions ranged from 3 – 36 kWh/m^3.

Table 2: Energy needs and emissions for an RO desalination plant

	Coal	Oil	Natural Gas	Nuclear	Solar	Wind
Energy need/ m^3	6.09 kWh/m^3	6.09 kWh/m^3	6.09 kWh/m^3	6.09 kWh/m^3	6.09 kWh/m^3	6.09 kWh/m^3
CO_2 emissions/ m^3	5481 g	3775 g	2253 g	18 g	0g	0g
Costs/m^3*	3.23	21.56	4.51	2.19	15	8.7

***(US prices 2011 NEI)**

As earlier stated, the most significant impact on the environment is through greenhouse gas emissions of fossil fuel powering the plant. In Israel for example, the average plant requires 3.7 to 4.5 kWh per m^3 of electricity making the relative environmental externality lower than the average of 6.09kWh/m^3. In order to assess the cost of the harmful output of NO_x, and SO_2, the European Cost Assessment for Sustainable Energy Systems (CASES) are used for the purpose of this study, as it is the only available reliable data. This study provides pollution costs measured in terms of tons of emissions for each country in the European Union as well as other neighbouring countries (Becker et al., 2010). Costs include simulations on climate, population density and epidemiological studies, which link pollutant concentrations to morbidity and mortality rates.

Resorting to desalination plants to satisfy freshwater needs has to be carefully weighed against the negative impacts associated with CO_2 emissions. That is why it is essential that alternative means for supplying water through technical and allocative efficiency have to be fully exhausted before embarking on desalination plants using fossil fuel as the main source of energy.

Capturing the full environmental implications as a result of supplying 20,000m^3/day of freshwater for the hypothetical community would be rather difficult to estimate in precise terms as the plant is not location specific. Moreover, figures arrived at by the CASES study do not consider the entire negative externality as it only accounts for air pollution.

Table 3: Air pollution externalities of desalination

	Pollution costs /ton emitted ($/ton)	Average emissions during electricity generation (gram/kWh)	Emission costs/kWh generation (cents/kWh)	Emissions costs/m^3 of desalinated water (cents/m^3)
SO_2	6.468	1.6	1.03	4.40
NO_x	3.746	1.7	0.64	2.71
PM_{10}	9.232	0.05	0.05	0.20
CO_2	19.39	707	1.37	5.83
Total				13.13

Source, (Becker et al., 2010)

Table 3 shows air pollution externalities of desalination for each pollutant calculated in US cents. Total cost was estimated at about US$0.13 per m^3. This figure reflects environmental costs using CASES and should be added to the UPC of desalination in order to internalize environmental externalities (Becker et al., 2010).

Air pollution and consequently CO_2 being the main environmental implications of desalination plants do not account for brine discharge both in SWRO and BWRO processes. Even though the environmental implications from wastewater resulting from desalination plants have not been adequately studied, it is however, recognized that brine discharge has a negative impact on marine life. In the 2007 World Bank report, it has been noted that there has been a negative impact of the discharge of brine, chlorine, trace metals, volatile hydrocarbons, and anti foaming and anti-scaling agents on the marine environment. RO processes allow for gases for the evaporation of brine in flashing chambers, which increases the CO_2 resulting in the release of other atmospheric gases such as O_2 and N_2. The more enclosed the sea or the less current flow is available the more detrimental the environmental impacts are. Build-up of brine in enclosed sea areas can damage the ecosystem. In the case of brackish water, the brine discharge is either spread over land, or allowed to drain back into the ground, or it is pumped into solar ponds in order to evaporate. These options are not sustainable. The excess salt or salinity disrupts the ecosystem and creates more arid zones in the case of the inland desalination plants. These externalities need to be internalized in order to account for the actual cost of a desalination plant. This can be addressed through price adjustments or the use of renewable energy sources which are less damaging to the environment. This requires the internalization of external costs in order to reflect the actual UPC of a desalination plant.

As can be seen from table 4, factors affecting the environment are not limited to emissions and brine discharge. For RO plants noise pollution is considered to be high. Other factors such as microelements, industrial risk and toxic material need to be considered for their environmental implications.

Another aspect to be taken into account is the number of jobs generated as a result of constructing a desalination plant. As will be seen below, the plant in Australia for example,

Qualitative Overview of Environmental Impacts of Three Desalination Technologies

Effect/type of plant	RO	MSF	E.D.
Noise	H	M	L
Water effluent	M	H	M
Microelements	L	H	L
Toxic material	M	H	M
Air pollution	L	H	M
Industrial risk	L	H	M

Note: H = high, M = medium, L = low.

Source World Bank, 2009 – Table 4

provided about 1700 building workers with average wages much higher than elsewhere in the country. The construction of a desalination plant as with any structure will primarily lead to increased employment in the construction sector and also in operating the plant. It will also result in increased employment in other sectors due to the increased availability of water that can be used in supporting activities in other sectors such as agriculture, industry, and tourism. Moreover, increased economic activity will generate incomes and contribute to GDP growth.

Country experiences

A number of desalination plants have been built in the SMCs. Israel is one of the countries in the region that has experienced several drought seasons in the last couple of decades, which led to water shortages reaching levels of about 520 million m^3/year. Water shortages in Israel have mainly been met through desalination. Israel's total production of desalinated water is approximately 300 million m^3 annually. These are supplied by using either natural gas or coal, resulting in negative environmental consequences. Several desalination plants were constructed in Israel one of which is in Tel Aviv. Costs associated with the construction of the plant are broken down in table 5 below.

Table 5: Test case for Tel Aviv

Volume, Mm^3	**100**
Investment, US$ mil	300
Capital, US$/$m^3$	0.17
Energy, US$/$m^3$	0.26
O&M, US$/$m^3$	0.20
Total, US$/$m^3$	0.63

Source: (Moatty, 2000)

The US$ 0.63/m^3 in the table represents the cost of supplying water through desalination in 2003 (Moatty, 2000). In 2012 the cost of supplying desalinated water has fallen to around US $0.5/$m^3$.

Capital costs are included in UPC based on a 50 million-m^3/year plant with a 20-year amortization and a 7% interest rate.

In 2005 Israel constructed a plant in Ashkelon, which had an output of 100 million m^3 a year. Along with the plant in Palmachim they provide about 8% of the total water in the country. This percentage is expected to increase to 30% in 2020. The coastal city of Hadera will host a plant, which will produce 127 million m^3 per year or about 347 thousand m^3 a day. This large plant will supply the drought ridden Israel with approximately 20% of its household needs. The estimated cost of the plant is US$ 425 million, with a unit cost of US$ 0.57 per m^3 while requiring 450 Giga watts annually to operate it (Rabinovitch, 2011).

Desalination projects are large in number but mostly small in size. Very few large-scale desalination plants actually exist and those that do exist adopt the more efficient but energy consuming technique of RO. One such example is found in Algeria. The construction of sixteen mega-plants that vary in capacity from 100,000m^3/day to 500,000m^3/day have made desalination in Algeria one of the world's fastest growing markets. Algeria aims to supply a total of 2,570,000 m^3/day of fresh water from SWRO. The actual current desalination capacity is about 1,462,000 m^3/day, which includes SWRO and BWRO as well as the use of MSF, vapour compression (VC) and electro dialysis (ED) technologies (Drouiche et al., 2011).

As indicated above, one main concern related to desalination plants is their high-energy requirement. For example, a desalination plant at Kwinana provides about 17% of Australia's water needs, while requiring about 50% more energy as compared to conventional water treatment plants (Knights, 2006). This becomes increasingly problematic with over 85% of Australia's energy needs being met through coal-fired power stations. The rest is either through gas or hydropower (Knights, 2006). This has raised a number of concerns with the development of desalination plants. In order to address this problem, renewable means of energy generation are being sought. Plans are being made to construct desalination plants powered by either solar, wind or geothermal energy (Heimbuch, 2009).

Increased greenhouse gas emissions are not the only negative externality caused by desalination plants. Both inland and coastline plants carry their own environmental drawbacks. Heavy consideration for the ecosystem and the society must be taken into account before any plant can be constructed. In Australia, under the Environmental Protection Act (EPA), due consideration is made before any structure is built. The coastline plants impose a heavy burden on the marine wildlife if not constructed following strict guidelines to avoid environmental damage to the marine ecosystem. Guidelines and restrictions as set out by the Australian EPA appear to be all encompassing. They even accounted for labour migrations and compensations for landowners. Landowners whose lands are being used for inland desalination plants have been compensated and new jobs and livelihoods were created (State Government Victoria, Department of Sustainability and Environment).

Given the high socio-economic and environmental costs of supplying water through desalination, a number of measures, should first be considered before resorting to this option. These measures are examined in more detail in section III and include the following:

- Undertake the necessary measures to reduce leakage from the water network.
- Measures should be introduced to reduce the life cycle cost of water.
- Introduce incentive and regulatory measures that encourage savings and efficient use of water.
- Enhance the role of private sector in the desalination industry.
- Shift the role of government to focus on regulating water supply than on operation.
- Invest in R&D with focus on innovation and technology development.
- Calculate the cost of larger plants in distant locations with increased cost of transportation, storage, and distribution compared to smaller ones close to urban areas.
- In many instances, smaller decentralized desalination plants are a more feasible option due to reduced costs of transportation and leakage, implementation schedules are shorter, and

water security is ensured by having a number of small plants, with the latter being more efficient to manage.

- Since desalination is energy intensive, solar power should be considered for desalination projects. Benefits derived include reducing CO_2 emissions and the resulting positive impacts on human health and the environment.
- Provide incentives for local entrepreneurs to invest in the production of key components of the desalination industry. One way of achieving this is requesting contractors providing the plants to manufacture the technology locally.

Desalination is an old concept, and has been used for nearly a century. It is important though to consider this option only after all potential alternative options have been examined and exhausted and with a long-term goal in mind. If it is ultimately to be resorted to and after all other options have been exhausted, costs will have to be cut down, as well as heavy reliance on fossil fuels as the main source of energy. Environmental damage resulting from desalination has to be avoided.

III. Identification and analysis of socio-economic and environmental costs of alternatives under technical efficiency and allocative efficiency

This section is intended to identify the potential socio-economic and environmental costs of supplying water through technical and allocative efficiency based on available data, previous studies, and country experiences**.** Information derived in this section will be used to estimate socio-economic and environmental costs of supplying 20,000 m^3/day for the hypothetical community being considered in this study in section IV.

Cost of alternative water systems

In general, cost of supplying water is expected to be reduced due to technological advancement, improved management of information and consequently performance and energy efficiency. Green technologies, natural engineered systems that use vegetation and soil to capture and purify water, and integrated water management and payment for ecosystem services can contribute to better allocation and efficient use of water, thus avoiding the construction of new infrastructure and treatment facilities.

Mismanagement can result in unnecessary high cost due to inappropriate location of the water plant thus requiring the transport of water over long distances, increased use of energy and the corresponding costs. It can also result in the depletion of ground water and degrading its quality, which in turn forces governments to subsidize its operations**.**

Assessing cost of alternative water systems

According to an analysis done by Marsden Jacob Associates (2006) for Australian cities, it was found that favourable locations to the alternative water supply systems had the lowest cost. In unfavourable locations it was as high as US$ 3.00/km, where water has to be distributed over long distances cost of pipelines and pumping increases. For wastewater reuse, the distance over which water has to be distributed affects the total cost of supplying water, it is more cost effective to provide the wastewater treatment facilities close to potential users, whether that is domestic, agricultural, or industrial.

It is estimated that the cost of collection systems is 80% or more of the total system costs. That is why it is essential that economies of scale should be achieved in these systems. It is therefore more expensive to have treatment plants at a central location. According to Marsden Jacob Associates (2006), treatment plants distantly located may cost the same or may even be more expensive than desalination plants. According to Rocky Mountain Institute (2004), decentralized treatment plants do not require major investment, thus reducing the financial burden for users. However, in case of decentralized systems, transaction costs are higher. Also being risker undertaking for lenders, the cost of capital may be higher than in the case of centralized plants.

Separate infrastructure and retrofitting are required for reclaimed water. It is estimated that the cost of providing this network in France is about Euros 20,000 for a public building. This cost is lower for an individual house. Other costs involve maintenance, operating, and monitoring costs. Benefits of this alternative are that it is less damaging to the environment since it reduces the discharge of wastewater in land and water bodies. As far as pay back period for the initial investment is concerned, according to Michel Le Sommer in France, where the average price of water is about Euros 3/m^3, is between 15 and 20 years.

Regulations affect the payback period, which is dependent on the kind of the specifications of water quality standards the regulator sets. It also depends on the level of water prices and the extent to which environmental externalities are reflected in fees for wastewater discharges.

Hiessl (2005) compares the costs for three options in two German cities up to 2050. The three options were the centralized system, municipal reuse, and recycling. Innovative technologies as well as organizational and institutional aspects were accounted in the analysis. The first alternative was the centralized option, whilst the second and third options were the decentralized option. The three alternatives were evaluated according to 44 criteria covering ecological, social, and economic aspects. The outcome indicated that the recycling option was the best.

The specific location in which water services are being provided will determine whether it is more cost effective to opt for a decentralized or a centralized water facility. It has been generally accepted that in large urban areas a centralized option is preferred. For suburban or industrial centres decentralized water facilities were found to be more viable (Freedman and Hotchkies, 2007).

Table 6 shows the pros and cons of supplying water through a centralized and decentralized water facility.

Table 6: Some Pros and Cons of a variety of ways of providing water

	Freshwater	Alternative Sources of Water
Central infrastructure	Pros · Scale effects · Provides consistent services · Financial solidarity at municipal level Cons: · A number of negative externalities (environmental, financial) · Capital intensive and fails to attract private capital	Pros · Positive environmental externalities (resource, wastewater discharge) · Financial solidarity at municipal level Cons · Costly (several networks) · Energy intensive
Decentralized infrastructure	Pros · Less water leakage in mains and less energy used to transport water · Reduced energy use · Flexible and resilient · Deferred and reduced investment costs Cons · Additional connections are needed for reliable sourcing	Pros · Positive environmental externalities (resource, wastewater discharge) · Reduced energy use · Flexible and resilient · Deferred and reduced investment costs · May harness new sources of finance Cons · Health issues related to potable reuse · Questions about relevance when

	Freshwater	Alternative Sources of Water
	· Unequal service provision in the municipality · Inadequate monitoring systems	central infrastructure is in place · Scale effect · Unequal service provision in the municipality · Inadequate monitoring and regulatory systems

Alternative ways of supplying water appear in light blue.
Source: Alternative Ways of Providing Water, Emerging Options and Their Policy Implications, OECD, 2007-2008.

It should be emphasized that public involvement is essential when deciding on the different options for water supply. It is important that the public accepts using recycled water. In many instances experience indicates that there has been resentment to this option. This has gradually changed, where in countries such as Australia, Singapore, the United States of America (USA) and generally in Europe, indirect potable reuse fed into a water body and then supplied through the drinking water system has been used (Marsdon Jacob Associates, 2006). Direct use is generally not accepted even if stringent quality measures are applied, as is the case in Singapore.

Water service recovery can encourage alternative water system markets. Full cost recovery for water supply and taxing wastewater discharge to reflect the actual cost involved or capping quantities to be discharged and pollution levels can shorten the payback for alternative options (OECD, 2008).

The extent to which wastewater is used depends on the price set for reclaimed as well as freshwater. The higher the cost of reclaimed wastewater the lower is the potential for wastewater reuse. And the lower the price of freshwater the lower is the potential for reuse of reclaimed water (Yang, 2007).

Cost of supplying freshwater

In calculating the cost of supplying water through centralized and decentralized water systems, socio-economic as well as environmental considerations should be taken into account. These costs will vary from one country to the other depending on labour cost, availability of local skills and expertise, and the extent of environmental damage. The following section provides a brief review of the situation in a number of countries.

Table 7 shows the average user tariff in a number of cities across the world.

Table 7: Average User Tariff (US$/m3)

London	Philadelphia	Istanbul	Johannesburg	Japan	Singapore
3.2	**1.9**	**1.8**	**0.7**	**2.5**	**1.3**
Damascus	**Jeddah**	**Tunisia**	**Egypt**	**Brazil Campinas**	**Mexico Guanajuato**
0.08	**0.01**	**0.7**	**0.9**	**0.3**	**0.4**

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan); Tunisia, London, Berlin, Damascus, and Jeddah (country reports); Singapore (estimate by the PUB website tariff table); Other Countries (Water Supply and Sanitation Working Notes No. 9, May 2006).
Notes: The average tariff of Singapore is estimated on the tariff structure on the PUB website. The tariffs of Japanese water and wastewater are combined for international comparison with some assumptions.

In ***Egypt***, expenditures on water services, including investment and maintenance costs are borne by the government. Recovery cost for water services are below international standards, thus highly indebting the sector. During the last two decades the percentage of funding devoted to new investments as opposed to operation and maintenance and debt services has been on the increase. In order to enable the financing of water services in Egypt, the government has identified a number of options. The first is to increase water charges. The second is to reduce transaction and operating costs through decentralization and efficiency. The third is to encourage the privatization of the water sector. The general trend in Egypt is that water corporations will be the main supplier of water.

Capital operation and management cost of supplying water in Egypt is between LE 0.8-1 per m^3. Water users pay an average tariff of LE 0.15 which is 20% of the treatment and delivery cost. Water subsidies in Egypt are estimated to be between 3-4 billion LE annually.

Tunisia is one of the most scarce resource countries in the region. Per capita water consumption is $500m^3$ and is expected to drop to $360m^3$ by 2030. The Government builds dams and storage facilities to manage water resources including underground water. These are unevenly distributed among different regions with about 81% concentrated in the north, 11% in the centre of Tunisia, while 8% in the south of the country. Some of its water resources are transboundary, where it shares a number of small rivers along the Algerian borders. The main underground water resource is located in Djeffara coastal basin shared with Libya, and the North West Sahara Aquifer shared with Algeria and Libya.

In order to face the water scarcity problem, Tunisia has been using alternative means for generating water. These included the reuse of treated wastewater, artificial recharging of underground water aquifers, and desalination of both brackish and salty water. Tunisia has been reusing treated wastewater for agricultural purposes since the 1970s. It also uses treated water to support an important wetland ecosystem. It is considered to have one of the highest rates of reuse in the world. However, the system is heavily subsidized.

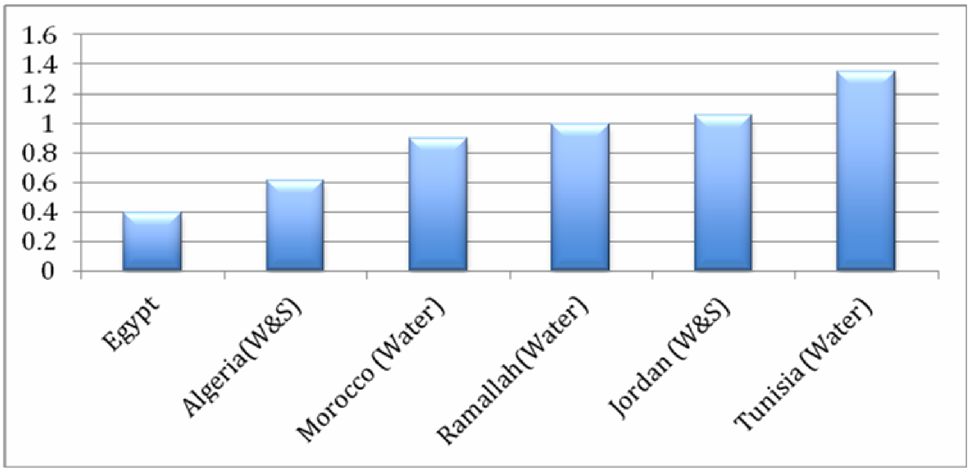
Desalination in Tunisia began in 1983 with the national authority providing 58,800 m^3/day. The private sector is also involved in desalination mainly for tourism, industry, and high value agricultural crops. Main technology used is RO. The Government plans to increase its capacity to 50 million m^3/day by 2030. This is in addition to recharging water aquifers artificially and the construction of dams to capture water in rainy periods, which is planned to increase water by 200 million m^3 by 2030.

Moreover, since 1980 Tunisia has adopted water conservation measures in the agriculture sector. This has resulted in a decline in consumption per hectare from 6,200 m^3/ha in 1990 to about 5,500 m^3/ha in 2005. The National Programme of Irrigation Water Conservation was launched in 1995 to use water resources more efficiently and to maximize economic returns from the agriculture sector. Water efficient systems such as sprinklers, gravity irrigation, and drip irrigation systems have been introduced. This has necessitated the government to provide subsidies to farms amounting to between 40%-60% of the cost of the programme.

It is apparent that the country has to conserve its limited water resources and achieve maximum efficiency in the use and allocation of resources. Involving users in the management plans for conserving and using water resources is expected to enhance the effectiveness and efficiency of the proposed measures (Jagannathan, Mohamed, Kremer, 2009).

Figure 1 below shows the cost recovery for a number of countries in the region**.**

Figure 1: Water Supply and Sanitation: Cost recovery (%)



Source: World Bank Cross- Country data (2003-2004)

Water Reuse

Treated wastewater is increasingly being recognized as one potential means of supplying water. In addition to reducing the negative environmental impacts resulting from the discharging of wastewater in waterways, it provides an additional source of water, which can be used for irrigation. It reduces pressure on available water resources for domestic use and the need for resorting to more expensive solutions such as storage, transfer and desalination.

Table 8 shows the potential economic impacts of wastewater reuse.

Table 8: Economic impacts of Wastewater Reuse

Costs	Benefits
Value-added from displaced water (if any)	Value-added from reused wastewater (varies based on quality and reliability differences)
Opportunity cost of reused water (if any)	Alternative use of displaced water (if any)
Collection and treatment of wastewater, final disposal costs	Reduced environmental degradation
Conveyance/storage of reused water, including water losses (evaporation, leakage) and retrofitting costs for participating farmers	Aquifer recharge, or value of reduced aquifer depletion
Salinity-related impacts	Increase in property values
Other pollution (nitrates, heavy metals, toxic substances)	Increased crop yields
Health, odour, and nuisance costs	Savings in fertilizers
Ecological impacts (opportunity cost of reused water for minimum flow or other purposes	Value of improvements or reform in the water sector due to water reuse.

Source: Water in the Arab World: Management Perspectives and Innovations: N. Vijay Jagannathan, Ahmed Shawky Mohamed, Alexander Kremer, 2009.

Moreover, cost implications of introducing reused water to farmers should be taken into account as it may involve reforming the pricing system to cover the cost of wastewater treatment. In several SMCs irrigation water is provided almost free of charge as it may be supplied directly from water bodies.

Table 9 shows cost of wastewater collection, treatment and reuse in the Arab world derived from a variety of sources.

Table 9: Cost of Wastewater Collection, Treatment, and Reuse

Component	Cost/m^3 (US$)	Notes	Sources
Conveyance to treatment works	Highly variable*		
Non mechanical secondary treatment	0.10-0.22	Necessary for restricted reuse	WHO 2005, Shelef 1996, Haruvy 1997, Amami 2005
Aerated secondary treatment/activated sludge	0.22-0.27	Lower land requirement	Kamizoulis 2003, Shelef 1996, Shelef 1991 Haruvy 1997
Tertiary treatment (in addition to secondary)	0.07-0.18	Necessary for unrestricted reuse	Shelef 1996, Haruvy 1997, Shelef 1994
Distribution	0.05-0.36		Shelef 1994
Total	0.16-0.53		Shelef 1994, Lee 2001

- **Costs come from a variety of sources and have not been standardized to a specific reference year.**

Source: Water in the Arab World: Management Perspectives and Innovations: N. Vijay Jagannathan, Ahmed Shawky Mohamed, Alexander Kremer, 2009.

Cost of reused Water

This sub section will provide a brief account of the experience of selected countries in the SMCs with wastewater treatment.

In the current five years development plan of ***Egypt***, about LE 5.55 billion are allocated for investment in the wastewater treatment sector. Egypt's wastewater treatment activities are part of a long-term programme to improve public health and environmental protection. One of its latest projects is stage II phase II of the Gabal El-Asfar wastewater treatment plant. The project aims at recycling an additional 500,000 m^3/day of primary and secondary wastewater. The estimated cost of the project, located in the lower eastern part of Cairo is Euros 233.5 million, is expected to be completed by 2014. The new phase of the project will benefit an additional 2.5 million people over about 8 million people already benefiting from the exiting facility. The treatment plant, will improve water quality that will allow it to be used for irrigation rather than discharged directly in lake Manzala and the Mediterranean. (African Development Bank, Gabal El-Asfar Wastewater Treatment Plant- Stage II Phase II project, Country: Egypt, 2009).

Israel has resorted to wastewater treatment since almost three decades in an effort to meet water demand without resorting to desalination as being the costlier option. Currently, Israel has more than 400 wastewater treatment projects. The projects are mainly subsidized, with subsidies representing about 60% of infrastructure costs. Prices charged by the government for reused water is 20% lower than that provided by the National Water Carrier (Libhaber, 2007). More that 80% of wastewater in Israel is treated, which is the highest in the region. Given the experience the country has had with wastewater treatment, it has developed extensive expertise in this area.

As mentioned earlier, ***Jordan*** is one of the most water scarce countries in the region with about 150 m^3/capita/year (FAO, 2006). It is also characterized by having the highest rates of depletion of underground water. In spite of the challenging water scarcity in the country, reclaimed water represents 10% of total water supply in Jordan. There are three types of reused water in Jordan, direct use or planned, unplanned in the *Wadis*, indirect use after mixing with water supplies (McCornick et al., 2001). Regulations related to wastewater, which was instituted since 1998 has encouraged wastewater use. These included measures that prohibit the discharge of wastewater and considering it as part of the water resource to be reclaimed. It has also indicated that those using treated wastewater should be charged (Nazzal et al., 2000). One of the drawbacks is the negative impact of discharging large amounts of wastewater into surface waterways. This was the case in 1996 with the El-Samra treatment plant, which has caused salinity of the soil in the summer season. Another problem was overloading the plant, which has resulted in lowering the quality of treated water.

In ***Tunisia*** demand for reused wastewater has been lagging behind in spite of strong government support (Bahri, 2008b; Benabdallah, 2003; Shetty, 2004). In many instances farmers prefer to use underground water for irrigation even after reclaimed water has been made available to them. Concerns stem from the negative impacts in terms of increased soil salinity. Another problem is failure to meet demand when needed due to inadequate storage facilities. Moreover, it is not possible to use treated wastewater for high value crops (Bahri 2008b). This has forced the government in 1997 to set the charge for treated wastewater at US$ 0.01/m^3 below the freshwater charge of US$ 0.08. This has still had little impact on the demand on reclaimed water (Shetty, 2004 and Bahri, 2008b). More efforts are therefore needed to be taken on the demand side of reclaimed water in Tunisia (Bahri 2008b).

A set of recommendations emanate from the experience of these countries:

- Wastewater treatment projects need to ensure that demand exists prior to construction to avoid idle capacity.
- Since full cost recovery is unlikely, it is important to ensure availability of funds to subsidize deficit.
- Since water conservation and demand management is the most cost effective, these measures should be introduced before embarking on waste treatment.
- Coordination between different relevant entities should be maintained. This includes apart from the water authority, sanitation, municipality, agriculture, and other potential users (Jagannathan, Mohamed, Kremer, 2009).

Technical and allocative Efficiency

The 2030 Water Resources Group in analysing water needs against supply have projected that by 2030 water demand will exceed water supply by 40%. Introducing water productivity measures is expected to close around 20% of the gap. Other measures such as the construction of dams and desalination projects, and increased recycling are expected to cover another 20% of the gap. The balance of 60% should come from increased in infrastructure investment, reforms in water policies and improved water efficiency.

This sub section will review the package of proposed measures proposed aimed at achieving technical and allocative efficiency in the water sector. Cost and benefits resulting from these interventions are estimated and accounted for in section IV providing an analysis of the opportunity cost of desalination versus technical efficiency and allocative efficiency.

Policy reforms and Governance

The 2030 Water Working Group (2010) estimates that with policy reforms and governance the global amount of funds needed to be invested in the water sector can be reduced by a factor of four. The absence of strong political support and strong governance structure represents an impediment for investment in the water sector (Global Water Partnership, 2009a). It is increasingly being recognized that effective governance structures offer the least cost solution for the efficient use and allocation of water (Ménard and Saleth, 2010). Related to this, is the issue of land and water rights. Clear property right to land and water encourages investment in water infrastructure projects and the judicious use of water resources.

Improving compliance and enforcement with water legislation

Regulations are one of the main policy tools for regulating activities in the different sectors. Adequate water regulations need to be introduced to encourage the efficient use of water as well as the use of new non-conventional sources of water. In many instances for example, countries lack regulations that include reclaimed wastewater as a water resource (Jimenez and Asano, 2008). However, monitoring and ensuring compliance involves costs, and in many instances is difficult to administer, particularly in developing countries. This is even more so in countries with weak governance structures as is the case in most of the SMCs. It is one thing to institute legislations, but with weak institutions and governance structures, monitoring and compliance, and imposing penalties for non-compliant parties would be lacking.

Use of economic instruments, application of full service cost recovery and through allocative efficiency

There has been an increased recognition in the last two decades of the importance of using economic instruments to achieve environmental objectives. Though economic instruments can be used as a tool to generate income for governments, this should not be the main objective. Market-based incentives should be mainly used to alter behaviour, consumption and production patterns towards more sustainable patterns. They could be effective tools in operationalizing the polluter pas principle (PPP) and the user pays principle (UPP). While the former is intended to encourage polluters to avoid or at least reduce pollution resulting from their activities, the latter will lead to a full cost recovery of the supplied water. The use of economic instruments should be designed to eventually capture the full cost of producing water, including environmental and social externalities resulting from the full life cycle of producing water. Economic instruments should be designed to complement regulations and address environmental, social and economic considerations.

Economic instruments include taxes, subsidies, charges, and fees. Other instruments include payments for ecosystem services (PES), consumer-driven accreditation and certification schemes, trading of pollution permits and access rights to water. Payments for ecosystem services can either be government financed or financed by the user. Experience indicates that those financed and managed by water users are more efficient (Pagiola and Patais 2007).

Entitlement and allocation systems have also been used in several countries, which have resulted in the efficient use of water and in economic gains. Under a solid property rights system mangers buy and sell entitlements for environmental purposes. In Oregon in the US, this practice has been in place since 1993 where the Water Trust has been buying water from farmers and using it to protect the watershed ecosystem (Neuman and Chapman 1999).

Investing in innovation and technology development

Most of the SMCs allocate meagre resources for R&D with the exception of Israel. Adequate financial resources should be allocated for research and development in the water sector to develop and improve water technologies and equipment. SMCs should gradually shift form primarily relying on outside water related technologies and equipment to locally developed ones. This will not only provide water-efficient technologies that are more appropriate for SMCs, and consequently cut costs, but can also create trade opportunities for countries of the region.

Education and public awareness

Education and public awareness campaigns have an important role in altering consumption patterns towards more sustainable practices. This applies to households, farmers, industrialists, and the public service sector itself. Efforts to promote efficiency in the allocation and use of water should be accompanied by a long-term educational and public awareness campaign about the necessity of reducing the wasteful use of water and promoting more efficient practices. These campaigns should be designed to target the different stakeholders. This is necessary in order to gage the interest of the different users, and encourage their involvement, and support in the implementation of policies and measures proposed by government aimed at maximizing the use of water resources for current and future generations. Integrating sustainable water management as in the education curricula will produce the necessary calibres needed at all levels to support the efficient and sustainable management of the water sector.

Service cost recovery

When setting a price for water, it is suggested that in situations where water is scarce this is done at the marginal cost of providing the next unit of water (Beato and Vives 2010). The most efficient charge is one where it equals the marginal cost i.e. the cost of producing the next unit of water. The unit cost declines with more water being provided. But the cost of providing the next unit of water is less than the average cost of supply. If water charges are fixed at the marginal cost, revenue collected will not be sufficient to cover average costs. In that case charges should be set above the average cost (Beato and Vives 2010).

Special considerations should be made when setting water charges to the poor and under privileged communities. Some countries use a cross subsidization system to provide water at affordable rates for the poor. On the other hand countries like Indonesia set different water charges for different income groups. It charges high income groups more than the cost of providing water and uses the difference to cover the cost of providing water to the poor (UNEP, 2011).

Water conservation measures for households

Water conservation measures are measures that result in the reduction in the use and loss of water. Such measures would also result in the preservation of water quality. This may be achieved through improved water management techniques and practices that result in the efficient use of water and the reduction or minimization of loss of water.

Goals for water conservation measures should be to ensure the following:

- Sustainability of water resources in terms of availability for current and future generations. Use and extraction of water should not exceed the pace of its replenishment.
- Energy conservation, since it is estimated that in some regions of the world over 15% of energy consumption is attributed to water management.
- Reduction in water consumption, thus reducing the need to build water infrastructure facilities.
- Preservation of the ecosystem and the services it provides as a habitat for indigenous populations and plant varieties.

Water management measures include using a metering system. In Canada for instance such a system is used to cover about 61% of Canadian homes (Environment Canada, 2005). According to the US Environmental Protection Agency, introducing a metering system reduces consumption by 20 to 40% (EPA, 2010). Other measures include water saving sanitary equipment for water taps, showers, and toilets. It is estimated for example, that using conventional showerheads uses about 100 litres in five minutes compared to 35 litres using a water efficient showerhead. Using water efficient faucets and taps can save up to 50% of water used during hand washing. Other measures to conserve water is using saline or recycled water for flushing toilets and watering gardens These measures can also be introduced in government buildings, including schools, hospitals, as well as public and private offices (AFED, 2010). The introduction of water saving equipment in the US was reported to have resulted in savings of between 6%-14% in water demand (Mysiak, Fo, 2012).

Water conservation measures for irrigation

However, since most of the water consumption is by the agricultural sector, water conservation measures should lay emphasis on that sector. This is particularly important as the SMCs are expected to increase their agricultural activities to meet increased demand for food. Efficiency in the use of water in agriculture means reducing evaporation, surface drainage without negatively impacting production and productivity. As a matter of fact improved and more efficient use of water should increases productivity. The predominant irrigation practice in the SMCs is flood irrigation. It is estimated that drip irrigation saves between 40%-80% in water consumption. However, without government support shifting to more efficient and water saving irrigation techniques will be difficult (AFED, 2010).

Apart from supplying the population with needed food, efficient and more sustainable practices in the agriculture sector will reduce the import bill as well as subsidies paid by most governments of the region for basic foodstuff. Making water supply in excess of human consumption will enable the channelling of water to support economic activities such as agriculture, industry and tourism.

It is essential that the right balance be made between selecting the crop that uses the least amount of water and the one that fetches the highest market value. This decision will be based on a number of factors, including the extent to which water prices reflect the cost of supplying it. Moreover, research indicates that the use of treated water for irrigation has far outweighed costs. Benefits are represented in reduced cost of pumping and quantity of freshwater saved (Mysiak, 2012). In most of the SMCs water for farmers is provided free of charge. This can be viewed as a subsidy for farmers, which results in inefficient and wasteful irrigation practices. Studies in Spain for example have indicated that benefits of using wastewater for agriculture have outweighed the cost by about Euros 9.5 million/year (Heinz, Salgot, Davila, J, 2011).

Investing in ecosystem services

As mentioned earlier, water ecosystems are rapidly being degraded in many parts of the world. A number of countries around the world are investing in river restorations and introducing measures to reduce their degradation. Table 10 below shows estimated returns on investments in ecosystems.

Table 10: Examples of estimated benefits and costs of restoration projects in different biomes

Biome/ecosystem	Typical cost of restora-tion (high -cost scenario	Estimated annual benefits from restoration (avg. cost scenario) US$/ha	Net present value of benefits over 40 years US$/ha	Internal rate of return %	Benefit/c ost Ratio
Coastal	232,700	73,900	935,400	11%	4.4
Mangroves	2,880	4,290	86,900	40%	26.4
Inland wetlands	33,000	14,200	171,300	12%	5.4
Lake/rivers	4,000	3,800	69,700	27%	15.5

Source: Adapted from TEEB (2009a)

Investing in freshwater supply and sanitation

Cost of achieving the Millennium Development Goals (MDG) is estimated at US$ 142 billion annually for sanitation and US$ 42 billion annually for drinking water (Hutton and Bartram, 2008). In terms of returns on investments, Sachs found that the average growth rate in developing countries where most of the poor have access to clean water and sanitation was 2.7% higher than countries that lacked those services (Sachs, 2001). Analysis undertaken by Tropp (2010), Ward et al. (2010), Grey and Sadoff (2007) indicates that investment in water infrastructure is necessary for development. As argued by Schreiner et al. (2010) providing small scale water projects such as storage facilities with the involvement of local communities are in many instances effective solutions for the provision of water.

Accessing new (non-traditional) sources of water

Rather than the construction of large dams for the provision of water, there are a number of less expensive solutions. These include water capture and storage of storm water, condensation of water from fog, inter-basin transfers, and transport of water through pipelines. Other solutions include recycling of sewage. In Singapore for example sewage is being recycled to a level allowing it to be used for drinking. However, there is much opposition by household to use recycled sewage (Dolnicar and Scahäfer, 2006). It should be noted that some of these solutions are energy intensive thus increasing the cost of water produced per unit. They are still however less energy intensive as compared to desalination, as the latter is the most energy intensive solution consuming double that of sewage recycling. Though in both cases the RO technology is used (Coté et al., 2005). Given the cost of these solutions, it is cheaper to invest in demand control measures (Beato and Vives, 2010).

Producing more food and energy with less water

Given that agriculture consumes at least three quarters of water consumption, crop productivity should increase in order to meet increased demand on water and food. In many developing countries Maize yield is in the range of three tonnes per hectare. It can for example reach as high as eight tonnes with improved cultivation practices (UNEP, 2011). Moreover, the issue of virtual water should also be seriously considered in this context.

Water and Energy

There is a close relationship between water and energy. Water is needed as a coolant for power plants. In the USA for example about 40% of water used by the industry sector is used by power plants. It is expected that by 2030, 31% of water for industrial use will be needed for power plants.

Moreover, energy is also needed for the provision of water and sanitary services. As water is heavy, large amounts of energy is needed to lift and pump water over long distances. Cost of providing water for irrigation is relatively high compared to the financial returns from agricultural produce. It is therefore essential that water treatment and distribution systems provided for agricultural activities, particularly in developing countries can be provided at reasonable rates.

Reduction in virtual water exports (rice, cotton, sugar cane, etc.)

The water content of crops or virtual water has increasingly been given wider attention with increased concerns over water scarcity. The issue is being debated within the context of international trade and food security. As much as countries are concerned about food security and the need to satisfy increased demand, this should to be strategically decided upon based on the water content of crops. The same argument is true whether the crop is either exported or imported. The question then is what weights a country would give to the production of a staple food crop such as rice or wheat to ensure food security vis a vis importing these crops, thus reducing water consumption. It is estimated for example that one ton of rice uses about 4000m^3 of water, and one ton of wheat uses about 1334 m^3 of water, while one ton of potatoes uses about 255m^3 (AFED, 2011). With increasing water shortages, countries in the region would have to optimize the allocation of available water resources against the different crops based on the water content of the crop and based on their preparedness to rely on imports. Growing low water content crops and importing high content ones contributes to the efficient use of water and increases water availability. Section IV provides estimates of savings resulting from growing a low water content crop such as potatoes vis a vis a high water content crop such as wheat.

Research so far undertaken reveals that there is no one simple solution to water scarcity. It is becoming evident that the responses to water challenges have to include a package of measures.

Increased economic activities due to water savings will result in job creation in the different sectors, thus absorbing an increased number of unemployed in the region. This will contribute to more social cohesion and integration of a larger segment of the population in economic activities. Social integration and justice are considered to be one of the main concerns and reasons that have sparked the uprisings in a number of SMCs. Creating jobs for the unemployed and lifting a larger percentage of the population from abject poverty will go a long way to providing a stable and more predictable environment for investment and development in the SMCs. Table 11 shows the projected changes in water supply based on a 2% of GDP investment in the water sector as well as the change in employment.

Table 11: 2% GDP invested in green sectors

	Unit	2030	2050
Additional investment in water sector	US$ Bn/year	191	311
Additional water from desalination	Km^3	27	38
Water from efficiency improvements	Km^3	604	1,322
Total employment in water sector	Mn people	38	43
Change in total employment in water sector relative to BAU 2*	%	-13	-22

***BAU refers to the BAU scenario with an additional 2% of global GDP per year invested according to current patterns and trends.**

IV. Examination of opportunity cost analysis of desalination versus technical efficiency and allocative efficiency

Cost of providing water by desalination

The cost of supplying desalinated water has been gradually decreasing as technologies advance. As earlier stated, the technology most used for desalination is RO. This is due to its efficiency and relative cost effectiveness. The average capital cost for a plant supplying 20,000m^3/day is about US$ 30 million for a seawater plant and about US$ 12 million for a brackish water desalination plant. These figures are derived from a study by Wittholz, where cost for a SWRO plant with capacity 10,000m^3/day and 50,000m^3/day, were estimated at US$ 20.1 million and US$ 74 million respectively. Thus, US$ 30 million is used as an approximation for a plant supplying 20,000m^3 of water. Operating costs are estimated at about US$ 5.1 million (0.7 x 20,000 x 365) and US$1.8 million (0.25 x 20,000 x 365) for SWRO and BWRO respectively.

A large share of the operating cost is attributed to energy. This results in increased cost of operation as well as the cost of environmental damage resulting from CO_2 emissions. Estimates will be calculated on the basis of the different sources of energy used. Global average energy requirement for a desalination plant of 6.09 kWh/m^3 will be used (Wittholz, 2007). For each source of energy, a distinction is made between direct cost of energy and those resulting from the potential environmental damage. Prices used are those provided by the Nuclear Energy Institute (NEI) in the United States. In case of coal for example US$ 0.032/ kWh is used resulting in about US$ 1.42 million annually in terms of energy consumption (44,457,000 x 0.032; 44,457,00 = 20,000m^3 x6.09kWh x365). Environmental costs are estimated using calculations by CASES for CO_2 emissions referred to earlier in the study. In case of coal, it is estimated that 5481 grams of CO_2 are emitted per m^3 of water supplied. Using the estimated figure provided by Becker et al., (Table 3) cost of environmental damage of CO_2 per gram is estimated at US$ 0.00001939 (US$ 19.39/1,000,000)*. Using this figure will provide us with an annual environmental cost of operating a desalination plant with a capacity of 20,000m^3 of US$ 775,325 ((0.00001939 x 5481) x 20,000 x 365). Direct and indirect costs of the other sources of energy are shown in Table 12 and are calculated using the same rationale.

Another indirect cost to be considered is the increased level of subsidy that will need to be incurred by the government to make up for the increased cost of supplying desalinated water. In Egypt for example the cost of supplying water is US$ 0.166 of which US$ 0.133 is the amount of subsidy. Thus, at these prices, for a plant of 20,000m^3 the subsidy is estimated at about US$ 970,000 annually (0.133 x 20000x365). An increase in prices of at least US$ 0.7 per m^3 would lead to a total subsidy of about US$ 4.8 million ((0.7-0.033) x 20000 x 365), an increase of about US$ 3.9 million (4.8 – 0.9).

Table 12 shows the total direct and indirect costs for each source of energy, generating electricity needed for a desalination plant with a capacity of 20,000m^3. Prices are subject to the prevailing prices in each country, but for the sake of the study, average prices from the US were used, as no data was available for the SMCs region.

Table 12: Direct and indirect energy costs in US$

Energy	Coal	Natural gas	Fuel	Nuclear	Solar	Wind
44,570,000 (kW/year)	1,422,624	2,005,011	9,584,929	973,608	6,668,550	3,867,759
Environmental effects	775,325	318,702	$534,000	2,546	-	-
Total	2,197,949	2,323,713	10,118,929	976,154	$6,668,550	3,867,759

Table 13 below shows total cost of desalination plants using differed energy sources (cost of fossil fuels and nuclear between US$ 0.5 to 0.8), as well as environmental costs. For wind and solar energy cost are in the range of US$ 0.9 and US$ 1.5 respectively.

Table 13: Cost of desalination plants by source of energy and environmental costs in US$

	Coal	Oil	Natural Gas	Nuclear	Solar	Wind
Operating cost of a desalination plant	5,110,000	5,110,000	5,110,000	5,110,000	7,950,000	6,570,000
Energy Cost	1,422,624	9,584,929	2,005,011	973,608	6,668,550	3,867,750
Environmental	775,325	534,000	318,702	2,546	0	0

* US$ 19.39 per ton was divided by 1,000,000 in order to have the cost per gram.

	Coal	Oil	Natural Gas	Nuclear	Solar	Wind
cost						
Total	5,885,325	5,644,000	5,428,000	5,112,546	7,950,000	6,570,000

Table 14 below shows the net present value of the stream of costs and benefits of supplying desalinated water (both seawater and brackish) over a 20 years period. A social discount rate of 3.5% was used in the calculations.

Table 14: Benefits and costs of supplying water through desalination

Measures	Costs US$	NPV US$
Capital Costs	30 million SWRO 12 million BWRO	60 million SWRO 24 million BWRO
Operating Costs	5.1 million SWRO 1.8 million BWRO	72 million SWRO 26 million BWRO
Energy	44,570,000 (kW/year)	
Coal	1,422,624	20 million
Natural gas	2,005,011	29 million
Fuel	9,584,929	136 million
Nuclear	973,608	14 million
Solar	6,668,550	95 million
Wind	3,867,759	55 million
Environmental impacts		
Coal	775,325	11 million
Natural gas	318,702	4.5 million
Fuel	534,000	7.5 million
Nuclear	2,546	36 thousand
Solar	-	
Wind	-	

Costs and Benefits of Water Supply through Technical and Allocative Efficiency

Based on available data, this section will provide a cost estimate in supplying 20,000 m^3/day for a hypothetical community through technical and allocative efficiency.

If we were to use the annual average water consumption for the MENA region of 1000 m^3/year, our hypothetical community will be around 7,300 inhabitants. Using world average water, annual water consumption of 6000 m^3, we are then talking of a community comprising of about 1216 inhabitants. For the purpose of this study we will use the average water consumption for MENA rounded up to 3m^3/day. We will also assume that the new community is being developed close to a larger community of a population of say about 500,000 inhabitants. Water needed for inhabitants of the new community is mainly for domestic use only. Introducing measures to enhance technical and allocative efficiency will involve costs as well as benefits accruing to the entire population living in the neighbouring city and the new community.

- In order to supply the new community with 20,000m^3/day of freshwater a decentralized wastewater plant is proposed. It is estimated that the cost of the plant will range between

US$ 4 million – US$ 6 million depending on the kind of technology used and quality of reclaimed water. Operating cost is estimated to be between US$ 0.10-0.19 m^3 depending on the type of technology used. A round figure of US$ 0.2 will be used for the purpose of our calculations in order to take into account expected increased cost of labour and energy.

- For the purpose of this analysis US$ 5 million for constructing a wastewater treatment plant to provide 20,000m^3 daily for the hypothetical community will be used. Operating cost is estimated at US$ 1.5 million/annually (US$ 0.2 x 20,000m^3 x 365).

- Improving water governance structure and institutions involved in the management of water supply system as well as introducing the necessary regulatory framework will involve costs represented in human hours spent. Time involved includes the development of regulations, work procedures that ensure transparency and accountability, monitoring, enforcement and compliance. In order to accomplish this task, it is assumed that about 10 staff members will be involved over a four months period. This will approximately cost US$ 60,000 (4 months 10 staff members x US$ 1,500). Functions preceding the initial activities related to the upgrading of the governance system should be performed by staff budgeted for by the national institutions.

- Efficiency in the use and allocation of water resources due to better governance and regulatory framework is expected to result in more freshwater being made available. If we assume an efficiency of at least 10% in water savings, it is estimated that around US$ 11 million will be saved each year (3m^3/day x 507,300 population x 10% savings in water x US$ 0.2 x 365 days).

- In terms of improved health due to the provision of clean water and sanitation to the community, country experiences indicate an estimated increase of 2% in GDP. Savings due to improved health conditions of the inhabitants of the new community and the adjacent larger community of 500,000 was calculated based on the % share to the total population and GDP using the 2% estimate for the project countries. Taking the average GDP will give a rough estimate of US$77 million annually.

- Efficiency in the supply of water will create employment in agriculture, industry and tourism. This is due to more water being made available offsetting the reduced labour in the water sector. If we assume that the additional water supply of treated water amounting to about 547,500,000m^3 (500,000 inhabitants x 3m^3/day x 365 days) is directed to the agriculture sector that should result in additional jobs created in that sector.

- The amount of water made available for agriculture can be used to grow 2,150,000 tons of potatoes (547,500,00 m^3 ÷ 255 m^3/ton). This quantity of water if used to cultivate wheat would only produce about 410,000 tons of wheat (547,500,00÷1,334m^3/ton) (Chapagain and Hoekstra, 2004). World prices of potatoes range from US$ 100- 200, while that for wheat is about US$ 270 (World Bank, 2012,). While due to the relatively high cost wheat fetches in the market it is more profitable to grow potatoes rather than wheat.

- Now, assuming that the smaller community requires 7.3 million m^3 of water annually (20,000m^3 x 365) leaves approximately 540 million m^3 to the larger community. This amount of water can produce 2,118,431 tons of potatoes (540,200,000÷255) resulting in about US$ 318 million (2,118,431tons x US$ 150) in revenue, an increase of about US$ 208 million from using all of the water only for wheat. This figure is based on the estimated amount of agricultural land in the proposed new community and does not include agricultural land, which may also be available in the adjacent population centre. These calculations do not also capture the benefits accruing from savings in the use of pesticides due to improved irrigation methods.

- In case 410,000 tons of wheat was imported using revenue generated from the sale of potatoes, then US$ 208 million will be generated in excess. This excess is equivalent to an increase in water content of 1.040 billion m^3 (US$ 208 million ÷ US$ 0.2).

- Apart from influencing attitudes towards more sustainable consumption and production patterns, economic instrument should be designed to capture a higher percentage of the recover cost of supplying freshwater. They should also be designed in such a way that it does not result in increased burden for the poor and low-income groups, where water provided for this category of consumers would have to continue to be subsidized. However, higher water charges should be charged for high-income groups as well as sectors such as tourism and industry. An increase in water charges by 10% to the richest 20% of the economy could generate an additional cost recovery of US$ 445,000 annually ($3m^3$/d x 101,460{507,300 x 0.2} x US$ 0.004{0.04 x 10%} x 365 days).

- Water conservation programmes include installing water conservation equipment and systems in buildings. It is estimated that the introduction of these equipment in buildings and houses in existing housing stock estimated at 126,825 units (507,300÷4 average family size) can cost between US$ 2,500 to 5,000 per unit i.e. between US$ 317 million and US$ 634 billion. For the purpose of this analysis we will use the average cost of US$ 475 million.

- Regarding irrigation efficient and saving equipment (drip irrigation system) this is estimated to cost US$ 2,500 per hectare. Cost estimated to grow about 350,000 tons of potatoes is about US$ 311 million (2,118,431 tons divided by 17 world average tonne/hectare x US$ 2,500 cost/hectare of installing new equipment).

- Savings resulting from investing in water conservation programmes for municipalities is expected to result in reduction in water consumption for households estimated at between 10%-20% amounting to 83 million m^3 (507,300 population x $3m^3$/d x 365 days x -15%). Thus resulting in savings amounting to US$ 17 million annually.

- Savings resulting from investing in water conservation in the agriculture sector due to the installation of a drip irrigation system for example is expected to result in between 40%-80% of savings in water consumption. This could save between 220 million m^3 and 440 million m^3 i.e. between US$ 44 million and US$ 88 million annually. Using an average between the two figures gives us an approximate figure of US$ 66 annually.

- It is estimated that generally about 15% total energy consumption is allocated to the water sector. Efficiency in the use of water should result in energy savings. Between 5%-10% per m^3 of water produced goes to energy. A saving of 5% in energy consumption could result in savings of US$ 5.5 million annually ($3m^3$ x 507,300 x 365 days x 0.2 x 0.05). Water saved due to efficiency measures will be used to support activities in other sectors.

- Other expected benefits in the agriculture sector are improved productivity and yields. This will enhance competitiveness of crops and access to international markets thus resulting in an increase in foreign external earnings. Improved irrigation and production methods could result in an increase in productivity of between 20%-30% i.e. 530,000 additional tons of potatoes (2,118,431 tons of potatoes x 25%). Using world market prices of potatoes of US$ 150/ton would result in US$ 80 million annually.

- Investment in infrastructure to capture rainwater, recharging natural aquifers, and in the proper maintenance of pipeline networks will vary according to the number of dams close to natural aquifers and the length of the water pipelines. Costs involved may range between 15% -25% of cost of supplying freshwater of US$ 0.2/m^3. If we use an average figure of 20% of unit cost we get a total capital cost of US$ 22 million ($507,300m^3$ x $3m^3$ x 365 x 20% x US$ 0.2) measures will result in an increase in water availability resulting from an increase in underground water, which could otherwise have been wasted as well as saved water due to reduced water leakages from the network. If we assume that this will result in about 15%

increase in water supply for the new community and the adjacent population centre, 83m^3 million/annually (507,300 x 3m^3 x 365 x 15%) i.e. about US$ 17 million annually (83 million tons of water x US$ 0.2/m^3). It will also result in savings in terms of reduced cost of additional capacity of plants supplying freshwater, and in the reduction of energy needed to provide water.

- Reclaimed water provided by a new wastewater treatment plant will provide 20,000 m^3 of treated water for irrigation, thus releasing the same amount of freshwater for domestic use. The entire amount of treated water could be used for irrigation purposes and freshwater needed for domestic use to be supplied through savings in water use resulting from technical and allocative efficiency.

Table 16 shows the estimated costs and benefits of supplying water through technical and allocative efficiency. A 3.5% social discount rate over a period of 20 years was used to arrive at the NPV.

Table 16: Estimated Benefits and Costs of Water Supply through Technical and Allocative Efficiency

Measures	Costs US$	NPV of Costs US$	Benefits (Annual) US$	NPV of Benefits US$
Capital cost of wastewater treatment plant	5 million	10 million		
Operational costs (Annual)	1.46 million	21 million		
Governance and regulatory framework	60,000	120 thousand		
Installing of conservation equipment and systems (households)	475 million	945 million	17million	240 million
Installing of drip irrigation using the assumptions in the study	311 million	618million	66 million	938 million
Capturing of rain water, recharging natural aquifers etc.	22 million	44 million	17 million	240 million
Energy Efficiency			5.5 million	80 million
Use of crops with lower virtual water content such as potatoes			208 million	3 billion
Increased productivity in agriculture (assuming 25%)			80 million	1.1 billion
Increase in water charges by 10% for high income or tourism			445 thousand	6.3 million
Annual saving through increased efficiency due to better governance			11 million	156 million

Measures	Costs US$	NPV of Costs US$	Benefits (Annual) US$	NPV of Benefits US$
Total	814 million		404 million	
Total NPV		1,638 million		5,760 million

Calculations reveal that supplying 20,000m^3/day through technical and allocative efficiency result in net benefits over costs amounting to about US$ 4.122 billion. Cost of supplying the same amount of water through desalination is estimated at US$ 203.5 million using fuel as the main source of energy and US$ 91 million using coal for SWRO. For BWRO the figures are US$ 167 million and US$ 55 million for fuel and coal respectively. These estimates are calculated on the basis of US prices for energy. Estimates for benefits resulting from improved health were not included in both cases.

V. Guidelines on performing opportunity cost analysis for desalination

This section provides an outline of steps to be followed when calculating the opportunity cost of a desalination plant. The analysis in this section will identify and estimate the costs of foregone benefits that may occur as a result for opting for supplying water through desalination. In doing so it will identify measures and policy interventions that are required to achieve technical and allocative efficiency and suggested means of estimating costs involved and potential benefits.

This section should be read in conjunction with sections II and III providing an analysis of the socioeconomic and environmental costs of desalination plants and of alternatives under technical and allocative efficiency respectively, as well as section IV examining the opportunity cost of desalination versus technical efficiency and allocative efficiency.

Cost and benefits of supplying water through desalination

The analysis made under section II provided the basis and rational for estimating the direct and indirect costs, including socioeconomic and environmental costs involved in supplying water through desalination. Costs arrived at would be evaluated against the foregone benefits resulting from opting for desalination as opposed to technical and allocative efficiency.

In order to estimate the socioeconomic and environmental cost of desalination, the starting point is to identify the potential direct costs and benefits. Costs involved can be classified into capital and operating costs, and those will depend on the capacity of the plant, location, technology used, and type of energy used. As indicated earlier since desalination is energy intensive, the potential of using solar energy should be considered. Even though initial capital cost for solar may be higher, it results in long term benefits in the form of reduced energy cost, and environmental benefits derived from reduced CO_2 emissions and impacts on health and the environment.

Benefits resulting from satisfying freshwater needs generally include improved sanitation and health. This result in increased productivity of workers as well as number of days spent on productive activities, and reduced medical bill due to the reduced negative impacts on health. A brief account on the different tools and methodologies for the economic valuation of the environment are provided in this section.

Table 17 below list the potential costs and benefits of supplying water through desalination.

Table 17: Benefits and Costs of providing desalinated water

Capital and operating costs	*Benefits* Increased supply of freshwater to meet domestic demand Increased activity in other sector (agriculture, industry, tourism) due to increased availability of water Increased contribution to GDP Costs Cost of constructing the desalination plant, including cost of land Cost of operation, including cost of energy, labour cost, spare parts and maintenance Government subsidies
Environmental Implications	*Costs* Increased CO_2 emissions with negative impacts on climate Impacts on coastal and marine life, including impacts of discharge of brine in the sea Impacts on wetlands, mangroves, forests, and biodiversity Impacts on desertification Noise pollution
Social Implications	*Costs* Increased medical cost due to increased incidence of disease due to increased CO_2 emissions resulting from increased economic activities *Benefits* Increase in number of jobs created to build and operate the desalination pant Increased number of jobs in other productive sectors due to increased water availability in other sectors Improved health conditions due to availability of clean freshwater Increased productivity of labour force due to better access to water and sanitation

Cost and benefits of good governance and regulatory framework

A necessary prerequisite to achieve technical and allocative efficiency is to ensure good governance and adequate regulatory frameworks involving the different sectors (water supply, agriculture, industry, tourism, municipalities, urban and physical planning). An assessment of current regulatory frameworks and governance structures should cover economic, environmental and social costs and benefits of existing regulatory an institutional setups. Regulatory frameworks targeting water should be designed to encourage the efficient use and allocation of water resources to the different sectors. They should be designed to maximize the use of water per unit of output, enhance economic activity in the different productive sectors, promote unsustainable patterns of consumption and production, encourage the use of treated wastewater for irrigation and industry, and restrict pollution of rivers, and the depletion of underground water and aquifers.

The socioeconomic and environmental implications of regulations should be identified and their implications fully assessed. Distributional and equity consideration should be taken into account in order to avoid placing an extra burden on the poor and lower income groups. A public consultation and participatory process should be adopted in the design of regulatory framework. This will ensure that the concerns and priorities of the different stakeholders are taken into account.

Good governance and efficient institutions are necessary to ensure the sound and sustainable management of water resources. This involves ensuring transparency and accountability in the functioning and operation of different institutions involved in management and use of water resources. Lines of command and responsibilities and coordination mechanisms should be clear and well established.

Costs involved will be country specific and will depend on the level and quality of institutions and regulatory frameworks available. It will depend on whether new institutions are required or current ones need to be restructured, and the level of intervention to provide efficient ones. Costs should include work days spent on the assessment of current institutions and regulatory frameworks, proposals for the types of institutions and regulatory frameworks needed, and their review and development.

Cost of administering, monitoring, and ensuring compliance to regulations

Key in overseeing the implementation of regulatory frameworks, monitoring, and ensuring compliance are qualified and well trained professionals. Strengthening national capacities and upgrading of staff may be needed depending on existing capacities. Estimates for the cost involved in conducting public consultations and awareness campaigns, monitoring, and compliance, and the strengthening of national capacities should be estimated.

Economic benefits resulting from regulations in terms of efficiency gains, and contribution to increased output of a product per unit of water input should also be estimated. This should cover the different sectors referred to above. This should be translated into savings in water use and increased contribution to GDP in terms of increased output per unit cost of water.

At least a 10% savings in water consumption can be captured from good governance and improved level of performance of institutions as a result of more efficient use and allocation of water resources. Estimated savings du to efficiency gains will depend on the level and quality of intervention and the effectiveness of the proposed regulatory frameworks and functioning of institutions.

Use of economic instruments, application of full service cost recovery and through allocative efficiency

Economic instruments are increasingly being used to support command and control mechanism to achieve environmental objectives. Well-designed and implemented economic instruments can be effective tools in promoting the allocation and use of water resources. As referred to in section III they can be used to operationalize the PPP and UPP hence influencing behaviour towards more sustainable consumption and production patterns of water. Internalizing externalities in water charges apart from promoting the judicial use of water will result in increased revenue for governments that can be channelled to support investment in the water infrastructure. Cost of designing, introducing, and monitoring the implementation of economic instruments should be captured. Benefits derived to be based on the extent to which the introduced measures are likely to result in efficiency gains in the use and allocation of water amongst competing uses. Governments may decide to increase the recovery rate of supplying water by 10% on certain users such as industry and tourism and high-income groups. It is essential that equity and distributional considerations be taken into account when setting water charges.

Cost for the construction and operation of a wastewater treatment plant

Freshwater is mainly provided from underground aquifers, precipitation, or water bodies. Underground aquifers could either be non-replenishable or the rate of extraction of water may be faster than the rate of replenishment. Rate of precipitation is affected by climate change, which also has an impact on increased rate of deforestation, desertification, and forest cover thus impacting water availability. It is therefore more rational to direct investment to wastewater treatment to maximize the use of available water resources. Capital cost of constructing a wastewater treatment plant as well as operating cost depends on the capacity of the plant. The larger the plant's capacity the lower is the unit cost of supplying water. In order to estimate cost of supplying water, the NPV of the capital and operational cost over a 20 years period may be calculated to obtain the current value for constructing and operating the plant. A social discount rate of 3.5% may be used to calculate the NPV.

Benefits resulting from increased competitiveness and trade

Efficient use of water reduces the overall costs of the final product. This results in increased competitiveness of final products, which opens up new market niches. Increased competitiveness results in a larger volume of trade and contributes to a positive balance of payments, creates employment opportunities, and contributes to GDP growth. Income expected to be generated from increased competitiveness and trade should be estimated and translated into financial gains, as well as projected increase in GDP calculated and included as part of the foregone benefits in investing in desalination. System dynamics models can be used to estimate impact of gains from efficient use of water on economic activities, employment, balance of payment, and GDP

Benefits resulting from improved access to education and productive activities

Less time spent on fetching clean water, particularly by women means more time that can be spent on education and productive activities. This in turn contributes to an increased percentage of the population receiving education and engaging in productive activities. The result is a positive impact on GDP. The percentage of the population affected by increased access to water and sanitation can be calculated based on the additional water supply to be made available. Based on that, the number of adults to be engaged in productive activities can be estimated and their contribution to GDP calculated based on national figures.

Increased land and property values as a result of a better environment

Regulations penalizing the dumping of industrial and domestic waste in water bodies results in clean rivers. Improved landscaping, and the provision of recreation areas, and space may also accompany this for pedestrians and cycling. This can result in increasing the value of properties and a source of income for municipalities. Increase in land and home values will depend on a number of factors, including the quality and extent of development. Benefits resulting from an improved environment may accrue to individual owners or to the government.

Benefits resulting from improved health

Providing clean water and sanitation improves health conditions of the population, particularly for the poor and underprivileged communities lacking access to clean water and sanitation. Benefits are derived from increased productivity of the labour force, reduced incidence of disease, reduced cost of medical bill, cost of building hospitals, clinics, and medicine. Country experiences indicate that improved health due to better water and sanitation increases GDP by 2%.

Social benefits in the form of additional number of jobs created

Though efficiency in the management of water resources is likely to result in a reduction in labour requirements, it is also likely that additional jobs are created in other economic sectors due to additional water supply made available to these sectors. Regulations may entail changing production processes in the different sectors to promote efficient use of water, avoidance or reduction of wastage of water. It may also involve requirements for treatment and water recycling which results in direct job creation. Reduction in labour in the water sector due to increased efficiency in the sector is likely to be absorbed by jobs created in other sectors due to the availability of water. It is therefore useful to be aware of the composition and structure of the labour force, and requirements for the different sectors in order to predict the labour movement between sectors and the net effect resulting form water efficiency.

Reduced cost of supplying freshwater

Laws requiring farmers to use recycled treated water for irrigation will reduce pressure on freshwater. The result is reduced cost of supplying freshwater for domestic consumption, and other uses such as industry and tourism. In other words the opportunity cost in this case is the savings in freshwater that can be channelled for other uses. Moreover, using treated wastewater for agriculture reduces the need for fertilizers and increases crop yields. Cost of supplying freshwater should be calculated based on the amount of treated wastewater supplied and the unit cost of providing freshwater. Increased crop productivity may be captured when calculating efficiency gains in agriculture.

Benefits of water conservation measures in the agriculture sector

It is estimated that at least 70% of water consumption in the SMCs is used by the agricultural sector. In Egypt that percentage reaches up to 85% of the water supply in the country. Measures to conserve water include installing water meters for irrigation and the use of drip irrigation and centre-pivot irrigation equipment. It is estimated that these measures alone result in large savings in water consumption estimated at about 40% over conventional irrigation systems. Installing meters would also enable governments to measure the amount of water consumed and collect charges accordingly. Savings in water consumption and additional income accruing to the government from collecting charges are benefits resulting from conservation measures, which should be accounted for.

Benefits resulting from saving in the use of virtual water

Selecting the kind of crops to be cultivated for domestic consumption and trade is important in maximizing the utilization of water resources. The selection of crops should be decided upon based on the least intensive water consuming crop varieties. In other word, available water supply should be used prudently to maximize yields as well as value of end product. Cultivating low water intensity consuming crops and importing high intensity water consuming crops results in maximizing available water supply in the country. Strategically planned in a manner that does not compromise water and food security can result not only in savings in the use of water, but also in increasing the amount of water supply. Once a decision is made on the kind of crops that should be cultivated and those that would need to be imported, the volume of water saved and important can be estimated and costs calculated. The associated savings in energy should also be calculated.

Financial flows generate income for the government and can therefore provide a good source for funding water and sanitation projects

Income generated due to the introduction of taxes, fees, and charges on water use as well as on polluting water bodies from the various sectors can be calculated and reflected as part of the opportunity cost for constructing a desalination plant. Cost of administering, monitoring, and collecting taxes, fees, and charges should be deducted from income generated and collected.

Benefits of water conservation in the household sector

It is estimated that about 8% of total water use is for domestic consumption. Introducing household equipment and devices is estimated to cut down on water consumption by that sector by 15%. Costs of installing water saving devices, which will vary according to the quality of devices and equipment installed, should also be calculated. These are one off initial costs, while the savings in water consumption are annual. Other measures in water savings are the use of recycled household wastewater for flushing and irrigating gardens. This involves the installing of the necessary piping systems in buildings.

Benefits in the reduction of energy use

It is estimated that roughly 15% out of the total energy use in most countries is used in water management projects**.** This percentage share will increase in case the predominant water supply facilities are desalinated plants. Efficient and improved management systems should result in energy savings. Efficient management systems and conservation measures may result in energy savings of about 5% out of the total estimated share of 15% of energy in water management projects. This cost will vary depending on the source of energy and the type of water technology used. The use of solar energy should be promoted as the main source of energy for supplying water. Factoring in the positive impacts of reduced energy use and CO_2 emissions is expected to offset the relative increase in initial capital cost for solar energy in the long run.

Benefits resulting from investing in ecosystems

Costs involved in ecosystem conservation vary depending on the biome in question. Different biome, which contribute to freshwater conservation in addition to rivers include wetlands and mangroves. Benefits derived will depend on the extent and effectiveness of the conservation project. Since ecosystems are an essential source of freshwater supply the proper conservation of these systems are vital in ensuring a sustained supply of freshwater. Benefits derived from such investment should therefore be captured in calculating the opportunity cost of water desalination. Economic valuation methods such as contingent valuation and WTP and WTA may be used to arrive at the benefits from investing in the ecosystem.

Access the costs and benefits of new (non-traditional) sources of water

Non-expensive solutions for the provision of water referred to earlier include water capture and storage of storm water, condensation of water from fog, inter-basin transfers, transport of water through pipelines or Medusa bags. Costs and benefits of these measures should be calculated and included in estimating the opportunity cost of desalinated water.

Estimate the costs and benefits of investing in water infrastructure

These include investment in rainwater capture infrastructure such as dams for the recharging of natural aquifers. It also includes the continuous maintenance of the pipeline network. Cost will depend on the number of dams and aquifers to be recharged and the length of the water pipelines.

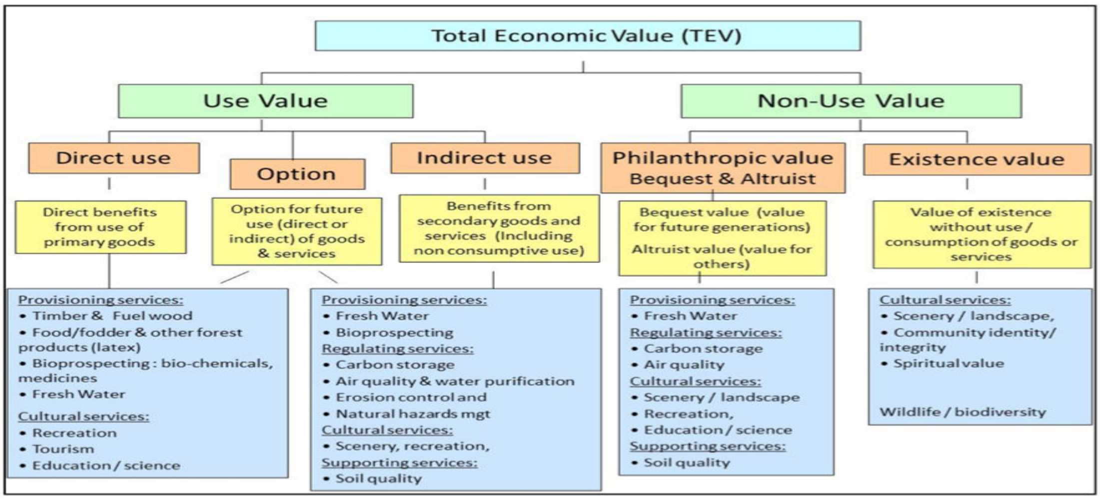
Regarding benefits, a percentage of at least 15% increase in water supply resulting from these investments may be used.

Economic values of the environment

Valuation methodologies have been used to estimate the cost and benefits of projects on the environment. The concept of economic valuation of the environment is grounded on the principle of welfare economics. It is based on the people's willingness to pay (WTP) or willingness to accept (WTA) (Hanemann, 1991; Shorgen and Hayes, 1997). Measuring economic values may be done on the basis of observed behaviour. These are divided into direct and indirect behaviour method. The former can use market prices, where the environmental impacts are on goods and services traded in the market. The indirect observed behaviour also uses observed behaviour but not for goods traded in the market. Valuation method used here is referred to as hedonic pricing method, which uses statistical techniques using implicit prices of the attribute of a product such as clean water, air and a travel cost method. The latter uses observed travel cost to reach a specific destination of value to the user. It also includes cost-based methods such as the replacement cost method, which values services provided based on cost of replacing it by the proposed project.

- Another economic valuation technique is based on hypothetical behaviour. This includes direct hypothetical valuation called contingent valuation and indirect hypothetical measures of WTP and WTA. Benefit transfer is also used to value economic benefits of the environment. This method simply uses estimates derived in one context to estimate values in another context. Though such a tool has been controversial, it has been accepted as a reliable tool if carefully applied in case the contexts are close enough and in hypothetical situations where no observed practices are available (Silva, Pagiola, 2003). Figure 2 below shows the different economic valuation tools for the environment.

Figure 2: Economic valuation Tool



Source: White et al, 2011, adapted from Kettunen et al (2009), adapted from Pearce & Moran 1994

Table 18 below summarizes the different costs and benefits that need to be considered when estimating the opportunity cost of desalination water, which is also represented in Figure 3.

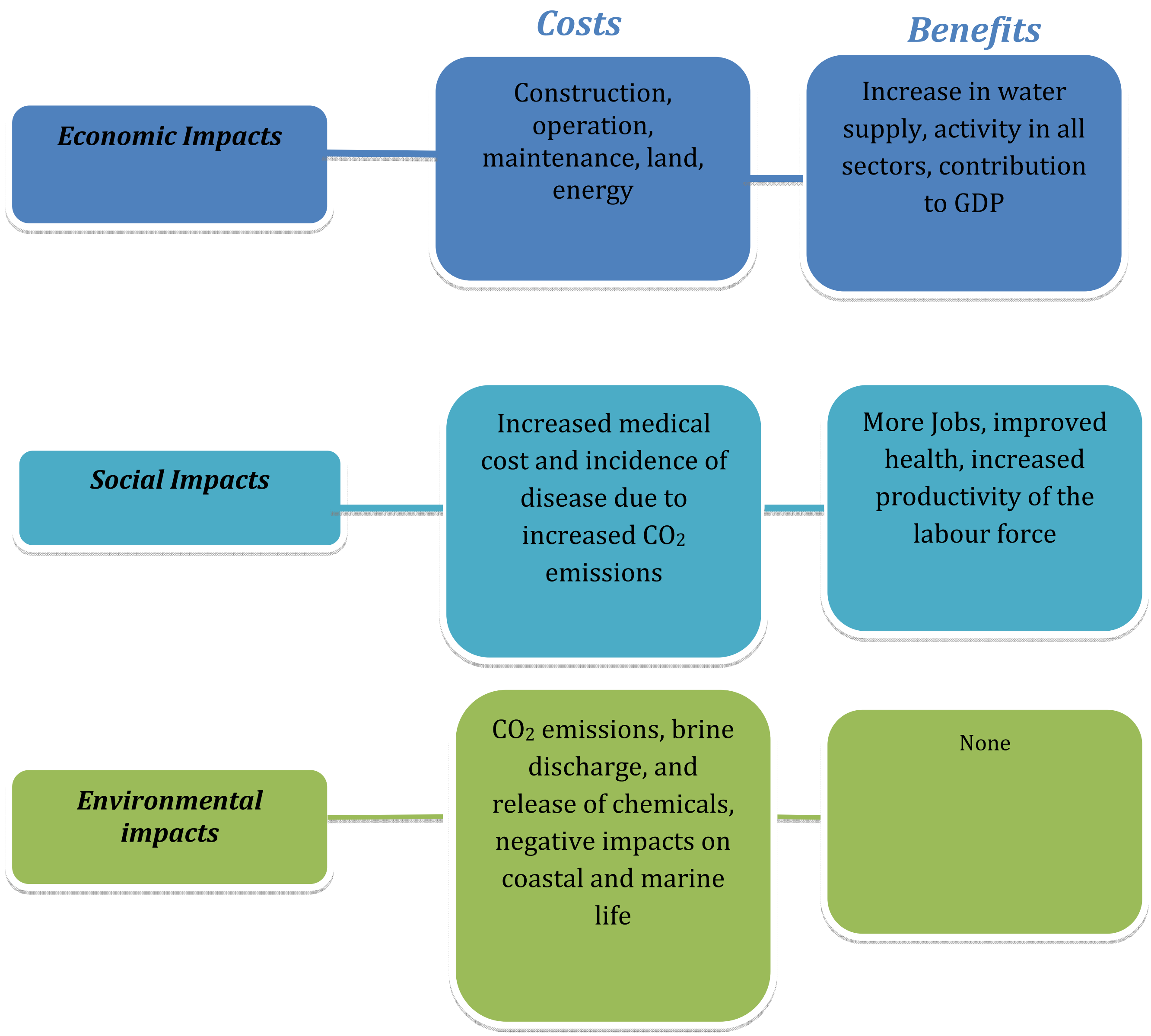
Table 18: Benefits and Costs of Technical Efficiency and Allocative Efficiency for Water Supply

Improved governance and institutions **Improved regulatory frameworks**	
Costs	*Benefits*
Cost of compliance, monitoring, and enforcement Cost of developing procedures that ensures good governance, transparency, and accountability Cost of formulating regulatory frameworks that ensures coherence between regulations related to different sectors as well as market incentives Cost of strengthening national capabilities to formulate regulator frameworks that promotes the efficient use and allocation of water resources, monitoring, and compliance	Reduction in amount of funds required for investment in water supply plants by a factor of 4 Postponement of investment in more expensive water desalination projects Reduced subsidies paid by government for supplied water Improved health (savings estimated at about 2% of GDP) Employment generated in agriculture, industry and tourism due to more water being made available sufficient to offset reduced labour in water sector due to efficiency
Use of economic instruments	
Costs	*Benefits*
Cost of enhancing local capacities in the design and implementation of economic instruments for the efficient and sustainable use of water resources	Increase in rate of cost recovery from industry, tourism, and high-income families is expected to result in a 20% additional revenues being generated Influencing consumption patterns towards more sustainable water consumption practices resulting in water saving of between 15%-25%
Water conservation programmes for municipalities	
Costs	*Benefits*
Cost of installing water saving equipment and devices in government public buildings (offices, schools, hospitals, post offices, etc.,) private houses and buildings	Sustainability of water resources in terms of availability for current and future generations Reduces the need to build water infrastructure facilities Reduction in per capita water consumption that could result in savings between 10%-20% water savings for households Estimated reduction of at least 5% savings out of the total 15% of energy attributed to water

	management
Water conservation programmes in the agriculture sector	
Costs Cost of installing water saving irrigation equipment and devices	*Benefits* Increased output per unit of water consumption Reduced cost of final product Improved crop productivity/yield Increased competitiveness of produced crops in international markets Reduction in per capita water consumption in the agriculture sector that could result in about 40% savings in water Reduced water content of traded crops (virtual water) Converting from high water content crops such as wheat to lower crops such as potatoes will saves water Reduction in the use of pesticides due to reduced amount of weeds and other fungi resulting from flood irrigation and other wasteful uses of water
Investment in ecosystems	
Costs Cost involved will vary according to the extent to which the government in question is committed to securing a continuous and sustainable supply of water for current and future generations.	*Benefits* Reduction in the pollution of rivers Reduction in the rate of depletion of underground water Improved quantity and quality of freshwater Reduced environmental degradation Enhances the preservation of habitats for indigenous wildlife Ecosystem conservation contributes to the preservation of the ecosystem responsible for the continuous supply of water on a sustainable basis
Water capture, storage of storm water, transport of water (pipelines/Medusa bags)	

Costs	Benefits
Costs involve the construction of small dams to recharge water aquifers, installation and extension of water pipelines, continuous maintenance to avoid water leakages from the network. Cost will vary according to the number of dams and area covered by water supply	*Benefits* Increase in the supply of freshwater from storms that could have otherwise been wasted Reduction in the cost of providing water supply facilities Reduction in the use of energy used in the operation of water plants
Decentralized wastewater treatment and recycling facility	
Costs	*Benefits*
Cost per cubic meter will depend on the type of technology used, labour cost, land cost, and distance to convey water to destinations an average cost of US$ .20 will be used and amortized over a 20 years period Increased salinity of soil Opportunity cost of reused water	Increased supply of water for irrigation and for some industrial use thus reducing pressure on freshwater for domestic use and by industry and tourism Reduced expenditures on water supply facilities and desalinated water plants Reclaimed water provided by a new wastewater treatment plant will provide 20,000 m^3 of treated water for irrigation, thus releasing the same amount of freshwater for domestic use. The entire amount of treated water could be used for irrigation purposes and freshwater needed for domestic use to be supplied through savings in water use resulting from technical and allocative efficiency.

Cost and benefits of supplying water through desalination



Cost and benefits of technical and allocative efficiency

	Costs	Benefits
Improved governance and institutions and regulatory frameworks	Developing procedures that ensure good governance including regulations, monitoring & compliance.	Reduction in funds required to supply water by a factor of 4; improved health (2% of GDP); reduced subsidies paid by Govt.
Use of economic instruments	Design and implementation for efficient and sustainable use of water resources	Cost-recovery from tourism, industry and high-income families to 20% additional revenues
Water conservation programmes for municipalities	Equipment and devices in houses, public buildings (schools, hospitals, post offices, etc.)	Reduction in per capita water consumption by 10-20% for households, savings of 5% out of the to 15 % of energy cons.
Water conservation programmes in the agricultural sector	Installing water saving irrigation equipment and devices	Improved crop productivity/yield, Reduction in per capita water consumption saving about 40%, Use low water content crops, Reduce the use of pesticides
Investment in ecosystems	Varies according to level of government commitment for sustainable supply of water	Reduction in pollution, improved quality of freshwater, reduced environmental degradation, preservation of habitats for indigenous wildlife
Water capture, storage of storm water, transport of water	Construction of small dams, installation and extension of water pipelines, maintenance and operation, cost of which will vary according to number of dams	Supply of freshwater from rains, reduction in energy consumption of water plants, less burden from water supply facilities
Decentralized wastewater treatment and recycling facility	Varies depending on technology, labour & land cost; increased salinity of soil; Opportunity cost of reused water	Increase supply of water for agriculture, industry, municipalities and tourism, reduced expenditures on water supply facilities and desalinated water plants.

VI. Recommendations

Opportunity cost analysis provides a tool for policy and decision makers to enable them take the right decision with respect the best possible investment option. In order to undertake effective opportunity cost analysis it is recommended that the following should be taken into account:

- Socio-economic and environmental cost and benefits for supplying water through desalination should, include the health and environmental costs of CO_2 emissions due to the extensive energy component of desalinated water as well as the discharge of brine water.

- Opportunity cost for desalination plants or in other words foregone benefits for investing in desalination versus other options should be fully considered and accounted for. This includes the socio-economic and environmental costs and benefits of technical and allocative efficiency, which covers cost and benefits of good governance, legislative framework, incentive system, public awareness and human resource development.

- Other investments include investing in a decentralized wastewater treatment facility, investing in upgrading and improving the water network to reduce wastage. Other demand management water saving measures, include investing in storage and recycling facilities, new irrigation techniques, wastewater treatment, reuse and recycling, ecosystems that promote water conservation and provides purification services.

- In estimating socio-economic and environmental costs and benefits, benefit transfer method may be used. Other economic valuation methods that can be used are the contingent valuation method.

- Virtual water is an important element that should be fully taken into account in technical and allocative efficiency and in calculating the opportunity cost of supplying water through desalination. Selecting low water content products to grow locally and import high-content products maximizes the use of available water resources and increases water availability in the country.

- Job creation is an important component in any type of investment, this is particularly important to factor in when calculating the benefits of technical and allocative efficiency. This is due to the potential number of jobs that are likely to be created in the chain of activities associated with this option.

- In calculating the positive impacts on health, factors such as increase in productivity, reduced medical bill, improved life expectancy, and reduced mortality rate especially for children should be accounted for.

- Benefits accruing from the release of freshwater due to the allocation of treated wastewater for agricultural use should be carefully estimated and costed.

- In order to calculate the NPV of investment cost a 3.5% social discount rate may be used to calculate investment cost at present value.

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