# Chapter 4

## Cost of water reuse projects in MENA and cost recovery mechanisms

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## Key messages

- Recovering the water, energy, nutrients and other materials embedded in wastewater is a key opportunity in water-scarce countries for meeting water demand as non-conventional water resources can be used for irrigation in agriculture, groundwater recharge and other uses.
- Understanding public perception about the use of reclaimed water for different purposes and addressing concerns of end-users are key in securing public support and hence in determining the willingness of end-users to pay for reclaimed water.
- The cost of energy is the major cost for wastewater treatment plants with tertiary treatment systems. On-site energy generation from wastewater has a high potential to contribute to energy cost savings and revenue generation through sales to other sectors.
- The pricing of reclaimed water depends on several factors and varies across countries and treatment plants in the MENA region. Most of the water reuse projects supplying water for irrigation charge lower water prices, are unlikely to achieve full operational cost recovery and are only able to cover part of the operational costs.
- Supplying reclaimed water to sectors with a high ability to pay such as for landscaping and golf courses achieves a higher cost recovery rate as the price charged for water is higher.
- Harnessing key resources in wastewater such as nutrients and energy can increase the likelihood of recovering operational and maintenance costs as well as generate revenues.

## 4.1. Introduction

Wastewater treatment and reuse is a viable way to address the water security risk in the MENA region (see Chapter 1). Among other things, wastewater treatment and reuse provides a reliable water supply when there is a regional shortage; improves local economic growth; it reduces freshwater withdrawals from aquifers and rivers; and reduces fertilizer usage in agriculture. The recovery of water, energy, nutrients and other materials embedded in wastewater is gaining more attention in water-scarce countries as an approach to meet water demands since non-conventional water resources can be used for irrigation in agriculture, industrial use and groundwater recharge.

Wastewater treatment and reuse requires large investments in infrastructure, equipment and capacity development and involves substantial recurrent costs in the operation and maintenance of the wastewater treatment plants (WWTPs) and transport and distribution networks. While the need for water reuse is generally well recognized, mechanisms to support implementation of water reuse projects in MENA region are sometimes lacking. Examples of hurdles identified include the lack of cost-effective investments in wastewater treatment, missing cost recovery mechanisms from water reuse with various value propositions, low pricing of irrigation water, lack of creating financial incentives for safe water reuse and lack of understanding among the public about the environmental benefits of wastewater treatment and reuse (Otoo and Dreschel 2018).

There are, however, an increasing number of examples where wastewater treatment and reuse projects have been successfully implemented for agriculture, forestry, industrial uses, landscaping and other useful purposes in MENA countries. Understanding the costs and benefits of water reuse for various value additions is important and can make a stronger case for investments in water reuse solutions for cost recovery.

This chapter assesses several wastewater treatment and reuse projects in the MENA region by focusing on their economic indicators such as their costs and cost recovery or revenue generation mechanisms and the associated technologies. We use the primary and secondary data collected from existing WWTPs in the region with varying value propositions to estimate the investment and operational cost of WWTPs per volume of wastewater treated and operational cost recovery from water reuse.

The analysis focuses on operational cost recovery from water reuse. In the context of water reuse, most water reuse projects such as those supplying water for irrigation are unlikely to achieve full cost recovery and might only recover part of the operation costs (Hanjira et al. 2015a). Cost recovery from water or sanitation fees charged to households as well as operational costs of on-farm treatment of wastewater are not included in the study.

## 4.2. Considerations for assessing costs, benefits and cost recovery of water reuse

The potential for enhanced reuse of water is possible when decision-makers understand the costs and associated benefits of water reuse in various sectors of the economy, especially in agriculture, while highlighting its implications for public health and the entire ecosystem (Hanjira et al. 2015b). Despite the investments on water reuse projects across MENA, the region still wastes millions of cubic meters of valuable resources in wastewater that are discharged to the sea or disposed in the environment and evaporated with no direct or indirect beneficial use (see Chapter 2).

Water reuse projects are developing at a slow pace in part due to an incomplete economic analysis of wastewater treatment and reuse options, which can provide a sound justification to invest. Additionally, there is a lack of economic incentives (or the removal of economic barriers) to invest once such investment has been economically justified. The few existing studies have been limited to financial feasibility analysis and have highlighted the high costs and low financial returns of developing wastewater collection networks and wastewater treatment plants with less focus on the water reuse components (Qadir et al. 2010).

### 4.2.1 Financial vs. economic analysis

*Financial analysis* considers the direct costs and benefits of a water reuse project. *Economic analysis* considers the viability of a project from a societal perspective. In contrast to a financial analysis, an economic analysis takes a broader perspective and determines the project's overall value to society. Furthermore, financial viability may not necessarily imply profit maximization in the case of water reuse projects but could be a cost recovery target depending on the objective of the water reuse project especially given that water reuse projects aim at improved living conditions or reduced environmental pollution (Otoo et al. 2016). The results of the financial and economic analyses can also be targeted to different users; for example, the results of financial analyses are usually used in informing business decisions or guiding potential investors. The findings of economic analysis will inform policy-makers to justify public co-funding.

In addition to the direct costs and benefits that are considered in the financial analysis, the economic analysis includes other indirect costs and benefits, which are also referred to as positive and negative externalities (Figure 4.1). The economic analysis thus relies largely on the overall financial analysis for direct costs and benefits, but also on the assessment of potential social and environmental impacts. Other methods such as cost-effectiveness analysis can also be implemented in choosing among alternative solutions to address water-related challenges (Box 4.1).

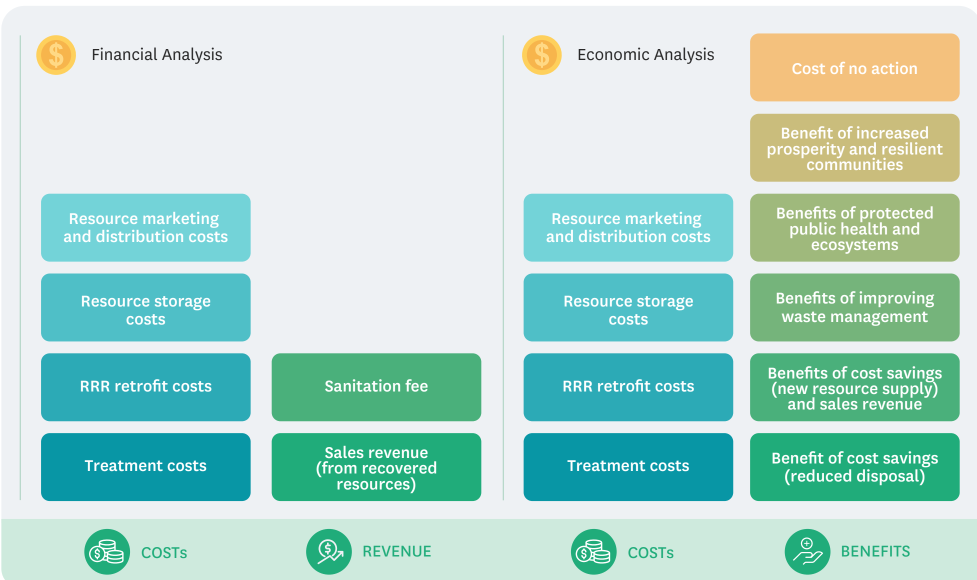


**FIGURE 4.1** Financial versus economic analysis of water reuse solutions (adapted from Otoo et al. 2016).

### 4.2.2. Determinants of willingness to use and pay for reclaimed water

Studies show that some farmers in the MENA region are willing to use reclaimed water; however, they are only willing to pay less amount for reclaimed water compared to freshwater (Saidan et al. 2020). Factors that potentially influence users' willingness to pay for reclaimed water include the price of alternative water sources such as potable, surface water and groundwater supplies; their perception about the scarcity of alternative sources; the capital and operating costs of switching to wastewater supply; and wastewater quality, quantity and levels of service and reliability of supply.

Various pricing systems for reclaimed water could be viable in different MENA countries depending on the local context. Alternative pricing schemes which can be employed as a stand-alone or in combination include:

- *Us*er fee systems where end-users finance the infrastructure installation and then the usage charge offsets the supply cost of the reclaimed water. The Australian government adopted this type of pricing mechanism in 2003 under the national water reform process.
- *Connection* fee system, where a one-time contribution is made toward the cost of infrastructure needed to deliver reclaimed water to the connecting industry delivery point. Such fees may be negotiated between the supplier and the industries to agree on a financial arrangement such that both parties may fully or partially cover the fee of the actual work to deliver the reclaimed water to the delivery point.
- Take or pay arrangement is a flat fee system regardless of use. For instance, it does not matter the rate or times of actual use – industries are obliged to pay for a certain

**BOX 4.1 Cost-effectiveness analysis**

Another crucial question to consider is whether there are other viable alternatives to water reuse to achieve a given objective and whether reuse is the cheapest alternative. For example, if the goal is to address water scarcity by increasing available water resources, potential alternatives could be rainwater harvesting and storage, water transfers from other basins or desalination of seawater, if the target area is close to the coast. The reliability of rainwater harvesting is often dependent on the local climate which makes the effectiveness of these systems difficult to predict, while wastewater is a resource less dependent on rainfall patterns.

Inter-basin transfers often require very high initial investments and have considerable operation and maintenance costs, including pumping costs. They also face significant environmental and political challenges, especially in the donor basins, which is why they are becoming less popular.

Seawater desalination can compete with water reuse in coastal areas if the water quality required is potable or pre-potable. Desalination costs tend to be higher, especially with energy costs, and the management of the resulting brines is a major environmental challenge.

On the other hand, reuse projects are gaining dynamism as they provide local solutions that are more flexible and robust and can be adjusted to local conditions. The cost of alternative options must be carefully examined before proceeding with a reuse project. If equally effective alternatives exist to deal with water scarcity, but if water reuse is the least expensive solution, then the choice of reuse project would be justified.

percentage of the contracted recycled water volume and for all water consumed by the industries above the contracted level. It is worthy of note that this system of pricing ensures that WWTPs have guaranteed income that sustains the financial needs to run. However, it could lead to the overuse of reclaimed water by the target industry as well as improper discharges to the environment potentially resulting in negative externalities.

Irrespective of the pricing mechanisms in place, certain agreements regarding supply and use should be in place to ensure an effective and efficient system, while guiding supply and use behaviors. Negotiations and agreements between suppliers of reclaimed water and potential end-users such as industries could result in establishing obligations and responsibilities under which the reclaimed water reuse scheme could operate (Gould et al. 2003; Saidan et al. 2020). Saidan et al. (2020) outline important aspects that reclaimed water agreements should cover, including:

- price, quantity and quality of reclaimed water;
- security of the reclaimed water supply;
- measures to identify, allocate and manage risks and ensure safe use of reclaimed water;
- liabilities and insurance for potential damages caused by supply and use; and
- compliance with legislative and common law requirements.

## 4.3. Financial costs and benefits and cost recovery mechanisms in water reuse projects in MENA

The investment cost of WWTPs with varying reuse options includes the cost of wastewater collection and transportation, cost of wastewater treatment and transportation of reclaimed water to end-users. The investment cost per unit of wastewater treated depends, among other factors, on the type and level of treatment, the targeted reuse option and the capacity of the wastewater treatment plant. Several studies estimate the cost of WWTPs using a variety of methods and types of costs addressed which renders comparability of results limited. For example, some studies consider the volume of wastewater treated, while others consider the quality of influent and effluent (Hernández-Sancho et al. 2015). Similarly, when estimating the cost of operations, some studies consider all costs of operation and maintenance, while others estimate these based only on estimated energy costs. In order to allow comparisons across scales, we need to identify common indicators across different scales (Murray et al. 2011).

In this section, we estimate the investment and operational cost of wastewater treatment plants per volume of wastewater treated based on primary and secondary data collected from existing WWTPs in the MENA region with varying value propositions. We assess the investment cost and operational cost of wastewater treatment plants at different scales across different countries to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated. The reuse purpose of the reclaimed water in these treatment plants is mainly for agriculture, landscaping and golf courses.

### 4.3.1 Water reuse for agriculture, landscaping and golf courses

Investment cost of wastewater treatment plants

Table 4.1 presents the investment cost of WWTPs in different countries in MENA. All treatment plants use the tertiary treatment method. Most WWTPs assessed are operated by public sector utilities and rely on financial support from government and other donors with few plants having public private financing models. The investment cost per volume of wastewater treated varies across cases and countries.

**TABLE 4.1** Investment cost of WWTPs with tertiary treatment system (USD/$m^3$).

| Wastewater treatment plant | Country | Treatment capacity ($m^3$/day) | Investment cost (USD/$m^3$) | Source[1] |
|---|---|---|---|---|
| South Amman | Jordan | 52,000 | 6.46 | Primary data |
| As Samra | Jordan | 364,000 | 3.34 | Drechsel et al. 2018 |
| Wadi Mousa | Jordan | 3,400 | - | Case Study #7; SWIM 2013 |
| Tala Bay | Jordan | 1,000 | - | Case Study #6 |
| Marrakech | Morocco | 143,606 | 3.52 | Case Study #1 |
| Tangier | Morocco | 42,700 | 1.63 | Case Study #2 |
| Draga | Morocco | 2,250 | 2.10 | Danso et al. 2018 |
| Nabeul SE3 and SE4 | Tunisia | 29,500 | - | Primary data |
| South Sfax | Tunisia | 49,500 | - | Case Study #3 |
| El Berka | Egypt | 450,000 | 0.20 | Kress and Targetti 2014 |
| Dowoud Jabal Ali | UAE | 1,050,000 | 1.61 | Primary data |
| Al Wathba II | UAE | 300,000 | 2.59 | Case Study #8; Dawoud 2017 |
| Jericho | Palestine | 9,600 | 6.66 | Case Study #5 |
| Haya Water | Oman | 100,000 | - | Zekri et al. 2014 |

*NOTES:* [1]Case studies refer to those published in Section 3 of this book.

In Jordan, the investment cost per volume treated is higher compared to the treatment plants assessed in the other countries based on the wastewater treatment assessed. In Morocco, the investment cost per volume treated was lower for the smaller plants (Tangier and Draga wastewater treatment plants) than for the larger plants. This disparity might indicate that there are no economies of scale, while in Jordan and UAE plants with higher treatment capacity have lower investment cost per unit of wastewater treated compared to the plants with lower treatment capacity. This might indicate that there are economies of scale in investment costs of wastewater treatment plants in those countries. However, to ascertain this, we need to assess a larger sample. The case from Egypt (El Berka) showed the lowest investment cost per volume treated, while the case from Palestine (Jericho) showed the highest investment cost per volume treated.

We also analyzed the investment and operational costs of WWTPs with different treatment systems in Egypt to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated using different treatment methods. The treatments considered include secondary and tertiary treatment systems. Table 4.2 shows the investment and operational cost for each type of treatment system. Looking at the type of treatment system, the natural pond system has less investment and operational cost per volume treated compared to the more advanced treatment systems.

**TABLE 4.2** Investment and operational cost of varying treatment systems in Egypt.

| Treatment plant | Treatment system | Capacity ($m^3$/day) | Investment cost (USD/$m^3$) | Operational cost (USD/$m^3$) | Source |
|---|---|---|---|---|---|
| El Barka | Biological and activated sludge (tertiary treatment) | 450,000 | 0.20 | 0.022 | Kress and Targetti 2014 |
| Serapium | Natural system (algae pond – primary treatment) | 91,250 | 0.06 | 0.001 | SWIM 2013 |
| El-Gabal El-Asfar | Secondary system | 450,000 | 0.30 | 0.019 | Drechsel and Hanjira 2018 |

## Operation costs of wastewater treatment plants

Wastewater treatment and reuse comprises different operational cost components, which include staff, energy and other costs such as chemicals and maintenance costs. Table 4.3 and Figure 4.2 are based on primary data collected from wastewater treatment plants and show the operation cost per each cost category and their importance in five plants in Tunisia, Jordan and Palestine. These costs relate to the direct treatment costs in Figure 4.1 (above).

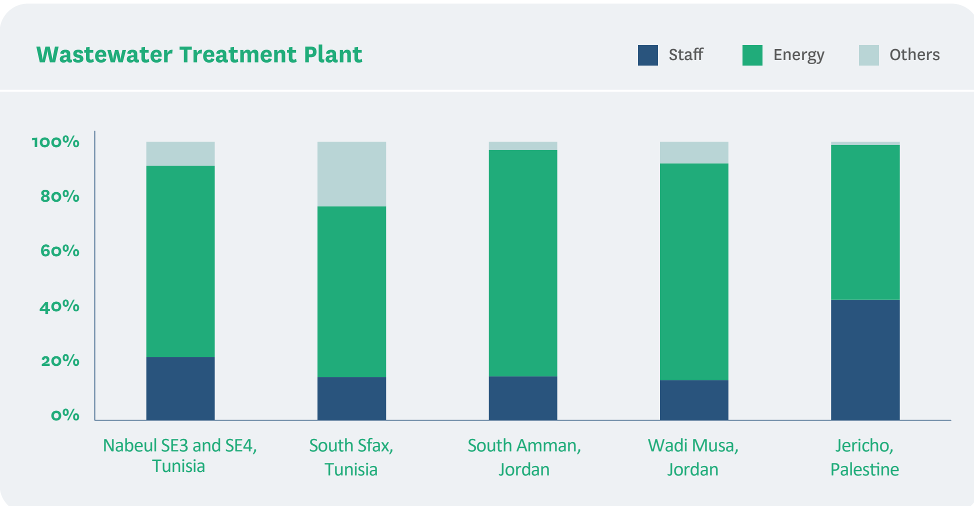


**FIGURE 4.2** Share of cost components in the total operational cost.

**TABLE 4.3** Operational cost per unit of wastewater treated with tertiary treatment systems (USD/$m^3$).

| Cost item | Nabeul SE3 and SE4, Tunisia | South Sfax, Tunisia | South Amman, Jordan | Wadi Musa, Jordan | Jericho, Palestine |
|---|---|---|---|---|---|
| Staff | 0.02 | 0.01 | 0.05 | 0.06 | 0.03 |
| Energy | 0.06 | 0.02 | 0.26 | 0.35 | 0.04 |
| Others | 0.01 | 0.01 | 0.01 | 0.03 | 0.00 |
| Total | 0.09 | 0.03 | 0.32 | 0.45 | 0.08 |

Energy cost stands out as the major cost for all plants accounting for more than 50% of the total cost of the plants in Tunisia and Palestine and 75% of the total cost of the plants in Jordan. This is because the plants use advanced treatment systems (tertiary treatment) with high energy usage. This is followed by staff costs accounting for 15% of the operational costs in Jordan and Tunisia. Staff cost in Palestine is, however, a major cost accounting for 45% of the total cost. The energy cost per volume of wastewater treated varies between the countries. Plants in Tunisia and Palestine have lower energy cost (USD 0.02–0.06/$m^3$), while in Jordan the energy cost per volume treated is USD 0.26–0.35/$m^3$.

### Cost recovery rates and mechanisms of wastewater treatment plants

The majority of WWTPs in the MENA region rely on subsidies and water fees charged to households as the main source of revenue for cost recovery. However, in some cases there is additional revenue generation through the sale of reclaimed water for different value creation. This is more frequent when reclaimed water is used by growing sectors with a high capacity to pay such as golf courses, hotels or industries. Farmers have less ability to pay. Their contribution to cost recovery of WWTPs through payments for reclaimed water is marginal. Irrigation water is in most cases subsidized and farmers have little willingness to pay more for reclaimed water.

The price of reclaimed water for irrigation varies across the MENA region depending on the local context and the end use. Factors that potentially influence users' willingness to pay for reclaimed water include price of alternative water sources, i.e., potable, surface water and groundwater supplies as well as the perception about and ability to pay for reclaimed water. Industries and golf courses or landscaping, for example, have a higher ability to pay than farmers.

Table 4.4 shows the volume of reclaimed water sold, the price per volume of reclaimed water and operational cost recovery from the use of reclaimed water for different end uses. The operational cost recovery rate is the ratio of total revenue from sales of reclaimed water to total operating costs and is a key indicator of financial performance.

In Tunisia and UAE, farmers are supplied with reclaimed water free of charge to promote the use of reclaimed water, while in other countries different pricing mechanisms are used. Depending on the end use, in Jordan the price of reclaimed water showed a high variation amongst the wastewater treatment plants assessed with higher prices charged for hotels and landscaping (USD 0.015–1.05/$m^3$). The operational cost recovery from the use of reclaimed water ranged from a maximum of 31% to a minimum of 3%. The As Samra wastewater treatment plant showed the highest cost recovery from sale of reclaimed water for irrigation at a price of USD 0.015/$m^3$ and 13 MW of energy production, which resulted in a savings in energy cost for the plant.

The wastewater treatment plants in Morocco showed the highest cost recovery from the use of reclaimed water for golf courses and landscaping. In Palestine and Oman, the cost recovery from water reuse for irrigation is 30%. In Tunisia and UAE, farmers are charged no fees and

**TABLE 4.4** Price and volume of reclaimed water and operational cost recovery from sales of water.

| Reuse project | Country | Volume of reclaimed water sold (million m³/year) | Price of reclaimed water (USD/m³) | Operational cost recovery through water sales (%) | Water user |
|---|---|---|---|---|---|
| South Amman | Jordan | 1.67 | 0.035 | 3% | Irrigation |
| As Samra[a] | Jordan | 133 | 0.015 | 31% | Irrigation and energy recovery |
| Wadi Mousa | Jordan | 0.54 | 0.2 | 23% | Irrigation |
| Talabay | Jordan | 0.06 | 1.05 | 21% | Hotels for landscaping |
| Marrakech | Morocco | 16.80 | 0.69 | 200% | Golf courses and landscaping |
| Tangier | Morocco | 0.78 | 0.27 | 218% | Golf courses and landscaping |
| Draga[b] | Morocco | | 0.05 | - | Irrigation |
| Nabeul SE3 and SE4 | Tunisia | | 0 | - | Irrigation (free of charge) |
| South Sfax | Tunisia | | 0 | - | Irrigation (free of charge) |
| Dowoud Jabal Ali | UAE | | 0 | - | Irrigation (fully subsidized by government) |
| Al Wathba II[c] | UAE | | 0.46 | - | Irrigation (currently fully subsidized but future plans to charge tariffs for water reuse) |
| Jericho | Palestine | 0.50 | 0.16 | 30% | Irrigation |
| Haya Water[d] | Oman | | 0.50 | 30% | Landscaping |

*NOTES:* [a] Drechsel et al. 2018, [b]Danso et al. 2018, [c]Dawoud, 2017, [d]Zekri et al. 2014.

thus no cost recovery from use of reclaimed water. The use of reclaimed water results in a freshwater savings, which has a high economic value but was not covered in our analysis. Furthermore, at the time of the assessment, the Al Wathba II WWTP in UAE supply water for irrigation at no cost to the farmers but, in the future, the plant plans to charge a fee of USD 0.46/m³ and this is estimated to recover about 32% of the operation costs.

Some countries such as Tunisia and Jordan consider reuse of reclaimed water as an important and strategic water and wastewater sector planning and management from a policy point of view. For example, Tunisia launched a nationwide water reuse program to increase the country's usable water resources in the early 1980s (Qadir et al. 2010). This program necessitated the treatment of municipal wastewater using secondary biological treatment, usually activated sludge as well as some tertiary treatment. Reclaimed water in Tunisia is mostly used for agricultural irrigation as well as for landscape irrigation in golf courses. Jordan is considered as a leader amongst the MENA countries with its well-developed policy framework on use of reclaimed water. The three key pillars of the 1998 wastewater policy of Jordan are:

- reclaimed water is considered as part of the water budget in the country;
- water reuse is planned at a basin scale; and
- fees for wastewater treatment are charged to water users (Qadir et al. 2010).

### 4.3.2. Water reuse for potable water or aquifer recharge

Some MENA countries are working to use reclaimed water for additional uses beyond irrigation in agriculture, agroforestry and landscaping. Some countries have made efforts to harness the potential of reclaimed water for use in other sectors such as for domestic use and/or aquifer recharge (Qadir et al. 2010). Water reuse increases supply of water and several countries in the MENA region are expanding the water supply through investments in recharging aquifers by reusing reclaimed water (Zekri et al. 2014).

The Tunisian government initiated some investigations through pilot projects to unearth the potential of reclaimed water for groundwater recharge, irrigation of forests and wetlands development. Experience has shown that successful reuse projects should be preceded by significant information dissemination that aims at addressing concerns of project communities and to ensure their active participation.

In Oman, domestic users rejected the potential of treated wastewater for aquifer recharge due to perceived health risks (Zekri et al. 2014). Similarly, in Mashhad, Iran's second largest city, untreated wastewater had been injected into the aquifer without proper treatment resulting in contamination of groundwater, rivers and their tributaries with pollutants (Alaei 2011). To address this, the Iranian government constructed two WWTPs to produce an estimated annual volume of treated wastewater of 253 million $m^3$ for groundwater recharge as well as for use in agriculture and green spaces (Qadir et al. 2015; Alaei 2011).

The difference between water price and reclaimed water price is key in the willingness of industries to accept reclaimed water as substitutes. The average cost of reclaimed water through a tertiary treatment method in Jordan is JOD 0.55, while the cost of fresh water is JOD 1.00/$m^3$ indicating that reclaimed water has a competitive advantage in terms of price over freshwater (Saidan et al. 2020). In cases where the reclaimed water had to be piped over a long distance to supply end-users, the cost of reclaimed water will be high (JOD 2.00/$m^3$) and will no doubt affect the willingness of end-users to pay for reclaimed water.

In such cases, to promote use of reclaimed water, subsidies in the form of discounted cost of water in combination with fund allocation for capital costs coverage may be useful when on-site treatment is needed (Saidan et al. 2020). Understanding public perception about use of reclaimed water for different purposes and addressing concerns of end-users would be helpful in securing public support. Furthermore, legal frameworks, supportive policies and institutions are key in promoting planned use of reclaimed water for aquifer recharge (Qadir et al. 2015).

Aquifer recharge can be i) unintentional, whereby recharge occurs through deep seepage under irrigation areas, leaks from water pipes and sewers, ii) unmanaged, such as stormwater drainage wells without intent for reuse or iii) managed, whereby recharge occurs through injection of storm and reclaimed water into wells as well as infiltration basins with the intention for subsequent reuse for urban, agricultural, environmental and industrial uses (Dillon 2009).

Table 4.5 shows the cost of aquifer recharge through injection wells for different technologies. The recharged water is treated wastewater through secondary treatment method, desalted brackish water reverse osmosis (BWRO) or desalted seawater reverse osmosis (SWRO). The volume recharged varied between 0.27 million and 1.95 million $m^3$/year in UAE, while the volumes in Oman and Cyprus are higher. The costs varied widely among countries with Oman reporting the lowest recharge cost of USD 0.10/$m^3$, while in Cyprus the recharge cost is USD 1.53/$m^3$ of wastewater treated using a secondary treatment method. In UAE, the recharge costs ranged between USD 0.37/$m^3$ and USD 0.59/$m^3$ for different technologies. The differences in costs arose, among others, from the size of the project and the type of treatment applied prior to recharge (Almulla et al. 2003; Aydarous 2006).

**TABLE 4.5** Cost of managed aquifer recharge for different technologies.

| Technology | Country | Capacity (million $m^3$/year) | Cost per unit of water recharged (USD/$m^3$) |
|---|---|---|---|
| Ultrafiltration | | 0.27 | 0.49 |
| Crystallization and ultrafiltration with pre-treatment by SWRO | UAE | 0.84 | 0.59 |
| Crystallization and UF with BWRO brine recovery | UAE | 1.95 | 0.46 |
| BWRO brine recovery – SWRO | UAE | 1.11 | 0.37 |
| Secondary treated wastewater | Oman | 5.48 | 0.10 |
| Secondary treated wastewater | Cyprus | 15.33 | 1.53 |

*SOURCES*: Zekri et al. 2014; Allmula et al. 2003; Aydarous 2006; Koussis et al. 2010

### 4.3.3. Value creation for on-site use

Small-scale sanitation is a promising solution as it permits reduction of operating and maintenance costs as well as the reuse of reclaimed water such as nutrients and energy close to the source of generation. Small-scale sanitation systems are widely implemented in Egypt, especially in touristic resorts because the enabling conditions already exist (Reymond et al. 2018). However, civil society such as building owners, peri-urban or rural communities are usually interested in, and are ready to finance, the construction of sewer systems rather than considering treatment facilities.

The Al Samra wastewater treatment plant produces energy for onsite use. It has a potential energy recovery of 95% of its needs through hydro energy and biogas production with only 5% of its energy needs taken from the national grid (Saidan et al. 2020). Furthermore, about 300,000 tons of carbon dioxide is saved each year through energy recovery and renewable energy utilization. Data in Jordan has shown that having anaerobic sludge digestion in a small- and medium-scale wastewater treatment plant (<10 x $10^4$ $m^3$/day) could produce electricity that would equate to an offset of about 0.11 – 0.53 kWh/$m^3$ (Saidan et al. 2020, 2019; Smith et al. 2018; McCarty et al. 2011). Moreover, energy produced from anaerobic sludge digestion could be increased by co-digestion of kitchen and other organic waste. However, in Jordan, co-digestion is only conducted at a laboratory scale (Saidan et al. 2020).

Other studies have evaluated the potential of biogas production from the co-digestion of food waste and wastewater sludge at refugee camps. Co-digesting organic waste and wastewater sludge can generate 38 $Nm^3$/day of methane – which in theory has the potential to generate about 4 MW in remote refugee camps (Al-Addous et al. 2019). In another study, Saidan et al. (2018) evaluate on-site treatment of institutional building's wastewater. They took samples on weekly basis to determine values of parameters such as BOD, COD, TSS, pH and *E. coli*, while investigating the effluent quality of 1 $m^3$ per day on-site wastewater treatment processes. They report that the process was modified with an installation of in-line UV unit to ensure highest disinfection of treated wastewater suitable for reuse especially in irrigation. Based on that and per Jordanian standards of treated wastewater quality, four classifications of plants have been proposed and two of these classifications have been recommended for irrigation with treated wastewater (Saidan et al. 2018). In this regard, it is recommended that such on-site treatment processes could be utilized in refugee camps where there are no centralized wastewater treatment plants.

## 4.4. Conclusion

The assessments of the costs and benefits of water reuse for agriculture, landscaping, aquifer recharge or energy recovery are important. They can make a stronger case for investment in water reuse solutions for cost recovery and overall sustainability. The potential for enhanced use of reclaimed water is possible when decision-makers understand the costs and the role of water reuse in recovering capital and operational costs of the wastewater treatment plants.

In this chapter, we assessed wastewater treatment and reuse projects with varying value propositions in the MENA region. We focused on their costs and cost recovery or revenue generation mechanisms across different countries to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated as well as the opportunities in recovering operational costs from water reuse. Most WWTPs assessed in this study are operated by public sector utilities and rely on financial support from government and other donors.

The investment cost per unit of wastewater treated depends on, among other factors, the type and level of treatment, the targeted reuse option as well as the treatment capacity of the wastewater treatment plant. Energy cost constitutes the major operational cost, accounting for more than 60% of total cost of WWTPs with tertiary treatment systems, indicating that energy is a critical input for the running of wastewater treatment plants with advanced treatment systems.

The ability to minimize energy cost and achieve cost savings through generation of energy for on-site use (as in the case of the As-Samra WWTPs) or revenue generation through sales of energy to external end-users can be considered as energy cost saving mechanisms for the waste treatment plant. Recovering energy can achieve up to 85% energy self-sufficiency as well as save on energy costs (Hanjira et al. 2015a).

The use of reclaimed water has the potential to recover part of the operational costs of the WWTPs. The majority of the plants assessed supply reclaimed water for agriculture with a few plants supplying reclaimed water for landscaping and golf courses. The pricing of reclaimed water depends on several factors and varies across countries and treatment plants in the region. Notable among these factors are the target end-users, prices of alternative water sources, perception about and willingness to pay for reclaimed water and strategic policy focus of the country.

Most of the water reuse projects supplying water for irrigation charge lower water prices. They are unlikely to achieve full operational cost recovery and are only able to cover part of the operational costs. On the other hand, higher prices are charged to sectors with a greater ability to pay such as golf courses, hotels or industries. For instance, in Jordan, the price of reclaimed water varies among the plants depending on the end-users with lower prices charged to farmers than to hotels. The WWTPs in Morocco generated revenues from sales of reclaimed water for golf courses and landscaping. Cases in Tunisia and UAE represent strategic policy focus where farmers are supplied with reclaimed water free of charge.

Harnessing key resources in wastewater such as nutrients and energy, in addition to supplying water for irrigation, can increase the likelihood of recovering operational and maintenance costs as well as the capital costs if these resources are sold to other end-users. Furthermore, water reuse projects should be assessed in terms of their overall economic costs and benefits to society and not just the financial implications.

This study focused on the financial aspects of water reuse projects; however, economic benefits and costs associated with the water reuse projects need to be considered. Assessing the economic viability of water reuse projects is an important tool for decision-making to ensure that the projects result in desired socioeconomic benefits to society and thus justify their development and promotion.

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