

Water Management in Israel

AUGUST 2017

Philippe Marin,
Shimon Tal,
Joshua Yeres, and
Klas Ringskog

Key Innovations and Lessons Learned
for Water-Scarce Countries



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Preface

This technical paper focuses on identifying and presenting elements of the Israeli water experience that will be of value to World Bank Group client countries and partners. It examines this experience within the ever-evolving context of climate change, urbanization, and water scarcity. The paper deliberately selected elements of policy and delivery mechanisms that highlight key aspects of water management in Israel and lessons that may be replicable and scalable elsewhere. It is technical in nature and focuses on the best practices of Israel in managing and providing water services.

The paper does not purport to present a comprehensive picture and analysis of the Israel water story nor claims to make any representations about the wider political economy associated with water resources management or development in the region. The paper focuses exclusively on the technical innovation and lessons that have arisen and that may be of interest to World Bank clients and member states around the world suffering from increasing water scarcity. The World Bank acknowledges that water issues in the region continue to be a point of contention.



Acknowledgments

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Executive Summary

Israel is one of the most water-stressed countries in the world. To provide its rapidly growing economy with sufficient and reliable water and achieve water security, it has gradually implemented a policy that combines institutional and regulatory reforms with massive infrastructure investment structured along the following:

- **Strong demand management** to increase water productivity, to reduce per capita potable water consumption, and shift water to higher value irrigated crops.
- **Using aquifers as reservoirs** with recharge of aquifers with treated wastewater during low-demand months, capture of occasional flash floods, and comprehensive monitoring and control of aquifers' levels and abstraction.
- **Reuse of treated wastewater for irrigation** to replace and release scarce fresh water for domestic and industrial uses and to safeguard the environment. More than 87 percent of treated wastewater effluents are reused for agriculture, representing approximately half of all irrigation water nationwide. Widespread tertiary wastewater treatment make unrestricted reuse for irrigation possible.
- **Large-scale desalination of seawater** and brackish water to supply almost all potable water that municipal and regional utilities distribute in the country. Five “mega” seawater reverse osmosis (SWRO) desalination plants supply 85 percent of domestic urban water.
- **A national bulk water conveyance system** that allows to optimize the distribution of water across the country from various sources depending on demand. It conveys 95 percent of Israel's potable water resources (surface water, groundwater, desalinated water) to the regional providers that supply end-users.
- **Major legal and institutional reforms, implemented over the course of the last 15 years, with regulatory and pricing policies to approach financial sustainability of the water sector as a whole.** This included changing the pricing principles of water from a public and social good to a commodity, institutional reforms with corporatization of service providers and the establishment of a strong national regulator.

Despite a situation of acute water scarcity, implementation of this policy for sustainable water management has allowed Israel to achieve water security while at the same time drastically reduce overexploitation of aquifers. This has been achieved through a massive increase in the production of non-conventional waters - wastewater reuse (since 1998) and seawater desalination (since 2006) - together with a legal framework that makes metering compulsory and asserts a strong government's control over water resources.

It is noteworthy that change in the Israeli water sector has been largely driven by crisis, since it took several major droughts to strengthen the political will to undertake ambitious water reforms. The drought that took place in 1998 resulted for the first time in shortages

and water rationing in major Israeli cities, and generated sufficient public outcry for the government to start embarking on far-ranging institutional reforms. A law was passed in 2001 requiring ring-fencing of municipal water services. A Parliamentary Investigation Committee for the water sector was launched in 2002. This inaugurated far-reaching reforms in water management over the course of the next 15 years.

A landmark of the reform was the establishment in 2007 of the Israel Water Authority (IWA) as an autonomous government agency combining planning and regulatory responsibilities for all the elements of the water chain (potable water and sanitation, irrigation, water resources management). This allowed Israel to draw a line between the political level, which is responsible for policy setting, and the professional level, which manages the water sector. All the various regulatory bodies in the water and sewage sectors became gradually transferred to the IWA within a few years.

Implementation of these ambitious reforms over the last decade has put the Israeli water sector on a course toward financial viability, based on the principles of full cost recovery through tariffs. A new financial framework was put in place gradually, under the direct control of IWA which as national water regulator sets tariffs for all water users. The national bulk water operator Mekorot (in charge of all potable water production and the national water conveyor) was corporatized and transformed into a regulated public company. Municipal water and sanitation services have been gradually transformed into corporatized regional utilities. Water tariffs for all users were gradually increased to approach full cost recovery for the overall water chain (although there are also significant cross-subsidies between water uses), while the regulator set performance targets for improved efficiency.

After many years of reforms and massive investment, the Israeli water sector has now achieved almost full financial autonomy—with the exception of wastewater reuse (still relying on investment subsidies)—together with water security. Almost all the costs of investing and operating the water infrastructure are now paid by users through tariffs. Furthermore, the country is in a position to meet all future demand from multiple users.

How was this achieved? Out of the whole “Israel water story,” there are **nine water innovations** that stand out and are analyzed in this report:

- First Innovation: National Water System to Connect all Water Infrastructure**
- Second Innovation: Large-Scale Reuse of Treated Wastewater for Irrigation**
- Third Innovation: Large-Scale Desalination PPP for Potable Water Independence**
- Fourth Innovation: Using Aquifers as Reservoirs**
- Fifth Innovation: Interception of Surface Water Run-Offs**
- Sixth Innovation: Promoting Crop Selectivity and Imports of Virtual Water**
- Seventh Innovation: Efficient Irrigation Technologies**
- Eighth Innovation: Demand Management and the Successful 2008 Campaign**
- Ninth Innovation: Creating a Supporting Environment for Water Innovation**

In addition to these innovations, along the road to national sustainable water balance, nine key lessons have been learned that should be of interest to other water-scarce countries:

First Lesson Learned: Importance of public awareness and demand management for being able to carry out efficient water management under scarcity. Public awareness campaigns have been carried out on a massive scale, so as to emphasize the value of water in a country suffering from acute water scarcity. This was accompanied by the move toward full cost recovery and pricing water at its actual cost, as a strong signal to users that water is a precious resource not to be wasted.

Second Lesson Learned: Strong control and enforcement of water allocations is crucial for mitigating extreme water scarcity. Pricing incentives are not sufficient. The Water Law of 1959 brought water under state control and gave state organizations the authority to regulate and allocate consumption for alternative uses. Control of consumption has been successful because of strong enforcement with sanctions - it has not relied exclusively on incentives.

Third Lesson Learned: Comprehensive, probabilistic, and timely data are crucial for efficient integrated management of water. The IWA relies on its Hydrological Services Unit to collect, analyze, and model water data and factors in the effects of global warming on Israel's natural water resources. This allows IWA and Mekorot to allocate and manage all water resources on a real-time basis.

Fourth Lesson Learned: A national conveyance water system can help optimize water management under conditions of scarcity, allocating supplies and uses of water across the country. Israel's small size and the institutional reforms made it possible to create a national integrated water infrastructure that is economically efficient and well managed. It proved essential to bringing efficiency, promoting alternative water resources, and being able to mitigate adverse hydrological variations.

Fifth Lesson Learned: Investing massively in new water infrastructure is not enough; this needs to be done in a financially sustainable manner through appropriate institutional reforms. This includes putting in place a clear separation of roles between policy setting, regulation and planning, and operation of infrastructure. In the specific case of Israel, the vesting of all planning and regulatory powers of the water sector (water supply and wastewater, irrigation, water resources management) under a single autonomous agency (IWA) proved a beneficial decision, since it is managed professionally and largely insulated from political influence.

Sixth Lesson Learned: The relatively low price obtained for desalinated water through Build-operate-transfer (BOT) schemes for Israel's desalination plants was contingent on a careful design of the PPP contracts—with more government guarantees being provided to private investors than what is typical for such public-private partnerships (PPP) projects.

This allowed Israel to get bid prices for desalinated water that are among the lowest in the world, in turn making large-scale access to desalination financially viable.

Seventh Lesson Learned: Wastewater reuse is beneficial when dealing with water scarcity, but is also costly and requires significant public subsidies - even in the case of Israel where farmers have achieved high levels of efficiency and are able to pay significant prices for reclaimed water. Subsidies are concentrated to the treatment of wastewater and storage of recycled water, while farmers do pay the incremental costs of conveying treated wastewater effluents to irrigated areas.

Eighth Lesson Learned: Corporatization and aggregation of water and sanitation services is a long process, that requires sound regulation and heavy-handed supervision to be successful. The regionalization of utilities has been a gradual process that is still not completed 15 years later. The performance of the newly ring-fenced utilities started to improve only after 2009, when the IWA started to regulate them and putting in place a mix of financial incentives through tariffs with enforcement of sanctions for the worst performers.

Ninth Lesson Learned: Even in a country with strong capacity and where huge efforts have been put on water reforms, there can still be areas for improvements. Despite the progress achieved, the optimization of the water sector is still incomplete. Not all of the Israeli water experiences can be qualified as best practice, and mistakes have been made along the way. The use of uniform water tariffs nationwide, both for municipal and now agricultural consumers, has introduced economic inefficiencies in the allocation of the water resources. The agglomeration of regional utilities is proving a lengthy process. Some large infrastructure projects have suffered set-backs, such as with the recent Ashdod desalination plant. Finally, the allocation of water and restrictions on aquifers abstraction for the Palestinian population is a contentious issue that remains outstanding.



Abbreviations

BOT	Build-Operate-Transfer
BOO	Build-Own-Operate
IPP	Independent Power Production
IWA	Israel Water Authority
MUA	Municipal Utilities Administration
NIS	New Israeli Shekel
NRW	Non-Revenue Water
O&M	Operation & Maintenance
PPP	Public-Private Partnership
SWRO	Sea Water Reverse Osmosis
WSS	Water Supply and Sanitation
WWTP	Wastewater Treatment Plant

US\$ 1=NIS 3.56 (New Israeli Shekel) as of July 26, 2017

The objective of this technical report is to document the key innovations and lessons learned from the Israeli water management experience, for the benefit of other countries around the world facing increasing challenges in dealing with water scarcity.

This technical report does not purport to present a comprehensive picture and analysis of the Israel water story. It focuses solely on identifying and presenting the technical elements of the Israeli water experience that can be valuable for other countries around the world, in a global context of climate change and increased water stress across all continents.

The report has been structured in order to provide a synthetic view of key elements in the water management reforms that have been carried out in Israel over the last 15 years, and that have led the country to achieve water security:

- The second chapter provides a brief overview of the Israeli water sector, outlining *inter alia* the overall situation and presenting the key players;
- The third chapter discusses how the reforms have allowed the Israeli water sector to achieve financial sustainability through a move toward full cost recovery through tariffs for all users. It presents the new financial and regulatory framework that was put in place under the national water regulator (Israel Water Authority [IWA]), along with the corporatization of national bulk water operator Mekorot and regional ring-fenced utilities;
- The fourth chapter discusses successively the nine innovations that have been identified as key in the success of the Israeli water story. These innovations represent the key elements of the reforms that have allowed Israel to achieve water security despite acute water scarcity in a financially sustainable manner;
- The fifth and concluding chapter identifies and discusses nine lessons learned from the Israel water story, that are deemed the most valuable for other countries facing increasing water scarcity.

Hydrological Situation: One of the Most Water-Stressed Countries in the World

Israel is located on the southeastern coast of the Mediterranean. Spread across four distinct regions—the Mediterranean coastal plain, the central hills (average altitude 600 meters), the Jordan Rift valley (the Dead Sea in the rift being the lowest point on Earth at 400 meters below sea level), and the Negev—most of the country has a semi-arid climate, and the Negev in the south is a desert. Within a 200-kilometer radius, annual rainfall varies from 600 millimeters in the north to less than 150 millimeters in the south. Extreme variations in precipitation between years are normal, and multiple years of drought are not uncommon.

Winter rainfall is characteristic of the Mediterranean climate, with 75 percent of annual precipitation falling within three months (December to February). Normally there are 60 to 70 rainy days with a few short rainstorms. The Sea of Galilee,¹ from which the Jordan River flows, is the only natural fresh surface water reservoir between the Jordan River and the Mediterranean. It provides approximately 20 percent to 30 percent of the state's fresh water supply and is the country's largest freshwater reservoir (at approximately 200 meters below sea level). Floods are also short but intense and contain up to 9 percent suspended solids, making it difficult to store and reuse flood flows. Most rainfall is lost to evapotranspiration (approximately 70 percent), and approximately 25 percent infiltrates to groundwater or remains in the soil to support vegetation and crops; only 5 percent flows as surface water.

Israel is one of the most water-scarce countries in the world. Since the establishment of the State of Israel in 1948, the population had grown to 8.6 million people in 2015. According to Troop and Jägerskog (2006), the total renewable volume of water per capita stands at 276 cubic meters per year, which is about half of the “shortage red line” of 500 cubic meters per capita per year, which defines a situation of water shortage.²

The Israeli Water Story: Achieving Water Security Despite Extreme Scarcity

Water scarcity has shaped the development of the Israeli water sector over the last five decades. The country has had no choice but to adapt and gradually develop a series of water innovations in operational practices, technologies, and institutions. Many valuable lessons about water reforms have been learned along the way.

Extreme changes in water yields between years have dictated the need to apply key principles for managing water variability. To ensure reliability, two fundamental rules must be observed. The first is that average water demands and average water resources must be broadly balanced—but this alone is not enough. The second is that water storage capacity sufficient to compensate for seasonal rainfall variability and multiyear droughts must be provided, with water stored in an economical manner. When the two sides of the equation are not

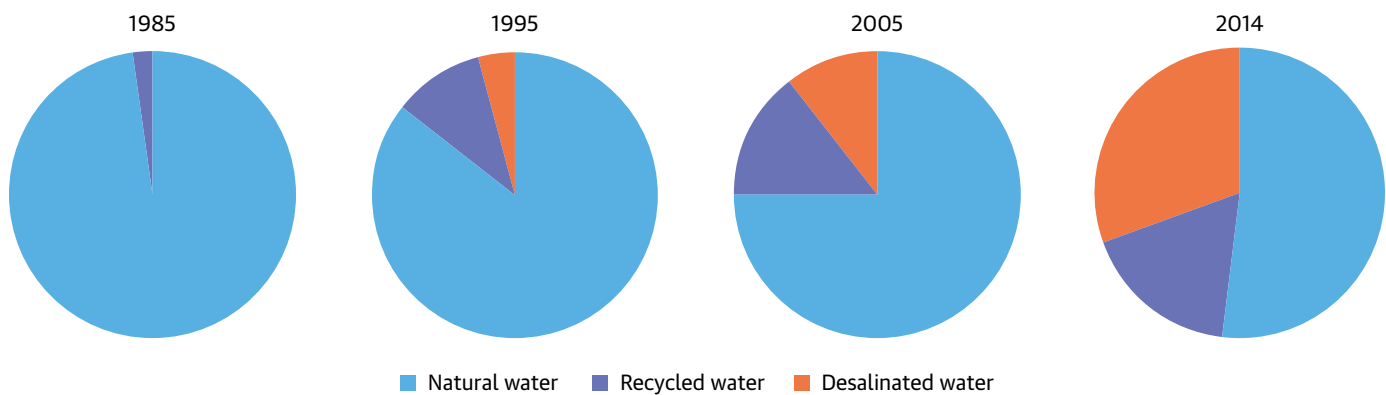
balanced, overexploitation of natural water resources occurs, with deterioration of aquifers and deterioration of water quality due to increased salinity.

To achieve a reliable water supply, Israel has gradually implemented a policy that combines institutional reforms and massive infrastructure investment that includes the following six major elements.

- **Strong demand management** to control aquifers abstraction (water permits, metering), improve efficiency, reduce domestic consumption (potable water per capita), and shift water use to higher value irrigated crops. Domestic per capita consumption of potable water now stands at approximately 90 cubic meters per capita per year, and farmers have switched to high-value production.
- **Reuse of treated wastewater for irrigation** to replace and release scarce fresh water for domestic uses and the environment. More than 87 percent of wastewater effluent is currently reused for agriculture, representing approximately half of total water that farmers use nationwide. A large proportion of wastewater receives tertiary treatment and can be used for any crops without restrictions.
- **Developing large-scale desalination of seawater** and brackish water, with 85 percent of all potable water that municipal and regional utilities distribute in the country now being desalinated water. This has allowed Israel to achieve potable water security for the population, with domestic potable water supply becoming largely independent from rainfall and aquifers abstraction.
- **Developing a national bulk water conveyance infrastructure** in order to optimize the use and distribution of water from various sources (aquifers, desalination, water treatment from Sea of Galilee, recycled wastewater)—depending on local demand and hydrological conditions—conveying surpluses of water from one place to the other.
- **Using aquifers as reservoirs** (in the absence of surface reservoirs and dams), with recharge of aquifers with treated wastewater during low-demand months, capture of occasional flash floods, and comprehensive monitoring and control of aquifers' levels and abstraction regime.
- **Institutional reforms to promote financial sustainability of the water sector as a whole, and separate political decisions from infrastructure planning and operations.** Corporatization of services providers and the establishment of a strong national regulator responsible for the whole water chain and setting tariffs across the whole spectrum of water users (abstraction, potable water for utilities, irrigated water, sanitation, reuse) have allowed Israel to move to full cost recovery through tariffs for most of the water infrastructure and services.

Despite a situation of acute water scarcity, implementation of this policy for sustainable water management has allowed Israel to gradually reduce overexploitation of aquifers through a massive increase in the volume of wastewater reuse (since 1998) and seawater desalination (since 2006). This is illustrated in figure 2.1, which compares the breakdown of

FIGURE 2.1. Breakdown of Water Sources in Israel, 1985, 1995, 2005, 2014



Source: IWA 2015.

water resources used for meeting national demand between 1985, 1995, 2005, and 2014. Thanks to the measures taken over the last two decades, the total amount of water production in 2014 has been maintained broadly at the 1985 level, despite a sharp drop in natural water supplied, and as a result, the recent major shortage of rainfall in 2014 (comparable to 1998 when a major drought occurred) had no effect on users.

Political Economy of Reforms: How Successive Crises Have Driven Change

It took several major droughts in Israel to strengthen the political will to undertake ambitious water reforms. Despite the manifold political risks and resistance from end users, the reform process illustrates well the common wisdom that “there is opportunity in crisis.”

Until 1996, the water sector was managed by the Ministry of Agriculture. The priority then was to rely on (and over-pump) natural water resources to meet all water demands, with agriculture being the main user. Shortages in some years were dealt with by reducing water supply to farmers during droughts and expecting the following rainy years to refill water resources. One major political objective was to keep tariffs low for farmers. Domestic water supply and wastewater collection were also heavily subsidized, but with constant population growth, this approach proved ever less sustainable and kept the Israeli water sector in a permanent state of vulnerability.

Three major water crises built gradual momentum for major reforms in the 2000s. In 1986, a major drought caused water allocations for agriculture to be reduced by 15 percent, for the first time. Then in 1989/90, a more significant drought occurred—requiring severe and unpopular water restrictions—but the consequences were rapidly forgotten because it was immediately followed by an extremely rainy winter in 1991-92 (a “once in 150 years” occurrence) that entirely replenished natural resources. An even harsher crisis was inevitable, and it finally happened with the 1998 drought, when shortages affected not just agriculture, but also municipal and industrial demand, with severe water shortages and rationing in most Israeli cities.

The 1998 water crisis provided a political window for action, and was the one that finally triggered far-reaching policy reforms. In 2000, the Government of Israel changed the policy for water sector management, to gradually adopt a sustainable approach to guaranteeing water security for the country. A Parliamentary Investigation Committee of the Water Sector was established. This led to the gradual establishment over the last 15 years of a modern institutional framework for water management.

Some of the reforms have necessitated years of implementation, followed by refinement, to optimize results. This required some difficult political decisions along the way, such as with the sharp rise in domestic water tariff in the aftermath of another major drought, this time in 2008. It also stimulated a series of innovations that succeeded in gradually restoring a sustainable water balance. As of 2017, the availability of quality water in Israel is deemed to be sufficient to meet the foreseeable needs of the country, even accounting for steady population growth and the foreseeable effects of climate change. Future growth in domestic and industrial demand is expected to be met through desalination, generating an equivalent increase in the amount of treated wastewater available to farmers for reuse.

Institutional Framework: Key National Players in the Water Sector

Table 2.1 provides a snapshot of the key institutional actors in Israel’s water sector. Together, they represent the cornerstone of the country’s water management, and are briefly described below.

Since the 2000 reform, the Ministry of Energy and Water has been the line ministry in charge of formulating and enforcing policies in the water sector. It directly supervises the

TABLE 2.1. Legal and Institutional Setting for Water Management

Institution	Scale	Main responsibilities
Ministry of Energy and Water	National	Policy
Israel Water Authority	National	Planning, allocation, and tariff regulation for all water use
Mekorot Water Company	National	Production and transmission of bulk water <ul style="list-style-type: none"> • Aquifer pumping and potable water treatment from the Sea of Galilee • Desalination of seawater (as off-taker under BOTs) and brackish water • Operation of national bulk water network
Municipal and regional water utilities	Municipal or regional	Distribution of potable water to domestic and industrial consumers, sewage collection and wastewater treatment
Drainage and river authorities	Basin	Management of basins, aquifers, flash floods, and surface waters

Note: BOT = build-operate-transfer.

drainage and river basin authorities, the Israel Water Authority (IWA), and Mekorot and indirectly supervises the water and sanitation providers through IWA.

Mekorot is the national bulk water provider, managing most of bulk water production and transmission to municipal utilities and farmers association. It was established in 1937 and as a company fully owned by the government has become the operating arm of the water sector. It has approximately 2,200 employees and supplies 1,600 million cubic meters of water per year (2016)³—85 percent of Israel’s domestic potable water consumed and 70 percent of Israel’s total water consumed—through the operation of as many as 3,000 installations and 12,000 kilometers of pipeline.⁴

The governmental authority for water and sewerage (IWA) is the national regulator for the whole water sector—covering the entire spectrum of potable water supply and wastewater services, irrigation services, and water resources management. It is in charge of planning overall investments, allocating and supervising water rights, and regulating tariffs and performance of services providers (including local water utilities).

IWA is the de facto “ruler” of the Israeli water sector, combining the functions of both national regulator and planning body. It was established in 2007 to replace the previous Office of the Water Commissioner as the cornerstone of the reorganization of the water sector and in response to the 2002 Parliamentary Investigation Committee of the Water Sector, which had recommended replacing it with a strong, independent authority. This recommendation was based on two key findings of the committee: (a) too many entities were involved in the management of the water sector, and the division of responsibilities was not clear, and (b) the political level was excessively involved in the day-to-day management of the water sector (e.g., tariffs were mainly determined according to political considerations)—a situation that was deemed to be largely responsible for the weaknesses of the water sector and the water crisis.

The establishment of IWA as an autonomous agency was essential to drawing a line between the political level, which is responsible for policy, and the professional level, which manages the water sector. All the regulatory bodies in the water and sewage sectors became gradually transferred to the IWA within a few years. This included the transfer from the Ministry of Interior of the departments in charge of supervising the municipal water and sanitation services—the Sewage Infrastructure Development Authority in 2009 and the Commissioner of Municipal Corporations, which the Municipal Utilities Authority (MUA) replaced in 2009—ultimately placing control of the whole water supply chain under direct IWA management.⁵

Other important government players include the Ministry of Agriculture (sets the criteria for the IWA to allocate water use between crops and ecological regions), the Ministry of Health (drinking water quality and reuse standards and regulates permits for agriculture reuse), the Ministry of Finance (responsible for the budgets), the Ministry of Environmental Protection (prevention of water resource contamination and effluent discharge monitoring), and the Ministry of Interior Affairs (local governments).

Legal and Regulatory Framework of the Israeli Water Sector

A codex of four laws was approved in the decade after the establishment of the State of Israel to establish the principles upon which the water sector was to be managed.

- The Law for Water Measurement (1955) establishes the crucial importance of metering water to enable water management and control of water flows and uses.
- The Law for Supervision of Water Drillings (1955) was passed to assert national control over the production of the water. Before the establishment of Israel, part of the coastal aquifer had already been depleted, and saline intrusion was occurring, threatening long-term damage of the aquifer.
- The Law for Drainage and Flood Prevention (1957) was enacted to help reduce and prevent floods due to the rapid urbanization.
- Finally, **the Water Law (1959) is the cornerstone of Israel's legal water framework**, setting the overall principles for managing the sector. It specifies that all water resources are public properties controlled by the state (there is no private ownership of water resources in Israel, even beneath privately owned land) and establishes the mechanisms for allocation of water rights.

It is remarkable that more than half a century since being enacted, these four fundamental laws are still in place—witness to the fact that they were based on sound water management principles. Other key legislations have been added in the last two decades, including the following:

- The Municipal Water and Sewage Incorporation Law (2001) requires local authorities and municipalities to establish public ring-fenced corporations to manage local water supply and sewage services, to improve performance and to promote the agglomeration of services into regional utilities.
- Two public health regulations set quality standards for reclaimed water (Sewage Effluents Quality Standards and Sewage Treatment Rules, 2010), and drinking water (Sanitary Quality of Drinking Water Law, 2013).

Notes

1. Also called Lake Kinneret or Lake Tiberias. The terminology Sea of Galilee will be used in the rest of the report.
2. Minimum allocation for a “nonwater-stressed country” is 1,100 cubic meters to 1,400 cubic meters per capita per year (Tropp and Jägerskog 2006).
3. Breakdown of water sources transported by Mekorot: desalinated seawater 601 million m³, desalinated brackish water 143 million cubic meters, natural freshwater 581 million cubic meters, and treated wastewater 270 million cubic meters.
4. Including 39 brackish water desalination plants, five seawater desalination plants (BOT, BOO), 8 potable water filtration plants (the one on the Sea of Galilee is the fourth largest in the world), 13 wastewater treatment plants, and approximately 1,200 boreholes and 1,000 pools and reservoirs.
5. The Water Authority Council, which serves as the IWA board of directors and comprises senior officials from government ministries (Finance, Agriculture, Interior, Environment, Water, Energy) and two representatives of the general public, facilitates stakeholder dialogue regarding the management and decision-making process in the water sector.

Moving toward Full Cost Recovery through Tariffs

A crucial element in the modernization of water management in Israel has been the move toward self-financing of the water sector—not just for domestic potable water supply in cities and towns but for all users of the water cycle chain, including farmers. This was achieved through a combination of institutional reforms—including inter alia the creation of a national regulator in charge of all water uses—together with pricing mechanisms based on full cost recovery, incentives for operational performance and the implementation of partnerships with the private sector. Direct budget subsidies to the sector were gradually phased out, and even though this was achieved with, at the end, still significant cross-subsidies between users, the move toward self-financing is still notable for a country where scarcity makes water particularly expensive to produce and deliver to users.

Achieving Self-Financing of the Water Sector, Despite Acute Water Scarcity

Implementation of reforms over the last decade has put the Israeli water sector on a course toward financial viability, based on full cost recovery through tariffs. Having a single regulator for all water activities and services (potable water, sanitation, irrigation, water resources management) has made possible to pursue this in an integrated manner.

As of 2017, the Israeli water sector has achieved almost full financial autonomy—with the exception of wastewater reuse (still relying on investment subsidies) and to a lesser extent seawater desalination (with government’s financial guarantees for build-operate-transfer [BOT] and build-own-operate [BOO] schemes with the private sector). Considering the massive investments required to deal with extreme water scarcity, and the high cost of operating the associated infrastructure, reaching almost full financial autonomy is a significant achievement.

This has been achieved by putting in place a new financial framework under the direct control of the Israel Water Authority (IWA), which as the national water regulator sets tariffs for all water users. Although essentially self-financed through tariffs revenues, it nonetheless relies significantly on cross-subsidies between users. The tariff-setting principles and mechanisms for Mekorot, for the regional and municipal potable water and sanitation utilities, and for irrigation services are outlined below.

Mekorot Has Been Transformed into a Corporatized Public Sector Company

Mekorot was strongly impacted by the reform since it went from being a government-owned company operating in a cost-plus environment (with government transfers covering any cost overruns) to becoming a regulated public sector company, still owned by the government but designed to operate as a completely commercial entity. In practice, this meant that the price of bulk water had to reflect henceforth its actual costs of production and bulk transportation.

Mekorot tariffs are now set by IWA annually based on five-year business plans, which incorporate performance targets in order to foster incentives for efficient infrastructure operation. Capital expenditures and private financing costs must be reflected fully in the bulk tariffs. Even though Mekorot does remain a government owned company operating in a monopolistic sector, the establishment of an arm's-length relationship with its owner, together with economic regulation by IWA, has fostered incentives for performance. For instance, the overall level of water losses for the national bulk water transportation system is reported at only three percent.

Potable Water and Sanitation Utilities: Corporatization and Regionalization

The disappointing performance of municipal water and sewerage departments¹ in the early 2000s prompted the government to implement an ambitious reform of water and sanitation services over the last 15 years. The law approved in 2001, under the auspices of the Ministry of Interior (as responsible for regulating the municipalities and local authorities), directed local governments to establish public ring-fenced corporations to manage local water supply and sewerage services.

Initial progress was slow until in 2009, when the responsibility of the Municipal Utilities Association (MUA) in charge of supervising potable water and sanitation services was transferred from the Ministry of Interior to the IWA. Municipal water and sanitation services have been gradually transformed into corporatized utilities, owned by local municipalities and regulated under licenses by the IWA. There was a steep rise in tariff levels in 2009 as a result of the application of the full cost recovery principle. Almost all investment is now funded through commercial debt financing.² In parallel, a process of consolidation has been taking place, with 56 regional water and sanitation utilities now serving 187 municipalities and local councils.³

Since it was transferred to the IWA, the MUA has taken a proactive role in helping the Israeli water and sanitation utilities improve their governance and overall operational performance. Significant improvements have been achieved, including for improving bill collections, performing network maintenance, and reducing nonrevenue water (NRW) levels. In the aggregate, many water utilities are now generating a small operating profit.

The reform process of Israeli water utilities is still very much ongoing. The agglomeration process has not yet been completely implemented.⁴

Salient Features of the Corporatization of Water Supply and Sanitation Utilities

There are several interesting features of the corporatization reform of water supply and sanitation (WSS) utilities that deserve to be highlighted. Not necessarily innovative by themselves, they can nonetheless provide food for thought for other countries engaged in the challenging task of turning around public water utilities. **The originality of the Israeli water utility reform does not lie in the principles that were introduced, but in the fact that these principles were actually implemented.** The framework of actions implemented by the MUA combines financial incentives and technical guidance with strong supervision of utilities—especially with regard to staffing and performance—including sanctions enforcement as necessary, as outlined below.

First, **financial incentives for operational performance were introduced, as tariff revenues became the sole source of financing for each utility.** The MUA uses the tariff-setting process as a regulatory tool, by establishing the portion of the national water tariff that each utility can keep. This is based on calculation of recognized expenditures that takes into account performance targets and the specific conditions of each utility. Any efficiency gains achieved by the utility's management are automatically translated into the utility's bottom line, and the regulator allows the resulting dividends to be transferred from the utility to the municipal budget—providing obvious financial incentives for local governments and mayors to support the performance improvement of their WSS services.

Also, **special attention was paid to reduce political interference in staffing.** Hiring and salary-setting procedures and salaries are linked to those applied to public sector or government-owned companies and are more demanding than those of local authorities. Managerial positions must meet specific requirements set at the national level with respect to professional credentials and undergo periodic reviews by a dedicated appointment committee at the national level.

Recognizing that many local utilities lacked technical capacity, **the MUA has been issuing on a regular basis technical guidance on operational issues.** The regular issuance of detailed standards has been an important tool in improving the efficiency of the water utilities. These include, among others, salary guidelines (2008), reporting (2010), industrial waste (2013), customer service (2015), and engineering standards (2016, including methodology for measuring for nonrevenue water [NRW]).

Benchmarking has also played an important role. The MUA has developed a long list of key performance indicators relating to a wide range of operational efficiency and customer relations matters. The MUA regularly audits each water utility and has started publishing⁵ the results (excellent, very good, good, requires significant improvement, failed) to put public pressure on bad performers to improve.

Finally, the MUA has not shied away from its supervisory role, which includes imposing sanctions and enforcing them, whenever necessary. Some of the technical guidelines and key performance indicator targets are mandatory, and not achieving them can lead to sanctions.

For example, if the NRW is not satisfactory, and the utility does not show any improvement, MUA-imposed sanctions can include not incorporating some costs into the allowed tariff, forced management changes, or even appointing external management. In 2015, five utilities received a failing grade, and another five received a not sufficient grade. All the utilities with a failing grade had management changes imposed, and all those rated not sufficient had extensive management changes.⁶

Partnering with the Private Sector for Financing Infrastructure Investment and to Improve Performance

The implementation of public-private partnerships (PPPs) as a tool to improve the operational performance of water services, raise private funding for investment, and ensure the sustainability of major infrastructures has been a key feature of the reforms. The seawater desalination program has been implemented through BOT or BOO schemes, in which private concessionaires entirely financed the investments and are responsible for operation and maintenance for 25 years (this will be analyzed in details under the so-called “third innovation”). The amount of private investment raised under the four desalination BOT-BOO projects with private concessionaires (Ashkelon, Palmachim, Hadera and Sorek) represents a total of about **US\$1,300 million**. Also, corporatized regional utilities as well as Mekorot are now financed through commercial debt with private banks or bonds issuances, without sovereign guarantees.

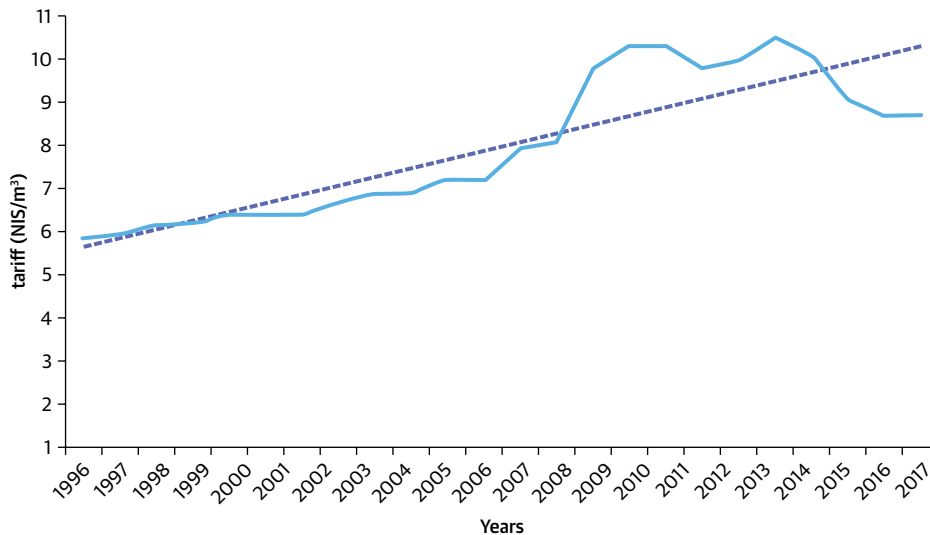
In addition, an important feature of the Israeli corporatization reform is that **the water utilities have been encouraged to seek a variety of partnership contracts with the national private sector in a move to improve operational performance and reduce costs.** Subcontracting arrangements are in place for a wide variety of operational tasks, including operations and maintenance (O&M) tasks in the plants and networks, commercial services (meter installation, meter reading and billing, debt collection, call centers), supervisory control and data acquisition systems and sensors typically purchased through a contract including long-term O&M. Private contractors now perform a large portion of the tasks of the most-advanced Israeli water utilities.⁷

Another example of innovative PPP is the independent power production (IPP) contract put in place for biogas production at the wastewater treatment plant (WWTP) of Kfar Saba-Hod Hasharon in the center of Israel (population 160,000). It is limited to the biogas production process (the operation of the WWTP being under the public utility) and began operation in 2016. It uses the biogas produced by the anaerobic digestion process to provide about 80 percent of the electricity needed by the plant, saving about 20 percent of the energy costs.

Regulation and Tariff-Setting Mechanisms for Water and Sanitation Utilities

As already indicated, tariff setting by the IWA has played a major role in the reform of WSS utilities. Following the incorporation of the MUA under IWA in 2009, a major tariff increase

FIGURE 3.1. Average Municipal Water Tariff in Israel 1996-2017



Sources: World Bank staff calculations based on data from IWA 2015.

took place for potable water and sanitation tariff (figure 3.1). This was necessary to ensure that the corporatized utilities would have sufficient revenues to cover all their costs and become financially independent from local governments. **The magnitude of the tariff increase that took place in just one year—almost doubling—underlines the magnitude of the subsidies to the sector that local authorities were providing before, as well as the strong political will to implement the reform.**

IWA now sets tariffs for all water and sanitation services, and a uniform tariff level and structure

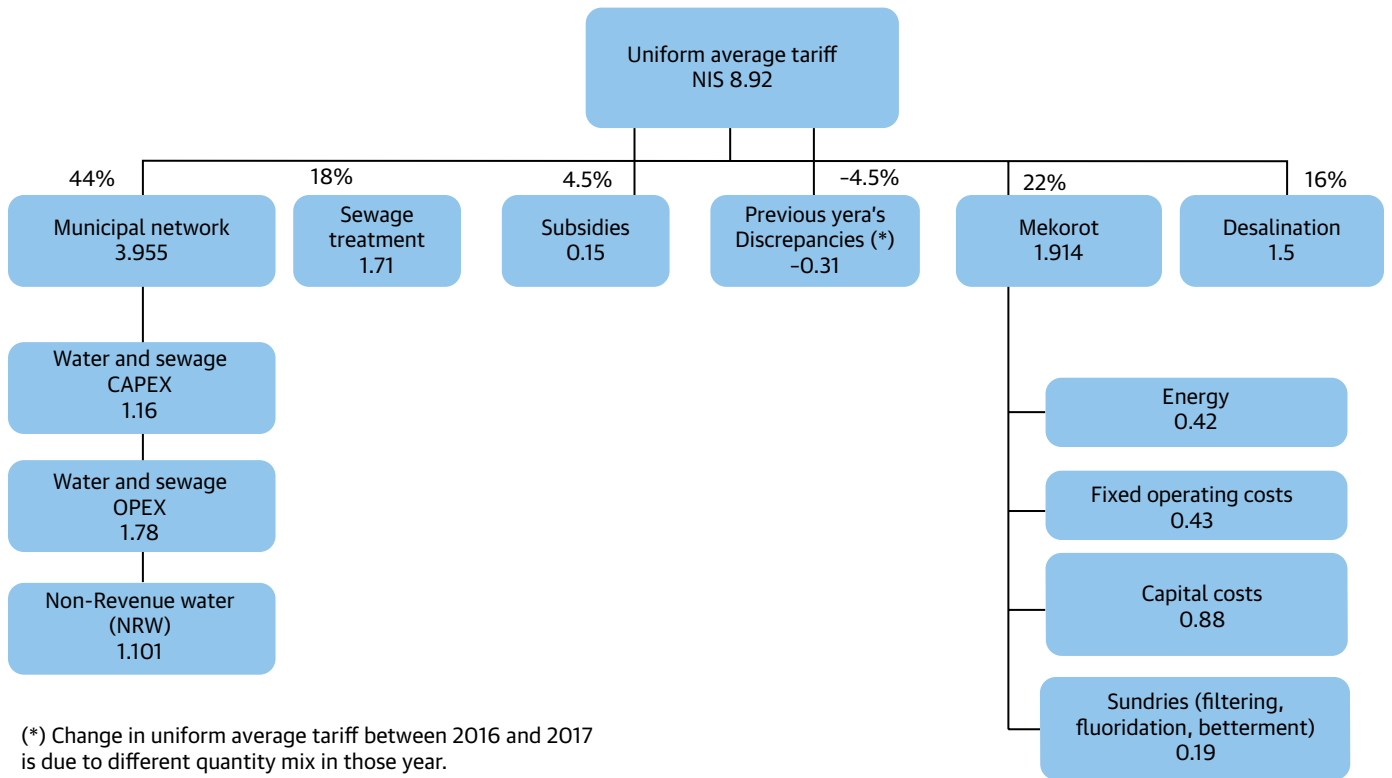
has been instituted for the country,⁸ with all potable water and sanitation customers paying the same price,⁹ the result being cross-subsidies between consumers who live close to water sources and those who live farther away and require additional pumping costs. The efficiency improvements that were achieved by the regional utilities in the 2009-13 period have allowed IWA to start reducing the tariff levels since 2014, gradually passing back part of the savings to consumers.

In 2017, the uniform average tariff for potable water and sanitation—calculated as the weighted average of a modeled representative home consumption—was NIS 8.92 (approximately US\$2.4) cubic meter (figure 3.2). On average, only 44 percent is allocated to the water utilities for water distribution and sewage collection, 22 percent goes to Mekorot for bulk water transport and freshwater production, 18 percent covers sewage treatment costs, 16 percent covers desalination costs, and 4.5 percent goes to subsidies.

The national tariff for potable water and sanitation services is based on a two-tier increasing-block structure. The tariff for the first block, corresponding to consumption up to 3.5 cubic meter per capita per month (115 liters per day) is NIS 6.56 (US\$1.8) per cubic meters (2016). The tariff for the second consumption block imposes a 61 percent markup of NIS 10.56 (US\$2.85) per cubic meters.¹⁰ This increasing block tariff structure is designed to encourage demand management while still ensuring that the population has access to a life-line consumption volume at an affordable price. Approximately 75 percent of residential consumption is billed at the lower tariff.

It must be noted that the application of a single national tariff for water and sanitation services poses special challenges for regulation. All households across the country pay the

FIGURE 3.2. Breakdown of Consumer Water Tariff, 2017



Source: IWA website.

same price, yet the actual cost structure of each utility (for water distribution and sewage collection) varies widely. This has been solved by using the bulk water tariff paid by the utilities to Mekorot as an adjustment factor. The share of the national tariff that each utility is allowed to retain from its customers' revenues is determined by IWA based on allowed expenditures (full cost recovery based on performance targets). The difference between the allowed expenditures of each utility and the national water tariff then determine the bulk water tariff billed by Mekorot which is therefore different for each utility, and therefore incorporates significant cross-subsidies between them.

Prices of Irrigation Services Are among the Highest in the World

Irrigation prices in Israel are well above what farmers pay in most other countries around the world. This has ensured that farmers are using water in the most efficient manner, and has promoted the development of modern farming practices for high value crops. The price structure is supported by a financial framework for irrigation which is also based on moving toward full cost recovery, albeit different from WSS services.

Overall, Mekorot provides more than 55 percent of water for agriculture, at prices that are set by the regulator IWA. Water sales from other suppliers, mainly private regional

associations, are billed at price that are also set by IWA and are supposed to reflect their actual production costs. In 2006, the government signed an agreement with farmers' representatives that linked water prices for agriculture to the average Mekorot cost of water supplied to the sector, including agriculture's share of desalinated water.

For irrigation water, tariffs have varied widely depending on the source of water, the region, and the time of the year. Extraction levies vary with the site and season of the water withdrawn. Freshwater prices are between NIS 0.8 (US\$0.22) and NIS 2.6 (US\$0.70) per m³ depending on the supplier and the region. The price of brackish water depends on the salinity and varies from NIS 0.9 (US\$0.24) to NIS 1.6 (US\$0.43) per cubic meter. The price of treated wastewater (NIS 0.8-1.25 (US\$0.22-0.34) per cubic meter) has been set below those of fresh and brackish as an incentive for farmers to use it.

The price of treated wastewater for irrigation is significantly subsidized to encourage farmers to substitute them for fresh water in irrigation. It reflects the cost of conveyance but does not cover treatment and storage costs (which other users pay through cross-subsidies and state subsidies for a portion of capital expenditure).¹¹ The government also subsidizes up to 60 percent of the marginal conveyance costs for reclaimed and brackish water.¹²

The above-mentioned framework for irrigation tariffs is due to change later in 2017, with the approval of new legislation by the national parliament to equalize agriculture water prices across the country, thus ending the prevailing wide variations in water prices between different regions and supply sources. As all Israeli farmers will pay henceforth the same tariff for irrigated water, this will result in wider ranging cross-subsidies between regions and water supply sources.

Notes

1. The 2000 report from the State Comptroller documents in details the waste, neglect, insufficient investments, and high levels of nonrevenue water in Israel's urban water utilities.
2. In special cases, based upon stringent criteria and during the initial organizational period, certain utilities are still awarded state grants to finance construction of sewage treatment facilities.
3. Twenty-seven municipalities serving approximately 4.5 percent of the population remain without a corporatized water utility.
4. The current plan is to have only 11 regional water utilities (water distribution and sewage collection) and seven regional sewerage companies (wastewater treatment).
5. The IWA has published only four audits to date, in 2014 and 2015.
6. As an example of MUA sanctions: one municipal water utility accumulated a debt of over NIS 100 million for not collecting payment for water supplied to local cultural and religious facilities. After other measures were not successful, the MUA intervened to replace the entire utility's management (board of directors and CEO).
7. For instance, Hagihon, which serves approximately 1 million people in Jerusalem and its Western suburbs, has a permanent workforce of 230 employees but also 150 workers under private contractors.
8. In addition to tariffs, setup fees (formerly called building taxes) that developers are required to pay are a major source of funding for infrastructure construction of municipal and regional utilities.
9. There remains a difference in price level and structure between the 56 municipal utilities supply and some local authorities that do not have corporatized utilities and pay a lower tariff supply.

10. The reduced tariff for local authorities without corporatized utilities in 2017 is NIS 4.17 per cubic meter for the first consumption block and NIS 9.21 per cubic meter above that.
11. It is estimated that full wastewater treatment costs are approximately US\$3.15 per cubic meter, of which US\$1.73 is for annuitized capex and US\$1.42 for operational expenditures.
12. The incremental cost of inter-seasonal storage (treated wastewater is produced year-round, but agricultural demand is concentrated in the summer) and conveyance is estimated at US\$0.28 per m³ (approximately 9 percent of total treatment costs).

First Innovation: National Water System to Connect All Water Infrastructure

Faced with the unequal spatial and seasonal variability of rainfall, Israel implemented early on an innovative system of storing and conveying water from its wetter north to the drier center and south—the main agricultural areas. The integrated use of surface and groundwater initially started with the first National Water Carrier, a giant pipeline that Mekorot developed and has operated since 1964 to transport water from the Sea of Galilee to the main population centers in the center and the Negev Desert in the south.

Since then, Mekorot has developed more water conveyance infrastructure, establishing **a national bulk water transmission system that conveys 95 percent of Israel's potable water resources (surface water, groundwater, desalinated water) to the regional providers that supply end-users (domestic, industrial, agriculture)**. This massive water infrastructure includes as many as 3,000 installations and 12,000 kilometers of transmission pipelines controlled by 10 main command centers across the country. The overall level of water losses in the bulk transportation system is reported to stand at 3 percent.

Connecting almost the entire country (with exception of Eilat), this water transmission infrastructure has enabled Israel to regulate the use of natural water resources depending on hydrological conditions, conveying surpluses of water from one resource to store in other resources, in order to meet demand in various regions. The operational flexibility that the National Water System provides has been essential for the strategic combination of water supply based on desalination and reuse with sustainable exploitation of natural water resources.

Two recent infrastructure developments have supported the massive development over the last decade of seawater desalination and wastewater reuse.

- The new National Water Carrier transports desalinated potable water from five plants along the coast (75 percent of all potable water transmitted by Mekorot) and integrates it into the national water system for supply nationwide. The cost of this 10-year development is NIS 5 billion (US\$1.3 billion) –including 100 kilometers of 2.0- to 2.5-meter diameter pipeline. The last segment (the fifth pipeline to Jerusalem) is expected to be completed by 2021.
- The Third Line to the Negev for the supply of reclaimed water supplies effluent that has undergone tertiary treatment (through aquifer recharge after secondary treatment at the Shafdan wastewater treatment plant ([WWTP] near Tel Aviv) for irrigation of all types of crops in the Negev. It was put into operation in 1989.

Developing and ensuring the sustainability of an infrastructure of such magnitude and strategic importance has required a financially solid operator. Mekorot has been able to maintain, so far, a healthy financial situation with total revenues of approximately US\$1 billion per annum and a AAA national rating (Ma'alot Standard & Poor, 2015).

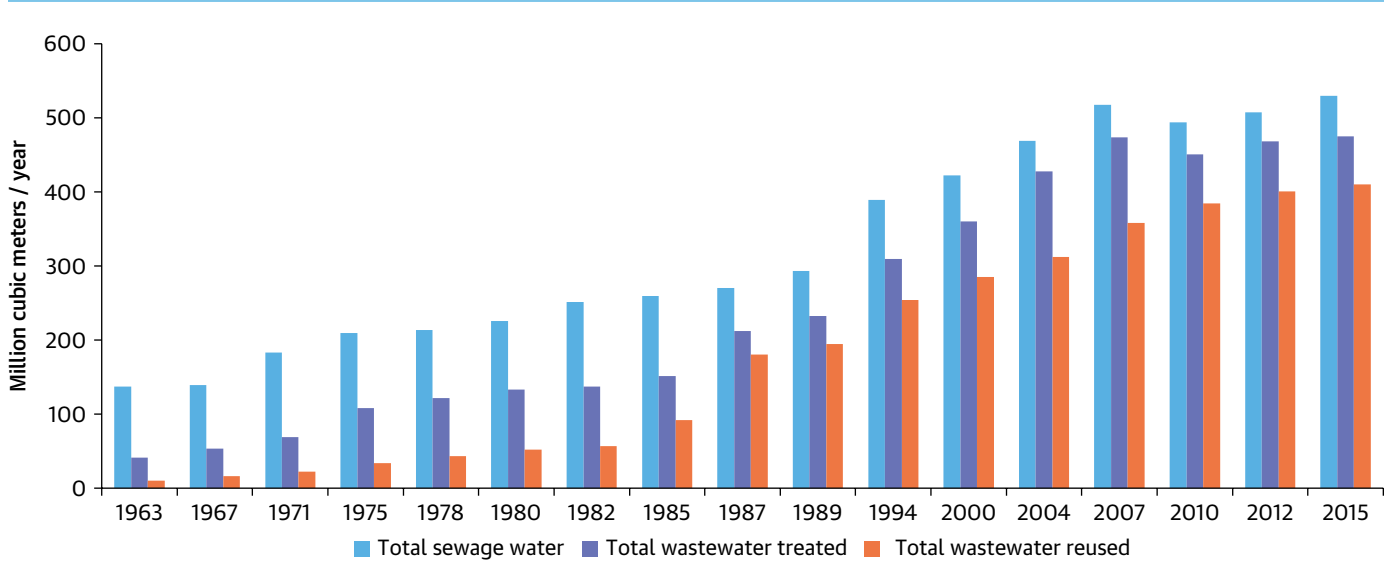
As a regulated public utility owned by the state and operating as a monopoly in a strategic sector, Mekorot has been able to raise as much as NIS 6,661 million (US\$1,800 million) of commercial debt through its balance sheet, with a debt gearing ratio of about 67 percent and a rate of return on equity of only 3.2 percent ((Ma'alot Standard & Poor, 2015). This has allowed Mekorot to raise on average approximately US\$300 million each year for investment over the last decade, at low interest rates through issuance of nonnegotiable bonds to institutional investors (without any explicit government guarantees).

Second Innovation: Large-Scale Reuse of Treated Wastewater for Irrigation

The constraints of water scarcity, combined with a fast-growing population and the decision to stop over-exploiting the aquifers, made it compulsory for Israel to engage in a massive program of reuse of treated wastewater. Gradually, reclaimed wastewater has become a major source of water for farmers, supplying more than 40 percent of the country's needs for irrigation and more than 87 percent of wastewater being reused. As such, Israel is today one of the few countries in the world that has managed to almost entirely close the urban water cycle.¹ In addition to providing a major alternative water source for agriculture, reuse is environmentally less damaging than the traditional methods of disposing of treated sewage into the environment, especially for ensuring the quality of bathing water in coastal tourist resorts.

Figure 4.1 shows how the share of reused treated sewage has risen from approximately 10 percent of 130 million cubic meters of collected wastewater in the early 1960s, to as much as 87 percent of 500 million cubic meters in 2015. It also shows that the reuse of treated

FIGURE 4.1. Collected, Treated, and Used Sewage, 1963-2015



Sources: Israel 2012; Israel Water Authority website.

effluents remained low until the first water crisis that occurred in 1985, which accelerated the reuse of treated sewage effluents.

Many of Israel's WWTPs were built in the 1950s and 1960s under the responsibility of municipalities, and water reuse was limited for many years. They were not well supervised and sometimes poorly managed. The situation started to change in the mid-1980s as large-scale immigration (mostly from the former Soviet Union) resulted in significant population increases. The volume of wastewater increased, several WWTPs experienced serious operational problems, and several outbreaks of infectious diseases were attributed to pollution from wastewater. Political pressure rose to improve wastewater treatment and better monitor the quality of reclaimed water.

Today, the country has 67 large WWTPs (greater than 1,500 cubic meters per day), and the 10 largest WWTPs treat approximately 298.5 million cubic meters per year (56 percent of total volume), most of which were developed by local authorities using traditional construction contracts such as design-build or turnkey. Figure 4.1 lists the major plants.

Apart from the Shafdan plant in Tel Aviv, most WWTPs are only now upgrading to tertiary treatment after the enactment of new wastewater reuse treatment standards in 2010 (box 4.1)—the goal being to allow treated wastewater to be used for all types of agricultural uses, without restrictions.

TABLE 4.1. Major Wastewater Treatment Plants in Israel

WWTP	Treated effluent 2015 1,000 m ³ /year	Population (thousands)	Type of treatment
Shafdan	134,188	2,500	Tertiary
Haifa	37,960	550	Secondary(a)
Jerusalem (Sorek)	33,772	635	Secondary(a)
Ayalon	20,173	358	Secondary(a)
Netanya	15,796	236	Tertiary
Beer Sheva	15,025	256	Secondary(a)
Ashdod	11,544	216	Tertiary
Hadera	10,420	184	Secondary
Kfar Saba - Hod Hasharon	10,145	162	Tertiary
Carmiel	9,508	200	Tertiary

Source: Israel Water Authority 2015.

Note: WWTP = wastewater treatment plant.

(a): Being upgraded to tertiary level treatment.

Since its commissioning in 1989, Israel's flagship project for effluent reuse for agricultural purposes has been the Shafdan WWTP and the Third Line to the Negev pipeline. It supplies treated effluent that has undergone tertiary treatment after secondary biological treatment in the Shafdan WWTP—the largest in Israel, it treats 140 million cubic meters of wastewater per year from Tel Aviv and seven neighboring towns (approximately 2.5 million people) to farmers in the Negev Desert in the South.

BOX 4.1. Introducing New Wastewater Reuse Regulations in 2010-15

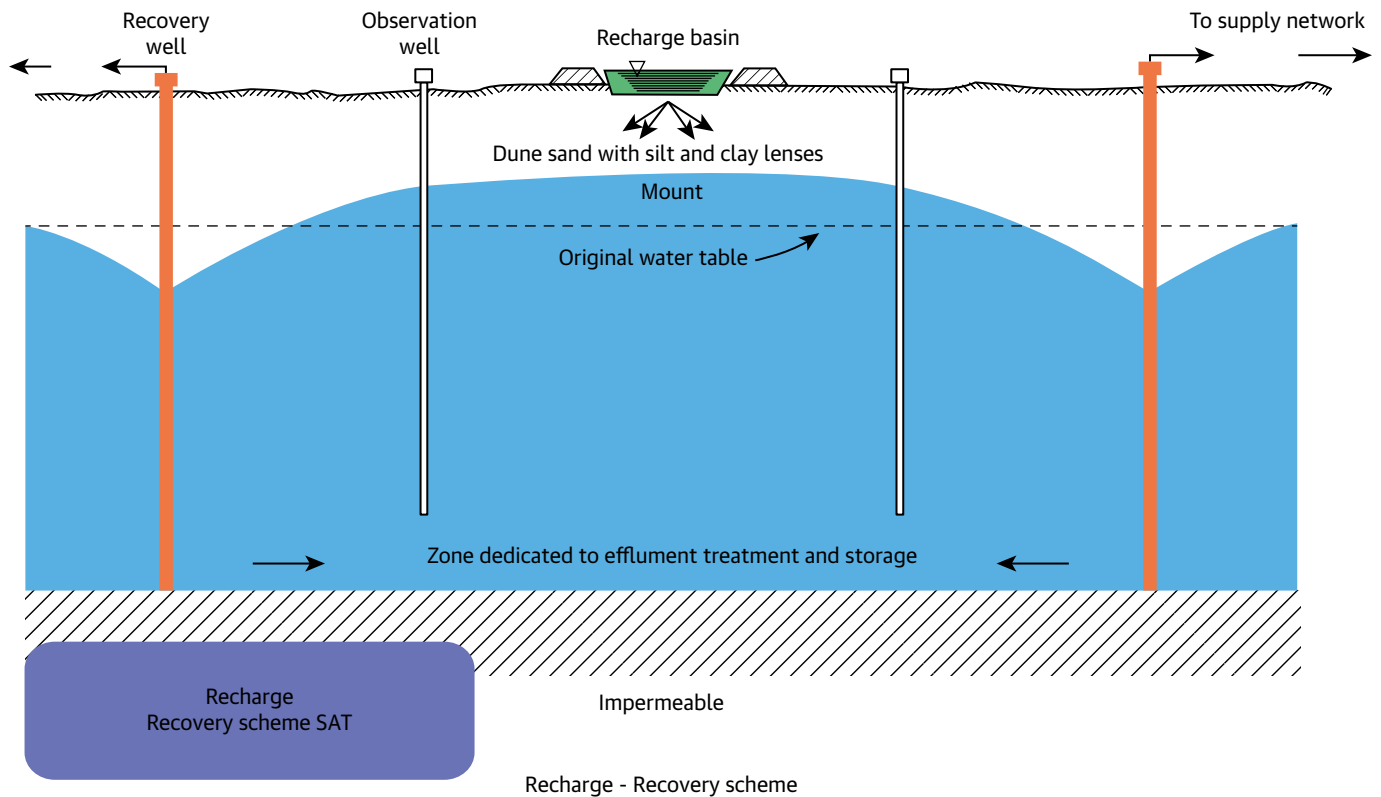
The Inbar Committee was established in 2001 to develop modern standards for quality of effluents in Israel. New regulations were required not only to address the sanitary aspect of reuse but also to prevent pollution of water resources and protect ecosystems and land while allowing wide use of reclaimed water in irrigation.

In January 2010, the Knesset approved the Inbar Committee regulations, which were officially named the Public Health Regulations (Effluent Quality Standards and Rules for Sewage Treatment). The new regulations were gradually introduced between 2010 and 2015 to give stakeholders time to adjust to major changes. Most wastewater in Israel must undergo tertiary treatment, with upgraded requirements for treated wastewater quality to allow a wider range of crops to be irrigated using wastewater while protecting public health (including, for the first time, requirements for salinity and concentrations of toxic metals). Only small WWTP (capacity lower than 5,000 people equivalent) are allowed for secondary treatment based on restricted use. One key feature of the new recycled water regulations is that it divides the country into multiple zones according to geographical and hydrological characteristics and forecasts of the different uses in wastewater, with each sub-region subject to different reuse standards.

The Shafdan WWTP achieves tertiary treatment through an innovative aquifer recharge method called soil aquifer treatment (figure 4.2). Wastewater treated to a secondary level is injected into specially designated recharge basins, where it naturally filtrates through the sand. To avoid contamination, there is complete separation between the reclaimed effluents introduced and the aquifer water, which is achieved by controlling the shape of an artificially created water level depression, which creates a hydrologic trough that prevents the reclaimed water from spreading. The treated water is later collected in peripheral reclamation wells after 6 to 12 months and pumped to the Negev. In dry months, Mekorot abstracts treated water from the aquifer and transports more than 130 million cubic meters to the Negev. The high treatment standards allow for unrestricted irrigation of all types of agricultural crops without any risk to public health.

Favorable pricing policies have been put in place to give farmers a strong incentive to use treated reclaimed wastewater for irrigation instead of freshwater. Wastewater is priced at US\$0.3 per cubic meter for unrestricted irrigation and US\$ 0.25 per cubic for restricted irrigation, less than half the tariff for freshwater for agriculture which stands at \$0.66 per cubic meter. These lower prices of reclaimed wastewater are possible thanks to large investment subsidies (60 percent to 70 percent of the investment, at an estimated total cost of US\$800 million) for wastewater treatment and storage. A large portion of the investment was for building artificial reservoirs to store the reclaimed wastewater (produced year-round

FIGURE 4.2. Shafdan Soil Aquifer Treatment Method, Israel



Source: Mekorot 2016.

but released during the summer growing season): more than 400 reservoirs have been built since the late 1980s. As an additional incentive for farmers to use reclaimed wastewater, they were also initially offered to convert their allocation of fresh water to reclaimed water using a ratio of 1 to 1.2 (20 percent higher allocated water volume).

Third Innovation: Large-Scale Desalination PPPs for Potable Water Independence

In the early 2000s, realizing that Israel faced structural water scarcity, the government made the strategic decision to develop desalination plants on a large scale. The aim was that most of the water supply for municipal consumption would come from desalinated water, to ensure the country's water security.

The parallel discovery of gas reserves offshore (enabling domestic energy supply for the plants) facilitated this strategic choice. **Over the last 15 years, five mega desalination plants based on seawater reverse osmosis (SWRO) were constructed along the Mediterranean Coast with a total capacity of 585 million cubic meter per year (table 4.2). Four of them were developed through public private partnerships (PPPs) with private concessionaires under build-operate-transfer (BOT) and build-operate-own (BOO) schemes.** Desalinated water now supplies

TABLE 4.2. Major Seawater Desalination Plants in Israel

Project	Year of operation	O&M duration	Concessionaires	Business model	Price per m ³ (US\$)	Production capacity (million m ³)	Estimated capex (US\$ billion)
Ashkelon	2005	25 years	IDE (50%) Oaktree (50%)	BOT	0.78	119	0.27
Palmachim	2007	25 years	Derech HaYam (100%)	BOO	0.86	90	0.16
Hadera	2010	25 years	IDE (50%), Shikun U'Binui (50%)	BOT	0.72	127	0.43
Sorek	2013	25 years	IDE (50%), Veolia (50%)	BOT	0.54	150	0.41–0.54
Ashdod	2016	25 years	Mekorot (100%)	BOT	0.65	100	0.41–0.54

Sources: (a) The Israeli Desalination Sector, Internal Research Paper by Variance-Ascola Economic Consulting, Tel Aviv, March 2017; (b) Ministry of Finance of Israel website, <http://www.mof.gov.il/>, Jerusalem, Feb. 2017; (c) Financing Projects of Desalination in Israel, Midroog Credit Rating Agency, Tel Aviv, 2012; (d) Global Issues in Water Policy: Desalination in Israel-Erica Spiritos and Clive Lipchin, Springer Dordrecht Heidelberg New York London, January 2013, (e) The National Inquiry Commission on water management in Israel, Government of Israel, Jerusalem, 2009; (f) Annual Report of Water Authority Activity, Israel Water Authority, Tel Aviv, 2015.

Note: BOO = build-own-operate; BOT = build-operate-transfer; capex = capital expenditure; O&M = operations and maintenance.

85 percent of domestic urban water consumption² and 40 percent of the country's total water consumption.

This move has allowed Israel to position itself as one of the world leaders in seawater desalination. Its large desalination plants have achieved good performance in terms of energy efficiency and price of desalinated water—from US\$0.78 per cubic meter in the first Ashkelon plant down to only US\$0.54 per cubic meter in the more recent Sorek plant (which is also the largest one). The prices for desalinated water are among the lowest in the world and have been key to ensuring the financial viability of the whole system so that desalinated water remains affordable for customers despite applying full cost recovery through tariff. They were achieved through a combination of two main factors: the size and operational mode of the new desalination plants and PPP schemes that were designed to minimize the level of risks for the private sector so as to secure large amounts of private financing on the best possible terms.

The first factor in the low desalinated water price has to do with the inherent cost structure of desalination plants and the fact that the Israeli desalination program took advantage of it by relying on a few large desalination plants that are mostly operated 24 hours per day, seven days per week. These operations made it possible to achieve significant economies of scale and absorb large fixed costs. It is important to highlight that the specificities of Israel's integrated water management made this possible:

- First, the existence of a national water carrier made it possible to restrict the number of new desalination plants to a few large ones, allowing desalinated water to be delivered

from just a few production plants to all cities and towns across the country. The resulting economies of scale translate into lower fixed costs per unit capacity.

- Second, the strategic decision to use desalinated water as “base load” to meet municipal demand, using the aquifer as a strategic reservoir to meet peak demand, translated into the plants being operated continuously (24 hours per day, seven days per week throughout the year) and close to full capacity. This is the opposite of the strategy of many other countries, which use desalinated water mostly to meet peak demand, the result being that, in Israel, fixed costs are absorbed through a larger production volume for a given plant capacity, resulting in a lower average cost per cubic meter.

The second major factor for low prices has been the adoption of a PPP approach through the BOT scheme.³ The government’s decision not to finance construction of these large-scale plants through the national budget and **recognition that the plants involved complex technologies and that the private sector would construct and operate these facilities more efficiently** than public sector entities drove adoption of the PPP model. It represented a major strategic move in a sector that had been historically dominated by government financing and public management.⁴ The Water Desalination Administration was established under the IWA to handle all aspects of desalination PPPs.

Adopting the BOT approach for large-scale seawater desalination—rather than a traditional construction contract approach—brought major benefits. Under such schemes, the private sector has strong incentives to build a plant that minimizes total costs (operating and capital) over the life of the plant, with flexibility (at its own risk) to make technological choices.⁵ In addition, the concessionaire bears all cost overruns due to delays and change orders—as opposed to the widespread practice under construction contracts of trying to charge more capex during construction to the public client than the price set under the tender process. Finally, the private concessionaire takes all operations and maintenance (O&M) risks during the operational period of the plant, with swift penalties incurred if the plant does not deliver the contracted amount and quality of water contracted—fostering, in the end, the sustainability and efficiency of the new plants.

In addition to the inherent benefits of the BOT approach, the specific design of the Israeli desalination PPPs included additional crucial elements that allowed the private sector to make more aggressive financial offers with rather low prices for desalinated water, thanks to the introduction of some innovative contractual features with significant financial guarantees provided by the public party. These clearly reflect the fact that the government wanted to reduce the level of risks for the private investors (compared to what has been the standard practice for desalination BOTs in other countries) in order to obtain better terms in terms of price of desalinated water; for example:

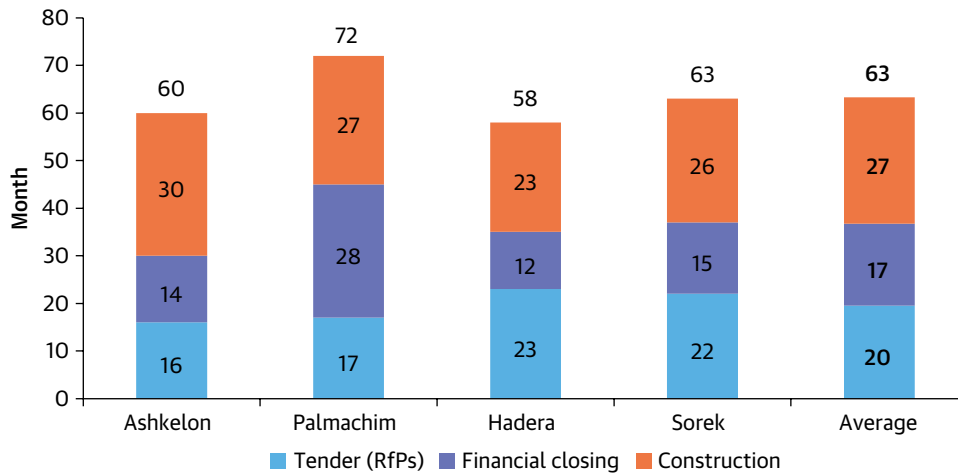
- **Interest change risk borne by the government:** The concessionaires have been provided with full protection against changes in the market base interest rate, allowing them to use cheaper variable short-term debt to finance the construction phase and refinance later to

long-term debt over the operational period. The PPPs were therefore able to take advantage of historically low interest rates without having to factor in the risk of increasing long-term interest rates. This also allowed private financing to be structured with a high level of gearing (senior debt of about 80 percent and equity at just 20 percent)—further reducing the average cost of capital.

- Enhanced indexation mechanism with all fluctuation risks borne by the government: the tenders have typically included a hedging mechanism that allows each bidder to include in its financial proposal its own indexation formula based on a predefined selection of market indices—as opposed to imposing the same pre-established indexation formula to all bidders. This hedging mechanism allowed for fine-tuning to the specific cost structure of each bidder and was more extensive than typically offered in a BOT contract.
- Optimizing the fixed payment under the “take-or-pay” guarantee: as is typical with BOTs, a portion of the remuneration of the concessionaire is made through a guaranteed fixed payment in exchange for a guaranteed volume of water available under a “take-or-pay” guarantee. To facilitate access to nonrecourse private debt, the fixed payment should cover all fixed costs, including fixed operational costs and debt service. Although the proportion of fixed to variable payment is often established ex ante in typical BOT tender documents, in Israel, a formula was introduced in the tender to allow bidders to optimize the proportion of fixed to variable fees based on their own cost structure, allowing each one to propose its own optimal mix.⁶
- Cost of land borne by the government: this was a significant factor given the high cost of land in Israel’s coastal areas. Only in the case of the Palmachim desalination plant (which was a BOO) had the land to be purchased by the private operator—an element that partly explains why this plant has the highest price per cubic meter.

Another crucial factor for the low price of desalinated water is the control of energy costs, which typically represents between half to two-third of the price of desalinated water. Most Israeli desalination plants have achieved strong performance in energy efficiency (e.g. 3.6 kilowatt-hours per cubic meter for Sorek), and energy costs in Israel are relatively low compared to many other countries (Israel uses gas-fired power plants supplied by its own gas fields in the Mediterranean).⁷ Desalination plants do not benefit from any preferential electrical prices from the grid, and each concessionaire must make arrangements to buy electricity either from the national grid (based on government regulated tariff) or IPPs (with a negotiated price). The tariff indexation formula takes into account the evolution of the average domestic electricity price per kilowatt hour from the grid as a pass-through. In some BOT projects, bidders were given the option to build gas-based power plants to reduce energy supply cost under a parallel independent power producer contract.⁸ The recent national program to develop IPPs on a large scale may provide opportunities to further reduce the price of desalinated water.

FIGURE 4.3. Time for Tendering and Construction of Build-Operate-Transfer Desalination Plants, Israel



Source: Variance-Ascola Economic Consulting 2017.

The last large seawater desalination plant in Ashdod, which started operation in 2016, is an outlier because the BOT contract was signed between Mekorot and the state. In fact, it provides a strong counter-example of the benefits of the PPP approach—and of what can happen when construction and O&M risks are not fully passed to a private party. Although the plant was built “nominally” as a BOT scheme, in practice the contract was signed between the state and a subsidiary of Mekorot as concessionaire.

This created an obvious conflict of interest that eliminated the inherent incentives of a PPP. While the Mekorot subsidiary did sign a turnkey contract with a private consortium for the construction of the plant, the transfer of risk to an outside private partner that normally take place under a BOT was not fully effective. This project has experienced major construction delays, cost overruns, and operational problems.

One last, important lesson from the Israeli seawater desalination experience is that careful design and tendering of BOT contracts takes time (figure 4.3). On average, the tender process for the four desalination BOTs with private concessionaires (from request for proposal issuance to award) took 20 months, to which must be added one year for the prequalification phase and 17 months for the financial closing (securing nonrecourse financing), which adds to about 4 years for the whole contracting and financial closing process before construction can start. This is much more than actual construction, which took 2.3 years on average—less than for many other large desalination plants built in other countries under the traditional design-build or turnkey approach—because private concessionaires had strong contractual incentives to avoid construction delays.

Fourth Innovation: Using Aquifers as Reservoirs

The first integrated supply scheme based on the national water system operated by Mekorot since the 1960s relied on the storage capacity of the Sea of Galilee and the Coastal and Western Mountain aquifers. Mekorot has added major infrastructure since then to connect and rationalize the operation of aquifers.

One of the most remarkable innovations of Israel water management is that aquifers have been gradually switched from being overexploited resources to becoming major storage reservoirs. The existence of the National Water Carrier and the large-scale use

of seawater desalination and reclaimed wastewater as alternative nonconventional water sources made this possible. The interconnected nature of the National Water Carrier affords the opportunity to optimize the operations of regional water schemes through over-pumping from local aquifers in dry years or artificial recharges in wetter years. **The aquifers therefore serve as swing suppliers (i.e., buffers) while also minimizing evaporation losses** that would have occurred had this water been stored in open reservoirs.

The hydraulic advantages of this integrated scheme are obvious in terms of higher reliability and lower losses to evaporation, although management of aquifers as reservoirs is delicate. It relies on an extensive network of piezometers, and solid monitoring of both supplies and the various types of demand (including to avoid illegal abstraction). Each aquifer has specific operational procedures and constraints, for instance, in the aquifer linked to the Sea of Galilee, the need to keep the variation level of the lake within a 4-meter range directs pumping, while in the Coastal aquifer, the need to protect against saline intrusion of seawater constrains pumping. The main operating approach for monitoring aquifers is described in the box 4.2.

BOX 4.2. Groundwater Monitoring Practices

For monitoring of the aquifers, Israel implements the concept of "reporting cells" for generating representative hydrological and hydro chemical data, with the following methodology:

- The Hydrological Service divides each aquifer into cells with similar hydrogeological properties and identifies representative wells in each reporting cell.
- The regional hydrogeologist defines the monitoring needs and formulates a list of wells and springs to be monitored and the frequency of the monitoring.
- Wells are divided to pumping wells, monitoring wells and specific purpose (e.g. industrial areas, gasoline stations) monitoring wells.
- Monitoring requirements are translated into work plan of the Hydrometric Unit of the Hydrological Service.
- Groundwater levels are measured in 1,500 wells (pumping and monitoring wells) at a frequency varying from monthly to annually. Spring and pumping wells discharge is measured monthly, with more than 800 samplings taken from pumping wells and springs. EC (electrical conductivity) profiles are performed on monitoring wells.
- Measurements are uploaded to the central database.
- Regional hydrologist reviews the data and if needed request repeat measurements.

Fifth Innovation: Interception of Surface Water Run-Off and Recharge

The pattern of short rainstorms coupled with a landscape that often lacks a mitigating cover of vegetation produces flash floods that, unless captured, are lost to the desert, the Mediterranean, or the Dead Sea. Early on, Israel invested in infrastructure to capture these flash floods.

Typically, such infrastructure combines retention walls and small dams that could capture and store water that would infiltrate into the underlying aquifers, from which they could subsequently be recovered. The amount that can be recharged varies with rainfall pattern and strength, reaching a maximum of 62 million cubic meters in 1980 and a minimum of 4 million cubic meters in 1990. The average recharge achieved in addition to natural replenishment has been estimated to be **8 percent. Although small compared to the massive contribution of the desalination and reuse programs, this infrastructure for flood interception underlines the efforts that Israel has made to capture all available water.**

Although it is not part sensu stricto of the water sector strategy, the national program of afforestation, in areas where forests have been absent in historical memory, has also helped mitigate flash floods and improved rainwater infiltration into the aquifers as one of its benefits. Israel is not the only country to have resorted to expanding tree coverage in order to reduce runoff, but it did so early on and on a large scale. The forested share of Israel rose from 2 percent in 1948 to more than 8 percent in 2014. An additional benefit has been sequestration of carbon to combat global warming and for esthetic and recreational benefits. The afforestation program in the arid Negev is noteworthy because it has revived old techniques for harvesting rainwater that the Nabatean people practiced from the fourth century before the Common Era until the Roman Empire conquered them. The revived techniques focus on areas with less than 100 millimeters of annual rainfall and where groves of 0.2 to 0.6 hectares thrive from water collected from watersheds that are 10 to 100 times as large as cultivated areas.⁹

Sixth Innovation: Promoting Crop Selectivity and Importation of Virtual Water

The State of Israel was originally established with strong reliance on agriculture, based on the well-known kibbutz model of collective farming, but as early as in the early 1960s, Israel had to address a growing scarcity of freshwater for irrigation of food crops, forcing national planners to reconsider how much food should be produced domestically and how much should be imported. Because there was not enough water to meet the growing demands, the government was faced early on with a fundamental trade-off of having to choose between water security and food security.

A major strategic decision was then made to increase food imports and reduce the country's reliance on domestic crops, effectively compensating for water scarcity by the massive import of virtual water imbedded in imported foods. The fact that it coincided with a time when international food prices were falling and imported food supplies were readily

available facilitated this decision. In addition, Israel had started to diversify its economy and could afford to import most of its food.

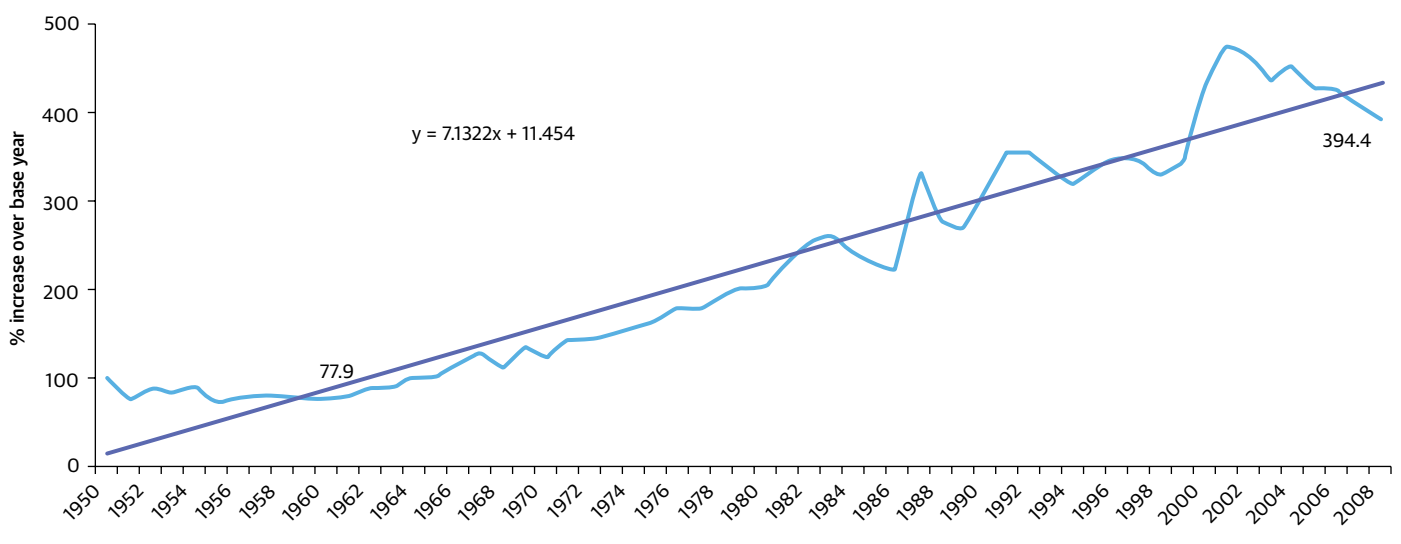
Greater selectivity of food crops grown for export paralleled the displacement of food crops that could be more cheaply imported than grown domestically. Instead of competing with countries that had cheaper, more abundant water and lower labor costs (e.g., in the production of lower priced oranges or cotton), more emphasis was placed on growing counterseasonal vegetables that could reach developed markets in the winter and fetch higher prices. The growth of counterseasonal crops is now largely done in green houses to reduce evapotranspiration.

Seventh Innovation: Efficient Irrigation Technologies

Maintaining a competitive agricultural sector has always been a national priority for Israel. Given the situation of extreme water scarcity and the constant emphasis on reducing allocation of water to farmers, this has been entirely contingent on putting in place efficient irrigation practices and farmers focusing on high-value crops so that they could afford to invest in modern irrigation techniques. The widespread development of efficient irrigation technologies, together with growing access to treated wastewater, have made it possible for the agricultural sector to continue to irrigate despite a sharp reduction in the amount of available fresh water.

Even though water quantity has not increased over the past four decades, the output of crops per unit of water has grown sevenfold (due to improved irrigation efficiency and intensification of farming practices). **Thanks to ever-increasing productivity of water use, the value of agricultural production has continued to rise in spite of the decreasing allocation of water to farmers** (figure 4.4). The efficiency of irrigation systems has been a major factor

FIGURE 4.4. Water Use Productivity, 1950-2008



Source: IWA 2015.

making possible the reduction in average water supply to agricultural land, down from 7,000 m³/ha in 1990 to 5,000 m³/ha in 2000.

Israeli companies were pioneers in the early 1950s in the development of efficient low-volume irrigation technologies such as drip irrigation and mini sprinklers. These technologies now include moisture-sensitive automated drips, automatic vales and sprinklers, low discharge sprayers, mini-sprinklers and compensated drippers that are computer-controlled. These technologies enabled the proper volume of water with the right concentration of fertilizers to be supplied to the crops' roots and were combined with control systems to ensure optimal application and timing. These systems can work efficiently with all types of water resources, including treated wastewater, and in different environmental regions. The systems work under low pressure (1-2 bars), and each dripper supplies only a few liters per hour. Drip irrigation enables 90 percent efficiency in water use as defined by the Food and Agriculture Organization (versus 75 percent for sprinklers and less than 60 percent for surface irrigation). The successful development of low-consumption irrigation technologies has allowed the development of a thriving irrigation industry in Israel. Approximately 80 percent of the irrigation equipment made in the country is exported.

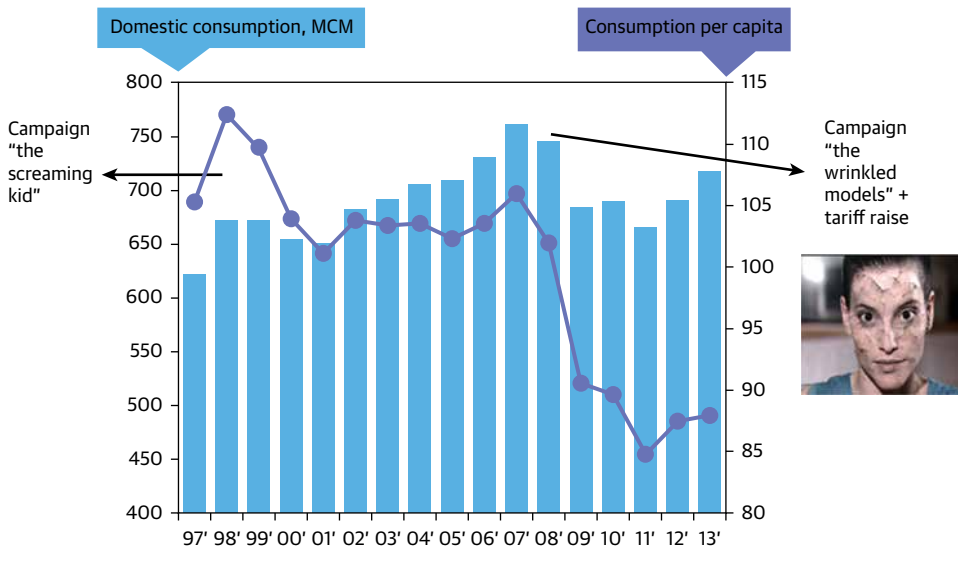
An important element in the adoption by farmers of efficient irrigation technologies has been the support that the regional irrigation companies and the Agricultural Extension Service of Israel have provided (under the auspices of the Ministry of Agriculture and Rural Development). Both have considerable planning and operational experience.

Eighth Innovation: Promoting Demand Management and Public Awareness

Demand management has always been an important component of Israel's efforts to achieve water security. In addition to strong enforcement of water rights for farmers and industrial users, significant financial incentives have also been put in place. The higher price of water for irrigation than in most other countries played an obvious role in encouraging farmers to improve their efficiency of water use. In the urban utility sector, the two-tier tariff structure for potable water and sanitation services provides incentives for customers to conserve water, with the first (reduced) consumption block set at 115 liters per capita per day since 2010.¹⁰

Effort on demand management was expanded in 2008 when the government initiated a major water conservation campaign, which proved quite successful. It promoted the installation of water-saving devices (bathrooms, toilets, kitchens), reaching 55 percent of all households and all public buildings and government offices. In parallel, a media awareness campaign was implemented over an 18-month period from 2008 to 2010 to educate consumers about water use. The main motto of the campaign was: "the basis for change is public acceptance," and it was structured around a combination of education and media activities, carefully targeted to the various segments of the population. Clear targets and objectives

FIGURE 4.5. Water Consumption in Israel, 1997-2013



Source: Zaide 2017.

Note: Left axis: cubic meters per capita per year; right axis: liters per capita per day.

were set for the campaign, and its implementation was accompanied by ongoing polls and focus groups to monitor the impact, allowing changes and adaptations to achieve optimal results.

The 2008 public awareness campaign has left a strong impact on the public. It used models with wrinkling faces as visual to symbolize the consequence of lacking water, and proved to be a very cost efficient initiative. While it represented a considerable expenditure—its total cost was approximately US\$7.5 million—this proved a valuable investment. Consumers reduced their consumption by

76 million cubic meters, and it was estimated that the campaign freed up water for alternative uses at a cost of only US\$0.10 per cubic meter, or a fraction of alternative supplies.

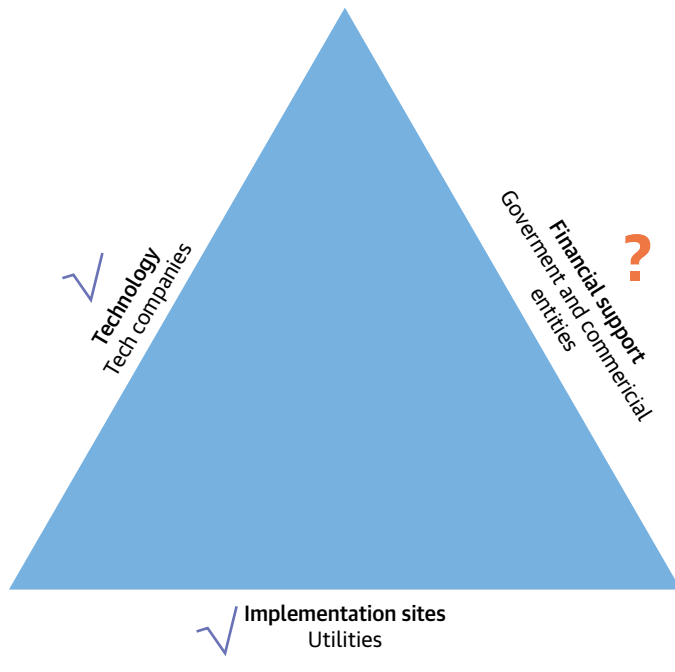
These steps, together with the near doubling of water tariffs that also took place in 2008-10, proved effective. Thus, Israel reduced urban water consumption per capita by 24 percent, to stand now at less than 100 liters per capita for domestic customers. It is estimated that 8 percent of this reduction was due to educational activities and 16 percent to higher water tariffs and installation of water-saving devices. Figure 4.5 illustrates the changes in water consumption in Israel from 1997 to 2013.

Ninth Innovation: Creating a Supporting Environment for Water Innovation

The water sector is not known around the world for being particularly innovative. This reflects the facts that it is about largely basic infrastructure, and that the public management model for water services is not particularly conducive to innovation. There are good reasons for this. This is a highly regulated, monopoly sector. Urban water utilities operate essential infrastructure and provide a critical service, so utility managers tend to be conservative and are not risk takers. They prefer to use proven systems and methodologies and not risking endangering a safe water supply in their city to try some new gadget. The statement “*if it’s not broken, why fix it?*” is often heard. The bottom line is that public managers are not supposed to take risks, and public water utilities do not normally seek profits.

This makes the challenge of developing water innovations particularly daunting. The “valley of death” concept—coined in the general venture capital investment market, and

FIGURE 4.6. Triangle of Water Technology Innovation



Source: Yeres 2016.

represents the long time between when an R&D department comes up with a new invention and when it starts being commercialized—is especially wide in the water sector. The length of time needed to pilot water-related technology is long because the technology should be tested over the different times, stresses, and seasons that characterize water networks. Throughout this period, the entrepreneur is addressing technology and financial challenges and has a long way to go before achieving revenues.

In this context, it is noteworthy that Israel has made a special effort to promote innovations in the water sector, with the establishment of a unique industry-utility-university ecosystem to support the development of innovative water technologies (figure 4.6).

This can be conceptualized through the “triangle of innovation,” which brings together private entrepreneurs, water utilities, and the government, each with a different contribution to ensure that water innovation can be developed and be brought to market:

- Private entrepreneurs bring new ideas and technologies: Israeli entrepreneurs have fostered many technical water innovations (e.g., drip irrigation). In recent years, with the advent of information and communications technologies, many high-technology concepts have penetrated the water sector, such as algorithm-based leak detection and cloud-based fixed leak detection. These technologies germinate in academia, private companies, or individual entrepreneurs.
- Water utilities provide trial and implementation sites: as described above, **making it possible for water entrepreneurs to work with utilities is challenging and critical. One aspect of the Israeli water sector is that leading utilities such as Mekorot and Hagihon have established technology collaboration frameworks with the private sector**, which allows entrepreneurs to test their innovations in “real size,” gaining feedback to improve systems and optimize them before they go to market. This also allows them to gain references and enables potential customers (and investors) to see actual technology performance. The benefit for the utilities is that they can be at the forefront of performance improvement.
- Government brings financial support: because water utilities are regulated monopolies, they cannot be expected to engage in risky venture investments, even if they are willing to try innovative technologies. It is here that the financial support side comes into play. Realizing the importance of innovation development, the Government of Israel has for years supported innovation at the academic, start-up, and commercial levels. Several governmental agencies manage programs to support water innovation, including the

Office of Chief Scientist under the Ministry of Economy (NIS 254 million 2007-15), the IWA (NIS 94 million since 2008), and the Chief Scientist of the Ministry of Energy and Water (NIS 20 million per year covering the R&D and pilot stages). Partnerships are also in place with EU and US research programs.

The result of this proactive policy to support innovations in the water sector has brought benefits that are twofold. First, water innovations have played a major role in allowing Israel to achieve water scarcity. Second, they generate a sizeable source of national income through exportations of equipment, licenses, and services.

Notes

1. Other noteworthy countries are Singapore (with full reuse but on a much smaller scale), and Cyprus where about 70 percent of treated wastewater is reused in agriculture.
2. In addition to the five large seawater desalination plants, there are many brackish water desalination plants, for a total capacity of 78 million cubic meters per year. Mekorot or municipal utilities operate them, and apart from the one in Eilat (20 million cubic meters per year), they are small and spread throughout the country.
3. Under a BOT contract, the public sector gives a private entity a concession to finance, construct, and operate the new plant and pays through a fee that covers O&M and the cost of the investment. At the end of the concession period, the project passes to the concession giver. A BOO project is similar to a BOT, with one major difference—ownership of the project remains with the private entity (which also means that the cost of land has to be factored into the price). Unless otherwise specified, the report uses the terminology BOT generically to cover both BOT and BOO.
4. Because adopting a PPP approach required agreement of the Minister of Finance and the Minister of Infrastructure, it is thought that the fact that it took place when the same person happened to be temporarily filling both positions facilitated this sensitive decision.
5. In the case of the Sorek plant, this allowed energy efficiency of 3.6 kWh per m³ was achieved through the use of innovative 16” instead of 8” reverse osmosis membranes, among other things. Membranes were installed vertically to reduce surface requirements and the cost of acquiring land.
6. The formula has an extra score for a lower fixed payment, up to a threshold. In the case of the Sorek BOT, the proportion between fixed and variable payment is about 50-50.
7. The average domestic electricity price from the grid stood at €0.11 per kilowatt-hour in May 2017. In practice the unit cost of kilowatt-hour paid by the private concessionaire is lower, either because they take advantage of high-voltage-off-peak tariffs, or are supplied through IPPs.
8. This was the case for Ashkelon, Sorek, and Ashdod. So far, Gas-fueled plants under IPP are in operation under an IPP only in Ashkelon (80 megawatts), and one is under construction for Sorek.
9. This type of afforestation is called *savanization* and differs from the larger programs in which the Aleppo pine was the tree of choice. The latter program has sometimes been criticized, in part because of the risks that such a monoculture entails and susceptibility to pests of the Aleppo pine.
10. Before the 2010 tariff reform, there was a three-block water tariff (first 8 cubic meters, next 7 cubic meters and then every additional cubic meters) and a separate sewerage tariff.

Chapter 5

Key Lessons Learned from the Israeli Water Sector

After many years of reforms and massive investment, Israel has now achieved water supply security despite being one of the most water-stressed countries in the world. Thanks to the massive development of non-conventional water sources—namely irrigation and treated wastewater—the water production capacity of Israel now exceeds demand. Even irrigation water is not constrained any more by volume but only by the capacity of farmers to pay its price. **Considering that a growing number of countries around the world are facing challenging conditions of increased water scarcity, the “Israel water story” holds many potentially valuable lessons.** From the innovations outlined in this report, nine key lessons can be identified and are outlined below:

First Lesson Learned: probably the first lesson is that **public awareness of the value of water, together with demand management and moving toward pricing water at its true cost,** are crucial for efficient water management under scarcity. Most Israelis understand the value of water and the need to use it wisely—a behavior that was reinforced by aggressive communication campaigns. This has not only allowed Israel to implement demand management policies, but also has made tough reforms in water management politically more acceptable. If water is a scarce and valuable resource it needs to be priced accordingly (while also remaining affordable for all) to discourage wasteful usage of a scarce and precious resource. Increasing water prices sharply in 2009 in conjunction with a major awareness campaign proved crucial for reducing domestic per capita consumption.

Second Lesson Learned: strong control and enforcement of water allocation has proved crucial in a context of extreme water scarcity, with proactive management of aquifers viewed as a valuable water resources management tools. Pricing incentives are not enough. This was initiated by the Water Law of 1959 that brought water under public property and state control and gave state organizations the full authority to regulate and allocate consumption for alternative uses. Control of consumption has been successful because of strong enforcement with sanctions, and this has received wide political support because a sustainable water balance in quantity and quality has been equated with national security. Such control on abstractions proved essential as the country embarked on the development of alternative nonconventional water resources (desalination and wastewater reuse): the switch from groundwater supply to nonconventional waters would not have been effective without a heavy-handed control of abstraction permits in parallel.

Third Lesson Learned: comprehensive, probabilistic, and timely data are crucial for efficient integrated management of water under scarcity conditions. To this end, the Hydrological Services Unit within the Israel Water Authority (IWA) has accumulated considerable

experience in collecting, analyzing, and modeling water data and is informed on the effects of global warming on Israel's natural water resources. The IWA is able to allocate and manage its natural, recycled, and manufactured water to remain within the maximum and minimum upper and lower red levels. Continual vigilance and control of natural resources are required to provide sufficient volumes of operational water to compensate for seasonal and annual fluctuations in effective rainwater and variation in the demand for water. On the operating side, the fact that one bulk water entity, Mekorot, is dominant has facilitated collection, analysis, and interpretation of water sector data—especially for the complex integrated management of aquifers.

Fourth Lesson Learned: a national conveyance water system can help optimize water management under conditions of extreme scarcity, Israel's relatively small size made it possible to create a nationwide water conveyance infrastructure that effectively connects 95 percent of the natural, marginal brackish, recycled effluent, and desalinated water resources. This integrated water infrastructure proved essential to bringing efficiency, promoting alternative water resources, and being able to mitigate hydrological variations. It does not provide for more water, but allows Israel to better match demand and supply in order to avoid local shortages. While such large and costly pipeline infrastructure may not be justified for all countries, in the case of Israel it was designed as part of a well-thought out plan for integrated water resources management, and developed so as to ensure its long-term financial sustainability.

Fifth Lesson Learned: investing massively in new water infrastructure is not enough; this needs to be done in a financially sustainable manner through appropriate institutional reforms. This includes putting in place a clear separation of roles between policy setting, regulation and planning, and operation of infrastructure. In the specific case of Israel, the vesting of all planning and regulatory powers of the water sector (water supply and wastewater, irrigation, water resources management) under a single autonomous agency (IWA) proved a beneficial decision. With the IWA's establishment in 2007, the water sector started operating within the constraints of a budget that reflected the real costs of the whole system, separating planning and management of the sector from the political process. The IWA's sound regulation, pushing for efficiency at the service provider level (water utilities, Mekorot, or build-operate-transfer [BOT] concessionaires), ultimately made it possible for the whole system to become financially viable and sustainable, and allowed for the gradual decoupling of the water sector from the national budget.

Sixth Lesson Learned: although the level of government guarantee for desalination BOT may not be replicable, it allowed Israel to achieve remarkably low prices of desalinated water. **The success of the BOT schemes for Israel's four major seawater reverse osmosis (SWRO) desalination plants with private operators has been contingent on the careful design of the public private partnership (PPP) contracts,** with several features introduced to reduce the risks for

private investors while allowing for the introduction of technological improvements to reduce the prices of desalinated water. This allowed prices to be obtained for desalinated water that are among the lowest in the world (in the case of the Sorek BOT project), in turn making large-scale access to desalination financially viable under a financial framework based on full cost recovery through tariffs. The resource constraint has been removed since the supply of seawater for desalination is limitless and the development of natural gas fields in the economic zone of Israel in the eastern Mediterranean provides a long-term economical supply of energy. The more recent case of the desalination plant in Ashdod, nominally a BOT but where state company Mekorot was both off-taker and concessionaire and which experienced multiple delays, cost overruns and difficulties, provides a strong counter-example of the benefits of the PPP approach.

Seventh Lesson Learned: while sustainable water management under scarcity conditions makes reuse of wastewater a must, this is also costly and cannot be realistically implemented without significant public subsidies. This has proven true even in the case of Israel, where farmers have achieved high levels of efficiency, focusing on high-value crops, and are able to pay significant prices for reclaimed water. Massive investments are needed not just to achieve tertiary level of wastewater treatment, but also to convey and store reclaimed water. Wastewater reuse is the only part in the Israeli water cycle in which full cost recovery through tariffs has not been achieved, and the sector still requires substantial investment subsidies.

Eight Lesson Learned: corporatization and aggregation of water and sanitation services is a long process that requires sound regulation and rather heavy-handed supervision to be successful. While the reform of municipal water and sanitation services started in 2001, the regionalization of utilities has been a gradual process that is still not completed 15 years later. And the performance of the newly ring-fenced utilities started to improve only after 2009, when the IWA started to regulate them, putting in place a mix of financial incentives through tariffs with enforcement of sanctions for the worst performers.

Ninth Lesson Learned: even in a country with strong capacity and where huge efforts have been put on water reforms, this has been a long and challenging process, and there are still areas for improvements. Also, mistakes can be made. This is unavoidable and does not diminish the value of the innovations previously outlined, yet it is important to highlight that not all of the Israeli water experiences can be qualified as best practice. One major weakness is the adoption of a single national water tariff—first for potable water supply and since 2017 also for irrigated water—which reduces economic incentives for users since it does not allow the price of water to reflect true local costs of water. The regionalization of municipal utilities has proved a rather slow process. The wide-scale recourse to seawater desalination generates a significant carbon footprint. The last desalination project in Ashdod, in which Mekorot ended up being both off-taker and contractor in a departure from the henceforth successful PPP approach, and which suffered multiple set-backs, is questionable.



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