Water use efficiency and economic approach

National study Israel

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Introduction

1. National Goals in the Context of Plan Bleu

Limited water resources that characterize the climatic conditions in the State of Israel have necessitated innovative government plans, initiatives, and policy-regulations for efficient water use in all sectors (domestic, agriculture, industry). Israel's national goal is to sustainably supply water to all consumers according to approved requirements for quality, quantity, efficiency, and economic reliability. Within the context of this national goal, the Plan Bleu's objectives have been addressed: improving water-use efficiency, limiting wastage of potable water, and limiting water losses (e.g. through leaky pipes). Achievements in these areas have been ongoing since the creation of the State of Israel, and they continue to be improved upon. Methods of excelling in these areas have been, and continue to be developed and refined in all sectors: domestic (including tourism), agricultural, and industrial.

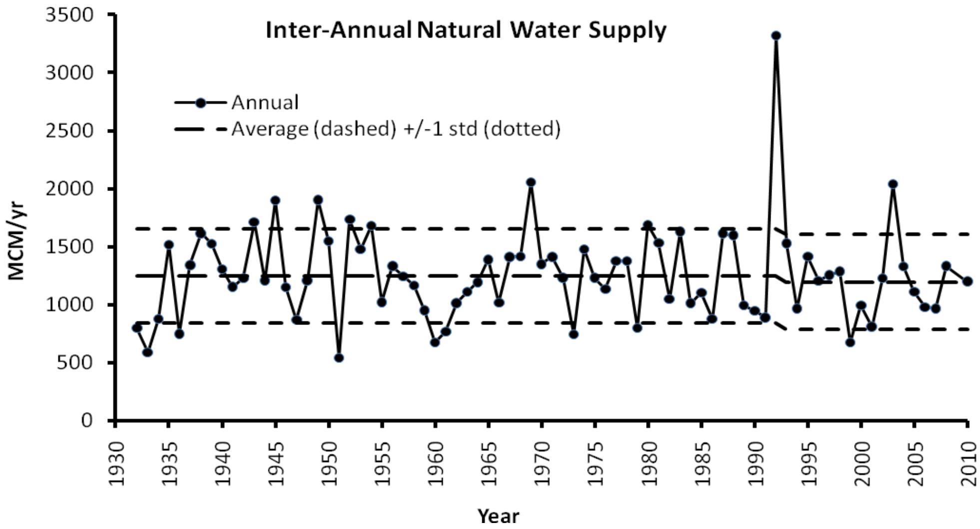
2. Overview of Existing and Future Water Provisions

The State of Israel is characterized by desert and semi-desert climatic conditions. Israel relies on the approximately 4 sporadically rainy months for the annual replenishment of all of the nation's natural water sources. This water is largely contained within three main aquifers, and the Sea of Galilee watershed.

The average annual 'natural supply' of potable[1] water (mainly precipitation) that replenishes Israel's natural water bodies is 1249 million cubic meters (MCM/yr). However, fluctuations in the extent of rainfall per year are typically very extreme, with series of consecutive drought years occurring frequently (Figure 1). Since 1993, the average natural supply was 1155 MCM/yr (9% below the long-term average of 1249 MCM/yr).

The sequences of dry years that have occurred in recent decades (Figure 1) have accelerated the cumulative loss and degradation in the natural water supplies. This draught status, combined with increasing demands from a growing population (Figure 2), has resulted in depletion from all natural water sources. Thus, there is a growing urgency for increased water conservation and use-efficiency, and the development of supplemental sources.

Figure 1 - Annual natural water supply entering Israel's natural water reserves via precipitation from 1932 to 2010, in millions of cubic meters (MCM/yr)

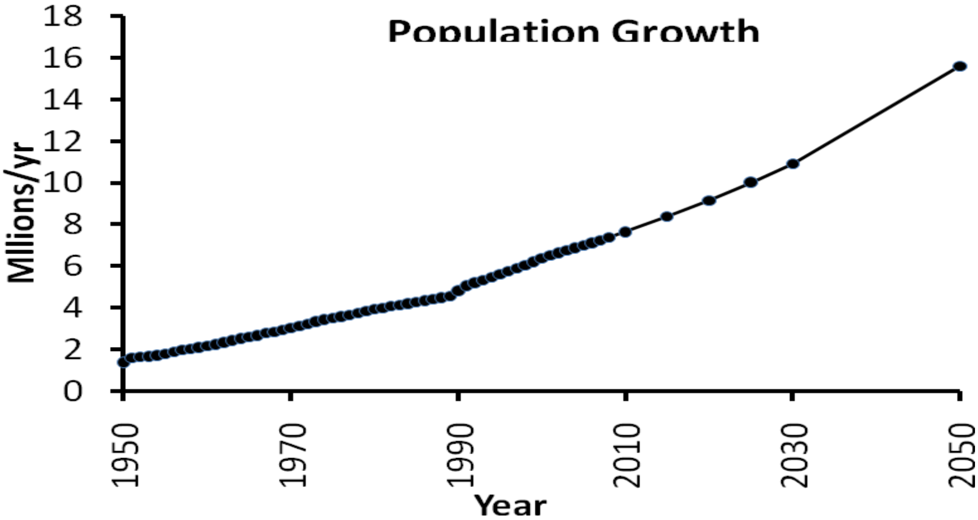


Source: Water Authority Planning Department

[1] Potable water means drinkable water (that meets Ministry of Health standards). This is the only type of water provided to the domestic (and tourism) sector. However, potable water is also used to some extent in the other (agricultural and industrial) sectors.

The average natural supply (central dashed line), and +/- 1 standard deviation (upper and lower dashed lines) is shown for the entire time series (1932-2010). The long-term (from 1932-2010) average natural supply is 1249 MCM/yr. In recent years (from 1993-2010, inclusive) the average natural supply has fallen to 1155 MCM/yr, which is 9% below the long-term average.

Figure 2 - Historical and projected national population size (millions) from 1949 to 2050 (avg. 2.7%/yr growth rate)



Data Sources are from the Israeli Central Bureau of Statistics. Source from 1950-2009: http://www.cbs.gov.il. From 2009 onwards: Statistical Abstract of Israel 2009.

In future years, water shortages may be exacerbated further by climate change effects on natural water supplies. A climate-change model[2] and other local climate change analyses predict an additional 15% drop in the average annual natural potable water supplies between 2011 and 2050.[3] These expectations are included in predictions of future natural supply rates used in this report.

Most of Israel's current and future water consumption is focused on the domestic and agricultural sectors, with consumption-requirements from the industrial sector being relatively minor (Figure 3). The nation's water resources consist of natural and desalinated potable water, effluent (treated wastewater from the domestic sector that is used in the agricultural sector) and brackish water. The brackish water comes mainly from several small brackish-water aquifers, and natural freshwater comes from the Sea of Galilee watershed, the Coastal Aquifer, the Eastern and Western Mountain Aquifers and several smaller aquifers.

Consumption from the agricultural sector is shown in two categories: (1) potable water and (2) alternative water sources (effluent and brackish water). The black dashed line identifies the average natural water supply: 1250 MCM/yr (1932 -1992), 1155 MCM/yr (1993 -2010), decline to 1020 MCM/yr (2011-2050).[4]

The dashed line in Figure 3 indicates the average annual natural water supply. This line illustrates the extremity of the water shortage in Israel. Excluding effluent and brackish water consumption (shown in black in Figure 3), potable water consumption has exceeded, and will potentially exceed the average natural supply in many of the years shown in the time series (the surface area above the dotted line, excluding the Effluent & Brackish section). Numerous important methods are currently employed for accomplishing sustainable water resource use in the face of these water shortages, and these will be discussed in detail in this report.

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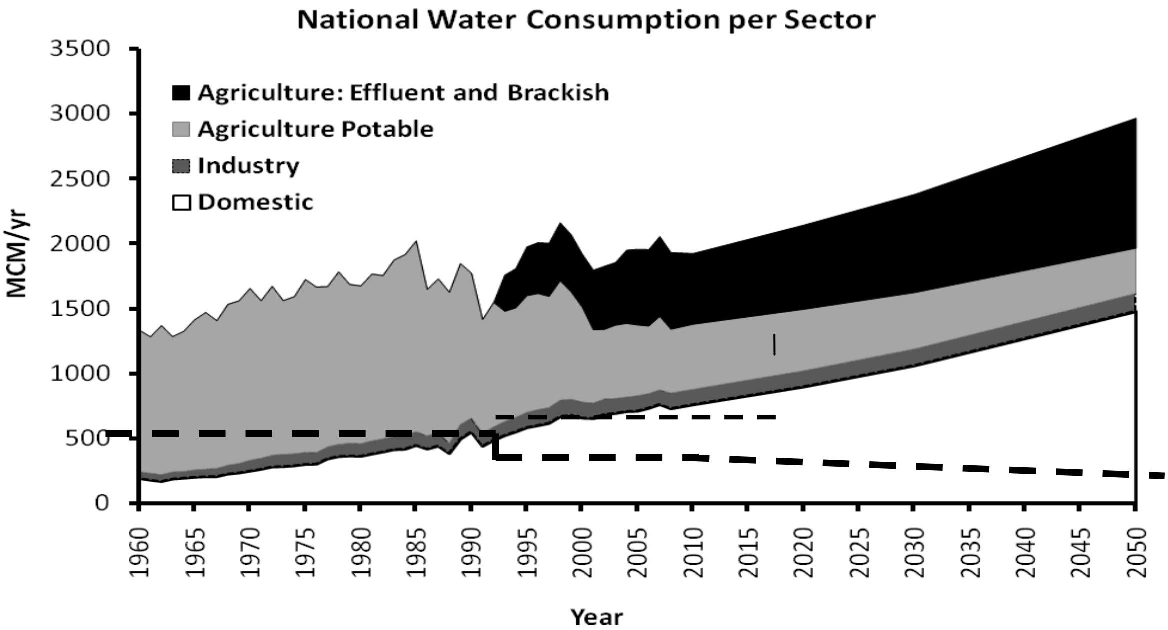
[2] Source: Givati, Samuels, Rimmer and Alpert. 2010. Using high resolution climate model to evaluate future water and solute budgets in the Sea of Galilee, In review, Journal of Hydrology

[3] Source: *A Long-Term Master Plan for the Water Sector* – 2010 Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

[4]Predicted consumption rates are a function of predicted population growth. Tourism is included in the domestic sector. See text for information regarding changes in the average natural supply rate (dashed line in figure).

Figure 3 - Historical and projected annual water consumption per sector from 1960-2050, in millions of cubic meters (MCM/yr)



Data source: Water Authority Planning Department; For 2010 onwards, source: A Long-Term Master Plan for the Water Sector – 2010 Policy Document of the Ministry of National Infrastructures, Water Authority, Planning Department.

3. Israel's Institutional Framework for Water Governance

The foundational law for water governance in the State of Israel is the Water Law, which was passed in 1955. It stipulates that all water resources are the property of the public. There is no private ownership of water resources in Israel, and virtually all water consumption is metered.

Israel's national administrative system has full responsibility for the sustainable use of all of the nation's water resources. All decision-making and management of the water supply in the State of Israel is accomplished at the national level. Sub-national level government entities do not take part in this process at all. For example, municipalities are not decision-makers regarding water use. Rather, they are consumer-liaisons who provide water to their constituents.

The primary governmental organization responsible for the planning, regulating, and policy creation relating to water is the Israeli Water Authority (a Department of the Ministry of Infrastructure). Its mandates are:

- To sustainably supply water to consumers, based on approved requirements for quality, quantity, efficiency, and economic reliability
- To treat sewage effluents according to required standards.

The Water Authority Council forum is responsible for the timely authorization of all decision making and policy-setting made by the Israeli Water Authority and any ministries. The 8-member Water Authority Council forum contains a leading representative from each of the government ministries: Infrastructure, Environmental Protection, Finance, Interior, and Health, and from the Water Authority, as well as two public interest group representatives. Together, the Israeli Water Authority, and the Water Authority Council forum effectively regulate very limited water resources, to provide for both short and long-term water requirements of the State of Israel.

I. Data collection methods: existing, improvement-priorities, costs

1. Quantity and quality of natural water sources

Natural potable water in the State of Israel comes from the Sea of Galilee and aquifer reserves: mainly the Eastern and Western Mountain Aquifers and the Coastal Aquifer. Due to the scarcity of potable water in the State of Israel, the quantity and quality, and removal rates of water from each of these natural water sources have been carefully monitored for many decades. The cost of monitoring water quantity and quality in the aquifers and the Sea of Galilee watershed is approximately US $ 1.9 million/year.[5]

The following section reviews the indices used to measure the quality and quantity of each of these natural water sources, planned improvements in data collection, and the estimated costs of those planned improvements.

1.1. The Sea of Galilee

Currently- The tasks of monitoring water quality and quantity as described are accomplished via a tender-bidding process. Water quantity in the Sea of Galilee is monitored and regulated according to its water level. Three indices, measured in meters below sea level delineate boundaries that are used as boundaries in regulating water-removals (Table 1).

Water quality is measured in various ways. First, the following ten variables are measured in the Sea of Galilee and watershed: chlorides, suspended solids, turbidity, total phosphorus, nitrogen, chlorophyll, primary production, cyanobacteria, fecal coliforms, and biological oxygen demand (BOD). This monitoring program has been ongoing since 1969 in the Sea itself and since 1970 in the surrounding watershed. In addition, heavy metals, herbicides, and pesticides have been monitored in the Sea and watershed over the past decade, and hormone levels have been monitored over the past few years.

Table 1 - The three water level-limits that delineate three respective levels of risk to continued pumping from the Sea of Galilee

Name of Limit	Water Level (meters below sea level)	Significance of Limit
Operational Upper red line	-208.9	There are spills above this water level to the Sothern Jordan River
Operational Lower red line	-213.0	Operational minimum water level
Black line	-214.9	Pumping is prohibited, since if water is withdrawn beyond this depth, there is a high risk of irreparable damage to the ecosystem.

Source: IWA, 2011

Priority Improvements: The data collection regime and the variables that are used, produce accurate estimates of the quality and quantity-indices of the Sea of Galilee. This is considered to be a high quality sampling regime by global standards, and no planned improvements in data monitoring of the Sea of Galilee watershed are deemed necessary at this time.

[5] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

1.2. Aquifers

Currently - Natural potable ground water is extracted mainly from the Mountain and Coastal aquifers via several hundred pumping stations across the aquifers. Other much smaller natural groundwater supplies contain brackish water, which is desalinated to supplement potable water supplies, or which is used as is, in the agricultural and industrial sectors.

At the pumping and monitoring locations, measurements are made of the volume extracted, the water table-level, as well as water quality measurements. These include salinity, volatile organic compounds, nitrates, magnesium, sulfates, and bacteria concentrations. Data collection occurs regularly and in many cases daily, with a frequency that depends on the variable in question. This comprehensive sampling regime has been ongoing for several decades. Among other advantages, vigilant monitoring as such has enabled the closure of wells when necessary, as well as the detection and closure of illegitimate wells.

Priority Improvements - The Water Authority (the national water-governing body in the State of Israel) is currently preparing proposed indices that delineate explicit limits in the volume and quality of each aquifer. These will enable the establishment of restrictions beyond which (i) pumping must occur sparingly; (ii) pumping should be suspended; and (iii) the aquifer-quality is on the brink of irreparable damage. These restrictions will enable more vigilant protection of the condition of each of the aquifers, and facilitate goal-setting for safe, sustainable long-term use of the aquifers. To ensure that accurate indices of quality are developed, a group of experts will be hired to accomplish this task at cost of approximately US $250,000.[6]

2. Data used in measuring Plan Bleu's efficiency indices

2.1. The national metering system and water losses in all sectors

Currently - Water supplies throughout the State of Israel are monitored via metering systems. These metering systems quantify the water volumes consumed per household in the domestic sector, per industry in the industrial sector, and per agricultural plot and water type in the agricultural sector. This provides estimates of volumes of water sent out to each sector (domestic, agriculture, industry), and the volumes of water reaching the consumers in each sector. Thus, among the many other advantages of this comprehensive monitoring system is that it enables estimation of water losses via pipe leakages, thefts, faulty meters, etc.

The manually-read water meters are read on a bi-monthly basis, and data from the automated meters are fed to a computer system continually. Manual meter-reading, data processing, and pipe or meter repairs are conducted by private companies that win tender bids issued by each separate municipality. The private companies are responsible for repairing any leaks or malfunctions. The Water Authority evaluates the results and any problems, to ensure that the data collection occurs seamlessly and efficiently. After monitoring water quality at the sources of the natural supplies, the national cost of meter-reading, water quality monitoring during conveyance, and data compilation is approximately US $18 million per year.[7]

Meters are read for each consumer in each sector. In the agricultural and industrial sectors, water types (potable, effluent, and brackish), are each explicitly monitored and analyzed separately. Data collection guidelines, such as the frequency with which the data are collected and analyzed from each meter are explicitly outlined in the tenders themselves, to ensure that the required protocol is adhered to.

Priority Improvements - There can be long delays (weeks or months) in detecting even large pipe leakages, since discrepancies between water sent out and received can only be detected once the manually-read meters have been read and analyzed. Alleviating this source of water loss is a high priority.

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[6] Source: Water Authority Planning Department

[7] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

A nation-wide upgrade to replace the existing manual metering systems with remotely operated Automated Meter Reading (AMR) systems in all sectors is currently underway. Currently approximately 15% of the replacements have been made, and completion of all replacements is expected to occur in 5-7 years (between 2016 and 2018). AMR's dramatically improve detection rates of pipe leakages, thereby minimizing this source of water loss. To date, AMR systems have replaced all manually read meters in 10 cities/towns. In the largest of these cities, 76,000 AMR's were installed at a cost of approximately US $7 million. The average cost per purchase and installation of a single AMR system is approximately US $90.[8]

Data provided from the automated meters are analyzed by companies that win tender bids for these tasks. Manual reading is not required from these systems. Instead meter readings are sent automatically and continuously through communication cables, to a central database, where analyses are conducted automatically. If a problem (such as a leak or a malfunctioning meter) is detected, these companies are responsible for repairing the problem.

2.2. Irrigation-methods in the agricultural sector

Currently - Irrigation in the State of Israel occurs by either drip (water drips slowly throughout perforated pipe systems that are lain on or under the earth), or by sprinkler. The Israeli Central Bureau of Statistics annually records the number of hectares used per crop type. Drip versus sprinkler irrigation is largely determined by crop type. Using the number of hectares per crop type, three water-agriculture experts provided precise estimates of areas irrigated by drip versus sprinkler irrigation for this report (see attached Excel file: WAT_PO1_Israel_2008).

The total amount of water consumed in the agricultural sector is 1045 MCM/year. Two types of alternative non-potable water sources comprise approximately 52% (544 MCM) of this total consumption. The first of these is treated domestic wastewater (hereafter referred to as 'effluent'), which supplies 38% (400 MCM) of agricultural consumption. The Israeli agricultural sector has also adapted to the use of brackish water for some crop types. Brackish water currently contributes approximately 14% (144 MCM) of the total water used for irrigation annually.[9] The quantity of potable water versus effluent and brackish volumes that are provided are separately monitored per agricultural plot throughout the State of Israel.

Priority Improvements – No large changes are scheduled in the procedures for measuring irrigation water efficiency within the Agricultural Sector.

[8] Source: Water Authority, Chief Engineer of Municipal Water Management

[9] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

II. Improving water-use efficiency in each sector: agricultural, domestic, industry, tourism

1. Objectives and timeline for improving efficiency

National plans for improvements in water consumption-efficiency between 2010 and 2050 include the following (quantifiable targets in Table 2):[10]

- Decrease reliance on potable water for irrigation in the agricultural sector from 42% currently, to 26% by 2050. Increase reliance on effluent for irrigation as shown in Figure 3;
- More than double the quantity of effluent provided for irrigation in the agricultural sector by 2050 (Figure 3);
- Continue national investments in research, development, training, and demand management incentives to increase conservation and use-efficiency in the agricultural sector;
- Maintain or decrease the domestic per capita water consumption at or below 100 m^3/person/year (as of 2009, it was 90 cm per capita);
- Maintain natural potable water consumption rates at or below the average natural supply rate (Figure 4);
- Replace natural potable water use with alternative sources: desalinated sea water, effluent, and brackish water (Figure 4 and Figure 5). Increase reliance on these alternative water sources. Supply more than half of the country's water requirements by 2015 (Figure 5) with these alternative water sources;
- More than double the contribution of desalinated water to the national potable water supply from 20% (307 MCM) in 2010 to 46% (809 MCM) in 2020;
- Increase water recycling in the industrial sector by approximately 10% by 2035.

Advancements in use-efficiency, including the use of alternative water sources (desalination, effluent, and brackish water), make essential contributions to ensuring sustainable long-term consumption of the natural supplies from the aquifers and the Sea of Galilee watershed (at or below the average natural potable water supply rate as shown by the dashed line in Figure 4).

Table 2 - National objectives and timeline for improving efficiency in each sector

Year	Total		Domestic Sector b	Agricultural Sector	
	% alternative water sources a	Volume in MCM of desalinated water	Per capita water consumption (m^3/pers/yr) c	% of irrigation from effluent	Volume of effluent (MCM)
2010	44	307	90	38	400
2015	54	558	99	43	464
2025	61	835	98	51	587
2050	71	1491	95	67	900

a Water resources used other than natural potable water: desalinated, effluent, and brackish.
b Tourism is included within the domestic sector
c 100 is the maximum desirable consumption rate across all years.
Data Source: A Long-Term Master Plan for the Water Sector – Policy Document of the Ministry of National Infrastructures, Water Authority, Planning Department.

[10] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, 2010, Ministry of National Infrastructures, Water Authority, Planning Department.

The vast majority of national water consumption is by the domestic and agricultural sectors. Thus, maximizing water-use efficiency and devising alternative water sources for these two sectors is a priority. The national actions and plans reflect this priority. Within these two sectors, changes have included a five-fold increase in agricultural output (by volume) per cubic meter of water consumed since 1948[11], nation-wide effluent re-use for irrigation (the extent of which probably exceeds all other countries), and extensive large-scale sea water desalination. Particularly in the past decade, these changes have already led to enormous reductions in annual national water consumption (Figure 4 and Figure 5).

The following extensive reductions in the already low agricultural per capita potable water consumption[12] are planned (Table 3). Even the current (2010) agricultural per capita consumption rates are very low relative to international estimates (One source (http://www.worldwater.org/table2.html) provides an average per capita agricultural water consumption estimate of 311 cubic meters/per/year, from 160 countries throughout the globe). In addition, agricultural water-use efficiency (Eirr)[13] is scheduled to increase from 77.3% in 2010 to 77.9% in 2020. Irrigation-efficiency (E2)[14] is scheduled to increase from 87.9% in 2010 to 88.5 in 2020.

Table 3 - Agricultural per capita water consumption

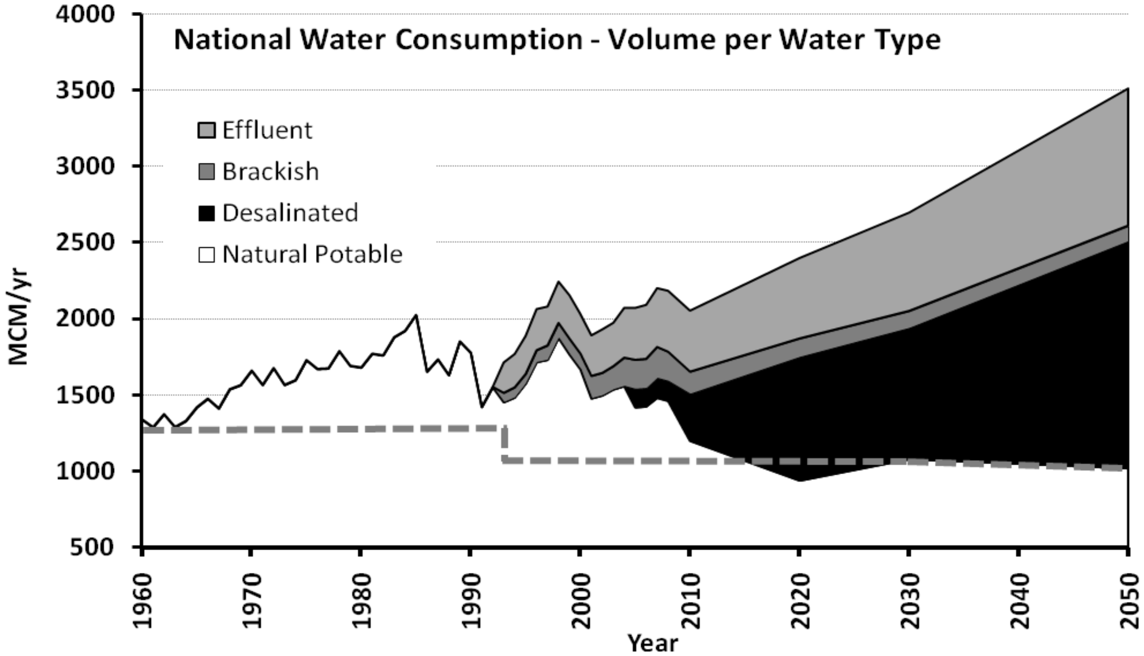
Year	Agricultural Per Capita Water Consumption (CM/per/yr)	
	Potable Water	All Water Types (Potable, Brackish, Effluent)
2010	65	137
2015	58	129
2020	52	123
2050	22	87

Source: IWA, 2011

Demand management measures contribute to achieving the planned changes in Table 2 and Table 3 in all three sectors. In the State of Israel, the only sector that is not supplied with a fixed quota of all combined water types per year for consumption is the domestic sector. The industrial and agricultural sectors each receive a fixed quota of water per year. Demand management tactics in the agricultural and industrial sectors provide consumers with the tools, knowledge, and incentives to limit wastage and to encourage consumption of re-used water (effluent) and/or brackish water. Demand management tactics are also used to encourage water re-use, to provide additional supplies to the very limited total water quota. In the domestic sector, demand management measures are used whenever necessary to maintain per capita consumption rates below 100 m^3/pers./yr.

[11] Israel's Agriculture: Innovations Make the Land Bloom, Part I., Ministry of Agriculture and the Israel Export & International Cooperation Institute. 2002.
[12] Agricultural per capita water consumption is calculated by: Annual agricultural potable water consumption (MCM/yr) divided by Israel's population size.
[13] Excel File provided to Plan Bleu from the Water Authority of the State of Israel in 2010: **WAT_P01_Israel_2008.xlsx**
[14] Excel File provided to Plan Bleu from the Water Authority of the State of Israel in 2010: **WAT_P01_Israel_2008.xlsx**

Figure 4 – National Water Consumption – Volume per Water Type

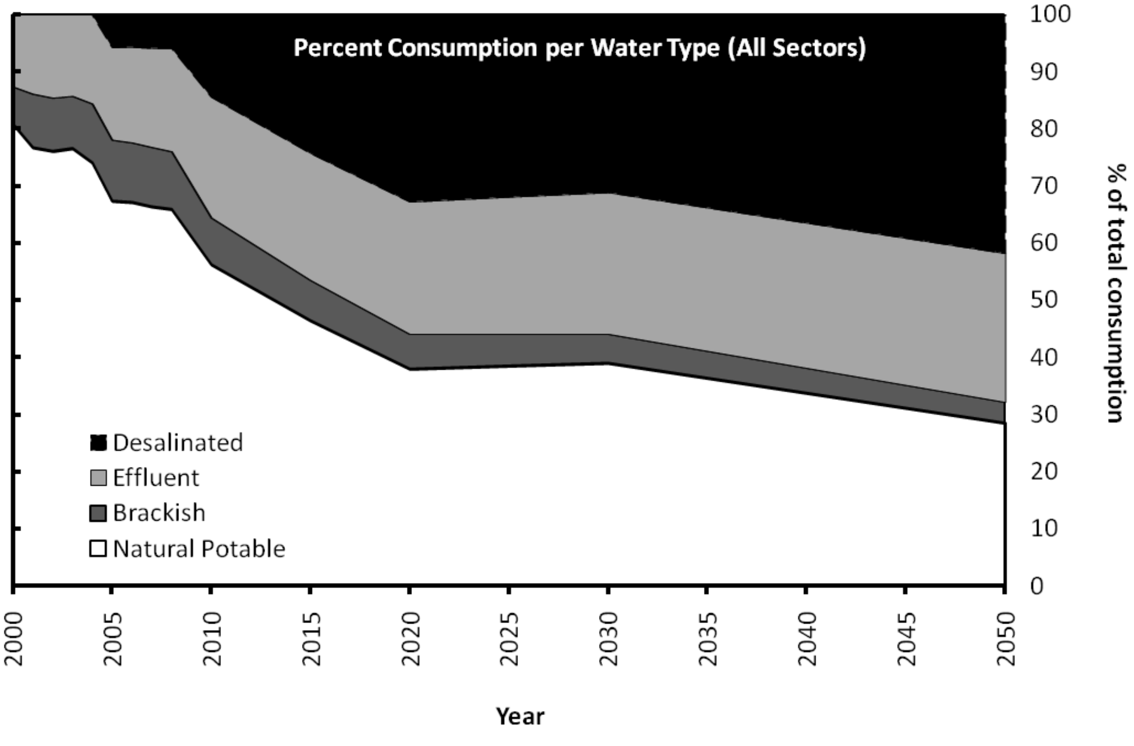


Historical, current, and predicted national consumption volumes (millions of cubic meters (MCM)) by water type: treated domestic wastewater ('Effluent') brackish water from semi-saline aquifers ('Brackish'), desalinated sea and semi-saline water ('Desalinated'), and natural potable water resources from the coastal and mountain aquifers and the Sea of Galilee watershed ('Natural Potable')

The dashed line delineates the average volume of water that replenishes the natural reserves across 3 time periods: 1960-1993 (1249 MCM), 1993-2015 (1155 MCM), and declining from 2015-2050 (to 1020 MCM; see text for details). Data Sources: Water Authority, Planning Department. For 2010 onwards,

Source: A Long-Term Master Plan for the Water Sector – Policy Document of the Ministry of National Infrastructures, 2010, Water Authority, Planning Department.

Figure 5 - Percent of total national water consumption (all combined sectors) between the years 2000-2050



Data Sources: Water Authority Planning Department; For 2010 onwards, source: A Long-Term Master Plan for the Water Sector – Policy Document of the Ministry of National Infrastructures, 2010, Water Authority, Planning Department.

Numerous national policies and projects (Table 4) are underway for excelling and improving in all three areas of concern of the Plan Bleu:

1) Reducing water losses during conveyance
2) Improved efficiencies in water use via increased reliance on effluent in the agricultural sector, and brackish and re-used water in the industrial sector.[15]
3) Reduced wasteful use of water in all sectors via several demand management policies.

Table 4 - Existing and planned (for 2010-2020) water policies and projects.

Domestic and Tourism	1) Compulsory water metering per customer 2) Water supply companies carry full responsibility for water losses in excess of 8%, during conveyance. 3) Installation of automated, remotely operated metering systems (NEW) 4) Large-scale wastewater treatment program, that will be enlarged further (Existing and NEW expansions) 5) Dramatically increased tariffs (NEW) 6) Two-category tariff system to impose higher tariffs on heavier users. Planned additional tariffs (Existing and NEW). 7) Effective multi-media awareness-raising campaigns for conservation (Existing and NEW) 8) Separate monitoring and quotas for municipal gardening (NEW) 9) Increased volume of reclaimed domestic wastewater provided for irrigation 10) Installation of a series of large-scale desalination plants (NEW)
Agriculture	1) Compulsory water metering per customer 2) Water supply companies carry full responsibility for water losses in excess of 8%, during conveyance. 3) The annual quota of water is provided, and no more. 4) Numerous policies to encourage research and development, farmer-education, and farmer-use of water conservation and use-efficiency tactics and technologies (Existing and NEW). 5) Numerous policies to encourage use of effluent and brackish water for irrigation 6) Increased tariffs, with the ultimate goal of charging the true cost of water (NEW-future)
Industry	1) Compulsory water metering per customer 2) Water supply companies carry full responsibility for water losses in excess of 8%, during conveyance. 3) Improve policies to encourage the consumption of brackish water and effluent (NEW) 4) Increased tariffs with ultimate goal of charging the true cost of water (NEW-future)

Source: A Long-Term Master Plan for the Water Sector – Policy Document of the Planning Department, Ministry of National Infrastructures, Water Authority, 2010.

2. Existing and planned demand management policies for water savings per sector

2.1. All sectors: reducing losses in water-conveyance

Potable water is conveyed from its various sources throughout Israel via a national pipe-grid that reaches all consumers. For many decades water conveyance throughout Israel was achieved via this nation-wide piping system. During water conveyance, approximately 10-12% of the water is lost. Losses are incurred by several causes, including thefts, pipe leakages, and faulty metering equipment. This conveyance-loss rate applies equally to all sectors (domestic (and tourism), agriculture, and industry).

Numerous challenges exist in reducing these conveyance-losses. One of these comes from delays in identifying leak locations from the enormous number (hundreds of thousands) of mostly manually-read

[15] All of these improved efficiencies minimize the consumption of the very limited natural potable water supplies in the State of Israel. Total consumption is also reduced via the consumption of effluent (re-used water).

water meters that are distributed throughout the national system. The annual national cost of pipe repairs and the development of new piping innovations is approximately US $570 million/year.[16]

Existing Policies – Pipe conveyance losses are minimized using two policies. First, is the mandatory use of meter systems for all water provisions in the State of Israel. This facilitates identification of thefts, leakages, and the general vicinity of the loss-locations.

Water pumping and conveyance is the responsibility of approximately 50 private and semi-private water corporations that supply water to all consumers throughout the State of Israel. The companies purchase the water from the State of Israel, and sell it to consumers. Pipe conveyance losses are not minimized by law. Instead, two policies are designed to provide incentives to these water-conveyance companies to minimize water losses in the pipe systems. The first of these is the provision of 8% of all conveyed water provided to the conveyance companies tariff-free. This is the loss-rate (from evaporation, etc.) that is considered unavoidable during conveyance. If conveyance-losses are greater than 8% of the total volume, the supply companies must pay for that lost water. This provides a strong incentive for prevention of losses during conveyance.

The second of the two policies is also aimed at the water-supply companies. They are granted permission to reduce water-pressure within the pipes to levels as low as 3 to 3.5 atmospheres (this minimum pressure is required to adequately supply fire-fighting services). Leak-loss rates can be minimized by more than 5% by reducing pipe-pressure. [17]

Within public park systems, water losses are also minimized by the use of tap systems that require the individual user's continuous pressure to produce water flow. This prevents unnecessary water-losses in public locations.

Future Policy Changes – A recent policy decision to replace the nation's manually-read water meters with highly advanced automated meter reading (AMR) will lead to a much more rapid rate of theft-detection or leak-detection and repair.

Significant increases in water tariffs are planned in all sectors over the coming two decades. In the domestic (and tourism) sector, these have already been initiated, with a 40% increase in the tariffs on water within the year 2010. Increased tariffs concomitantly increase the impact of leaky pipes on supply companies' profits. A large effort to minimize pipe losses is currently already underway, in response to the increase in water tariffs in 2010. The increased vigilance of these companies is expected to escalate over the coming years, in tandem with each increase in water tariffs.

2.2. Domestic and tourism sector

Numerous demand management policies are currently used in the domestic sector to minimize water consumption. While some of these policies have been in place for several decades, several policies are new, having been initiated within the past couple of years. These policies also apply to tourism, since water management of tourism industry is encompassed within domestic sector. All of these policies are elaborated upon below, according to their relevance to each of the two areas of water use-efficiency: I) Reduction of wasteful use, and II) Wastewater treatment and re-use.

Treatment and Reuse of Domestic Wastewater

Existing Policies – In 1990, the State of Israel initiated a series of policies for large-scale (nation-wide) effluent re-use in the agricultural sector. The goal of this was to provide badly needed additional water resources to the agricultural sector. By 1993, effluent was supplying 25% of irrigation requirements, and supplies have continued to increase since then. Currently, effluent supplies approximately 38% (400 MCM)

[16] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.
[17] Source: Water Authority, Chief Engineer of Municipal Water Management

of irrigation requirements (Figure 6 and Figure 7). This national effluent re-use policy has been vital to sustainable water consumption in the State of Israel. Without it, there would have been insufficient water supplies from within Israel during this past decade.

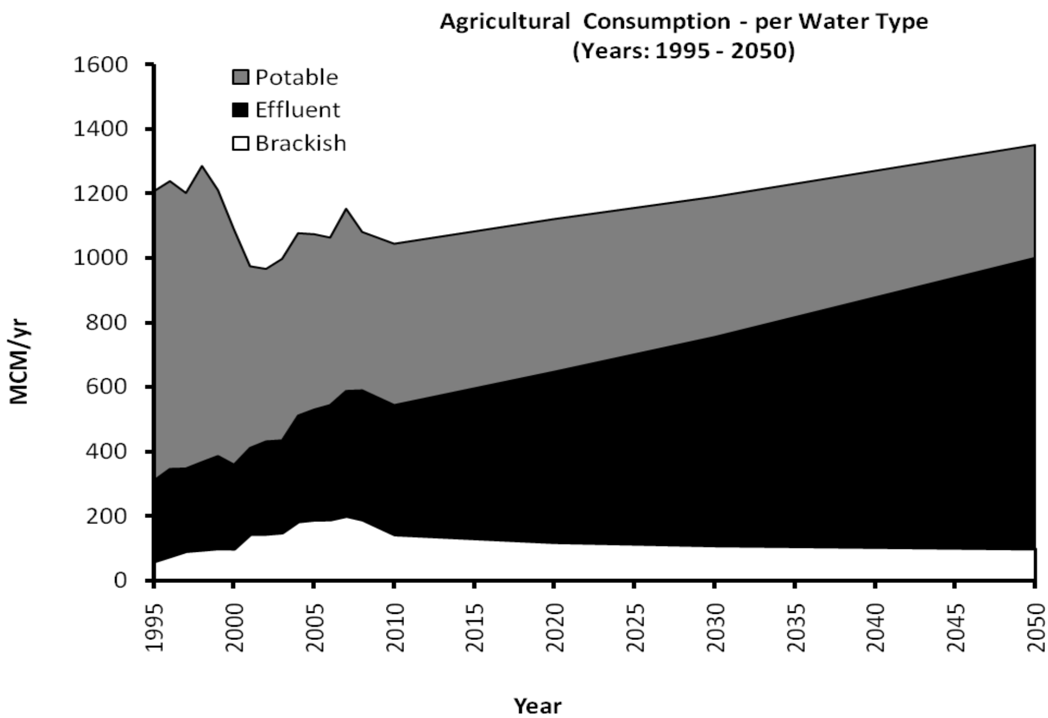
The process of domestic wastewater treatment and re-use currently involves combining black and grey wastewater from the domestic sector, and treating this in any one of numerous treatment facilities located throughout Israel. 95% of the State of Israel's domestic water is treated, and final treatment levels range from secondary, to tertiary, to more stringent than tertiary (to a level considered drinkable by the Ministry of Health). Stringent standards, involving 37 parameter measurements, ensure that effluent quality is suitable for irrigation.

Approximately 84% of Israel's domestic wastewater is re-claimed for irrigation in the agricultural sector. The 16% of the remaining wastewater and effluent is either lost through evaporation, or is sent to the sea rather than to the agricultural sector, since some locations lack the effluent pipe-infrastructure for conveyance to the agricultural sector.

Future Policy Changes – The State of Israel aims to more than double the capacity of today's volumes of effluent provisions to the agricultural sector by the year 2050 (Figure 6). These increases will be achieved by enlarging existing wastewater treatment facilities and constructing new facilities. The timing of construction will be in tandem with the rate of increase of domestic wastewater production.

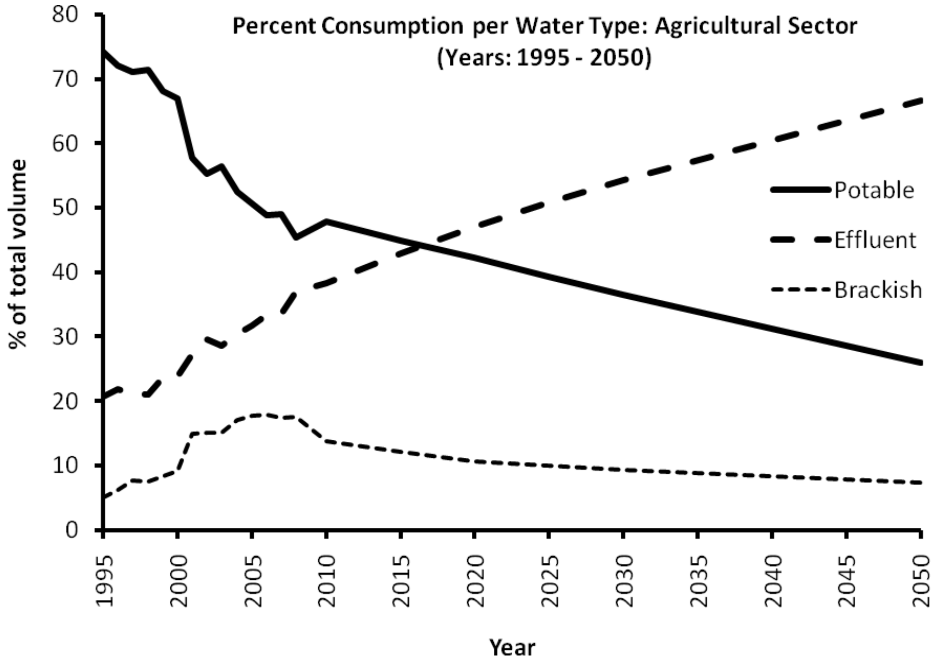
To minimize water wastage from taps, water pressure will be reduced in many municipalities. This has been initiated as of October 2009, and the changes are expected to reduce water consumption in the affected regions by more than 5%. This conservation measure will be particularly effective in the mountainous regions of Israel, where water pressures in the pipes are typically relatively high. The State is also in the midst of installing water conservation devices on household taps that will further reduce domestic consumption.

Figure 6 – Transition of the volume in MCM (millions of cubic meters) of potable, effluent, and brackish water used annually in the agricultural sector



All effluent originates from treated domestic wastewater. Estimates after 2010 are based on predicted increases in population size and proportional increases in domestic consumption.
Source: Water Authority Planning Department; For 2010 onwards, source: A Long-Term Master Plan for the Water Sector – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

Figure 7 - Transition in relative proportions of potable versus effluent and brackish water used in the agricultural sector in Israel



All effluent comes from treated domestic wastewater. Predictions after 2010 are based on predicted increases in population size and proportional increases in domestic consumption.
Source: Water Authority Planning Department; For 2010 onwards, source: A Long-Term Master Plan for the Water Sector – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

Reduced Wasteful Use of Water

Existing Policies - Several policies have been employed to limit wasteful use of water in the domestic (and tourism) sector. First, consumers pay according to the volume that they consume. In the cities and towns where the automated meter reading (AMR) systems have been installed, water consumption rates have dropped by 15%, in part, due to conservation practices from a greater awareness of the extent of self-usage.

A second policy sets a two-category water tariff system based on the volume of water consumed per person. By this method, heavier water-consumers (individuals who consume more than 2.5m^3/month) pay a much higher price ($3/$m^3$/person as of January 2011) for water than those who consume less ($2/$m^3$/person).[18]

Since 2009, three additional demand management policies have been employed in response to several years of drought conditions. First, a multi-media campaign was conducted to warn the public of the water crisis, and to request their prudence in water use. This campaign was conducted via television, radio, newspaper, and internet media sources.

The campaign exceeded expectations in benefits, with a large (10%; 76 MCM) reduction in domestic consumption in 2009. Per capita consumption rates decreased from approximately 100 cubic meters per person per year prior to the campaign to approximately 90 cubic meters per person in 2009.[19] The impact of this multimedia campaign lingers, since consumption rates have remained at this lowered level currently (as of April 2010). Expectations were that domestic consumption would decrease by no more than 8%, and would not persevere beyond the end date of the campaign. Thus, this demand management policy has been a great success.

A second new policy that was employed in January 2010 was the aforementioned 40% increase in water tariffs in the domestic sector within the year 2010. This increase was imposed in order to pay for the large

[18] Source: Water Authority Website Information
[19] Source: Water Authority Planning Department

scale sea water desalination facilities that have recently been built. The increase is expected to maintain or enhance the conservation-ethic that was imposed via the multi-media campaign.

A third and final recent set of policy changes focused on municipal water consumption, specifically for irrigation of public parks and gardens. The quantity of water used for watering public parks and gardens was the subject of concern. However, exact consumption rates were not known until 2009, since these volumes were not explicitly monitored.

Policy changes regarding municipal garden-watering first involved enforcement of meter-installations for each separate garden, and for reporting the exact surface areas that are irrigated for each of three garden (and water requirement) types: a) trees and bushes, b) flowers, and c) grass. These two changes were strictly enforced, such that water supplies to the gardens were turned off to municipalities that did not install meters and report their accurate garden surface areas per garden type and estimated water usage, by the set deadline.

Based on surface areas of each garden type, a water quota was given to each municipality for the gardens. In 2007, prior to initiation of this change, municipal garden-watering was estimated at 45 MCM/year. In 2009, water provisions to municipalities for gardens were separately regulated, and were strictly limited to a quota of 20 MCM. Water consumption was thereby reduced to less than half between 2007 and 2009. In future years, this quota may be increased slightly in non-drought years, or otherwise maintained.

Finally, although desalination is not a means of increasing efficiency in water use, it is an extremely effective resource for decreasing unsustainable demands on the natural potable water resources in Israel. Currently, several large-scale desalination facilities collectively provide 307 MCM (approximately 40%) of the national domestic water requirements.

Future Policy Changes - Over the next few decades, the goal for the domestic sector will be to maintain the domestic per capita water consumption at or below 100m^3/person/year by use of the following policies. First, the multi-media awareness campaign that was so effective in 2009 will be re-employed if per capita consumption begins to increase. So far, this has not been necessary.

In the event of exacerbated drought conditions, a three-category tariff system may be enforced by adding a third tariff category to the two-categories that are currently used. Under such circumstances, the highest consumers will pay extremely high tariffs ($6.95/m^3/person).

With the addition of several more desalination facilities, the supply of desalinated water is expected to provide approximately 62.5% and 70% of the domestic water demands by 2015 and 2025, respectively (Figure 5). Ideally, desalinated water will also be used to supplement Israel's aquifers. Upon completing construction of each large-scale desalination facility the water tariffs in all sectors will be raised. Each of these increases is expected to cause a concomitant reduction in demand.

2.3. Agricultural Sector

Demand management policies in the agricultural sector are designed to accomplish two objectives: 1) maximize efficiency in the overall use of water for irrigation, and 2) to irrigate with non-potable water (effluent or brackish water) wherever possible.

Increased use of Effluent and Brackish Water

Existing Policies – Several policies encourage farmers to irrigate with brackish water or reclaimed domestic wastewater, rather than using potable water. These policies have been so effective that the constraint to using an even greater proportion of non-potable water sources in irrigation is the amount of available effluent and brackish water. As noted in the discussion of domestic policies, one priority over the coming decades is to increase the volume of effluent to supply irrigation in the agricultural sector.

The policies that have created this high demand for effluent (and to a lesser extent, brackish water) are as follows. Effluent and brackish water tariffs are lower (\$0.26/m^3, and 0.28/m^3, respectively) than the tariffs on potable water (\$0.44/m^3).[20]

Secondly, each farmer is provided with a restricted amount of potable water per year. If the farmer exchanges part of this volume for effluent or brackish water, an extra 20% by volume of effluent is provided for free. This encourages the farmers to use less than their allotment of potable water if possible. The State of Israel also provides the funding for 60% of pipe-installation costs that are necessary for conveyance of wastewater or brackish water from the source locations to each of the agricultural plots.

Future Policy Changes - The State of Israel has a very effective policy infrastructure for encouraging the use of alternatives to potable water in irrigation. In the coming years, this policy infrastructure will be maintained. No major changes are planned in this regard. In regard to further limiting the use of potable water in the agricultural sector, please see the following section (below).

Maximizing Efficiency in Water Consumption (Reducing Waste)

Existing Policies - Since only a fixed and extremely limited quota of potable water is provided to the Agricultural Sector each year, efficient water use is compulsory. It is important to note that the level of severity of these water restrictions is and has been extreme, particularly over the past two decades. In the past year, these restrictions caused a particularly great strain on the agricultural sector. Any further restrictions on water consumption would have potentially led to the closure of a large proportion of the sector.

Future Policy Changes - While in the domestic sector, the water tariff is equal to the cost of production and conveyance (minimum of US \$2/m^3), the water tariff for potable water in the agricultural sector is currently approximately US \$0.44/m^3.[21] It will be gradually raised to the cost of production and conveyance to the agricultural sector of US \$0.52/m^3) by 2020.[22] Note that the cost of production and conveyance is cheaper (\$0.52/m^3) for the agricultural sector than the domestic sector (\$2/m^3).

As indicated in the 'Existing Policies' subsection (above), demand management measures do not limit the total quantity of water consumed in the agricultural sector. This is due to the fact that only an extremely limited (and strictly enforced) quota of water is allocated to the agricultural sector annually. The a) total and b) potable water per capita consumption rates for the agricultural sector (total agricultural consumption per year divided by total national population size) in the year 2010 were: a) 137 and b) 65m^3/person/year respectively. These are very low agricultural per capita consumption rates relative to international estimates (One source (http://www.worldwater.org/table2.html) provides per capita agricultural water consumption data from 160 countries from all over the world, with an average of 311m^3/per/year).

The agricultural sector is characterized by extremely high use-efficiency and conservation tactics, and continual improvements in these areas. The extremely limited annual national agricultural quota forces each individual farmer to find and use every possible means for increased use-efficiency. The government provides numerous incentives and assistance measures to maximize farmers' use-efficiency. Consequently, widespread improvements in use-efficiency have been made, particularly over the past two decades. Furthermore, continual improvements are underway, including continual research, development and use of state-of-the art methods and technology.

Some of the specific methods that have been developed (and continue to be improved upon) include reductions in the total irrigated area (by reducing water-thirsty crops, and developing drought-resistant strains, etc.), research and adaptations in crop patterns and species selections that minimize water consumption, and highly advanced state-of-the art technological innovations for leak detection and for

[20] Tariffs quoted in Hebrew: http://www.meniv-rishon.co.il/taarifim.pdf
[21] Tariffs quoted in Hebrew: http://www.meniv-rishon.co.il/taarifim.pdf
[22] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

minimizing losses during irrigation. Israel is considered to be a world leader in its development and use of technology and methodology for water conservation and for minimizing water loss.

The underlying government incentives and support programs for water conservation and use efficiency in agriculture include a national investment support-program for farmers that employ advanced water-saving and other technologies, and grants for rain-supplied wheat farming in the southern (particularly dry) part of the country. Rain-supplied resources come from both natural rainfall and rain-fed reservoirs. The government also funds research and development in technologies that increase agricultural irrigation-efficiency, provides funds for investments in regional drainage and water conservation projects, and offers free education of the most recent technologies to farmers.[23,24]

Technological improvements include the use of micro-sprinklers and ultra-small drip-irrigation methods with computerized control systems that provide the exact water requirements directly to the plant-roots. [25] The Israeli irrigation industry is internationally known, and exports more than 80% of its products. [26] Israeli research has also led to the development of crop-strains that require minimal water supplies, and/or can thrive on brackish rather than fresh water. Research and development has been an enormous driving force in increasing use-efficiency. One key strategy that has optimized the effectiveness of R&D is the close three-way cooperation between researchers, farmers, and agriculture-related industries. Essential, is the active involvement of farmers in presenting their latest challenges to researchers and industry, and in providing their input and evaluations at all phases of the R&D process.[27,28,29]

2.4. Industrial Sector

Increased Use of Effluent and Brackish Water

Existing Policies – Approximately 30% (30 MCM) of the total water (120 MCM) currently consumed in the industrial sector is brackish rather than potable water. The policies that lead to this use of brackish instead of potable water are similar in nature to those used in the agricultural sector: Incentives are provided for use of alternatives to potable water, such as reduced rates for the purchase of brackish (US $0.3/m^3$) rather than potable water (US $1.3/m^3$).

Future Policy Changes - A target within the coming decades is to modify the policies in the industrial sector to more effectively provide incentives for the increased use of both brackish water and internally re-used water in place of potable water. For example, one new policy decision is to provide industries with the option to receive a government grant for building their own water treatment plants. Overall, the exact details of the policy changes have not yet been finalized. At this time, the approximate target (not yet finalized) will be an increase in efficiency by 10% by the year 2035.[30]

Maximizing Efficiency in Water Consumption (Reducing Waste)

Existing Policies – Efficiency in overall consumption in the industrial sector is entirely controlled by a quota system, whereby water provisions are limited to the quota volume, and no more. This is the same

[23] "Water Conservation in Different Sectors", Israel Ministry of Environmental Protection, http://sviva.gov.il/bin/en.jsp?enPage=e_BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals^l2066&enZone=Water_Conservation
[24] OECD Review of Agricultural Policies: Israel (2010)
[25] Israel's Agriculture in the 21st Century, J. Fedler, Israel Ministry of Foreign Affairs, http://www.mfa.gov.il/MFA/Facts+About+Israel/Economy/Focus+on+Israel-+Israel-s+Agriculture+in+the+21st.htm
[26] Israel's Agriculture: Innovations Make the Land Bloom, Part I., Ministry of Agriculture and the Israel Export & International Cooperation Institute. 2002.
[27] Israel's Agriculture: Innovations Make the Land Bloom, Part I., Ministry of Agriculture and the Israel Export & International Cooperation Institute. 2002.
[28] Israel's Agriculture in the 21st Century, J. Fedler, Israel Ministry of Foreign Affairs, http://www.mfa.gov.il/MFA/Facts+About+Israel/Economy/Focus+on+Israel-+Israel-s+Agriculture+in+the+21st.htm
[29] "Water Conservation in Different Sectors", Israel Ministry of Environmental Protection, http://sviva.gov.il/bin/en.jsp?enPage=e_BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals^l2066&enZone=Water_Conservation
[30] Source: Water Authority Planning Department

setup as in the agricultural sector, and it enforces efficiency in usage. Water pricing is currently equal to the cost of supply and conveyance to the industrial sector.[31]

Table 5 - Performance Indicators

All Sectors	
Total Consumption	Volumes (MCM/yr) consumed (water meter data) Sea of Galilee – quantity and quality indices Aquifers – quantity and quality indices
Conveyance Efficiency	% lost in the pipes
Domestic and Tourism	
Increased Wastewater-Treatment & Reuse	Volume (MCM/yr) and % of domestic wastewater treated and transported for use in the agricultural sector
Reduced wastage	Per capita consumption (m^3/person/year) MCM/ha/yr consumed by parks and gardens in municipalities
Agriculture	
Increased Treatment/Reuse	Percent of total consumption that is potable, vs treated vs brackish.
Reduced wastage	Water use efficiency: Production in dollars of agricultural products sold per m^3 of water.
Industry	
Increased Treatment/Reuse	Percent of total consumption that is potable, vs re-used vs brackish.
Reduced wastage	Israel is in the process of developing an index to measure overall water use efficiency in the industrial sector.

Source: IWA, 2011

[31] Source: *A Long-Term Master Plan for the Water Sector* – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

III. Economic approach to water management

1. Overview

In response to the drought conditions and water shortages that have prevailed in recent years, the State of Israel employed numerous policies for increasing efficiency in water usage, and for providing alternative water sources (as described in previous sections of this report). Among these initiatives, the monetary cost versus benefits of three key initiatives will be discussed here: the demand management multi-media awareness campaign of 2009, reclamation of domestic effluent for irrigation in the agricultural sector, and the production of new water from large-scale desalination facilities. The severity of the water shortages in recent years and projections for future demands are sufficient to necessitate all of these responses: demand management measures, wastewater re-use, and expenditures on new water sources.

Contained first, are brief overviews of the costs of these three policy initiatives and their benefits, as measured by the quantity of water saved/produced from each. The following Cost-Benefit Description contains a brief synthesis of the relative merits of these three policy initiatives.

2. Cost-benefit description of three main policy initiatives

Demand Management Media Awareness Campaign - During 2009, a nation-wide, multi-media awareness campaign was launched by the Israeli Water Authority. The goal of the campaign was to convince citizens to reduce their water consumption by emphasizing the severe depletion of the State of Israel's natural water resources. The extremely low water level of the State of Israel's only lake, the Sea of Galilee, was used as a prominent symbol of the water crisis.

The awareness-raising campaign was initiated in 2008, and was run throughout 2009 and part of 2010, using television, radio, newspaper, and the internet. The campaign was highly successful at reaching all citizens. Indeed, all citizens are well aware of the urgent need to conserve water.

The total cost of the campaign that continued for approximately 1.5 years was approximately US $7.5 million. The ensuing benefit was a 10% reduction in domestic consumption in 2009 (approximately 76 MCM).[32] Thus, the cost-effectiveness of the media campaign was $\$0.10/m^3$ as of the end of 2009. The conservation-mentality that was generated has persevered beyond the end of the campaign. Even currently, several months after its end, domestic per capita consumption rates remain at the lowered level. Thus, the ultimate cost-effectiveness (the cost relative to volume of water saved) of the campaign is expected to be greater than US $\$0.10/m^3$.

Re-Use of Effluent- Treated wastewater from the domestic sector comprises the effluent that is reclaimed for irrigation in the agricultural sector. Approximately 508 MCM of domestic wastewater is conveyed to treatment facilities, and subsequent to treatment, approximately 450 MCM of effluent are conveyed to the agricultural sector.[33] The operational costs of effluent re-use involve pipe conveyance costs from the treatment facilities to the agricultural plots throughout Israel. The wastewater treatment process itself is not considered to be a direct cost of effluent-re-use, since stringent wastewater treatment procedures are necessary for environmental preservation, regardless of whether or not the effluent is re-used. Nevertheless, the costs of the entire wastewater treatment and conveyance process are presented here.

Two large improvements in wastewater treatment are planned for the coming decade (by the end of 2020). These are: 1) the upgrade of any wastewater treatment facilities that treat to below tertiary, to at least tertiary-level, and 2) the construction of new as well as enlarged existing wastewater treatment facilities. The

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[32] Source: Water Authority Planning Department

[33] Source: *A Long-Term Master Plan for the Water Sector* – 2010 Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

operational costs, together with these improvements are shown in Table 6. The cost per unit volume of effluent re-used (cost-effectiveness) is US $0.23/m³ (Table 6 a, right-most column).

Table 6 - Costs of Wastewater Treatment and reused

		2010	2015	2020	
	Wastewater Treatment	Millions US $/yr			US $/m³
a)	Effluent Re-Use: Conveyance from treatment facilities to agriculture sector & nature	113	129	143	0.23
b)	Transport to treatment facilities	117	122	128	0.45
	Wastewater Treatment Operation (Running)	454	514	573	0.91
	Upgrade existing secondary treatment facilities to tertiary 4		52		0.17
	Construction of new treatment facilities		42	41	3.37
	Construction of new piping systems		39	38	3.11
	Class A Treatment & Sludge transport: disposal or use as fertilizer 5	6	6	7	61.09
	Total	690	903	931	
c)	Effluent Produced	MCM/yr			
	Total volume of effluent produced	508	554	599	
	Volume reclaimed for agriculture & nature	450	512	573	
d)	Cost per m³ Produced	US $/m³			
	Total cost/ m³ of all effluent produced	1.36	1.63	1.55	
	Construction cost/m³ of new additional effluent produced	--	2.90	1.73	
	Operation costs only/m³ of all effluent produced	1.36	1.39	1.42	
	Conveyance cost / m³ sent to agriculture & nature	0.23	0.23	0.23	

1 Data Sources: Internal documents from the Israeli Water Authority, and A Long-Term Master Plan for the Water Sector – Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.
2 Data sources:
a) Pareto Engineering Consultant Report: "Normative structure of operating costs of sewage treatment institutes", 2006, by Y. Gurion, Y. Daniel, L. Yonah.
b) Personal communication with Prof. Asher Brenner, Ben-Gurion University of The Negev, Faculty of Engineering Sciences, Biotechnology and Environmental Engineering, Beer-Sheva, 84105 ISRAEL
3 $US estimates are calculated using an exchange rate of 1 $US : 3.863 NIS.
4 Any facilities with existing secondary-level treatment will be upgraded to at least tertiary-level treatment. This upgrade process applies only to some of the older treatment facilities. The planned completion-year for all upgrades is 2015.
5. Sludge is transported to disposal sites or the agricultural sector (fertilizer). Data sources: Estimates are from internal documents and from experts in the Israeli Water Authority and the Ministry of Environmental Protection.
Annual costs and benefits of wastewater treatment are shown within each of three time periods: 2010, 2015, & 2020. Estimated annual costs1,2,3($US/yr) of a): only transporting effluent to the agricultural sector for irrigation, and b) all other procedures associated with wastewater treatment: of treating and transporting domestic wastewater, effluent, and sludge. Benefits1: c) are shown in millions of cubic meters (MCM/yr) of effluent that reach the agricultural sector for irrigation. The costs per unit volume of benefits are shown in d). All cost data in this table are approximates, since costs vary within and between municipalities according to differences in fees charged by private companies per tender. All cost estimates for the future are based on 2010 market prices and do not include potential future innovations for improved efficiency.

Inset 1 - Example: Costs of Wastewater Treatment

Within the table below are the running-expenses ($US/m^3) for two of Israel's wastewater treatment facilities in the year 2010. The most important factor responsible for the cost differences between the two facilities is their capacity (cubic meters of wastewater processed/day). Running expenses of larger facilities are lower (per cubic meter). Data source: Pareto Engineering Consultant Report: "Normative structure of operating costs of sewage treatment institutes", 2006, by Y. Gurion, Y. Daniel, L. Yonah. The examples were originally reported as 2004 prices and were adjusted to 2010 prices by approximating 2% inflation/year (average annual inflation in Israel between 2004 and 2010)[1].

Production Volume (m^3/day):	Facility 1 75,000 m^3/day	Facility 2 4,520 m^3/day
Secondary Treatment		
Cost of treatment	0.16	0.28
Additional miscellaneous expenses	0.08	0.17
Energy	0.01	0.09
Chemical	0.03	0.01
Sludge removal	0.02	0.03
Total	0.30	0.57
Capital costs[2]	0.87	1.68
Secondary + Tertiary Treatment		
Total and capital costs	0.94	1.75

[1] Data source for annual inflation rates: http://www.tradingeconomics.com/Economics/Inflation-CPI.aspx?Symbol=ILS

[2] This includes taxes, loans, & overhead expenses.

Producing New Water Via Desalination - The long-term construction program of large-scale sea water desalination began contributing potable water to the national potable water supply in 2005. The three large-scale seawater desalination facilities were built at a cost of US $750 million.[34] The large-scale seawater desalination facilities, together with several smaller brackish water desalination facilities currently (as of 2010) provide water for approximately 42% of the domestic requirements. [35]

In addition to the desalination facilities themselves, the construction of a pipe/pumping conveyance system is required to transport this water throughout the State of Israel. The pipe-conveyance system that has supplied potable water from the Sea of Galilee and the aquifers for several decades, moves water predominantly from the north towards the south and west. With the advent of the desalinated water supplies, a new piping system has become necessary, to transport the desalinated water in the opposite direction (predominantly towards the north and east). Construction of this new pipe-infrastructure is a 10-year project which will be completed by 2020.

Expenses for operating the desalination facilities, for water conveyance to the users, and for the construction of additional desalination facilities are shown in Table 7 for current and future years. The operating costs are particularly low (on average $0.54/m^3) relative to international facilities (Figure 8).

[34] Source: Water Authority Planning Department

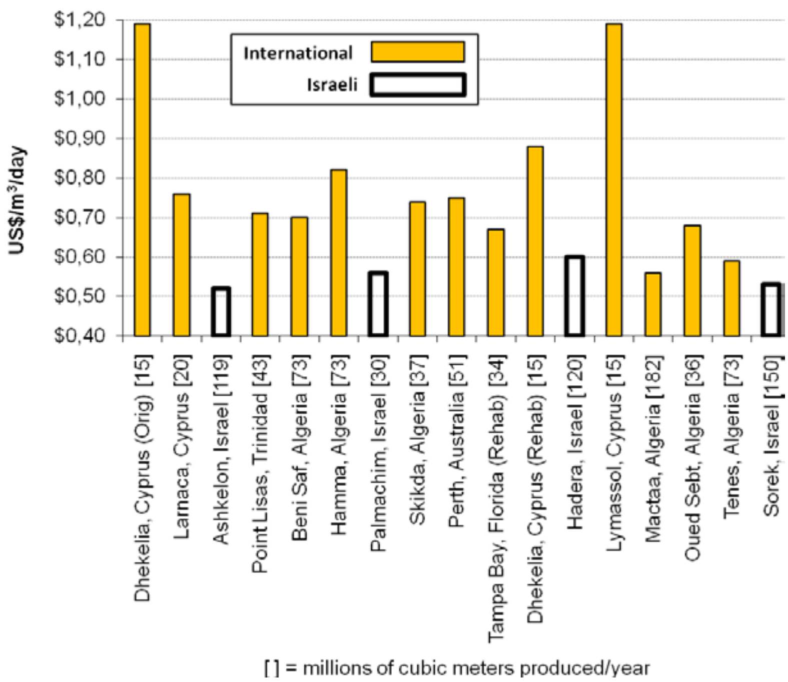
[35] Source: *A Long-Term Master Plan for the Water Sector* – 2010 Policy Document of the State of Israel, Ministry of National Infrastructures, Water Authority, Planning Department.

Table 7 - : a) Costs (US $/yr)[1], b) benefits (million cubic meters (MCM/yr)), and c) costs per unit benefit (production) of seawater desalination and conveyance throughout the national pipe-grid. Estimates are provided for the years: 2010, 2015, and 2020.[2]

	Desalination	2010	2015	2020	
a)	Expenses	Millions US $/yr			US $ /m³
	Desalination operating expenses	166	301	437	0.54
	Water conveyance	223	404	586	0.72
	Construction of facilities	125	155	118	3.88
	Construction of new pipe infrastructure	78	349	349	1.84
	Total	591	1211	1490	6.99
b)	Production	MCM/yr			
	Total desalinated production	307	558	809	
c)	Cost per m³ Produced	US $/m³			
	All expenses in section a) per m³	1.92	2.17	1.84	
	Operating expenses/m³	0.54	0.54	0.54	

1 All units are in millions of US $, except the column: Cost/m³, which is in US $ (not in millions). All cost estimates are as of the year 2010.
2 Data Sources: Internal documents, and A Long-Term Master Plan for the Water Sector – Policy Document of the State of Israel, 2010, Ministry of National Infrastructures, Water Authority, Planning Department.

Figure 8 - cost-comparison among international large-scale seawater reverse osmosis (SWRO) desalination plants that have been built between 1997 and 2010



A cost-comparison among international large-scale seawater reverse osmosis (SWRO) desalination plants that have been built between 1997 and 2010 (ordered from left to right by operation-launch date). Israeli desalination facilities are shown in open bars, and facilities from other countries are shown by closed bars. Annual production volumes are indicated within square-brackets on the x-axis, in millions of cubic meters.
Source: Water Authority, Desalination Department

Energy and Cost-Efficiency - A myriad of policy-based, technological, mechanical, architectural, and managerial factors contribute to making Israel's large-scale desalination facilities among the most energy-efficient and cost-efficient in the world (Figure 8). Currently, the national average energetic and financial cost of production per cubic meter of desalinating water in Israel is 3.5 kilowatt hours and US $0.54 (respectively).

The Israeli Water Authority (IWA) uses its tender-bidding process to maximize efficiency and promote energy conservation in the desalination process. For example:

- Scores on the bidding system favor natural gas power generation rather than coal generators. Natural gas power generation is approximately 7 to 8% cheaper than the energy provided by the national (coal-driven) power system. This savings reduces the cost of producing the desalinated water, thereby raising the bid-score further (since cheaper water scores higher).
- Builders of the desalination facility are permitted to build a power facility that not only provides power supplies to the facility, but provides additional energy that can be sold to the national power grid, at a profit to the builders. This allows further reductions in the bid-costs of the desalinated water-product (thereby increasing the bid-score further).

Two examples of the many other important factors responsible for the energy and cost-efficiency of Israel's large-scale desalination facilities are:

- Efficient technological energy recovery systems that re-use energy in the midst of the desalination process
- A government policy for dividing all risks between the private companies that receive the tender, and the government. For example, the take-or-pay policy ensures that the government will pay for the agreed-upon volume of water that is supplied by the desalination facility each year, even if less than that volume is actually required or consumed.

Upon completing construction of each large-scale desalination facility, water tariffs are raised. Each of these increases in tariffs is expected to cause a concomitant reduction in water-demand (a natural demand-management mechanism).

Inset 2 - Example: Ashkelon Desalination Plant

The reverse osmosis sea water desalination plant that occupies 75,000 m^3 of the coastal city of Ashkelon was the first of Israel's 3 large-scale desalination facilities to be built. It received a Global Water Award for 'Desalination Plant of the Year' in 2006. Its annual production of approximately 120 million cubic meters supplies approximately 16% of the national domestic water requirements as of 2010. The operating expenses of this desalination facility remain among the lowest in the world, even five years after production was initiated (in 2005). Among reverse-osmosis desalination facilities (which are typically relatively low energy systems), operating expenses of the Ashkelon desalination facility are among the most economical in the world (Figure 8).

Numerous technological and operating innovations reduce the cost of production far below the operating costs of most international desalination facilities, to $0.53/$m^3$. Among the many cost-reducing innovations is inclusion of 40 double work-exchanger energy recovery devices (DWEER) that reclaim and re-use the energy from the pressurization procedures that are involved in the desalination procedure.

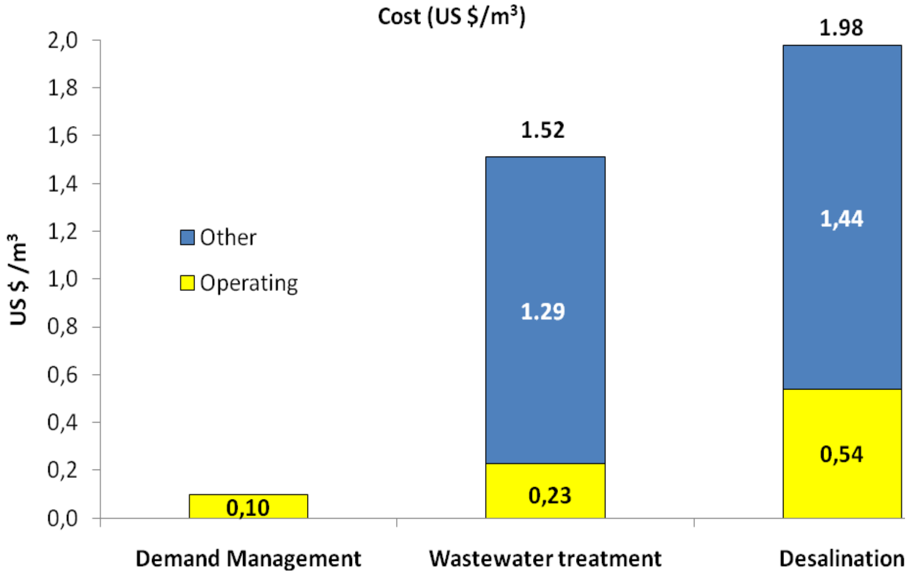
The construction, operation, and water conveyance to the main grid-system ('Build-Operate-Transfer) was accomplished by private companies that won a tender that was elaborately designed to maximize energy efficiency and minimize costs. The cost of the project was $ 212 million, and the overall revenue over the 25 year contract is expected to be approximately $825 million.

The facility includes membrane desalination units, seawater pumping systems, pre-treatment, and product water treatment systems (including 32 reverse osmosis banks and the use of multi-stage reverse osmosis and boron removal procedures). The facility also includes workshop and laboratory buildings, access roads, and a gas-turbine power station.

3. Cost-benefit analysis among three water savings/production initiatives

Employment of all three initiatives (demand management, effluent re-use, and desalination) is essential for sustainable water use in Israel. Thus, although the cost effectiveness (cost-per cubic meter of water conserved/produced) of the demand management campaign is much lower than effluent re-use, which in turn, is lower than costs of desalination (Figure 9), these differences in cost-effectiveness would not preclude wastewater treatment, or production of desalinated water.

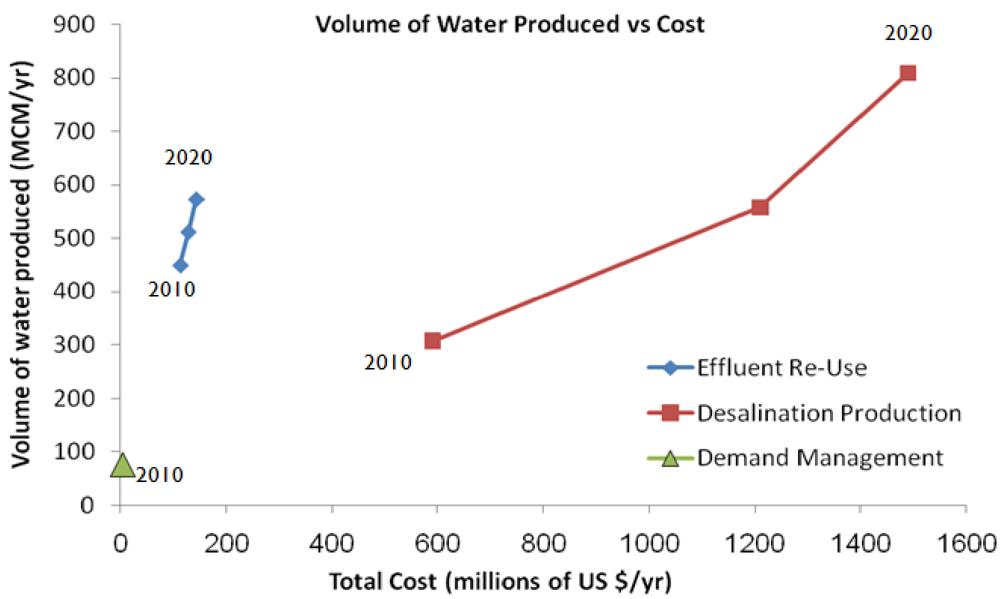
Figure 9 – Total cost of a sample of three water supply/efficiency initiatives in Israel



Total cost (US $/m³) of a sample of three water supply/efficiency initiatives in Israel. The cost of effluent conveyance from wastewater treatment facilities to the agricultural sector & nature ($0.23/m³) is distinguished from the remaining wastewater treatment and conveyance to the treatment facilities from the domestic sector ($1.29/m³). Desalination running costs ($0.54/m³) are distinguished from all other costs of desalination (construction and conveyance; $1.44/m³).

Additional means of ensuring an adequate supply of water are imperative in the State of Israel, since available natural supplies are insufficient for the growing population (Figure 4). This is the case despite effluent re-use and effective demand management initiatives such as the awareness campaign and initiatives that promote agricultural use-efficiency. Desalination provides a large and growing alternative water source for Israel (Figure 4). Together, all three initiatives make essential contributions to water management in Israel. Investments in existing and planned expansions in effluent re-use and desalination are shown, as well as investments in the existing media awareness campaign (Figure 10).

Figure 10 – between the overall costs ($US/yr) and benefits (MCM/yr) of three water savings or production methods



Comparison between the overall costs ($US/yr) and benefits (MCM/yr) of three water savings or production methods. The three methods are: demand management ('Demand Management'), effluent re-use in the agricultural sector & nature ('Effluent Re-Use'), and the production of new water ('Desalination Production'). Desalination and wastewater treatment facilities will be in a growth (construction) phase over the coming decade. Demand management-data are shown only for 2010. Effluent re-use and desalination are shown for 2010, 2015, and 2020 (chronologically from left to right, and connected by a line).

IV. Synthesis

The arid climatic conditions and very limited natural water resources that characterize the State of Israel and the surrounding region merit a large investment in water conservation tactics, as well as the development of alternative water supplies. The State of Israel seeks to employ effective policy initiatives for increasing water use-efficiency, as well as for increasing water supply. These include policies for minimizing per capita consumption in the domestic sector. Policies for the agricultural sector encourage use-efficiency and conservation via technological, crop-selection, and methodological improvements, and increased reliance on brackish or effluent water. Policies for the industrial sector encourage use-efficiency via the use of brackish and re-used water. Policies are also employed to reduce water losses in all sectors during conveyance, and to maximize overall water use-efficiency. To date, these initiatives, in addition to policies associated with the large-scale production of desalinated water, have provided enormous gains in water conservation and supply. They have great potential for continuing gains during the coming decades (e.g. Figure 4 and Figure 5).

The water conservation and production methods that have been so effective in the State of Israel may provide valuable options to other countries experiencing severe and growing challenges in water supply. Examples include the innovations in large-scale effluent reclamation for irrigation in the agricultural sector, the technological, crop-selection, and methodological innovations that increase use-efficiency in the agricultural sector, the numerous policy-innovations for effective water management, and highly economical operational costs of desalination facilities. The State of Israel would welcome information and technological sharing among nations to optimize efficiency in water use.

Table of illustrations