Friends of the Earth Middle East

An Economic Analysis of Policy Options for Water Conservation in Israel

July 2010

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Amman, Bethlehem, Tel Aviv
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Note of Gratitude

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Contents

1 | Introduction

The following analysis attempts to identify opportunities to conserve freshwater within Israel. It estimates the water savings from a range of different policies. The water savings identified from each individual policy can be considered as a "wedge" or piece of a pie towards a given conservation goal. This methodology of identifying conservation wedges has been developed by researchers at Princeton University in the context of greenhouse gas reduction and has been employed by numerous academic, government, private sector, and non-governmental researchers.[1]

Because water within Israel is managed at a national level, integrating surface and groundwater, this study does not limit itself to the waters of the Jordan River Basin, but rather, addresses all possible opportunities for freshwater conservation within Israel. While the ultimate goal of Friends of the Earth Middle East (FoEME), the organization sponsoring the research, is to identify wedges available for water conservation in order to facilitate the rehabilitation of the Lower Jordan River system, the study itself merely identifies the opportunities for conservation, given certain policy and cost constraints. Should such conservation measures be implemented, the ultimate use of the water saved is, of course, a matter for policy-makers to decide.

The study proceeds as follows: First, a brief overview of Israel's current water resources is provided, including a review of supplies, consumption, and pricing. This is followed by a presentation of anticipated future changes in supply and demand, especially as a result of climate change. A review of major legislation affecting water policies is then presented. The subsequent sections identify opportunities for conservation in the domestic and commercial sectors, the agricultural sector, and from upgrading and improving the national water storage and delivery infrastructure. A summary of findings and conclusions are offered in the final section.

The study attempts to estimate the costs of each water-saving measure, when possible. In many cases, estimates of either the amount of water to be conserved or the cost of the conservation measure are uncertain. In such cases best estimates are given, often with a range of potential reasonable values. The study primarily addresses demand management measures, as these have already been identified as

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1 Pacala and Socolow (2004); Mui et al (2007); Nicols et al (2009); http://cmi.princeton.edu/wedges; http://www.wri.org/project/climate-wedges

representing the cheapest, technologically easiest, and most environmentally beneficial means of living within a strict water budget.[2] However, this study also identifies supply augmentation measures that would result in more efficient use of available water resources. Estimates are based on available data, literature reviews, and interviews with experts in their respective fields. The study concludes with a summary of the findings, a discussion of study limitations and a discussion of implications of the study's findings for policy.

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2   See for example, IWA 2005.

2 | Current Freshwater Balances in Israel

2.1 Current Supply and Demand

Past estimates of Israel's average renewable rainfall are in the range of 1500-1800 million cubic meters (mcm) per year. Rainfall is highly stochastic with high year-to-year variance, and so actual rainfall in any given year may be several hundred mcm more or less than the range indicated. Moreover, as will be discussed more in detail later, many experts believe that the 1500-1800 mcm figure is an over-estimate, and that annual rainfall is on a downward trend.[3]

Israel has been consuming water at or beyond renewable rates since the 1970s. Growing demand, especially for household (and urban commercial) use, has put increasing pressure on the nation's water supplies. Israel has responded by cutting allocations to agriculture and by pioneering several methods for increasing the technological efficiency of use in the agricultural sector, including drip irrigation and development of salt tolerant crops, and by augmenting supplies via reuse of treated sewage and construction of desalination plants. Indeed, Israel is a world leader in these fields. Water consumption by sector is detailed in Table 1. As can be seen, the share of freshwater consumed by the agricultural sector has declined significantly, mirroring the increase in the domestic sector, which is now the largest consumer of freshwater in Israel. Absolute consumption of water by agriculture has remained relatively constant; however, with decreases in freshwater allocations being compensated for by treated sewage and by saline water. Beginning in 2007, Israel also began major desalination projects. As of February 2010, Israel is set to desalinate 270-300 mcm per year, or roughly one-third of the household consumption. Desalination is expected to produce 650-750 mcm by 2020.[4]

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3   IWA, 2009.
4   Dreizen et al, 2008; IWA website, http://www.water.gov.il.

Table 1. Israeli Water Consumption by Sector 1996 – 2008 (mcm)

Year	Total	Domestic	Agriculture					Industry		
		Total	Fresh-water	Reclaimed Wastewater	Brackish	Flood-waters	Total	Fresh-water	Marginal	Total
1996	2012.7	604.0	892.3	270.0	76.3	45.7	1284.3	94.5	29.9	124.4
		38%	56%					6%		
1997	2007.8	621.2	854.1	255.4	92.4	61.9	1263.8	87.8	35.0	122.8
		40%	55%					6%		
1998	2165.8	671.7	918.3	271.0	96.4	79.2	1364.9	92.6	36.6	129.2
		40%	55%					6%		
1999	2072.9	681.8	824.3	285.5	100.8	54.0	1264.6	91.0	35.5	126.5
		43%	52%					6%		
2000	1923.7	662.1	729.1	259.7	99.9	48.7	1137.4	90.2	34.0	124.2
		45%	49%					6%		
2001	1800.4	658.4	563.2	266.3	145.1	47.3	1021.9	85.4	34.7	120.1
		50%	43%					7%		
2002	1830.7	688.4	534.9	285.8	145.9	54.0	1020.5	85.4	36.4	121.8
		53%	41%					7%		
2003	1859.6	698.0	562.5	285.0	150.0	47.6	1045.1	83.9	32.6	116.5
		52%	42%					6%		
2004	1954.3	711.8	565.6	327.3	184.5	52.0	1129.4	81.6	31.5	113.1
		52%	42%					6%		
2005	1961.4	715.2	543.8	340.7	189.7	52.4	1126.6	85.1	34.5	119.6
		53%	40%					6%		
2006	1959.1	737.4	519.3	354.1	190.3	44.1	1107.8	83.8	30.0	113.8
		55%	39%					6%		
2007	2071.7	767.3	551.1	386.6	201.5	46.0	1185.2	89.6	29.6	119.2
		54%	39%					6%		
2008	2000.8	758.5	490.7	399.3	188.2	43.2	1121.4	87.9	33.1	120.2
		57%	37%					7%		

Source: Israeli Water Authority (IWA), 2009.
Note: Percentage figures represent sector's share of freshwater consumed annually.

Despite cuts in allocation of freshwater to agriculture, increases in efficiency of use, and supply augmentation, Israel has been extracting water at beyond renewable rates. This has led to a severe degradation of both the nation's streams and aquifers, in terms of both quantity and quality.[5] The over-extraction has resulted in depleted reserves. While planned desalination capacity as of 2013 is expected to close the gap between annual supply and demand, it will take an additional number of years until the depleted reserves are restored to their previous levels.

2.2 Future Water Balances

Recent estimates by the Israeli Water Authority (IWA) indicate that long term annual rainfall may be only 1100-1200 mcm per year, rather than the 1500-1800 mcm previously believed, and that annual rainfall measurements have been on a downward trend over the past two decades. Furthermore, as a result of anticipated climate change, extended drought periods may be more likely and more severe. Precipitation is expected to decrease by 10% by 2020 and by up to 20% by 2050.[6] In addition, rising sea levels could

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5   Such environmental damage has been well documented elsewhere and will not be detailed here.
6   Ministry of Environment (MoE), 2009.

threaten the coastal aquifer, which represents 30% of Israel's natural freshwater reserves. Table 3 shows anticipated water balances based on expected rainfall, technical capacity, and demand estimates for the years 2010, 2020, and 2040. While supply is expected to increase by over 60% in the next 30 years, primarily due to increased desalination, demand is expected to keep pace, unless innovative new water savings measures are implemented.

The figures in Table 2 are annual averages. While the Water Authority has stated that increased desalination capacity will solve Israel's water shortages by 2013, it will take several years to recharge depleted aquifers, the Sea of Galilee, and other reservoirs that have been severely depleted over the past decade.

Table 2. Projected Water Balances (figures in mcm)

		2010	2020	2040
	Estimated Population (in millions)	7.7	9.1	12.3
Supply	Freshwater pumped	1170	1170	1170
	Brackish	230	230	230
	Floodwaters	35	35	35
	Treated Wastewater	355	564	760
	Desalination	225	692	1170
	Total Supply	1994	2596	3370

Demand	Domestic	769	974	1312
	Industry	85	95	125
	Agriculture	990	1279	1475
	Water to nature	10	50	70
	Transfers to neighboring countries	140	198	388
	Total Demand	1994	2596	3370

Sources: Based on figures from IWA, http://www.water.gov.il, current commitments and projections based on current trends.
Notes:
1. Population growth is estimated at 1.7% annually until 2020 and then at 1.5%.
2. Recharge is based on 20 year averages with 10% reduction for climate change and 10% reduction for losses to the sea.
3. The amount for treated wastewater given in Table 2 is lower than that given for previous years in Table 1, despite the fact that percentage of wastewater treated, and thus absolute quantities, are increasing. The discrepancy is due to roughly 40 mcm of freshwater that is mixed with wastewater at the Shafdan treatment plant and is counted in official figures given in Table 1 as wastewater, whereas in Table 2, this is listed as freshwater.
4. Domestic consumption was estimated at 107 m3 per capita in 2007, 92 in 2010, and 104 in 2020 and 2040. The drop for 2010 is based on consumption in 2009, which was lower than previous years due to a combination of a drought awareness campaign and an increase in water prices for the municipal sector.
5. Water transfers to neighboring countries include 72 mcm transferred to the Palestinian Authority (PA) and 55 mcm transferred to Jordan in 2007. In following years the amount transferred to the PA is estimated to increase at 4% annually. (IWA presentation, November 2009, to Interministerial Committee on Climate Change).
6. Water supply figures for desalination in 2010 are based on operation of the Hadera plant for only part of the year. The 2020 and 2040 figures are based on amounts calculated as necessary to balance demand in those years.

Water transfers to Palestinians made according to the Oslo Peace Accords and to Jordan according to the Israeli-Jordanian Peace Treaty and according to subsequent arrangements between the parties are included in Table 2 under the category "Transfers to other countries".[7] According to agreements between Israeli and Palestinian negotiators, Palestinians will eventually get full access to the Eastern Aquifer. Palestinians also demand an increased share of the Mountain Aquifer as a whole and direct access to the waters of the lower Jordan River. Under a final status peace agreement, water supply to Israeli settlers in the West Bank will likely be reduced significantly or ceased completely. Future political agreements regarding Jewish settlers

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7 These figures represent official and external estimates and do not represent the position of FoEME which advocates for water allocation based on criteria of fairness and needs.

are unlikely to make a difference in terms of Israel's internal overall water demand however, as any reduction in their water consumption from sources in the West Bank would be replaced by increased consumption within Israel proper. Thus, the net effect on Israeli water consumption would likely be marginal.

2.3 Water Pricing and Shadow Values

Although water in the agricultural and industrial sectors is allocated by the government, consumption of water in all three primary sectors (agriculture, industrial, and domestic) is a function of price. For all sectors, however, the price of water is determined by regulatory bodies, and thus, is not reflective of its true market value or shadow price. The cost of desalination can be seen as representative of the marginal cost of additional water production. This is estimated at $0.56 per cubic meter. Actual costs are dependent on energy prices, and would likely increase should some type of carbon tax be implemented or should there be some spike in energy prices for other reasons.

In order to calculate the shadow value of freshwater, one needs to take into account environmental externalities associated with desalination as well. There are three primary environmental externalities associated with desalination: 1) emissions from energy consumption (primarily emissions of CO_2, SO_2, NO_x, and particulate matter), 2) expropriation and exploitation of coastal land; and 3) damage to the marine environment from seawater intake and brine discharge. The cost of environmental damage due to energy-related emissions and shore-land expropriation are estimated at roughly $0.19 and $0.06-0.10 per cubic meter respectively.[8] While several environmental impacts of desalination on the marine environment have been identified, their effects on the ecosystem and on ecosystem services are still not well understood. Therefore, no cost estimates are available. Thus, the $0.19 per cubic meter assessment of the value of the external costs associated with desalination should be viewed as a conservative, lower-bound estimated. Added to the cost of the desalination process itself, this places the shadow price of water at $0.88- 0.92 per cubic meter (see Table 3).

In evaluating the costs of use of desalination as a potential replacement for freshwater delivered via the National Water Carrier (NWC), the nation's primary water delivery system, it is necessary to consider the relative costs of water delivery as well. Pumping and transport of water demand significant energy.[9] Located closer to major population centers, desalination benefits from reduced delivery costs compared to the NWC. Should policy determine that less water be pumped into the NWC and kept in the Jordan River system, one would also need to subtract the saved delivery costs and the avoided externality costs from delivery via the NWC. In such a case, the adjusted shadow price of freshwater would be $0.65-0.69 (see Table 3).

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8   These figures were based on a carbon price of $30 per ton. For a more detailed explanation of these costs, see the notes in Table 3 below. For a more detailed explanation of calculations of externalities associated with desalination in Israel in general, see Becker 2004 or Pareto 2008.
9   Pumping and treatment costs for water mean that transfer of water from the Kinneret (Sea of Galilee) to the southern coastal areas is only slightly cheaper (roughly $0.10 per cubic meter) than desalination. Actual differences in price depend on distance from the Kinneret and, given the mix of surface and groundwater, the relative share of Kinneret water consumed.

Table 3. Shadow Prices of Freshwater in Israel

	US$/m3
Desalination (direct costs)	0.56
Storage and treatment costs	0.07
Emissions externalities	0.19
Expropriation of coastal land	0.06 - 0.10
Damage to marine environment	n.a.
Total Cost	**0.88 – 0.92**

Avoided delivery costs	-0.20
Avoided emissions from delivery	-0.03
Total	**0.65 – 0.69**

Sources: Ministry of Environmental Protection and Pareto Engineering Ltd, 2008; Israeli Electric Company Emissions Report, 2007.
Notes:
Figures for external costs from emissions were based on energy consumption of an average of 3.7-4.2 kilowatt hour (kwh) per m^2 water and emissions per kwh produced as of 2007 as shown in the table below. In addition, a carbon price of $30 per ton was added to these costs. This is roughly double current carbon prices in the European carbon market, however, the price is expected to increase once a new global climate agreement comes into effect. Costs for coastal land were based on a land value of US$5-25 per m^2 per year based on cost-benefit analyses and US$50 per m^2 per year based on retail real estate values. The area of a desalination plant was estimated at 250,000 square meters for a plant with 100 mcm/year capacity and valued at US$40 per cubic meter.

Estimated Pollution by Type per Kilowatt Hour Generated

	CO2	S02	NOX	Particulate Matter
Emissions (gram/kwh)	741	1.71	1.8	0.06
Cost ($/kwh)	3.00	1.14	0.70	0.06

Pricing of water is a critical element in demand management. Israel currently prices water differently according to sector and water type (e.g., fresh, brackish, treated wastewater), and according to region in the case of agricultural use. For all sectors there is an increasing block rate tariff structure. The prices for the different sectors, as of January 2010, are presented in Table 4. The prices for agriculture and industry are lower than that of the domestic sector. While it is true that domestic use demands a greater security of supply and quality, the price for delivery before treatment for agriculture and industry is still significantly lower than that of domestic use. Thus, these sectors can be seen as receiving a subsidized water rate. The difference in marginal water prices among competing sectors indicates that water is currently inefficiently allocated.

Table 4. Water Pricing in Israel as of January 1, 2010

Freshwater in US$/m3		Price (including VAT)
Agriculture	Up to 50% of allocation	0.496
	50-80% of allocation	0.571
	80-100% of allocation	0.724
	100-108% of allocation	0.887
	>108% of allocation	1.049
Industry	Up to 100% of allocation	1.180
	100-108% of allocation	1.475
	>108% of allocation	1.770
Domestic	Up to 5 cubic meters per 2 month period	1.224
	> 5 cubic meters per 2 month period	2.237
	Hospitals and other recognized uses	0.691
	All other non-household uses	2.237

Treated Wastewater & Brackish Water		Price (including VAT)
Treated Sewage	Up to 100% of allocation	0.226
	100-108% of allocation	0.282
	>108% of allocation	0.338
Brackish	Up to 100% of allocation	0.300
	100-108% of allocation	0.375
	>108% of allocation	0.450

Source: IWA 2010 http://www.water.gov.il/NR/rdonlyres/20F7141C-EF2F-4F41-A952-45EF3196649A/0/TarifaiMaim250310.pdf
Notes:
1. The prices listed above include the cost of delivery only and do not include wastewater treatment costs.
2. Prices as of January 1, 2010 using the interbank exchange rate on this day. These prices are updated regularly, and their dollar value varies with fluctuations in currency exchange rates. As such, they are presented in this document primarily for illustrative purposes in order to demonstrate the relative differences in sector prices.
3. Prices for agriculture can vary by region. The prices listed above are representative of typical costs.
4. The prices for treated sewage are for wastewater treated to quality necessary for unrestricted use. Wastewater for limited uses is slightly cheaper, while higher quality wastewater from the Shafdan treatment center is slightly more expensive.

In 2009, the Israeli Water Authority (IWA) announced plans to raise prices to reflect actual production costs (not including environmental externalities). These included a policy to significantly raise the tariff rate on marginal consumption, i.e., on the third of a three block tariff, affecting consumption beyond 16 cubic meters per month per household.[10] In addition, it called for a broader reform of prices to be implemented beginning in 2010.[11] Although deemed necessary for limiting consumption by both the Head of the IWA and by an outside advisory panel, both policies encountered significant popular and political resistance by politicians and by the State Comptroller, who claimed that such reforms placed an unfair burden on poorer populations.[12]

Initial experience from the first reform, popularly dubbed the "drought tax", indicated that it was effective in lowering consumption patterns by up to 20% from the previous year.[13] Lowered consumption was evident even among those who were not affected by the increase in the marginal tariff rate, indicating that reduction was caused in part through the public awareness campaign and pressure on municipalities to cut use. Also surveys indicate that many, possibly most, people are unaware of their water consumption,[14] and therefore were likely reacting to fears of price increases based on high profile coverage in news reports. As a result of the political protest, the drought tax was temporarily suspended and the future of both price policies is uncertain.

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10 This is a representative figure. Actual amounts are adjusted per number of residents per household.
11 The prices for domestic use provided in Table 5 are after the general reform. They do not include the drought tax, which was frozen as of the time of publication of this report.
12 State Comptroller Report, 2009. The National Committee of Inquiry Regarding the Management of the Water Economy in Israel, 2009.
13 Hovel, 2010.
14 According to a study reported by Peled (2009) 65% of Israelis did not know how much water they consume, and 77% did not know how much they will pay for water.

3 | Overview of Existing Policies & Regulations Governing Water in Israel

Several laws and regulations currently govern Israeli water management. Regulatory oversight is split among several governmental ministries and agencies, leading to overlapping jurisdiction and institutional conflicts of interest in national water management. Several powers were centralized in a Water Authority in 2008 in order to minimize the fractured nature of the water regulatory framework; however, problems of coordination of regulatory oversight still exist in Israel and inhibit efficient water management.

The primary legislation governing Israeli water management is summarized below:

- **The Water Law** of 1959 is the most significant piece of legislation overseeing water management in Israel. The law declares all water property of the government and mandates that the government manage these waters for the public good. It establishes a water commission (now part of the Water Authority) that is responsible for allocations of water among competing sectors and for pricing of water. Additionally, it has the responsibility of protecting the natural sources of water. According to the law, water can be allocated only to recognized objectives. Currently, the agricultural and industrial sectors receive water allocations, while the domestic sector has largely unrestricted access to water. A 2004 amendment to the Water Law added environmental and aesthetic causes to the list of legitimate objectives. Prior to this period streams and other aquatic ecosystems tended to be allocated only what little was left over after other uses received their allocations. The change, while significant from a legal perspective, has yet to result in substantial increases in allocation to environmental flows.
- **The Streams and Springs Authorities Law** allows the government (now the Minister of the Environment, after consultation with local authorities and the Minister of the Interior) to establish a regulatory authority for a particular river or other water source. Such authorities are empowered to undertake steps to protect and conserve the stream and its banks, to abate nuisances and prevent pollution. River Authorities have been created for the Yarkon and Kishon Rivers. The Jordan River does not have an individual authority to oversee its management.
- **The Drainage and Flood Prevention Law** creates Drainage Authorities for specific streams. A Lower Jordan River Drainage Basin (LJRDB) exists under the mandate of this law. While the primary function of drainage authorities has been channelization of streams and ensuring proper drainage of agricultural runoff, the LJRDB lists as its official objectives protection of water quality from pollution and planning and protection of water sources including environmental values.
- **The Local Authorities Sewage Law** requires local authorities to maintain sewage systems. Successive regulation pursuant to this law has detailed standards for minimum treatment levels.

- **The Public Health Ordinance** grants the Ministry of Health oversight of drinking water standards. Rules promulgated under the Public Health Ordinance dictate standards for treatment and reuse of wastewater for agricultural products.
- **The Water and Sewage Association Law**, passed in 2001, calls for the privatization of municipal water delivery and wastewater treatment.

National Planning Outlines #34 and #35, national statutory planning guidelines, call for integrated land and water management in general and specifically call for the development of a master plan for each river and major stream. A statutory agency, the River Restoration Administration, was created by the Ministry of Environment and the Jewish National Fund (KKL) in 1993 to promote and oversee the rehabilitation of Israel's streams. The Lower Jordan River Drainage Authority with responsibility from the Sea of Galilee to the Bezeq Stream on the Green Line has created a Lower Jordan River Management Committee who under the auspices of the Ministry of Environment has issued Terms of Reference for the preparation of a master plan for the river's rehabilitation. The master plan is expected to be completed by 2011.

Several other laws and regulations also impact water use, water quality, or other aspects of river management, which are not detailed above. These include those regulating solid waste, public health, business licensing and zoning, and others.

4 | Potential for Water Conservation in the Domestic and Municipal Sector

4.1 Composition of Domestic and Municipal Water Consumption

As mentioned above, domestic and municipal water consumption now represents the largest consumer of freshwater in Israel. For the 2005-2007 period, water consumption for household use amounted to roughly 66 cubic meters per capita (Table 5). Of this, toilet flushing and showering represent the largest individual uses, accounting for 35% each of household use. Household consumption represents over 62% of urban water consumption. Other urban water uses, such as irrigation of public parks and gardens, commercial and other non-residential urban uses, account for an additional 31 cubic meters per capita, or roughly 29% of urban use. Water losses from leakage in the urban sector account for an additional 10-15% of water delivered. (Figures for water losses are debated, and are believed to be highly variable across municipalities.[15])

Table 5. Domestic and Municipal Water Consumption by Use

Uses	%	liters/cap/day	m³/cap/year
Toilet Flushing	35%	60	21
Drinking, cooking, and dishwashing	20%	30	12
Bathing	35%	60	21
Laundry and cleaning	5%	8	3
Home gardening	5%	8	3
Total Household	100%	166	66
Municipal gardening			17
Commercial and other non-domestic urban uses			9
Leakage and losses			16
Miscellaneous			5
Total Domestic and Municipal			107

Source: IWA website, http:www.water.gov.il.
Note: Based on 2005-2007 figures

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15 Eilon, 2009.

Several options exist for reducing water consumption and for improving efficiency of water used in the domestic and municipal sector. Options explored in this study include awareness raising, alterations to types of plants in gardens and parks, reduction in water losses due to leakages, rainwater collection, and reuse of grey-water (water recycled within the household). Each option will be discussed separately below.

As mentioned above, price reforms are also an integral component in any plan for water management. Given both the government's stated commitment to pricing water such that it reflects actual supply costs and to implement the polluter pays principle, it is clear that higher prices are necessary. Conducting an actual estimate of elasticity of demand for urban water in order to calculate the water savings and economic cost of various water pricing reforms is beyond the scope of this study. As such, water pricing measures are not listed among the policy options investigated. It should be noted, however, that while domestic and municipal sector water demand is generally relatively inelastic, it is not completely so. In fact, several studies of urban water demand from around the world have showed that elasticities tend to range from -0.3 to -0.8, meaning that a 10% rise in prices would result in a 3%-8% decline in consumption.[16] One study on water demand in Jerusalem indicated that elasticity may be low, as low as -0.18.[17] However, demand is still responsive to pricing, and it is clear that price reform should be considered as an essential part of any and all other policies to reduce water consumption.

4.2 Awareness-Raising for Urban Water Demand Management

In response to the current drought, the IWA has, for the past several years, run campaigns designed to raise public awareness regarding the need for water conservation. These campaigns included use of celebrities in television, radio, newsprint, and billboard ads, classroom learning units in schools, distribution of materials for posting in workplaces and public buildings, and more. The campaigns are believed to have had some success in lowering consumption. Other campaigns such as distribution of water-saving filters ("chaschamim") to be placed in faucets are planned at a relatively low cost, but have yet to be implemented.

In terms of savings potential, three scenarios were explored. These are listed as low, moderate, and high conservation potential. A breakdown of the assumptions behind the different scenarios and the amount of water assumed to be conserved under each is offered in Table 6. Over the course of 2009, Israel has demonstrated that the high range scenario is indeed feasible, as a nearly 20% reduction in overall domestic use has already taken place through a combination of awareness raising and pricing.[18] Whether this reduction is sustainable over the long term and whether further reductions will be as easily achieved are open questions, as the campaign was calling for temporary sacrifice to avert a drought. However, the initial results are at least encouraging. Other countries have examples of reductions of rates exceeding 40% due largely to awareness raising campaigns. In such cases, initial levels of per capita water use were higher than in Israel making the percentage reductions easier.

It is important to note that decreased consumption brings with it decreased costs, making these options desirable from both an environmental and economic perspective. Decreased demand will reduce the need for desalination saving the treatment, delivery, and externality costs. This is not all a net benefit, however, because decreased consumption will also reduce the amount of sewage available for reuse. Furthermore, the sewage that is produced will have a higher concentration of contaminants, and thus, will likely need additional treatment. Thus, the opportunity costs of decreased sewage need to be subtracted from the benefits of avoided desalination costs. Assuming that an awareness raising campaign would cost roughly US$10 million, the cost per cubic meter conserved would be between US$0.07-0.13. When considering avoided desalination, delivery, and sewage treatment costs, this puts the cost at roughly 10% that of desalinated water.

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16 See, for example, Bauman et al, 1998; Dalhuisen et al, 2003; Fredrick et al, 1996; Olmstead, 2007.
17 Dahan and Nisan, 2007.
18 Hovel, 2010.

Table 6. Water Savings from Awareness-Raising in the Domestic Sector

	Low	Medium	High
Toilet Flushing	10%	10%	10%
Drinking, cooking, and dishwashing	10%	10%	10%
Laundry and cleaning	10%	20%	30%
Bathing	20%	30%	40%
Home gardening	20%	30%	40%

	Low	Medium	High
m3/capita/year	8.4	11.9	13.8
% of total household consumption	12.7%	16.8%	20.9%
Water Savings in mcmper year	76.4	101.0	125.5

Note: MCM per year figure based on estimated 2020 population.

4.3 Changes in Plant Types in Parks & Gardens

Irrigation of parks and gardens is responsible for nearly 20% of domestic and municipal water consumption. Much of the flora – flowers, plants, shrubs, and trees – in parks and gardens, both public and private, are water intensive. According to discussions with landscape architects, the IWA's Master Plan for Water Conservation, and reports by the Ministry of Environmental Protection,[19] replacing such flora with varieties with low water needs and improved irrigation techniques could result in a 50% decrease in water consumption for urban irrigation.

Again, three possible scenarios are considered which differ based on the percentage of parks and gardens that switch plant varieties and irrigation techniques – low (25%), medium (50%), and high (75%) (see Table 7). Such scenarios would result in water savings of 23, 46, or 68 mcm per year, respectively. This would also save money in terms of avoided desalination and delivery. The transition would not be costless, however. Costs would include an information campaign, estimated at US$ 6 million, and the costs of purchase of new plants and labor. As can be seen in Table 7, we also assume a one-off government incentive payment and a 10% cost of capital. Given such assumptions, the net economic benefits would outweigh the net costs by $0.39 per cubic meter of water conserved.

Table 7. Change to Less Water-Intensive Flora in Parks and Gardens

		Low	Medium	High
Gardens switching (%)		25%	50%	75%
Water saved (m3/cap/year)		2.5	5	7.5
Water saved (mcm/year)		23	46	68

	US$/per m3	Million US$/Year		
Avoided desalination and delivery costs	0.87	20.01	40.02	59.16
Avoided environmental costs	0.13	2.99	5.98	8.84
Total Benefits	1.00	23	46	68
Costs*	0.61	14.03	28.06	41.48
Net Benefits	0.39	8.97	17.94	26.52

*** Cost Assumptions**
Investment costs per dunum	US$ 7,500
Government support (one time)	US$ 1,900
Government support per dunam	US$ 0.48
Capital Costs (at 10%) yearly	US$ 190
m3 saved per dunam	400

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19 Israeli Water Authority, 2005; Ministry of Environment 2009.

4.4 Reduction in Leakages and Associated Water Losses

Water losses in delivery, measured as water pumped into the delivery system minus metered water consumed at the final destination, accounts for 10-15% of domestic water consumption.[20] Most of this is due to leakages in the system, although some portion may be attributed to illegal connections and other non-metered uses. Such a percentage of water losses is not considered high by international standards. Many urban areas in both developing and industrialized countries have water loss rates double or triple that found in Israel. This is especially common in cities with aging infrastructure. Still, the rate of water losses can be reduced in Israel.

In the three scenarios considered, water losses are reduced by 20%, 35%, and 50%. These result in water savings of 29, 51, or 73 mcm per year, respectively (see Table 8). Cost savings from reduced leakage were calculated at $1.05 per cubic meter conserved (in line with the assumptions made for the previous two conservation options). The cost of upgrading infrastructure is estimated at $0.30 - $0.60. Thus, such measures would result in a net cost savings of $0.45 - $0.75 per cubic meter.

Table 8. Reduction of Leakage and Water Losses

		Low	Medium	High
Losses reduced (%)		20%	35%	50%
Water saved (m3/cap/year)		3.2	5.6	8
Water saved (mcm/year)		29	51	73

	US$/per m3	Million US$/Year		
Costs (roughly)	0.30-0.60	8.7-17.4	15.3-30.6	21.90-43.80
Benefits (avoided costs)	1.05	30.45-60.9	53.55-107.10	76.65-153.30
Net Benefits	0.45-0.75	13.05-52.2	22.95-91.80	32.85-131.40

Note: Benefits do not include environmental impacts.

4.5 Decentralized Rainwater Collection and Storage

According to some reports up to 100 mcm of water is lost due to uncaptured stormwater runoff in urban areas in Israel.[21] Capture of runoff in urban areas requires both infrastructure and areas for storage. Given that large storm events that generate large amounts of runoff are infrequent, that appropriate areas for storage are not always available in built environments, and the opportunity cost of land in urban areas is often quite high, many believe that large-scale urban stormwater retention facilities in Israel are still not economically justified.[22] That said, the Jewish National Fund (KKL) is developing a pilot project for urban stormwater capture,[23] the results of which are still unknown. As such projects are uncertain and are already incorporated into government estimates of future available supplies, they are not considered further here.

Rather than large-scale centralized stormwater retention systems, in many countries, rainwater is collected using rooftop or garden systems. In Israel such systems would be most valuable in the coastal regions for capture of water that would otherwise flow into the sea unutilized. To date, the Ministry of Health has not approved the use of such rooftop collection systems. We undertake an estimate of the potential water savings under the assumption that approval will not be an issue. There is no available data on how much water could be captured with decentralized rooftop collection systems, and it should be noted that not all water that would be stored by such systems would represent a net savings of water, as some of this would have gone towards recharging groundwater. Furthermore, it should be noted that not all buildings are appropriate for such storage systems.

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20 Eilon, 2009
21 Shmueli, 2008A.
22 Shmueli, 2008B.
23 Shmueli, 2008A; Ministry of Environment, 2009.

Assuming that all new buildings are required to be built in such a manner as to collect rainwater and that a share of existing buildings are equipped with rainwater collection systems, it is calculated that between 4 and 13 mcm could be conserved per year by 2020 and that 15 to 24 mcm could be conserved by 2040 (see Table 9). Assuming roughly 350 millimeters (mm) of rainfall captured yearly,[24] new buildings added to the existing housing stock at a rate of 1.4% yearly, and initial investments of $3000 per structure, net costs of such a policy are anticipated to outweigh net cost savings by roughly $1.55 per cubic meter. This does not include any costs that would be necessary to treat the water or the costs of any hazards or nuisances that might occur, such as mosquito breeding, damage to rooftops, etc. As the amount of potential water conserved is relatively small and costs are relatively high, such a decentralized rooftop collection system does not seem to be an efficient means of large-scale water conservation in Israel, although it may be efficient for certain households. Several households have, in fact, installed such systems, which has both a direct water conservation value as well as an educational value to stress the capacity of individual action.

Table 9. Rainwater Collection and Storage

		Low	Medium	High
New buildings		100%	100%	100%
Existing buildings		0	10%	30%
Water saved by 2020 (mcm/year)		4	7	13
Water saved by 2040 (mcm/year)		15	18	24

	US$/per m3	Million US$/Year (2020 / 2040)		
Avoided desalination and delivery costs	0.87	3.48 / 13.05	6.09 / 15.66	11.31 / 20.88
Avoided environmental costs	0.13	0.52 / 1.95	0.91 / 2.34	1.69 / 3.12
Total benefits	1.00	4.00 / 15.00	7.00 / 18.00	13.00 / 24.00
Costs	2.14	8.56 / 32.10	14.98 / 38.52	27.82 / 51.36
Net Costs	**1.14**	**4.56 / 17.10**	**7.98 / 20.52**	**14.82 / 27.36**

4.6 Grey Water

Reuse of water within a household – so called grey water – is another possibility for water conservation. Such systems recycle water from uses such as bathing and cooking to uses such as toilet flushing and gardening, which do not need water of drinking quality. Such systems not only offer potential water savings for households, but also reduce the need for sewage transport and treatment, and save the associated direct and environmental costs.

As opposed to reuse of treated sewage, for which Israel is a world leader, little progress has been made on grey water systems in Israel. Several reasons account for this relative lack of adoption of grey water in Israel:

- Household grey water systems require new separate piping, storage facilities, and new building codes which demand both infrastructure and administrative costs;
- The Ministry of Health has not approved widespread use of grey water, although there is considerable public pressure to do so, including a private Member's bill submitted to Knesset;
- Reuse of grey water for gardening and irrigation would likely have a negative effect on soil quality and on groundwater quality;
- Although less sewage would be produced, the sewage that is sent would be of worse quality (more concentrated), increasing the cost of treatment, which would offset some of the savings from reduced quantities delivered;

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24 Not all rainfall, which averages 500-600 mm in the coastal areas, could be captured.

Currently most household wastewater is reused in agriculture. By reducing total quantities of sewage produced, grey water systems would save households the costs of water delivery and treatment, but would reduce the amount of sewage available for treatment and reuse by farmers.

Several systems for grey water reuse exist. This study examines two such systems:

- A system in which grey water is used within the household itself by channeling water from showers and sinks into toilets so that no freshwater is used for toilet flushing.
- A system in which grey water is used to irrigate gardens.

All three scenarios investigated for the first system assume that all new buildings would have grey water systems beginning in 2015. They differ in the assumptions regarding the conversion of existing buildings to accommodate grey water, with 0%, 10%, 30% of existing buildings converting to grey water systems in the low, medium, and high range scenarios, respectively. Under such assumptions, 13, 27, or 55 mcm of water would be conserved annually by 2020, and 87, 101, or 129 mcm would be conserved by 2040 (see Table 10). Based on estimates made by Pareto Engineering,[25] an Israeli consulting firm, the economic benefits per cubic meter of water saved would be $1.34. The costs would differ between existing and new buildings, as retrofitting existing buildings would be significantly more expensive. Costs would be $2.21 per cubic meter for new buildings and $5.50 for existing buildings. Thus, net costs would be $0.87 and $4.16 for new and existing buildings, respectively.

At least two reservations to the above figures are in order. Firstly, these benefit and cost estimates are for installation of water systems and saved water production and delivery only. They do not take into consideration environmental costs from avoided desalination, from construction of duel piping, or from the change in composition of sewage discharged. While some of the costs of anticipated environmental damages are unknown, they likely would not be large enough to offset the net costs. Secondly, the benefit cost assessment is at a national level, not an individual level. The cost of water as seen by the consumer is higher (often by a factor of 3 or more) than the actual cost of delivery and treatment. As such, for individual consumers in new buildings installation of grey water systems will often be economically rational.

Table 10. Reuse of Grey Water (for Toilet Flushing)

	Low	Medium	High
New buildings (% from 2015)	100	100	100
Existing buildings (% from 2015)	0	10	30
Water saved by 2020 (mcm/year)	13	27	55
Water saved by 2040 (mcm/year)	87	101	129

	New Buildings	Existing Buildings
Benefits (US$/m3)	1.34	1.34
Costs (US$/m3)	2.21	5.50
Net Costs (US$/m3)	0.87	4.16

Source: Pareto, 2007

Under the second system, in which grey water is used for irrigation of lawns and gardens, infrastructure costs would be significantly lower. The three scenarios looked at differ in terms of the rate of application of systems and their ultimate uses. The low, medium, and high adoption rate scenarios would conserve 26, 76, or 116 mcm, respectively by 2020, and 48, 102, or 152 mcm by 2040. The economic benefits of avoided

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25 Pareto Engineering, 2007.

water delivery would be roughly $0.87 per cubic meter. The costs differ based on whether public or private gardens were being irrigated (see Table 11). Net costs for grey water for irrigation are estimated at $1.26 and $0.45 per cubic meter for private and public gardens respectively. Again, such costs do not include environmental costs, which in this case would also include possible soil contamination and degradation of groundwater quality.

Table 11. Reuse of Grey Water (for Irrigation of Parks and Gardens)

	Low	Medium	High
Public parks irrigated (%)	25	50	75
Private gardens irrigated (%)	0	15	35
Water saved by 2020 (mcm/year)	36	76	118
Water saved by 2040 (mcm/year)	48	102	156

	Public Parks	Private Gardens
Benefits (US$/m3)	0.87	0.87
Costs (US$/m3)	1.32	2.13
Net Costs (US$/m3)	0.45	1.26

Source: Pareto, 2007

4.7 Summary of Domestic and Municipal Water Conservation Options

Of the six options examined, three appear to offer genuine cost savings: awareness raising, change in plants and gardening techniques, and water loss reductions. Thus, these should be prioritized for implementation as they offer both environmental and economic benefits. Together they would conserve up to 267 mcm per year, or up to one third of total anticipated domestic and municipal consumption. Rainwater catchment and storage and grey water systems demonstrated water conservation potential but were relatively expensive options, with costs higher than that of desalination. The potential water savings and costs per cubic meter saved are summarized in Table 12.

Table 12. Summary of Potential Water Conservation in Domestic and Municipal Sector

Cost Grouping	Policy Wedge	Water Conserved by 2020 (mcm/year)			Cost (US$/m3)	
		Low	Medium	High	Gross	Net
Low Cost	Awareness Raising	76	101	126	0.12	-1.22
Moderate Cost	Water-conserving Plants	23	46	68	0.61	-0.39
	Reduced Water Losses	29	51	73	0.45	-0.6
High Cost	Rooftop Rainwater Collection	4	7	13	2.14	1.14
	Grey water Use (Toilets)	13	27	55	2.21	1.34
	Grey water Use (Irrigation)	36	76	116	1.32	0.45

5 | Potential for Water Conservation in the Agricultural Sector

5.1 Composition of Agricultural Water Consumption

Though its share of national freshwater resources has declined steadily over the past two decades, including its use of reclaimed wastewater and brackish water, agriculture is still the largest water consuming sector in Israel. Agriculture accounts for nearly 40% of freshwater consumption in Israel and over 50% of total water consumption (see Table 1). In contrast, it contributes only roughly 1-2% to national Gross Domestic Product (GDP) and employment (CBS, 2009).

Table 13 provides water consumption figures for the agricultural sector by crop type for 2007. Citrus and other orchard crops make up nearly half of all freshwater and total water consumption, and vegetable crops account for nearly another quarter. Table 14 also indicates whether the crops are primarily for domestic consumption or for export.

Table 13. Agricultural Water Consumption by Crop Type (2007)

Water Type		Freshwater	Brackish	Reclaimed Wastewater	Other (Stormwater)	Total
Crop Type	Primary Market*					
Citrus	1	28	5	145	0	178
Other Orchard Crops	1-0	262	10	50	29	351
Feedstock	0	46	0	20	0	66
Nuts and Cotton	1	25	0	64	35	124
Vegetables	1	139	76	60	0	275
Flowers	1	41	5	5	0	51
Livestock	0	35	0	0	0	35
Aquaculture	0	11	49	0	45	106
Total		587	145	345	109	1186

Sources: Israeli Water Authority, 2009 and Ministry of Agriculture, 2009
* Note: 0 = domestic, 1 = export
Figures based on 2007 consumption, updated with current values of sewage.

5.2 Effects of Water Price Increases on Freshwater Consumption

In general, the price of fresh water for agriculture covers the cost of pumping and delivery. As such, it is higher than the price of water to agriculture in most of the world. However, it is still below market rates in Israel, at less than half the price of desalinated water. As such, it can still be viewed as subsidized. Because of below market pricing of freshwater in agriculture there are opportunities for relatively low-cost water savings in this sector.

Agriculture produces numerous environmental impacts, both positive (e.g., preservation of open spaces which face continuous development threats) and negative (e.g., soil erosion, dispersion of pesticides into the soil and water). To the extent that they produce positive externalities, agriculture warrants government assistance, but this support need not be given via water subsidies. This is especially true of agriculture that does not provide such benefits, e.g., greenhouse agriculture, for which water use differs little than industrial uses.

Similarly, agriculture also provides food security to the country, and thus, it can be argued that it is providing a national service. However, such a rationale is not valid for export crops or non-edible crops such as cotton. To the extent that it is valid, the question is whether the contribution to food security outweighs the depletion of water reserves and associated environmental damages.

Comparing the price for water by crop type, which differs by region, with a baseline of the cost of desalinated water (adjusted to account for delivery costs), it is possible to estimate the relative amount of water that could be saved and thus, desalination avoided. Table 14 shows this data, along with an estimation of the relative profitability of each crop. In interpreting the data, several comments are in order. Firstly, much of the crops are already planned to be irrigated primarily by reclaimed wastewater in the near future. Secondly, prices for the crops, especially more profitable orchard crops like apples, can be volatile. Changes in their relatively profitability would make cuts in water supply less justifiable economically. Thirdly, one can assume that at least some of the water savings from less profitable crops would be rechanneled into more profitable crops, and thus, stay within agriculture. Lastly, high-end crops would continue to be grown, and in such cases, price rises would simply be a transfer of money from farmers to water suppliers.

Costs of price rises in the agricultural sector include the loss in profits to farmers, the loss of sunk costs in infrastructure, the effect of any long-term unemployment in the sector, and the loss of environmental services in terms of preservation of open space and provision of habitat.[26] Unemployment is generally not considered as a cost in most economic models, which assume full employment. However, if price rises force farmers to leave agriculture and these farmers do not find employment in other sectors, the price rises would have a social cost. Furthermore, it is likely that any price increases to farmers would be accompanied by government compensation, at least for a period of several years. These costs would obviously reduce the economic benefits of water savings. On the other hand, much of agricultural work is done by foreign laborers. Any reduction in societal costs due to declines in the number of foreign labors due to declines in agricultural production, would therefore add economic benefits. No attempt to quantify such costs has been undertaken, however.

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26 In strictly environmental terms, loss of these environmental benefits would be partially offset by the avoided environmental damage from desalination. It should be noted too, that vegetables and flowers which are generally grown in greenhouses that involve high sunk capital costs, are generally less sensitive to price increases. These crops, however, also provide less environmental benefits in terms of preservation of open space and therefore are less justified in receiving water at low prices.

Table 14. Estimate of Price Increases on Agricultural Freshwater Consumption

Crop Type	Primary Market*	Freshwater (mcm/yr)	Primary Growing Location	2009 Price (US$/m³)	Profitability	Reduction in Demand (mcm/year)
Citrus	1	28	Golan, Hula, Jezreel Valley	0.18	Moderate	18
Other Orchard Crops	1-0	262	Golan, Galilee, Jordan Valley	0.18-0.35	Moderate	40
Animal Feed	0	46	Hula, Jordan Valley	0.18	Moderate	0
Nuts and Cotton	1	25	Hula, Jordan Valley	0.18	Moderate	15
Vegetables	1	139	Center, South	0.35	Moderate-High	50
Flowers	1	41	Center, South	0.35	Moderate-High	15
Livestock & Aquaculture	0	46	Broadly distributed	0.35	High	0
Total		587				138

* Note: 0 = domestic, 1 = export

5.3 Effect of International Trade Barriers on Agricultural Water Consumption

In addition to changes in the price of water, changes in levels of international trade barriers, both tariff and non-tariff, can affect water demand in the agricultural sector. Currently, trade barriers protecting local industry exist in the dairy industry, which is nearly completely protected from exports (with the exception of minor imports required by the World Trade Organization (WTO) and bilateral trade agreements), and to some degree in the fruit and vegetable sector, depending on the crop, the local price, and the growing season. Domestic banana production benefits from phyto-sanitary regulations which serve as non-tariff barriers. Most other agricultural production is not seen as likely to be affected by removal of trade barriers. [27]

Removal of trade protection such as quotas for dairy products would primarily affect the demand for powdered milk, not fresh dairy products. Removal of such barriers could make related production facilities for up to half of current production redundant. The estimated water savings from such measures is 30 mcm per year, nearly two thirds of the freshwater use in this sector (see Table 15). Bananas are water-intensive crops, grown in Israel primarily in the Jordan River basin and, but for the trade barriers, would likely not be competitive vis-à-vis robust and high quality international supplies. Removal or relaxation of the phyto-sanitary restrictions would result in water savings of up to 15 mcm per year, or roughly three-fourths of the freshwater consumption dedicated to banana production.

In the case of both dairy and bananas, the effects on the market would likely be dramatic, and one can expect fierce political resistance to removal of current protections. If such barriers were to be removed, it is likely that farmers would be awarded compensation. The economic benefits of removal of such trade barriers would be largely contingent on the scale of compensation, and thus, no estimates are made herein.

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27 Meat (primarily beef, lamb, and poultry) production would likely not be affected by international trade policies, for several reasons, including concerns over freshness, demand primarily for kosher meats, and the fact that imports for frozen meats already face little restrictions. Also, Israeli tastes have become accustomed to local varieties of fruits and vegetables, meaning that they may not be completely substitutable with foreign imports. This study focuses on dairy and bananas as the agricultural commodities most threatened by trade liberalization.

Table 15. Effect of Removal of Trade Barriers on Agricultural Freshwater Consumption

Product Type	Measure	Current Water Consumption (mcm/year)	Reduction in Water Demand (mcm/year)
Milk powder	Removal of protection for milk powder	46	30
Bananas	Removal of phyto-sanitary regulations protecting bananas	20	15
Total		**66**	**45**

Sources: Israeli Water Authority, 2009; Ministry of Agriculture, 2009.

6 | Reduced Water Losses from Reservoirs

Because of high temperatures, considerable amounts of Israel's annual rainfall evaporate before they are utilized. For instance, according to estimates, roughly 280 mcm evaporates per year annually from the Kinneret (Sea of Galilee) alone.[28] This compares to 380 mcm that is pumped annually from the Sea into the national water system. There are also indications that temperatures have been rising and evaporation increasing in the region over the last 30 years, and that these changes may be indicative of future trends due to long term climate change.[29] Reducing water losses due to evaporation from exposed surface water reservoirs represents another possible option for conservation.

In terms of fresh water, we estimate that covering the reservoir at Beit Netufa could conserve up to 25 mcm per year. Other freshwater reservoirs could add additional supplies. Given the relatively paucity of natural wetlands in the region, covering natural reservoirs would, however, have undesirable environmental impacts in terms of reducing available freshwater habitat. Therefore such policies should be evaluated critically. The major opportunity for water savings from covering of reservoirs is likely to be from covering of treated sewage reservoirs. In 2008, Israel produced nearly 400 mcm of treated sewage. This amount is expected to increase to 564 mcm by 2020 and 760 mcm by 2030. Evaporation from these reservoirs is estimated at 12-15%. In this analysis we assume that covering the reservoirs will reduce evaporation by 60-75%, that is, it will save 10% of the total amount of water used (see Table 16).

Several methods for reducing such losses exist, ranging from coagulating powders to simple plastic or material covers to covering with solar panels. At this stage, only the powders and plastic and material covers are technologically and economically feasible. Should the solar panels become feasible, this would generate energy that would offset the costs. It is estimated that current methods for covering reservoirs would cost roughly US$1.25-1.50 per dunam per year. This would result in water savings of US$0.007 per cubic meter saved, making such methods extremely cost effective.

Several problems exist with implementing measures limiting evaporation losses from reservoirs. From a technical perspective, there are problems with covering of reservoirs, for instance, development of algae on the interior of the coverings and coverings blowing away or becoming detached. Several more advanced

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28 Feitelson, Gazit, Fischhendler, 2005.
29 Kafle and Bruins, 2009.

systems are available which claim to be more reliable and sturdy, which maintain water quality. Some of these, e.g. companies such as Aquate and Hexa-cover, are equipped with solar panels. Although these systems have higher upfront costs than simpler covers, they claim to offer returns through energy produced.

As in the case of freshwater, covering treated wastewater reservoirs also would involve a loss of habitat and water for wildlife. The costs of these losses of ecological services are not included in the estimates in this study and should be evaluated on a case by case basis.

Table 16. Reduced Evaporation from Reservoirs

Water Source / Year	2010	2020	2030
Freshwater (mcm)	25	25	25
Treated Wastewater (mcm)	40	56	76
Total (mcm)	65	81	101
Cost (US$)	400,000	530,000	660,000

7 | Summary and Conclusions

In sum, a broad range of policy options, or wedges, exist to reduce water demand or augment supply. These options vary greatly in terms of cost per cubic meter of water conserved, and in terms of political feasibility. Political feasibility is a function of economic costs, likely opposition by negatively affected stakeholders, and of the technological ease of implementation.

A simple summation of the water conservation options provided in this paper produces potential water savings of roughly 800 mcm per year. This is likely to be an over-estimate, as certain options overlap or partially crowd out others. Moreover, certain options may be undesirable from an environmental or social perspective, such as covering of freshwater reservoirs. In order to compensate for potential overlap between options and to eliminate options that are undesirable, adjusted figures are given which are 15% lower than the unadjusted figures. From these adjusted figures, over 690 mcm of freshwater per year was identified as being potentially available for conservation (see Table 17). Of this, over 500 mcm can potentially be conserved at costs less than the marginal cost of water, i.e., the cost of desalination. An additional 150+ mcm of water per year can be conserved with current technology, but at costs that make it uncompetitive with desalination. Implementing the cost-effective measures would make unnecessary three large desalination plants, or alternatively, would free up water that could be returned to the natural flows of rivers. This amount represents nearly half of the natural flow of the Lower Jordan River.

The economic feasibility of the options shown was based on current prices. Changes in future prices of technologies, commodities, and externalities are likely to change the relative profitability of water saving options. Options such as grey water systems in new buildings, while not cheaper than desalinated water, are likely to be economically rational for individual domestic consumers who face much higher costs than those used for the basis of this analysis, and so, may see increased popularity. It should also be noted that other options for conservation exist that have not been fully explored in this study, for instance, replacement of impervious surfaces with more pervious materials, reclamation of contaminated groundwater, the replacement of water-cooled air-conditioners with air-cooled systems, and many others. By necessity this study had to limit its focus to options for which available data was available. As such, it should be seen as an initial estimate, which can be the basis for future studies. Future studies may identify more cost-effective methods for reducing water demand and/or augmenting supplies. Even with its limited focus, however, this study was able to identify numerous cost-effective options for water conservation at scales that would allow for significant stream restoration and/or reduction in the need for desalination.

Table 17. Summary of Policy Wedges Examined

	Policy Wedge	Water Conserved by 2020 (mcm/year)			Cost Effectiveness (US$/m3)	Feasibility 1-Low 5-High
		Low	Medium	High		
Supply	Reduced water losses from leakages	29	51	73	0.45	4-5
Supply	Reduced water losses from reservoirs	65	81	101	0.007	4-5
Supply	Rooftop rainwater collection	4	7	13	2.14	1-2
Supply						
Demand	Awareness raising	76	101	126	0.10	4-5
Demand	Change in plants used in gardens	23	46	68	0.61	4-5
Demand	Price increases or reduced allocations in agricultural sector	70	138	200	0.30	3
Demand	Grey water use (irrigation)	36	76	118	1.32	1-2
Demand	Grey water use (toilets)	13	27	55	2.21	1
Demand	Removal of trade restrictions	30	45	60	High	1
Demand						
Unadjusted	Total - net cost less than desalination	293	462	628		
Unadjusted	Total - net cost more than desalination	53	110	186		
Unadjusted	Total	346	572	814		
Adjusted	Total - net cost less than desalination	249	393	534		
Adjusted	Total - net cost more than desalination	45	94	158		
Adjusted	**Total**	**294**	**486**	**692**		

Note: The figures for total water saved in the last three rows of the table have been reduced by 15% from the figures above to adjust for likely double-counting, as each option's water saving potential was evaluated in isolation, and for options whose environmental desirability or technical feasibility is questionable, such as covering freshwater reservoirs.

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