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**THE INFLUENCE OF REGULATION AND ECONOMIC POLICY IN THE WATER SECTOR ON
THE LEVEL OF TECHNOLOGY INNOVATION IN THE SECTOR AND ITS CONTRIBUTION TO
THE ENVIRONMENT**

The case of the State of Israel

This paper was prepared by Dr. Sinaia Netanyahu of the consultancy firm Tahal in Israel, as a case study for the project on Taxation, Innovation and the Environment. The paper discusses the impacts of policies applied over the last decades in the water sector in Israel on technological innovation and on the environment.

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FOREWORD

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**THE INFLUENCE OF REGULATION AND ECONOMIC POLICY IN THE WATER SECTOR
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CONTRIBUTION TO THE ENVIRONMENT: THE CASE OF THE STATE OF ISRAEL**

1. Background and objectives of the paper

1.1 Background and objectives of the paper

1. Technological innovation and the use of inputs (natural resources, human capital, capital, etc.) enable production and contribute to economic growth. However, input scarcity may slow down economic growth unless technological progress exists to compensate for input scarcity. Such technologies may produce a substitute for the scarce input or enable a more efficient use of that input. For example, a water scarcity constraint can be alleviated using technologies that produce desalinated water (sea-water reverse osmosis technology), treat/recycle water (sewage treatment technologies) and use water efficiently (drip irrigation). When technological change occurs in such environments, it undoubtedly becomes a key to ensuring co-existence of economic growth and environmental improvements. This paper presents the Israeli case in dealing with water scarcity and water-related environmental threats, by using advanced administrative and economic tools and incentives and innovative technologies.

1.2 The uniqueness and experience of the Israeli water sector

2. Water scarcity and water-related environmental threats have made Israeli policy-makers introduce advanced regulations, standards, administrative tools and economic incentives to the water sector in order to manage the sector efficiently. That, in turn, has promoted the need for research and development of water and wastewater technologies – some of which financed by public funds and some by the private sector.

3. The unique experience of Israel can be attributed to several factors. Israel, a semi-arid area with an uneven distribution of its water resources, decided already in its early days of its establishment to develop regions that were also remote from water sources. “Blooming the desert” was perhaps one of the initial driving forces for the Israeli economy and for which the water sector responded with the building of the National Water Carrier from north to south. Border security settlements, food security and agricultural development put further pressure on water resources. The response was a further development of physical infrastructure and efficient drip irrigation technologies. Increasing population growth and a large inflow of immigration have created an additional burden on the already overexploited and environmentally degraded resources, thus requiring reallocating renewable water from the agricultural sector to the urban sector for drinking purposes. The need to supply water from alternative sources to the agricultural sector has pushed forward innovation in sewage treatment technologies that produced recycled water suitable for irrigation. Over the years, regulation and standards related to the quality of treated sewage have also contributed to advancing sewage treatment technologies.

4. Water scarcity has also created markets for water-saving technologies for domestic and municipal uses. Economic incentives designed to reduce water demand in the urban and in the agricultural sectors based on increasing block tariffs resulted in the development of innovative water management devices, such as water meters that are read remotely and more accurately (including measuring small drops, so leakages would be fixed), pressure optimizers devices, computerized irrigation systems, etc. In recent

years, increasing standards of living, consecutive years of droughts and peace agreement obligations have put further stress on water resources, pushing the economy to adapt to water production using sea-water reverse osmosis desalination technologies that were developed in Israel over the last few decades.

5. Contaminated drinking wells and aquifers are also a major factor in developing innovative purification/filter/membrane technologies. Economic incentives for rehabilitation of such water sources are today in place, pushing technology implementation, but also innovation, as investors are searching to minimize operation cost of such activities. Finally, highly educated human capital, supported by excellent universities and research centres enabled the industry to use well-trained human power for developing innovative water and waste water technologies.

2. The structure of the Israeli water sector – major trends

6. In recent years, the rationale motivating the water sector in Israel underwent changes, embedding economic incentives and environmental and health considerations, striving to become more efficient and responsible for future generations and therefore enhancing innovation of water and wastewater technologies. The changes result from deficiencies of various origins in the past management of the water sector. The changes indicate a very dynamic and advanced sector that deals with substantial risks and large climatic uncertainty by implementing new technologies of water production and water treatment and advanced supply and demand management tools.

7. Among Israel's notable achievements are: the establishment (2005) of one of the world largest reverse osmosis sea-water desalination plants, with a capacity of 120 million m³ per year, along with additional plants (2007) with a capacity of 30 million m³ per year. A major recent Government decision is to augment the sea-water desalination capacity to 750 million m³ per year by 2020. Additional achievements are: structural changes related to the creation of the Governmental Water and Sewage Authority (GWSA); treatment of sewage and recycling of treated effluents for agricultural purposes, thereby freeing up potable water for other uses; raising the quality standards of drinking water and of treated sewage; changes in the structure and the rates of water pricing in all sectors to reflect marginal cost, in order to improve efficiency in use; an innovative residential water-saving campaign, which transfers the implementation-risk to the private sector; and implementation of public-private projects through international bids for new infrastructures and technologies.

8. This section presents a discussion and indicators that demonstrate the major changes in the water sector since the 1980s and those that are planned for implementation by 2015/2025, taking into account already approved development plans. The four areas to be addressed are: (1) resources, their mobilization and unconventional production; (2) water demand and pressure on resources; (3) degradations and threats affecting water resources, facilities, ecosystems and populations; and (4) access to drinking water and to sanitation and collection and treatment of wastewater. The major development plan documents available at the GWSA are: the Transitional Plan for 2002-2010 (Water Authority, 2002) and the Israeli Government's decision on a sustainable development program in the areas of water and sewage (2003).

2.1 Resources, their mobilization and unconventional water production

2.1.1 Natural resources

9. Most of the renewable water resources of Israel are regulated by natural groundwater reservoirs and by Israel's largest natural surface reservoir, the Sea of Galilee (Lake Kinneret). The multi-annual average total replenishment of all resources is estimated at 1,840 million m³ per year (Hydrological Service Annual Report, 2004), which is distributed among the country's surface and groundwater basins (Table 1). This yield is achieved by controlled outflows for salinity flushing, uncontrolled outflows to the

Mediterranean and to the Dead Sea due to water table variations, releases to external trans-boundary users or direct use by such users. The natural groundwater resources combine also recharge of flood water and return flows from irrigation to the Coastal Aquifer. Controlled mining in the Arava basins increases their useful yield. Some of the natural resources are saline beyond drinking water standards and require desalination or alternatively to be directed to salinity-tolerant uses. The resultant total safe sustainable yield (excluding mining, regulation and other losses) from the natural resources is 1,564 million m³ per year.

10. The controlled flow is the uncontrolled replenishment (1,840 million m³ per year) reduced by regulation losses of spills and flushing of saline water (117 million m³ per year), *i.e.*, 1,723 million m³ per year. *The regulation index* of these resources is defined as the controlled flow over the uncontrolled replenishment, and is therefore 94%.

11. The variations in replenishment, both seasonal and annual, are high. The coefficient of variation of annual replenishment is 32%. The minimum annual replenishment observed was 45% of the average and the lower decennial was 64% of the average. The Transitional Master plan (Water Commission, 2002) shows that the multi-annual cumulative deviation of replenishment from the mean may reach 150% of the mean replenishment in the five largest water resources (see Table 1) in an extreme time series. A clear impact of global climate change remains unnoticed, as compared to the high 'regular' hydrologic variations. However, recent observations suggest that the replenishment to the Upper Jordan basin has decreased in the last decades by 15%.

Table 1. Renewable natural water resources (including mining in the Arava)
Million m³ per year

Basin	Natural Replenishment	Deductions and additions (Diversions, losses, recharge, return flows)			Safe Sustainable Yield		
		Regulation	Other	Source	Total	Saline	Fresh
Kinneret and Upper Jordan Basin	659	-22 - 18		Spills and diversion of Saline water	619		619
Coastal Aquifer	248	-30		Flushing of Saline water to the sea	218	20	198
			20+31	Flood water recharge and irrigation return flow	51		51
Yarkon-Tanninim	361	-25	- 30	Flushing of Saline water and external users	306	5	301
Western Galilee	140	-12		Flushing of Saline water	128	10	118
Carmel	47	-10		Flushing of Saline water	37	5	32
Eastern Mountain	353		-180	External users	173	19	154
Negev and Arava	32		(+63)	Mining	32	(63)	32
Total renewable	1840	-117	-159		1564	59	1505
Total renewable including mining (Arava)	1840	-117	-96		1627	122	1505
Total available per capita (m ³ per year)*	268	-17	-14		237		219

Source: Hydrological Service Annual Report, 2004. * Year 2004, population 6,869,500 (Israeli Bureau of Statistics).

2.1.2 Mobilization of natural resources

12. The largest mobilization of natural water resources began in 1964 with the operation of the National Carrier, a North to South conveyance that supports mobilization of water from the Sea of Galilee to the southern parts of the country. Also, trans-boundary seasonal mobilisation of some 55 million m³ per year of water is done between Israel and the Kingdom of Jordan according to the Peace Agreement; from that amount, some 22 million m³ per year of the water is diverted to the Kinneret reservoir from the Yarmuk in the winter and is returned back to the Kingdom of Jordan during the summer. Treated sewage effluents (112 million m³ in 2004) are recharged in a Soil Aquifer Treatment (SAT) process to the southern

part of the Coastal Aquifer in an enclosed area as part of the Shafdan sewage treatment and reclamation project. Total inflow to all natural sources for the year 2003/4 was 2,085 million m³ and total outflow was 2,146 million m³. Over-exploitation in this year reached 61 million m³. The average over-exploitation for the years 1997-2004 was 59 million m³ per year (Compiled from the Hydrological Service Annual Reports, 2005).

13. Some naturally unregulated surface runoff, mostly flash floods flowing to the Mediterranean Sea, are not included in the resources listed in Table 1. The multi-annual average of this runoff is estimated at 182 million m³ per year, with a standard deviation of 182 million m³ (Coefficient of variation=1.0) (Hydrological Service Annual Report, 2004). In 2003/4, the runoff flow was estimated at 188 million m³. Part of this water is utilized for recharge to the Coastal Aquifer and included in the safe sustainable yield balance (Table 1). Part is used by small surface reservoirs as marginal water (53 million m³ in 2004). Unused surface runoff is: $182 - 20 - 53 = 109$ million m³. *The regulation index of surface runoff* is therefore: $1 - 109/182 = 40\%$. *The mean total regulation index* of the naturally regulated resources and surface runoff is: $1 - (117+109)/(1840+182) = 89\%$.

2.1.3 Production of unconventional water

14. The main production facilities on which Israel relies to meet increasing water demand are: (1) Sea-water desalination plants and (2) expansion and upgrade of wastewater treatment plants (WWTPs). The second type of facility would also allow meeting new stringent effluent quality requirements expected for industrial and agricultural reuse.

15. Sea-water desalination was a relatively negligible source until recently. In late 2005, a large-scale desalination plant located by the shore in Ashkelon began producing some 120 million m³ per year. Additional production of 30 million m³ per year of desalinated sea-water is done in Palmachim beginning from mid-2007 and some extra 100 million m³ per year is expected to be produced in Hadera by 2009. Sea-water desalination is expected to reach 505 million m³ per year by 2013, and is then expected to be expanded at a rate of over 20 million m³ per year per year, on average, to meet the expected increase of domestic consumption. By 2020, production of desalinated water is expected to reach some 750 million m³ per year.

16. Reclaimed sewage effluents are also been used as marginal water. In 2004, some 451 million m³ sewage was collected, of which 428 million m³ was treated, and of that 312 million m³ reused. Some 186 million m³ was collected in the Tel-Aviv metropolitan area. The sewage of the Tel-Aviv metropolitan area is sent to the Shafdan conventional and to SAT reclamation system, where effluents are recharged to the coastal Aquifer and reclaimed by pumping to a marginal water supply system. In 2004, 144 million m³ of Shafdan marginal water was supplied. Part of it (112 million m³) was supplied as recharged effluents, and the remaining (32 million m³) became part of the natural resources system.

17. The grand total of water supplied from all sources in 2004 was 2,054 million m³, out of which 100 million m³ was supplied to the Kingdom of Jordan and to the Palestinian Water Authority. The use of natural water resources amounted to 1,670 million m³. In that year, 385 million m³ of marginal water (sewage effluents and flood water) were used (53 million m³ flood water in addition to the 20 million m³ flood water recharged). The use of natural resources in 2004 was 1,702 million m³, including the 32 million m³ augmentation of Shafdan with fresh water.

2.2 Water demand and pressure on resources

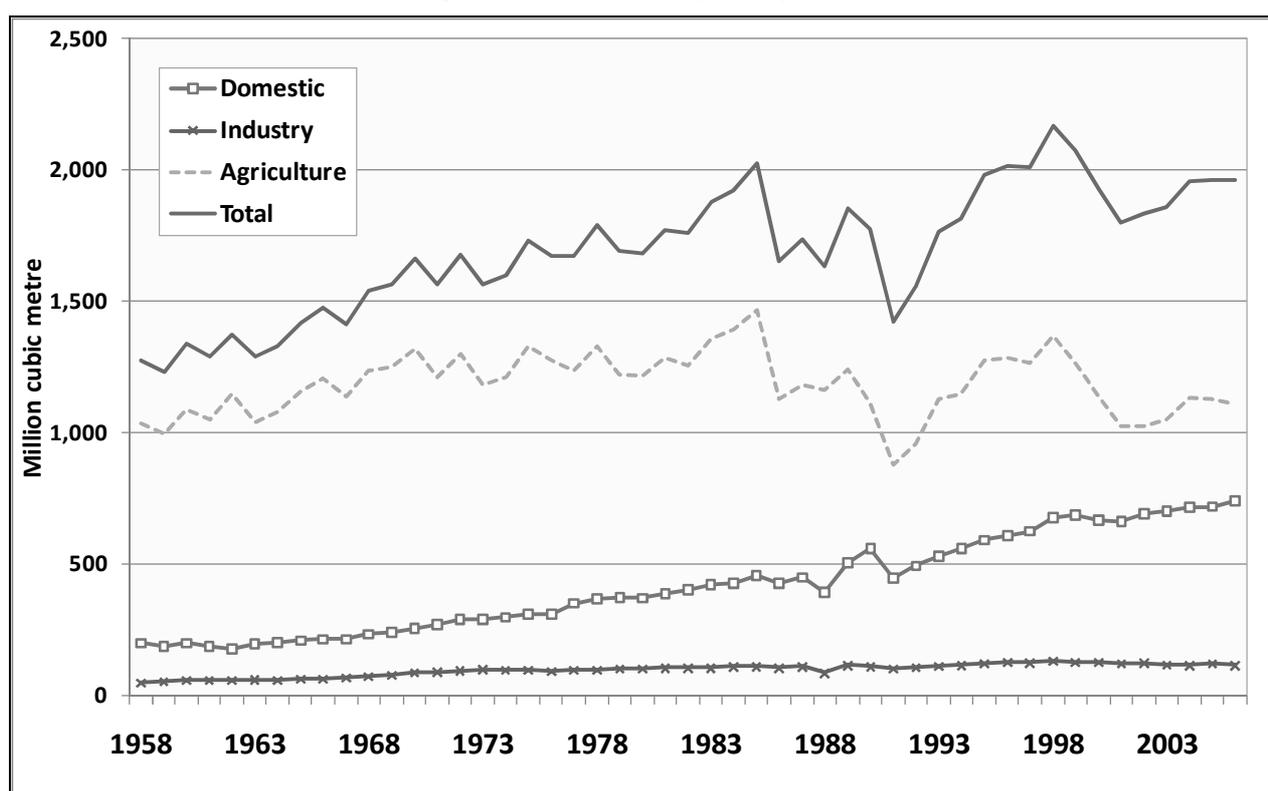
2.2.1 Withdrawals and demands: Total withdrawals in renewable natural resources

18. The current situation will be mentioned as well as any changes since 1980. Possible changes that will be the main objective of the report, will be discussed further in chapters 3 and 4.

19. The total water demanded in Israel for local consumption and for keeping external, trans-boundary obligations in 2004 was 2,054 million m³ (Israeli Water Commission, 2005). Sectorial water demand and trans-boundary obligations for 2004, by quality type, are reported in Table 2.

20. The three main economic sectors – agriculture, domestic and industry – consume most of Israel's renewable water supply. Total demand has grown over the years (Figure 1). In 2004, total domestic demand for fresh, saline and marginal water was 1,954 million m³, according to: 1129 million m³ for the agricultural sector, 712 million m³ from domestic uses (urban and residential use) and 113 million m³ for industrial purposes. *Auto-supply* (fresh water for industry and agriculture) in 2004 was 647 million m³. *Relative shares (%) of each sector of activity* (Table 2) were 58% for agriculture, 6% for industry and 36% for domestic.

Figure 1. Water consumption by sector



21. Demand was supplied from the following withdrawals/abstraction from renewable natural resources: 54.3% surface water and 45.7% ground water (IWC, 2005).

22. Water consumed by the agricultural and industrial sectors reached 85% and 75%, respectively, of the official quantities allocated to them. Consumption lower than allocated quotas is not unique to the year of 2005, and has been observed before; it originates from trends in the market, such as economic slow-

downs and an effective adoption of the water-pricing mechanism by those two major profit-maximizing sectors of the market (for a detailed analysis, see Just *et al.*, 1999).

Table 2. Water demand by sectors 2004
Million m³

Sector	Total	Fresh (Potable)	Saline	Marginal
Irrigation	1,129	565	185	379
Industrial	113	82	30	2
Urban	712	705	3	3
Total	1,954	1,352	218	384
Palestinian Authority	44	44		
Jordan	56	56		
Grand total	2,054	1,452	218	384

Source: Water Commission, 2005.

23. Water allocated to neighbouring entities as part of peace agreements was 55.4 million m³ for the Hashemite Kingdom of Jordan and 44.36 million m³ for the Palestinian Authority in 2004. Finally, 25 million m³ remained untouched at the source as part of allocation for nature and for landscape purposes (correspondence with GWSA, 2008).

24. An interesting development has occurred in the agricultural sector, where the share of high-quality fresh water has diminished relative to the total supply. Following implementation of policies directed to achieving this goal, fresh-water consumption stands at about 50% of the total water consumed by this sector. The share of recycled and other marginal sources of lower-quality water has grown (Figure 2). Fresh-water to be allocated to the agricultural sector is expected to remain approximately the same.

25. Table 3 presents past and forecasted water consumption by sectors. A long-term perspective of Israel's water demand suggests a gradual significant increase in domestic water consumption. This is explained by natural growth of the population (1.5% per year), immigration, and an increase in the standard of living, and an increase in the Palestinian Authority water needs. An effective means for alleviating water demand pressure is promoting domestic water saving. This is achieved by regulating the installation of water-saving devices in new housing and by national campaigns that encourage water-saving use patterns. Currently, a 3-years National Residential Water Saving Pilot in Urban Areas is conducted in approximately 45 towns, attempting to reduce water use among 1.5 million residents across the country.

26. As mentioned above, in 2004 some 25 million m³ were left aside and not extracted, as part of a policy for conservation and rehabilitation of the ecosystem (although this allocation was not indicated in the official water allocation database). The policy of River Planning (Ministry of the environment, 2004, and also Section 4.1 in the following) indicates a requirement of 122 million m³ per year for river restoration. However 50% of the quantity is non-consumptive and can be from recycled sources. The net demand for rivers is 61 million m³ per year. Only 50 million m³ per year were approved by the Government and are included in GSWA forecasts beginning from 2010 (Table 3). Additional ecosystem requirement in the upper Jordan basin (Hula) is estimated at 5 million m³ per year. This quantity is included in the Natural replenishment compilation (Table 1).

Figure 2. Agricultural Water Use by Quality
1996 - 2006

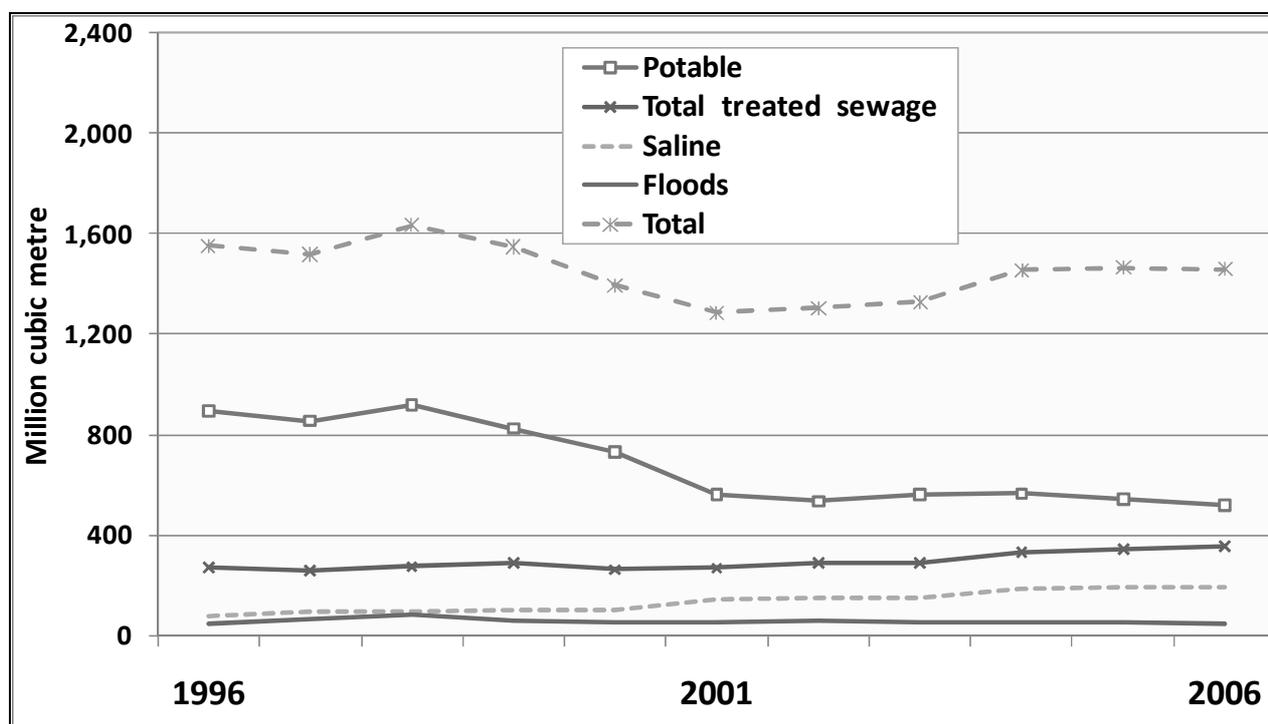


Table 3. Past and forecasted population and water consumption
Million m³ per year

Year		1980	1990	2000	2004	2005	2015	2025
Population	Million	3.922	4.822	6.369	6.869	6.991	8.136	9.498
Total Water Consumption	mcm/yr	1678.9	1804	1923.7	1954.3	1961.4	2330	2690
Urban	mcm/yr	367.6	482	662.1	711.8	715.3	917	1107
Irrigation	mcm/yr	1211.6	1216	1137.4	1129.4	1126.5	1235	1395
Industrial	mcm/yr	99.7	106	124.2	113.1	119.6	129	139
Environmental	mcm/yr			25	25	25	50	50
Total per capita supply	m ³ /yr	428	374	302	285	281	286	284
Urban per capita supply	m ³ /yr	94	100	104	104	102	113	116

* Projections of water demand are based on the following assumptions: 1.5% annual population growth; 110 m³ per year in 2010 and 115 m³ per year in 2020 as per capita urban demand; 1% industrial fresh water annual growth; 560 million m³ per year potable water and 200 million m³ per year saline water for irrigation; 40% in 2010, 50% in 2020 and 60% in 2040 of urban and industrial water recycled directed to irrigation; 50 million m³ per year environmental water demand.

2.2.2 Pressures exerted on the renewable and non-renewable resources

27. The *exploitation index of renewable natural resources* for 2004 was 107%. This index is based on the total of fresh and saline water demand (1452+218=1670 in Table 2) and the safe sustainable yield of the renewable resources (1564 million m³ per year in Table 1).

28. The *non-sustainable water production index* has changed from 8% in 1980 to 11% in 2005. Calculations are based on an annual volume of water withdrawn from non-renewable aquifers in the Negev and Arava: 14 million m³ in 1980 and 63 million m³ in 2005. Annual volume coming from the over-exploitation of water tables of renewable water resources when withdrawals exceed the average annual renewal or involves undesirable impact is estimated at 148 million m³ for 1980 and at 166 million m³ for 2005.

29. *Emissions of organic water pollutants in kg per day:* Industrial sewage discharges are available in two industrial locations (Kishon and Netanya). In 1980, on-site treatment was scarce and BOD was estimated at 34,250 kg per day. The record from 2005 shows a significant reduction, to 1,500 kg per day after an on-site treatment. Records on industrial sewage are summarized in Table 4. Despite reduction in pollutants, emissions of organic water pollutants are still found at most Israeli streams at various degrees. One source of organic water pollutants is the untreated sewage emitted from the Palestinian Authority.

Table 4. Total estimated BOD emissions

Year		1980	1990	2005
Biochemical Oxygen Demand during 5 days (BOD ₅)	mg/l	250	200	10
Average annual discharge of industrial wastewater	mcm/yr	50	54.9	54.9
Total BOD	Kg/day	34,250	30,000	1500

Source: Ministry of Environmental Protection.

2.3 *Degradations and threats affecting water resources, facilities, ecosystems and populations*

2.3.1 *Main degradation and threats*

30. While quality standards for drinking water and for sewage treatment have become stringent in recent years, in an effort to assure public health and to support ecosystems, the quality of the national water resources, and the quality of water facilities in local and regional municipalities, has generally deteriorated, and additional new threats have appeared. In order to satisfy versatile demands made by consumers, a careful management of water resources, and of water supply facilities, is required. Concern is not limited to the quality of water at the water source. Action is taken in order to prevent pollution from reaching water bodies, and in order to assure high water-quality along the production, treatment, and delivery systems.

31. Five major categories are identified as risks and threats to the water resources and facilities and to the ecosystems. Each category is followed with some leading national concerns and issues:

Interface with the hydrological balance

32. Sea-water intrusion to the coastal aquifer as a result of lowered water tables; Interference with the hydrological balance and saline water intrusion; Lowering of the Kinneret water level and saline water intrusion; Entrance of pollutants to the Kinneret.

Environmental Risks

33. Urban sewage; Agricultural pollutants; Industrial, oil and transportation pollutants; VOC's, nitrates; pollution of rivers by sewage from the Palestinian Authority.

Operational Risks

34. Pollution at wells; Failure in supply systems and facilities; Residuals of water treatment materials; Degradation of pipelines; Non-intentional pollution of the supply systems; Pollution of natural resources originated from irrigation using recycled water that was treated insufficiently.

Risks associated with intentional or trans-boundary activities

35. Vandalism; Terror; Risks associated with trans-boundary pollution (e.g., emission of untreated sewage from the Palestinian Authority).

Natural hazards

36. Impact of earthquakes on the water network; Impact of climate change on water availability and potential rise of sea water level.

37. Preventing pollution and other risk factors at their source is likely to be the most cost-effective mechanism in the management of water resources. Monitoring systems are set at a safe-radius from water sources, at the source and along the water supply chain, in order to assure appropriate level of water quality.

38. The following two tables demonstrate a concrete example of degradation of water resources, by presenting the quality state and trend of Israel's major water sources according to two leading parameters. Table 5 shows that the mean values of chloride and nitrate concentrations have increased since 1980. Variations within the groundwater basins are shown to be much larger. Table 6 indicates a critical state of once Israel's major water sources: the Coastal Aquifer.

Table 5. Mean Chloride and Nitrate concentrations (ppm)

	1980		1990		2000		2004	
	Chloride	Nitrate	Chloride	Nitrate	Chloride	Nitrate	Chloride	Nitrate
Lake Kinneret	230		220		250		235	
Coastal Aquifer	145	45	175	50	195	60	200	60
Yarkon-Tanninim	140	20	160	23	140	28	140	
Western Galilee	147	18	140	22	155	27	155	29
Carmel	500	32	500	28	550	34	550	32
Eastern Mountain	255	14	275	11	320	13	300	18

Source: Hydrological Service Annual Report, 2004.

Table 6. Classification by quality of extracted water in 2003/4 (%)

	Very Good	Passable		Bad
		<250	250-600	>600
Range of Chlorides [ppm]	<250	<250	250-600	>600
Range of Nitrates [ppm]	<45	45-70	<45	>70
Kinnereth Basin	100%			
Coastal Aquifer	47%		39%	14%
Yarkon-Tanninim	89%		10%	1%
Western Galilee	82%		2%	16%
Carmel	20%		64%	16%
Eastern Mountain	35%		65%	-
Negev and Arava	6%		31%	63%

Source: Compiled from Israel Hydrological Service, 2005.

39. *Overexploitation of aquifers* resulted due to excessive continuous decrease of water tables which resulted, in turn, in intrusion of sea-water. For example, due to sea-water intrusion, less than a half of the water extracted from the Coastal Aquifer is classified as "very good" (Table 6).

40. By the end of 2006, water tables at the aquifers were at 500 million m³ under their targeted goal.

41. *Alteration in the quality of the water and the ecosystems:* A summary of microbiological tests of drinking water by type of locality (Statistical Abstract of Israel No. 57 p. 870 section 27.10) shows that in

urban and in rural areas, only 0.3%, and 0.5%, respectively, of the microbiological tests exceeded the acceptable water quality in the supply networks.

42. *Water general quality index*: This index is defined as the percentage of control points affected by the presence of pollution (organic, nutritive substances, heavy metals, pesticides, etc.). However, the data available under this category is limited to a few parameters where data have been collected for in Lake Kinneret only. Results are presented in Table 7.

Table 7. Quality of Kinneret water (2004)

Parameter	Average annual value	Unit	Index
BOD ₅	2.25	mgL ⁻¹	very good
Chlorophyll	19.35	µgL ⁻¹	good
Total Nitrogen	0.73	mgL ⁻¹	very good
Total Phosphorus	20	µgL ⁻¹	very good

43. The size of *wetlands areas* declared in 2005 was 8.5 km² at the Hula. This amounts to 0.04% of the total land area of Israel.

44. *Silting up of dam reserves* is estimated to be small, at about 1%.

45. *Degradation cost (separating repercussion costs and repair costs) and of the rise in vulnerability to these risks*: An initial degradation cost of water resources as a % GDP can be estimated using the total annual quantity of water used to be pumped from a currently banned-polluted-wells (50 million m³ per year), plus total annual quantity of water pumped from resources (33 million m³ per year) that have become too saline for industry, domestic and some agricultural uses, multiplying the total by the rehabilitation cost per m³, or alternatively, by the cost of desalination per m³ (USD 0.6) and dividing by GDP (USD 132 billion). This results in an insignificant cost relative to GDP.

46. *Human and economic impacts of the floods*: The portion of constructions built in floodable areas in the last 30-40 years is difficult to quantify. The building of such constructions used to be motivated by avoiding floods on agricultural land. In recent decades, the need to prevent floods in urban areas has risen due to an increase in covered land by houses and roads. Also, the economic impact of floods has increased tremendously for individuals and for the economy as a whole, due a high value of valuables that may be lost and due to a shut-down of the economy which, in the case of Israel, is characterized by a high opportunity cost per business day.

2.4 Sanitation and collection and treatment of waste water

2.4.1 Share of collected and treated wastewater by the public sewerage system

47. The proportion of wastewater produced that was subjected both to collection and was adequately treated was 94% in 2005, while in 1980 the proportion was 59%. The potential of wastewater recycling is the volume of sewage produced, its share in the water demand and the percentage of sewage collected, treated and reused. These indicators and their variation since 1980 are shown in Table 8. Of the 428 million m³ per of treated sewage in 2004, 112 million m³ (26.2%) were treated at the SAT facility of the Shafdan. Overall, out the 428 million m³, 70% are treated under a secondary treatment and the rest are treated under a triatory treatment (112 million m³ at the Shafdan and an additional total sum of 16.6 million m³ at Lehavim, Omer, Ben-Gurion Airport, Lev-Hasharon, Ramat-Hashron, and Carmiel).

48. Since recycled sewage water is now a customary water source for non-drinking purposes, Israel has made progress by establishing and approving new standards for upgrading the treatment level of sewage water. The use of recycled water on agricultural fields is conditioned, among other things, by an

approval from the Ministry of Health and the Hydrological Service of the Israeli Water Commission, in order to avoid irrigation along sensitive hydrological spots which may affect sources of drinking water.

49. The MSSD takes up the Millennium Development Objectives concerning access to drinking water and water treatment. It would be suitable to point out the progress made and expected by 2015 compared to 1990. The progress made for the collection and treatment of wastewater and, if it is the case, the objectives set by the country for 2015/2025.

Table 8. Sewage production, treatment and reuse
Million cubic meters per year

Year	1980	1989	1994	2004
Total sewage	225	293	389	470
Collected	205	273	364	451
Treated	133	232	309	428
Reused	52	195	254	312
Percentage treated	59%	79%	80%	91%
Percentage reused	23%	66%	65%	66%
Water demand				
Urban	368	501	556	705
Industry	100	114	114	113
Total	467	614	669	818
Percentage of sewage out of water demand				
Sewage	48%	48%	58%	57%
Reused	11%	32%	38%	38%

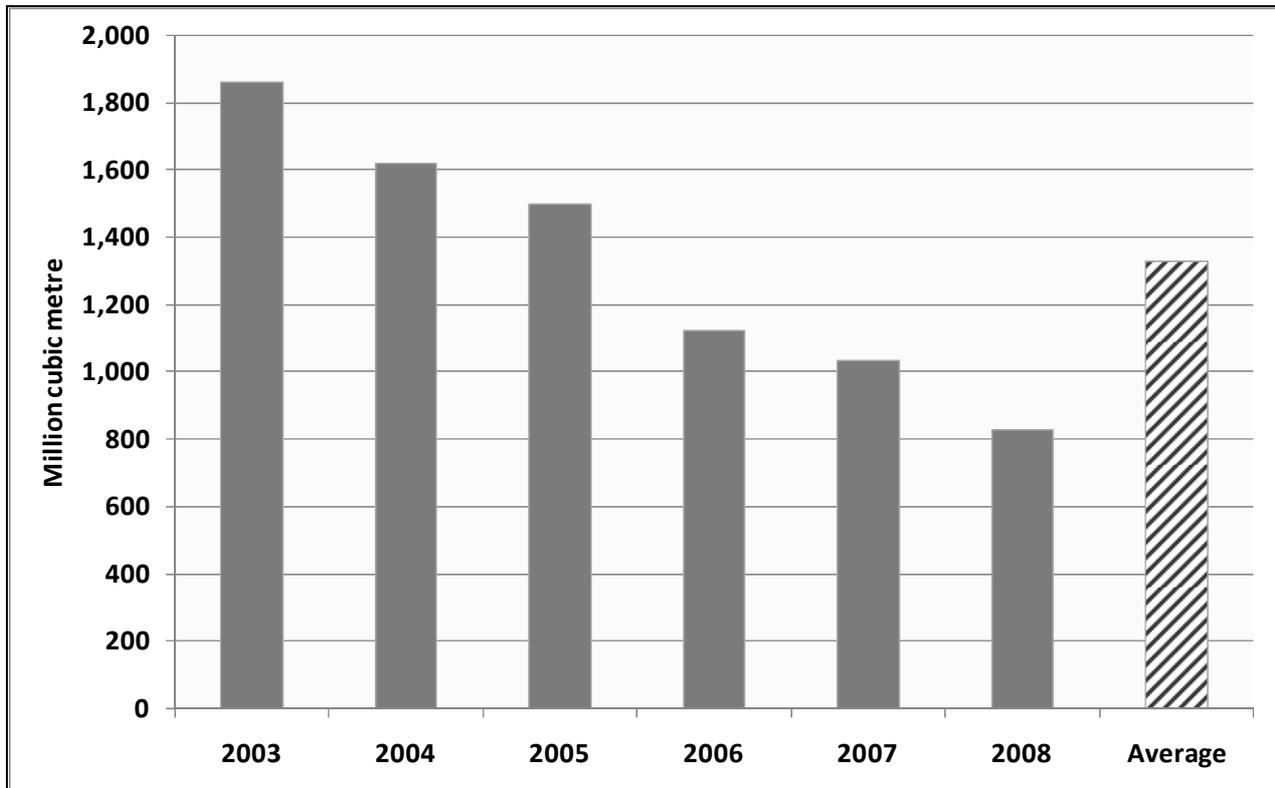
50. *Share of industrial wastewater treated on site:* Many of the industries that are connected to the public sewage collection and treatment facilities have their own pre-treatment facilities on site, as required to meet municipal sewage quality requirements. The proportion of wastewater produced by industry and receiving autonomous non-public treatment was 35% in 2005 (Ministry of Environmental Protection, 2006).

2.5 *What motivated formation of regulations and the use of economic tools?*

51. Water scarcity is a growing concern in Israel. As of 2009, Israel is experiencing a fifth year of drought. Rainfall is much below average, and so are quantities of natural water recharge (Figure 3).¹ High population growth due to immigration, rapid industrial growth, bilateral agreements and extensive economic development are placing increased demands on scarce water resources. Degradation of existing resources also threatens historical supplies. That situation requires formation of means to regulate the water sector.

¹. The natural recharge of aquifers is lower than the rainfall amounts because not all rainwater will eventually feed into the aquifers. In rural areas, where land is available and water aquifers are not large, some large reservoirs were built in order to collect floods. In urban areas, storm-water collection has been largely been neglected due to land scarcity, urban activities, etc. In two cities, there is some effort to collect storm-water drainage and artificially recharge the aquifers with what has been collected. The natural recharge of aquifers is also lower than the amount of rainfall due to natural evaporation, e.g. in the Sinai Desert.

Figure 3. Natural Water Recharge in Recent Years



52. During the first four decades after Israel’s establishment, the main task was to develop water resources and build infrastructure to mobilize water resources, especially from the North to the South. The National Water Carrier was built (1964), along with extensive construction of associated facilities and infrastructure. Supply management overshadowed demand management. The goal was to distribute the water to those locations that were away from the sources, in order to empower settlements along boundaries and away from the centre. In addition to mobilization of surface water from Kinneret, groundwater resources were explored and integrated into the national water management. Today, Israel leads a fully integrated system of surface water together with two of its major groundwater sources in order to efficiently manage this conjunctive use. Moreover, the current water system integrates two other major sources of water: desalinated sea-water and recycled sewage water (effluents). Water prices, while being low for the agricultural and industrial sectors relative to those that for domestic users, were equal within each sector across the country, regardless to distance from sources, in order to enhance equality. It was just a matter of time that water demand in the young flourishing state would begin to reach a point where it threatened the ability to remain at a supply level comparable to the safe sustainable yield. In addition, degradation of existing resources by sea-water intrusion, lowering of the water table by continuous over-extraction and man-made pollution has threatened historical resources. Consecutive years of drought added to the problem. Improving the efficiency of water use has become a necessity, especially in the largest consuming sector, agriculture, that began developing and adopting innovative water-saving irrigation methods (e.g., drip irrigation) and salinity-resistant crops already by late 1960s. In the late 1980s, it was evident that there must be a major transition to stringent water management strategies and policies including enhancement of water plans toward efficient water use for all sectors.

53. The Degradation of existing resources by continuous over-exploitation and by pollution also threatens historical supplies. Improving on efficiency in water use has become a necessity, especially in the traditional large water consuming sector; agriculture.

54. *Improvement in efficiency in the sectors of activity:* agriculture, domestic and industry, using water demand management policies were developed using basic economic tools and incentive mechanisms, such as multi-level water tariffs, regulations and its enforcement, penalty mechanism for municipalities for reducing water losses, water-saving education, training and campaigns. To enhance dissemination of water demand policies, steps were made enabling means and operations that increase the value added created per unit of mobilized resources. For example, in order to save fresh, high quality water, and free it up to other high-value uses and hence delaying costly desalination, programmes have been set to encourage the use of recycled water for irrigation, the use of saline water for inland fishery and the shift from extensive to intensive management of fish ponds.

2.6 *Structure of water pricing and water quotas*

55. Water in Israel is metered and is charged according to the volume actually used. The pricing structure changed in the late 1980s, as part of a new water demand management policy, to an increasing block tariff that intended to achieve efficient water-use patterns. Currently, water prices vary widely across and within sectors, and across regions, according to local agreements and national policy for development of rural areas. Water prices differ among users in three ways: (i) agricultural users pay lower prices than industrial users, who pay lower prices than households; (ii) prices differ among regions in ways that are consistent with water transportation costs (with some minor exceptions)²; and (iii) consumers face an increasing block-rate pricing structure, whereby higher prices are paid at higher levels of consumption. The increasing block tariff for agriculture is based on three levels of quotas of fresh water that are re-announced annually, prices of recycled water are set lower, to encourage farmers to increase use for recycled water. Domestic users pay three different rates according to three levels of quantities used; industrial users pay a fixed price according to permitted quota.

56. Beginning from 2007, as part of a new *Economic Arrangement of the Water Sector* (March, 2006), water producers are charged an *Extraction Levy*. An extraction levy, once set properly, reflects scarcity of water resources, and together with the production and distribution costs, it is possible to set the water prices such that they reflect the true value of water. The economic rationale behind this new water demand management approach is to correct for the market failures in the water sector and to prevent over-extractions from the aquifers, and to be a supplement tool to other administrative tools (quotas) along with subsidized tariffs and levies. While setting the economic mechanism and the structure of the extraction levy, the new Economic Arrangement sets two leading goals according to the activity sectors: (a) domestic and industry – creating a management tool for the overall aquifer production using economic incentives, creating incentives for self-water-producing local municipalities to connect to the national water network in order to increase reliability in supply and reduce the chance of shutting down sea water desalination plants (especially in the winter) and to avoid scarcity, to regulate among production sources according to the needs of the water sector while avoiding scarcity, especially to regulate production from aquifers from winter to summer and rehabilitation of the coastal aquifer by reducing over-extraction that originates from economic considerations; and (b) agriculture – encouraging farmers to switch to recycled water, using efficiently the nation's water resources, creating tools to manage overall water production using economic incentives, creating tools for regional management of water quantity and water scarcity, encouraging the development of new water sources and agricultural preservation and the preservation of nature and landscape. For activities in the domestic and industrial sector, the plan determines three specific levies for

². The water price within each sector is the same for all, regardless to geographic location. That is, total water prices are the same for those who consume water in locations close to water sources and for those in locations far away from water sources. Equivalently, one can say that prices are different, in the sense that those who live close to source pay higher prices than those who live far away. Consumers who live far away from source pay a reduced price for the water itself and an additional price that reflects the transportation cost of the water.

aquifer water production by self-water-producing municipalities, in order to regulate between water supply from local wells and water supply from main aquifers that is been directed to the national water network and from there to municipalities for domestic and industrial purposes: (a) *preservation levy* – in order to preserve municipal production wells at minimum recommended production level, (b) *encouragement levy* – in order to encourage water production at local wells located in municipalities over water purchases from the national water network for quantities above the determined preservation level, and (c) *avoidance levy* – in order to encourage purchases from the national water network over self water production for quantities above the licensed production level and on winter water production. These levies are to be activated gradually and according to seasonal variations and other hydrological considerations.

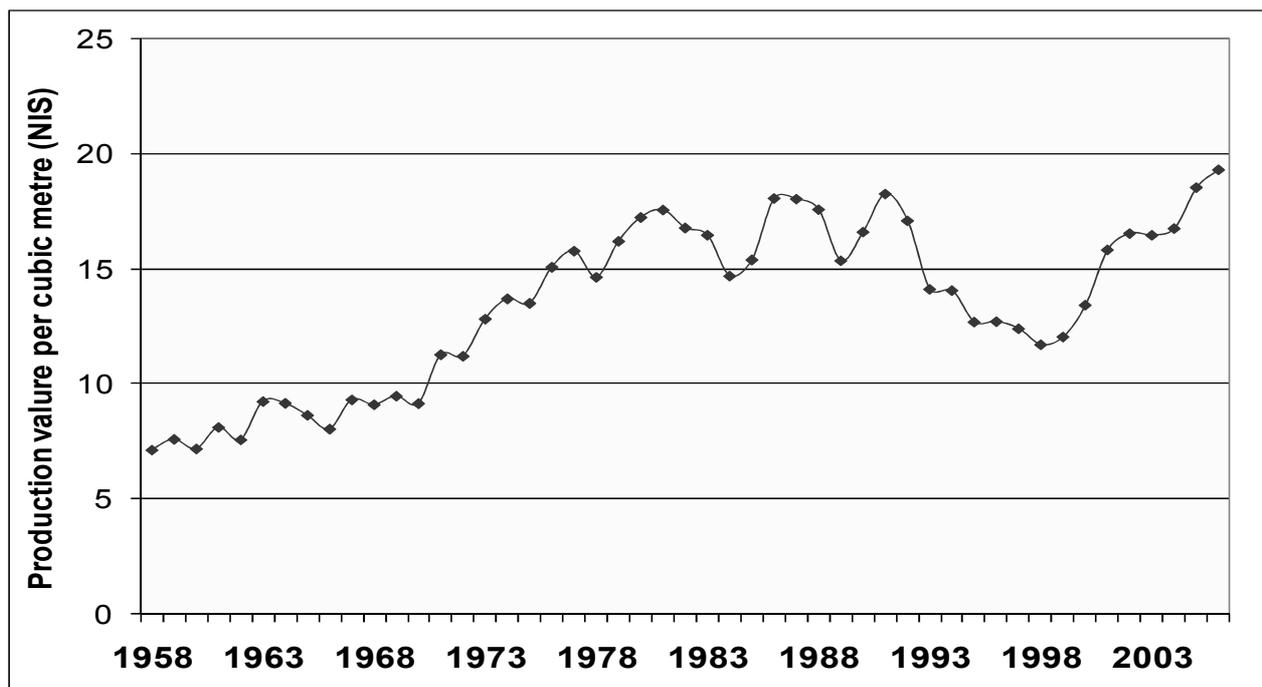
3. Policy and economic incentives in the water sector

57. In order to get a deep understanding of Israeli water policy, it is worth looking into policy and economic tools developed and implemented for each of the three major sectors of the economy: agriculture, industry and domestic and tourism.

3.1 Water for Agriculture

58. Agriculture has historically used around 70% of the water, but use has been decreasing since the mid-1980s. Reduced potable water allocation to agriculture used to be viewed as a primary mean of dealing with increased scarcity and rising household and industrial demand. In recent years, the agricultural sector relies on recycled and saline water sources for irrigation at about 50% of total water demand for irrigation. Interestingly, decreased agricultural potable water use has not been accompanied by a decrease in the overall value of agricultural output (Figure 4.) In fact, absolute agricultural water use has declined even as a share of policy-imposed water use quotas. Farm water quotas were reduced in 1991 as a result of drought, but water use did not increase accordingly when quotas were again increased. Beyond the continuous increase in efficiency in the use of each unit of water, this reduced use relative to quota is explained by changes in the agricultural water pricing structure, and by the fact that price of water in agriculture rose 100% over the last decade.

Figure 4. Agricultural Output Value and Irrigation



59. For agricultural users, there are price steps, but the quantities to which they apply are determined by farm-specific quotas. Availability of water beyond allocated quota is not guaranteed, but the “quotas” are not constraints. Farms can, in most cases, use more than their quota, but a higher price is paid for over-quota use and a lower price is paid if use is sufficiently less than quota. Since each farmer is free to adjust use within these intervals, each farmer’s marginal price bracket tends to reflect the true marginal value of water on that farm (unless the quota is not fully used). Most importantly, individual quotas serve to differentiate water prices among users because they determine the levels where rate steps occur.

60. Increasing water scarcity and price inequities have led to questions regarding agricultural water subsidization and social efficiency of the agricultural sector under its present structure. The drought of the early 1990s suggests potential for allocation of water away from agriculture. Largely because of consecutive years of drought in 1990 and 1991, the real price of water to agriculture was increased and the quota was reduced as a means of dealing with the temporary shortage. Some 47% increase in agricultural water prices occurred from July 1990 to May 1992 for use levels at 80-100% of quota, suggesting a substantial reduction in the indirect agricultural subsidy (See Just *et al.*, 1999). In the last few years, water quotas were cut by at least 40%.

61. However, many farms that were able to adjust to the progressive pricing schedule attained a lower water price bracket by reducing use relative to quota. The decline in national agricultural water use as a share of quota, from 89% in 1990 to 70% in 1992, suggests that many farmers moved to lower price brackets. Thus, the marginal water price (averaged among all farmers) increased less than the 47% increase in price schedule. Agricultural prices (2005) are summarized in Table 9, according to quota level.

Table 9. Agricultural water prices
USD per m³, at 2005 prices

Level	1995	2005	Increase (%)
A	0.165	0.282	70.9
B	0.199	0.335	68.3
C	0.267	0.441	65.2
Mean	0.196	0.330	68.3

62. Changes in recent years in water used in the agricultural sector indicate that farms do respond to changes in price. For example, an increase of 11.7% in water prices resulted in a 2.4% increase in quantity demanded in 2003 relative to previous year. In 2005, an increase of 12.4% in water prices created a greater impact and reduced demand by 2.3% relative to previous year (Statistical Abstract of Israel, 2006). This price increase kept farms at 74.5% use of water out of the total allocated quotas for 2005. Total value of water as total input in agriculture was 7.9% in 2003, rising to 8.9% in 2005, increasing the significance of water in the farmers’ budgets and hence created motivation for water saving (Statistical Abstract of Israel, 2006).

63. To overcome the increase in water scarcity, substantial public investment in highly efficient irrigation technology that was taking effect when quotas were decreased and a progressive water pricing schedule was introduced. Computerized sprinklers and drip irrigation systems have led to increasing efficiency of water use in agriculture. Water-saving technology has evidently caused a decline in agricultural water demand.

64. Israeli agriculture has been able to reduce water consumption substantially over the years without a loss in agricultural production. For example, between 2000 and 2005, the fruits sector, that was exposed on average to a 35% cut in water quotas, increased its production by 42%. Whether agricultural demand for water will continue to decline depends both on opportunities to expand use of currently available irrigation technologies and on discovery of new irrigation technologies and new sources of recycled or saline water, such as in the case of citrus, where the majority of the plantations are now been irrigated using recycled

reclaimed water, or in the case of fish growing using saline water (see box on Beit-Shean). These two examples represent the ongoing effort and a recent decision to further enhance government support (March, 2006) in *increasing the added-value created per unit of mobilized resources* by developing new reclamation plants for recycling water for irrigation, improving banned wells and increasing the use of marginal water for irrigation. A budget of approximately USD 43 million was recently allotted for the materialization of these purposes.

65. *Agro-environmental aid* has been promoted in recent years. For example, financial resources have been directed to prevent drainage of polluted water and material from dairy farms reaching into water basins. Another example of a 2006 project is a prevention of drainage of water from fishery pools into streams by appropriate technologies that treat the water prior to draining them into streams.

66. *Agricultural aid* in the area of *water saving* has been directed to two major targets: (1) removal of marginal plantations (especially in years 2001-2002) and planting water-saving trees, such as olive and almond trees; and (2) water-saving technologies. Accumulated budget from 2001 to 2005 for plantation removal and planting was about USD 12.7 million, and for water-saving technologies, the budget was USD 26.1 million. Total aid (grants) for these two targets in 2005 alone stood on 8.7% of the total budget of the Ministry of Agriculture allocated to development grants.

3.1.1 *Agricultural organisations and associations for managing water demand*

67. The agricultural lobby in Israel has been strong and very successful in representing farmers' interests regarding water and other issues. Since water sources for agricultural demand vary by quality and type of producers, interests regarding water issues are represented collectively. Issues related to water produced by Agricultural Water Associations represent only part of general water aspects. About 32% of total water production in Israel is supplied by producers other than the National Water Company, Mekorot. Out of the 1,129 million m³ supplied to the agricultural sector in 2004, about 41% (458 million m³) was produced by suppliers other than Mekorot. About 72% of that production (330 million m³) was from sources other than recycled water (mostly fresh water from wells). This last quantity is produced by Agricultural Water Associations located in rural areas according to licences issued by the Water Authority. Beginning from 2007, as part of a new arrangement plan for the water sector, such producers, similarly to all other producers, are charged the *Extraction Levy* adjusted according to factors such as the type of production, the hydrological situation and production site. The extraction levy on fresh water pumped out of wells intends to encourage farmers to switch to recycled water and is under a larger national scheme of improving efficiency in water production using economic incentives, efficient use of the nation's water resources, encouragement of development of new water sources and agricultural preservation and the preservation of nature and landscape.

3.1.2 *Investment in research and development, technical progress and popularising it*

68. The Ministry of Agriculture carries out an R&D programme. Efficient use of water, improving efficiency by technologies, and switching to use in recycled water are major subjects in the research programme. Research also been conducted via bi-national programmes, such as the U.S-Israel Bi-national Agricultural Research and Development and various international programmes, such as the EU-Frameworks.

3.2 *Water for Industry*

69. Industrial water use increased about 3.5% per year from 1960 to 1980. From 1980 to 2000, water use increased on average by 1.7% per year. From 2002 to 2004, water use has declined by 7.4%, perhaps in anticipation of price increases and due to an economic slowdown. About 22% of the water consumed by

the industry comes from saline and marginal sources. Despite the gradual slowdown in demand growth until 2000, and the absolute decline in demand since 2002, industrial product value per unit of water use has increased steadily and future industrial water consumption is expected to increase roughly in proportion to population, corrected by the declined achieved due to improve efficiency in industrial production processes that use water. Stringent environmental regulations related to the quality of industrial effluents impose on the polluting industry the responsibility to treat industrial sewage on the factory site prior to leaving the plant and reaching the public sewage facilities. The treatment cost and related operation along with the purchasing cost of water and sewage levies imply a loss in potential profit and hence motivate the industry to, voluntarily, conserve on water, develop water-saving production processes, and increasing the use of recycled and marginal water in industrial operation.

70. Industrial users also have individual water quotas and pay a higher price for above-quota use. Industrial quotas are set on an individual basis according to production norms. Firms can submit petitions for increased quota when businesses expand. Industry paid approximately the same average prices as agriculture from 1966 until May 1994, but has paid roughly 35% more than agriculture since. Currently, industrial water prices are close to the gate price paid by municipalities.

3.3 *Water for Domestic and Tourism*

71. Water for households users is delivered by municipalities or by newly established local Water Consortiums who buy at Mekorot-established prices or extract water locally, paying the government *Extraction Levy*, and sell at much higher prices to residents which more than cover the costs of local water delivery. Water consumption is been metered and users face increasing block-rate pricing.

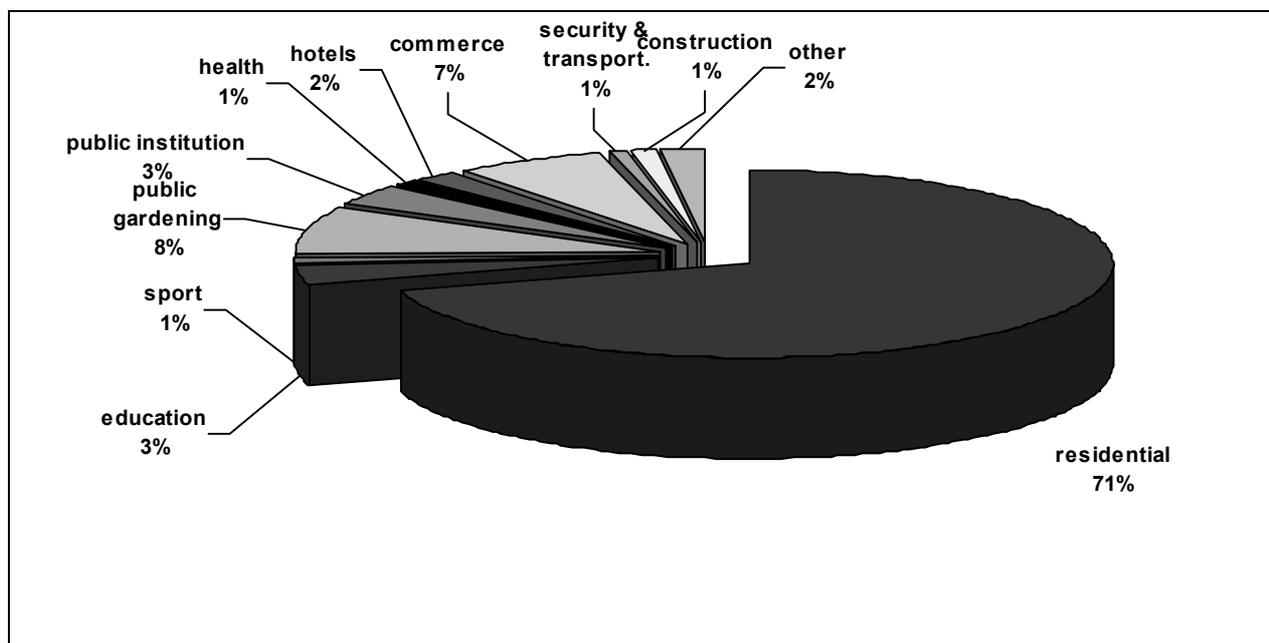
72. All households face the same block-rate schedule. Domestic consumers pay for water according to three increasing block rates: first level covers the first 8 m³ per month per family of up to 4 people, second level cover up to 7 more m³ per month and a third level is any consumption above that. Families with more than four members are entitled to apply for an additional 20 m³ per month at a reduced price. The average the rate is USD 1.02 per m³, where the third level is approximately double than the first level, cf. Table 10.

Table 10. Domestic water prices -- Increasing Block Tariff
NIS per cubic meter, at nominal prices

Consumption Level	2004	2005	2006	2007	2008	% change, 2004-08
Level C: For consumption above 15 m ³ per month	6.132	6.648	6.471	6.695	7.648	24.7
Level B: From 8cm to 15 m ³ per month	4.342	4.779	4.651	4.811	5.495	26.6
Level A: The first 8 m ³ per month	3.042	3.521	3.329	3.444	3.934	29.3

73. Household consumption of water in Israel has been growing at roughly 2.5% per year. About 80% of this growth is due to population growth, with the rest attributed to income growth. Increased demand due to population growth is predicted to cause serious water shortages. Water demand from the sector has increased tremendously during the years. For example, from 1970 to 1980, it increased by 56%, from 1980 to 1990 by 28.5%, from 1990 to 2000 by 37.4%, and from 2000 to 2005, the increase has relatively stabilized and was only 8%. Figure 5 presents the distribution of water consumption among various uses in the urban area in Israel, with the vast consumption attributed to residential uses. Per capita domestic water demand reflects a rise in the standard of living. In 1970, demand per capita was 79.3 m³, 94 m³ in 1980, 100 m³ in 1990, and since it has relatively stabilized to 104 m³ in 2000, 103.4 m³ in 2002 and in 2003, a slight increase in 2004 and a small decline to 102.32 m³ in 2005.

Figure 5. Distribution of Water Consumption among Various Uses in Urban Municipalities 2007



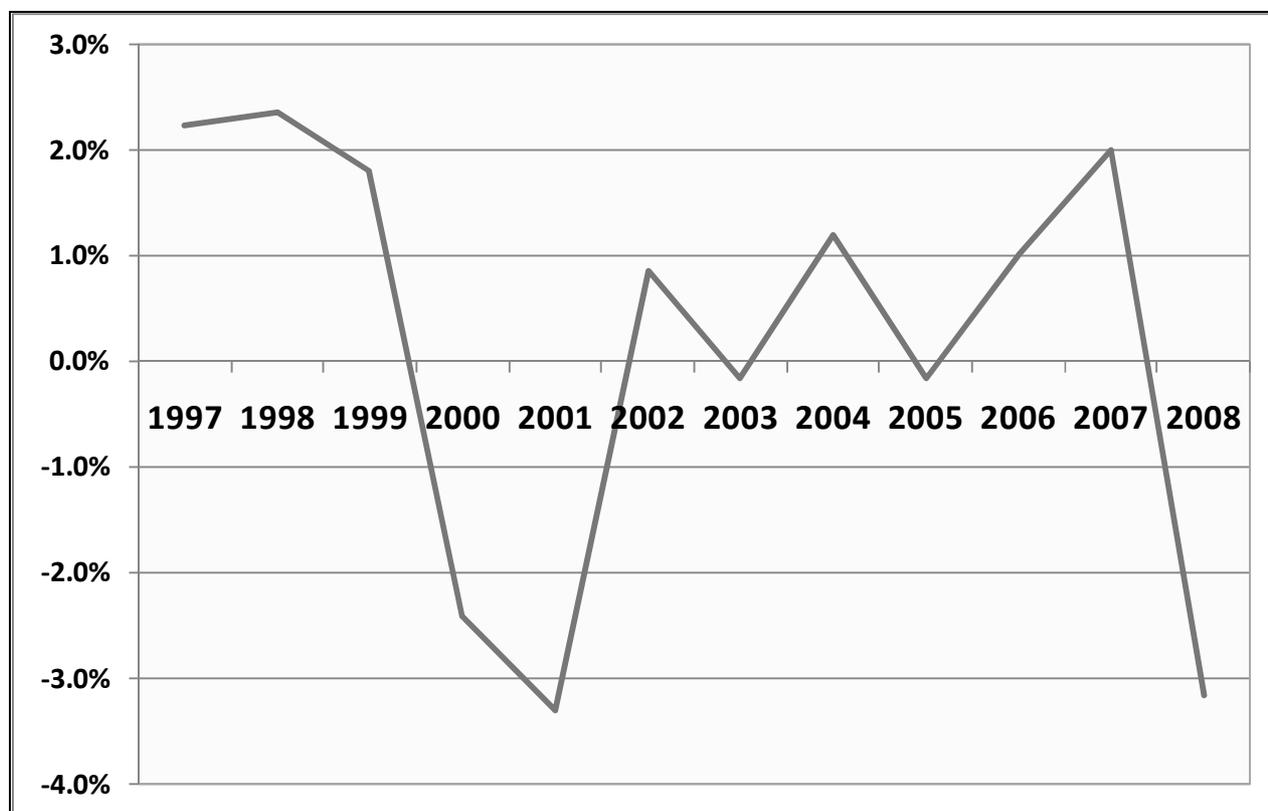
Source: IWA (2008).

74. Domestic users, in general, are not influenced much by water prices, and demand remains relatively inelastic when water prices increase. Laws and ordinances, such as limiting irrigation of private gardens to specific months and metering quantities used, prohibition on washing cars with pipes, use of dual-flushing toilets, water-saving devices for faucets and shower heads, etc., are in place, but rarely enforced unless a year of drought is been officially announced. National *water-saving campaigns* have been proven to be effective in lowering consumption for the duration of the campaign. The inter-ministerial 2000-1 water-saving media campaign was successful in reducing domestic consumption in 2001 by 6% relative to 1999 using a budget of about USD 2.3 million. In 2008, the national water saving campaign lead by the Water Authority had an impact of 3.3% relative to average residential consumption in 2007. However, once the campaign was over, domestic consumption began to rise again (Figure 6). This suggested that a water-saving campaign must focus on tools and methods that would cause a long-lasting water saving (*i.e.*, education and technology). In 2004, the Ministry of Interior led a programme in public institutions in local municipalities where water-saving devices were installed on faucets.

75. In January 2007, a water-saving campaign directed towards domestic users began running as a pilot in 40 urban towns across Israel by two private firms who won in a bid commissioned by the Water Authority. The current campaigns are being conducted in selected towns. Although there are differences in the working plans of the pilot run by the two firms, they both attempt to create an impact on day-by-day use patterns and to motivate consumers to install water-saving devices at home. Specifically, the pilots include public awareness campaigns, educational programmes for schools and for the community, dissemination of water-saving-devices for faucets and showers and for the main entrance of water for apartments and buildings, encouraging the public to fix leakages in pipes and in toilets, switching to water-saving 2-functions-toilets and transform gardens in private houses and in buildings to water-saving gardens. Due to its success, the project got extended, covering the period 2007-2009. Conclusions to be reached from the pilots are expected to be implemented nation-wide. This is important as water consumption per capita is expected to rise. It is important to stress that a significant saving in the domestic sector has the potential in delaying costly investment in desalination plants. For example, a 5% decrease in

domestic water use is comparable to a desalination plant with a production capacity of 35 million m³ per year, such as the plant that is been built now.

Figure 6. Impact of the National Water Saving Campaign
Percentage change in residential per capita water consumption compared to previous year



3.3.1 Volume of water lost or wasted

76. On average, water lost due to leakages in local municipalities reaches 10%. Municipalities are subject to fine once unbilled water quantities exceed 12% of total water consumed by the town. Since water lost in the system is a waste of income to municipalities, they make an effort to fix leakages. Financial support is given by the Water Administration of the Ministry of Interior. Despite that, many municipalities fail in managing and maintaining their water infrastructure at a good shape. A 2004 government's decision called for local municipalities to privatize their water operation under the law for Water and Sewage Corporations. The law called that by January 2007, 30 corporations, each supplies water for at least 200,000 residents (unless approved otherwise), would be established. As of today, only eight corporations operate. Some supply to a smaller number of resident then directed by law.

77. The *main obstacles* currently encountered for better efficiency in water management is largely with the domestic sector. The agricultural sector has decreased its dependency on fresh water and relies on recycled and marginal water for 50% of its irrigation need. This process is a result of a massive effort done not only in converting to drip irrigation, but also with adjusting to appropriate crops, including cutting off water wasting trees and replanting water-saving types, training farmers in educational programmes and awareness campaigns. The industry as well is investing its share in water-saving. However, the industry and the agricultural sector's water consumption patterns reflect their motivation as profit maximisers. They operate in competing local and international markets and are obligated to a continuous improvement in order to become more efficient in their input use and production processes. On the other hand, the domestic

sector operates differently. First, the domestic sector combines three major users: local small business, residents, and the municipalities (public gardens, public institutions, leakages). The difficulties rest with the last two users. Residents' water consumption at home and in private gardens is largely insensitive to prices and they require constant reminders through costly campaigns regarding the scarcity of water, or alternatively stronger local enforcement of water-related ordinances. The other users of domestic water, the municipalities, place further obstacles. While the problems are not uniform among local municipalities, data indicate that there is an average of 10% water waste due to old and leaking infrastructure across the towns' networks and within the municipalities' public institutions. Also, public gardening is often wasteful either due to inappropriate irrigation schedules or inadequate planting. A common assessment is now that the new Urban Water Corporations, which are driven by for-profit motivation, would increase efficiency in water use within urban areas (*e.g.*, by fixing leaking infrastructures, etc.).³

4. Technology innovation in the Israeli water sector

78. Along the years, new water-related technologies have been invented and developed in Israel. Starting with irrigation technologies where the focus was and remained on water saving and water efficiency, the sector of water technology is using the dynamic local market as a lab, gaining experience in trying the technologies at home prior to spreading them out overseas.

4.1 The development of innovation

4.1.1 Water technologies

79. Water technologies accommodate needs for efficient management of the supply side and of the demand side of the water sector. Some examples of such technologies are:

- Managing the supply: flow control market, including valves, corrosion-resistant materials, fluid control technology and dynamic pressure control.
- Managing the demand: Water meters, remote reading meters, UFR (accurate reading of use) and water saving devices.

80. In particular, the agricultural sector has concentrated on irrigation technologies such as computerized irrigation control systems for agricultural, domestic & public gardening, drip irrigation.

81. Water shortages has improved desalination technologies associated with Sea-water reverse osmosis and brackish water reverse osmosis.

82. Deteriorating quality of aquifers and surface water and stricter water standards have pushed forward quality improvement technologies such as: drinking water treatment and purification technologies (UV, electro-magnetic sensors, laser, filters, membranes).

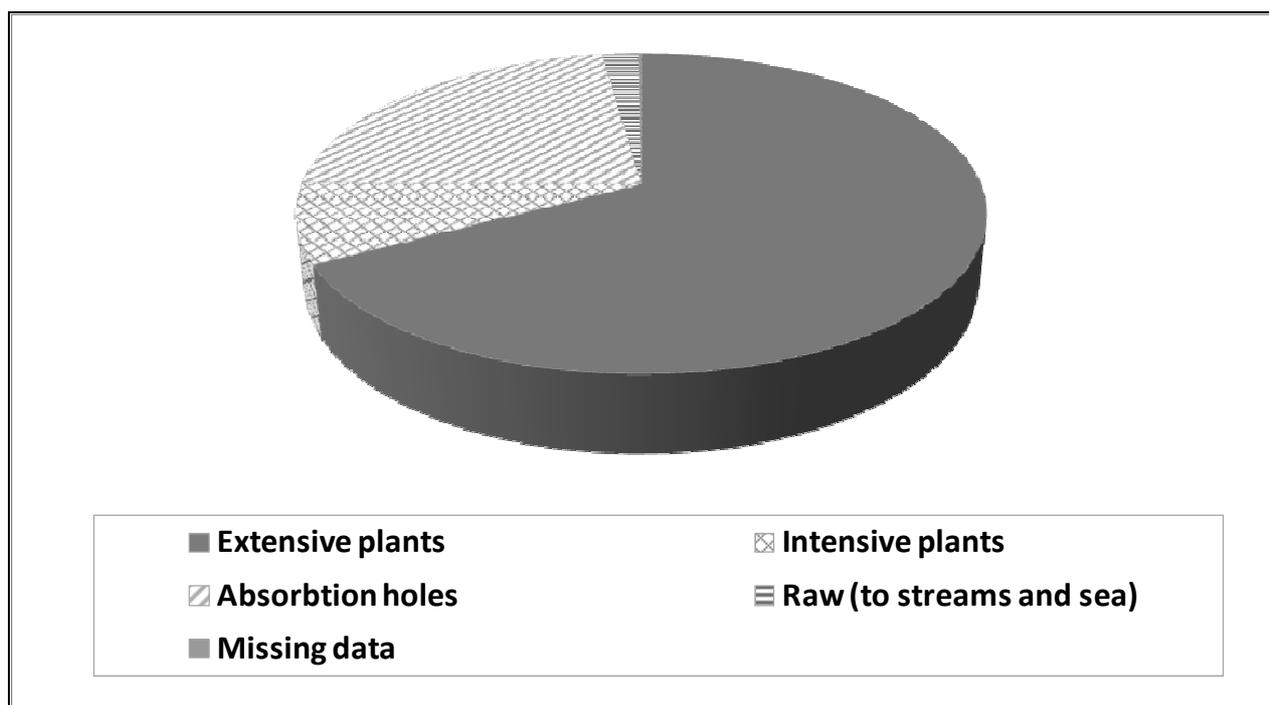
³. By the end of 2008, 14 Urban Water Corporations functioned in Israel, serving 20 municipalities and 35% of the urban population. All the rest of the urban water consumption within 170 towns was still supplied by municipalities. Water losses reported by the Urban Water Corporations reveal higher figures than reported prior to the corporations' establishment. This may suggest that the business motivation of the water corporations pushes them to measure losses more accurately, in order to fix infrastructure and avoid losing water and hence money. For example, in one city, the water loss was estimated at 14% prior to the establishment of the corporation and a year after it was estimated at 24%. After 2 years, the corporation had already reduced water loss to 19.5%.

4.1.2 Wastewater collection and treatment

83. Scarcity in potable water and the strategy of maintaining open-space and agriculture and prevention of environmental contamination of sewage have together led to new and improved water quality treatment and improvement. Increasing demand for water reuse has resulted in sewage treatment by means of intensive plants and extensive plant (Soil-Aquifer Treatment).

84. Distribution of quantity of collected sewage according to treatment technology is described in Figure 7.

Figure 7. Collected sewage water according to treatment technology



4.2 Israeli technology innovation vs. technology innovation in other countries

85. The special characteristics of the Israeli climate, water scarcity and settlement motivation, among other things, have pushed policy and regulation in water supply and demand and the local industry has responded. It what follows, the relative Israeli advantage and the unique local constraints are described.

4.2.1 Relative advantage of the Israeli industry motivating development and innovation

86. Israel has a relative advantage in water technologies which can be characterized as follows:

- Leader in drip irrigation, desalination, sewage treatment, management and monitoring of water resources
- Experience in fighting desertification
- Well-trained human capital (Academia, public sector, national and municipal public sector)
- Universities and research centres
- R&D reputation
- Technological incubators
- National water company, Mekorot, provides opportunities for building beta-site plants

- Practical reputation: Israel is already in many of the world's market
- Trade agreements that enable entrance to markets
- Potential of getting venture capital funds to be interested in the water market.

87. Although some of these factors are common to water sectors in other countries, perhaps what is unique in Israel is the close and dynamic collaboration between the public sector, the private sector and the high-education institutions. Also, transition from theory to practical solution has become relatively short due to periodic water stress and the urgency associated with finding solutions but also due to a relatively easy access to experimental technologies and knowledge in national water facilities. The productive collaboration has yielded further synergies in recent years since the Government also decided on developing the water technology industry as part of a declared and budgeted national agenda.

4.2.2 *Constraints as motivating development and innovation*

88. While being unique and dynamic, Israel's market is small and has limited opportunity in local growth. In addition, although improving in recent years, the market lacks of awareness to worldwide potential in the government and in the private sector. Also there are inefficiencies in government financial support in the industry where at the same time not many venture capital funds are willing to carry large R&D. Lack of finance to build beta-site plants also delays entrance to foreign markets.

4.2.3 *Indicators for technological innovation*

89. Various measures can be established to indicate technological innovation. Such measure can be for example growth in export, research and development fund as a share on GDP, water saving, leakages/loss in water networks, etc. We indicate a few. Water loss in Israeli municipalities has declined dramatically in recent years, to a national average of 10% (2007) of the total water consumed in the municipalities (in comparison to a European average of around 25%). Leakage detection technologies contribute to this measure. Another indicator is the agricultural output value per cubic meter of water that was used for irrigation. Figure 4 indicates a 4-times increase in real agricultural output value per cubic meter of water in 4 decades. This means that the Israeli agricultural sector produces much more per cubic meter used, but also with much less water and in particular with much less potable water (see also Figure 2). An additional example is the ability to increase revenue from water sales in urban areas by introducing dynamic pressure control system that minimise energy use and water loss, and maximises water sale. A pilot that was conducted in areas in Jerusalem has indicated a 10% increase in revenues from water sales.

5. The impact of policy on technology innovation

90. Policy tools and economic incentives have impact on technology innovation. Policy and economic tools appear as catalysts for technological progress in order to either increase efficiency in water use and/or increase profitability in case where water prices or quota are effective. Major examples are: Water quotas in the agricultural sector enforced farmers to save water and hence pushed forward innovation in drip irrigation where water-use is highly efficient. Increased prices of potable water for irrigation were a catalyst for advance sewage treatment technologies and their reuse for irrigation. That followed with an economic incentive in the form of lower prices for treated water for irrigation. Stringent environmental policy for sewage dumping also contributed to a range of technological developments in water treatment technologies. High prices for industrial and domestic water have contributed to water saving devices for domestic use and for domestic and public irrigation. Water loss fines for municipalities at a level of above 12% water loss created incentives for development of water loss detection and dynamic water pressure equipments. Economic incentives and support in private initiatives in improving water quality in closed drinking wells also brought improvement in low-scale water treatment technologies.

91. From time to time, due to cyclical droughts, especially when droughts have lasted a few consecutive years, or when the economy experienced a dramatic increase in consumption (for example, due to large immigration influx in the early to mid-1990s), the administrative and economic systems reacted with discrete changes in prices and/or quotas. Periods of water droughts in late 1980s pushed forward the establishment of a three-tier quota regime in the agricultural sector where quotas were began to be sold in a progressive rate. Farms have adjusted by adopting water saving technologies and related farm practices to reduce water consumption. In years when the country experienced quantities of renewable water sources close to a multi-year average level, water prices were only adjusted according to consumer price index. In the years characterized by hydrological shortages or sharp increases in consumption, one could notice an increase in the motivation to find technological solutions, either pushing innovation or simply adopting technology that previously was not economically feasible. For example, the recent 5 consecutive years of drought led to a significant increase in water prices. In 2009, an additional “surplus use” fee has been imposed on domestic uses, to discourage excessive water consumption. During these years, one could observe establishment of many water technology start-ups and also implementation of technologies at all scales – from home water-saving devices to accurate reading of water meters to establishment of new desalination plants. Also, stricter environmental enforcement activities and litigation in the area of urban and industrial sewage disposal have increased innovation and adoption of sewage treatment technologies in various scales and directions.

6. Technology innovation and its impact on economic development in the water sector

92. Technology innovation has a growing impact on the Israeli economic development in general and in the water sector in particular. As of 2007, 270 water-technology companies operated in Israel, employing almost 8,000 people. About 60 companies among the 270 were start-up companies, established after 2001, and were involved in R&D (Ministry of Industry, Trade and Labor, 2008).

93. Exports of the water technology sector grew from 700 million USD in 2005 to some 850 million USD in 2006, a 21% increase. In 2007, export was estimated at around 1,100 million USD, which is a 28% increase relative to 2006.

94. Water technologies and economic development in the water demand side, such as water efficient irrigation technology, was estimated at 300 million USD in 2007, 30% growth per year, produced by 3 major Israeli companies. Another technology area that is growing fast, oriented to domestic water use, is monitoring and water meters. In the water supply side, some 50 companies associated with conveyance systems, valves, etc., employed some 3000 employees and generated 430 million USD in 2007. Desalination firms are operating in a larger scale in Israel in recent years following the Government’s decision regarding sea-water desalination production. Previously, these firms operated mostly abroad. The area of wastewater technologies attracts start-ups and some 60% of the start-up in water technologies are in this area.

7. Technology innovation in the water and wastewater sector and its impact on the environment

95. In recent years, environmental objectives and considerations are been taken into account in water policies related to water allocation, water pollution, drainage, trans-boundary aspects, etc.

96. Among the *main determinants* that brought to incorporation of environmental objectives into water policies, and hence expedite technology innovation and implementation, were the increase in pollution level in drinking-water wells, making them unfit for drinking, and so to an increased stress of available supply; the destruction of ecosystems in and around streams due to inflow of untreated sewage, diversion of water up-stream for other uses and lack of drainage management.

97. *Concrete examples* for taking environmental allocation into water policies can be drawn from several cases: rehabilitation of streams, monitoring of Lake Kinneret and rehabilitation of the Tel Aviv metropolitan aquifer.

98. Activities of river and stream rehabilitation begun in 1989 with the creation of the Yarkon River Authority. In November 1993, the Ministry of the Environment and the Jewish National Fund established the National River Administration to oversee the restoration of the country's streams. The Administration is dedicated to the: Restoration of rivers through clean up and prevention of pollution, release of sufficient quantities of good quality water to river channels, and rehabilitation of adjacent landscapes and ecosystems; Promotion of the ability of rivers to serve as drainage channels for flood control; and controlled development in the environs of rivers on the basis of existing and potential nature and landscape values for purposes of nature protection, recreation, tourism, education and research. In addition, the Administration is responsible for: Collecting data and creating databases on natural and heritage values in rivers and their physical, chemical and biological condition; Formulating an integrated national policy for preservation and controlled development of the streams' environment, based on guidelines which balance between effective land use and preservation of natural ecosystems and landscapes; Preparing master-plans for river restoration; Advancing preparation and implementation of detailed plans for river restoration according to a list of priorities; and Increasing public awareness and participation in river rehabilitation and landscape protection.

99. Following a 1996 national survey commissioned by the Administration on water allocations for streams and on requested quantities for rehabilitation of selected streams, the government decided in year 2000 to allocate 50 million m³ per year to nature and to streams. So far, only small quantities have been allocated to three streams (the Yarkon, Ein-Afek and Alexander streams). In 2003, the government gave a first significant expression to this decision by allocating more than a million m³ per year of fresh water for the rehabilitation of the upstream of the Yarkon. This quantity increased by 50% in 2004. These allocations were part of an extensive program supported by more than 20 million USD for the rehabilitation of the Yarkon streams, banks and environment.

Box 1. Israeli-Palestinian co-operation on Alexander stream's restoration

In 2003, the Alexander Stream Restoration Project won the International RiverPrize in Brisbane Australia. The award recognized the efforts to restore the river and the Israeli-Palestinian co-operation on the project.

100. Additional streams currently undergoing restoration include: the Lachish, Zippori, Yarkon, Taninim, Hadera, Ayalon, Alexander, Soreq, Harod, Na'aman, Kishon, Besor and Beersheba on the coastal basin and the Harod and Southern Jordan on the eastern basin. Notable examples in which recreation and tourism sites have been established include sections of the Kishon, Taninim, Hadera, Alexander, Yarkon, Lachish, Beersheba and Harod Rivers. Restoration of water to rivers is currently being undertaken in the Harod, Taninim, Alexander and Yarkon Rivers.

101. Another concrete example is the water monitoring of Lake Kinneret that is surrounded by substantial human and agricultural activity, but still is used as a significant source of drinking water and a major ecological, recreational and landscape amenity.

Box 2. Water Monitoring in Lake Kinneret and its watershed

Lake Kinneret and its watershed supply 27% of total annual water supply in Israel. The lake is the main water source for the Israel National Water System (NWS) and for the surrounding population and its activities. The quality of the water supplied and its required treatment depend on water quality in the lake. This quality is a result of many factors in the lake and its watershed: the lake's limnological system which includes phytoplankton, zooplankton and fish, inflow of saline water from beach and seabed springs, organic and inorganic contaminants created in the basin by human activities and natural processes (sewage, fertilization, pesticides) and are flushed to the lake, and changes of land use.

A monitoring-management program of these factors in the lake and its watershed is carried out by a number of institutions and coordinated by the Israeli Water Authority. Water quality components, such as dissolved materials, phytoplankton, zooplankton and fish in the lake are measured periodically by Lake Kinneret Lab of IOLR. Additional sampling points of dissolved and suspended materials are distributed along the tributaries and basin which are measured by the Watershed Unit of Mekorot. Lake water level, groundwater level and tributaries discharge is measured by the Hydrological Service. Salinity is also monitored in groundwater aquifers discharging to the lake. Kinneret Authority officials control contaminating activities on beaches and in the basin as a part of the coordinated management program run by the Israeli Water Authority.

102. Another example is the effort invested in rehabilitation of contaminated aquifers. The following box describes the case of the Tel Aviv metropolitan aquifer.

Box 3. Contamination of Tel Aviv metropolitan area aquifer

Israel Military Industry Magen site was established in Tel Aviv in 1949 for the manufacture of small arms and was in operation until 1996. A number of contaminating manufacturing processes occurred at the site, such as corrosion-resistant coatings and colouring, and hardening through various chemical processes. As the IMI Magen site was closed and evacuated, the problem of soil and groundwater contamination by volatile organic compounds became evident by investigations of soil and groundwater contaminations at the site and its surroundings. Excavation and disposal of contaminated soil at the site did not solve the problem. The extent and configuration of the polluted area show that not only the Magen site is contaminated. The study concluded that contamination is a result of spills from a number of sources. Several soil and groundwater remedial technologies have been evaluated to address the immediate and long term health risks. Three have been selected for implementation: groundwater pump and treat, soil gas vapour extraction, and enhanced biodegradation by injection of hydrogen releasing materials.

103. The main *instruments* implemented in water policies to ensure safekeeping of resources as well as the good ecological state of the ecosystems are: a formal allocation of fresh water to the environment out of the national water budget, stringent ordinances and enforcement activities against industrial, urban and agricultural polluters, rehabilitation of polluted aquifers and streams, expending monitoring to eliminate potential sources to reach water resources, establishment of Drainage Authority of which is now also responsible on rehabilitation of streams.

104. *Main obstacles* to having better protection of the resources and of the aquatic ecosystems lay with financial, structural and technical factors such as: lack of monitoring of point-sources pollution at the source, monitoring of non-point-sources pollution, halting the spread of polluted areas in aquifers, a need to enrol various sectors into protection activities (*e.g.*, dairy farms), lack of sufficient drinking water and other prioritized obligations to domestic, agricultural and industrial users and trans-boundary agreements that do not enable the water sector to immediately allocate the full needed and approved amount of 50 million m³ per year. Also, limited budget for establishing, rehabilitating and/or upgrading of sewage treatment plants and for enforcement of pollution ordinances cause further difficulties in protecting water resources and the aquatic ecosystems.

105. *Objectives and measures* that can be proposed for progress in the medium to long term in the policies relies on freeing up water quantities for the environment by increasing quantities of water production and recycled water on one hand, and by reducing water consumption by promoting awareness to saving in water use. Such actions, including tight enforcement, require allocation of financial resources.

8. Summary

106. There is a clear impact of policy and economic tools and incentives on technology innovation in the Israeli water and wastewater sectors. Water scarcity necessitated policy-makers to develop economic incentives and tools in order to manage the water sector more efficiently on both the demand and supply sides. Scarcity also forces policy-makers not to differentiate among economic sectors and hence to introduce economic mechanisms to the three main economic sectors, namely: agriculture, domestic and industry. Policies are affecting individuals (farmers, industrialists, residential users) but are also affecting public entities, such as water associations, municipalities, etc. Hence, we observe a large range of technological innovations suitable for the various needs. Stringent policies in the area of drinking water quality standards and in sewage treatment, and water reuse standards, contributed as well to development of water and wastewater technologies. In the area of waste water technology, an impact on the environment in Israel is also observed, with less and less raw sewage is released untreated. Finally, policies and economic incentives in the area of rehabilitation of drinking wells create an incentive for development of appropriate water treatment technologies, helping the environment in two ways: limiting the spread of the contamination to other wells but also reducing the stress and over-exploitation on the reset of the aquifer.

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