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## Desalination in Israel: Status, Prospects, and Contexts

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### Overview

Desalination is a marvelous technical feat, separating pure water out of the salt water of seas, brackish aquifers, and wastewater. With membrane technologies improving and the costs of desalinated water dropping, this once exotic water source is fast becoming a mainstay of Israel's water system. The Ashkelon plant, for example, the first of five new facilities planned for Israel, is the largest reverse-osmosis plant in the world, producing 100 million m<sup>3</sup>/year, or 15% of total domestic demand. This plant's successful operation has started to shift the perceptions and decisions of the water community in Israel, and some expect Israel to eventually derive half of its potable water from desalination (Dreizin, Tenne, Hoffman, 2008).

Abroad as well, the pricing, technologies, as well as the sophisticated fiscal and institutional structures of private sector involvement in Israel's desalination projects have been regarded with keen interest by water professionals. The Ashkelon plant, for example, was voted "Desalination Plant of the year" in the Global Water Awards of 2006 in Dubai, and the Ashdod plant was awarded the title of "Deal of the Year" for 2007 by *Project Finance*.

Desalination has been a technological holy grail for water-scarce regions, breaking the constraints of local hydrological circumstances with the prospect of a drought-proof independent and predictable supply of "new water." Some form of desalination has been developed in 130 countries, with over 10,000 plants (over a threshold of 100 m<sup>3</sup>/day), and an installed capacity growing at 7% a year (Cooley et

al, 2006). But desalination must be located as one element within a range of approaches and technologies for managing water needs and provision, with ramified inputs and implications. In this broader context, the creation of new water through desalination in plants such as the Ashkelon plant is distinctive in the degree to which it is, at once, energy intensive, technology-intensive, capital intensive, centralized, and privatized. Similarly, the costs of desalinated water should be contextualized to include the cost of land and negative externalities (the discharge of brine and chemicals, the energy use and air pollutants associated with this, thermal effects and loss of coastal lands) as well as more subtle benefits, such as the value of water reliability and the benefits of relieving water stress, which may reduce political tensions or aquifer depletion.

This chapter gives a brief history of desalination in Israel and an overview of the current scope and consequences of its adoption, and frames these within some larger contextual questions regarding Israel's overall water system. While Israel's aggressive engagement with desalination is one of the more well considered internationally, and more justified than in some other contexts, questions remain about whether this should become the country's central escape path from water-constraints, especially as the world stands at the threshold of an energy-limited and carbon constrained era.

### **The take-off of desalination in Israel**

Israeli decision makers and politicians have long had a soft spot for hard technical fixes, and from the State's early history there was a tradition of visionary thinking and bold execution related to water technologies. By the mid 1950s, Israel had extended irrigation pipes to the Negev desert, was well on its way to a national-scale Water Carrier, and desalination had already been employed for drinking water in Eilat. In the late 1950s the Israeli government was presciently investing a relatively large amount on R&D on desalination, and Israel became an exporter of various desalination technologies (for example the vacuum freezing-vapor compression (the Zarchin process or VFVC) and a battery of other acronymed technologies: SRFD, LT-MVC, LT-TVC, LT-MED. . .).

Despite this, Israel itself employed only a few small reverse osmosis plants in the southern Arava areas, which are not connected to the National Water Carrier, notably a major facility in Eilat. Elsewhere, with prices typically upwards of one dollar/cubic meter of water, desalination was not considered as a feasible option on the supply side with most of the country relying on the Water Carrier and local aquifer utilization through wells. There was also room for demand-side improvements through increased agricultural water efficiencies and the use of treated wastewater for irrigation.

Given Israel's semi-arid and arid provenance, more sweeping visions of desalination's potential, which had been raised by Ben Gurion, were nurtured by water professionals. As early as 1965 TAHAL, the government (now private) company in charge of water resources planning and development in Israel, had formulated and obtained government adoption in principle for a grand (15 year, \$100 million) desalination venture. The enthusiasm of engineers, however, repeatedly encountered the cold feet of decision makers (and, in particular, the Ministry of Finance) when it came to actually getting large desalination ideas funded. For a long time, the Ministry of Finance was convinced that other sources of water must be exploited, and agricultural use reduced (through pricing reform), before the "last resort" of seawater desalination could be considered. Additionally, the powerful agricultural lobby was hesitant about desalination, fearful that this would prompt such a reform, which would de-subsidize their water.

Desalination plans were quiescent for some decades, but by the 1990s several cycles of drought and instances of overpumping accompanied by the steady growth of urban water consumption made the crisis of Israel's water economy salient enough to prompt intensive desalination planning. The Israeli Water Commission embarked on the planning of mega-scale desalination solutions to meet the increasingly painful gaps between supply and demand and prevent further deterioration of groundwater. An intensive planning process was begun, and a Desalination Master Plan was completed in 1997. This was the fruit of a comprehensive examination of various water sources and demand scenarios, of optimal sites for and capacities of desalination plants, and of desalination costs and benefits (both direct and indirect).

The Commission's planners produced a flexible staged "road map" for using these desalination plants to meet needs as they developed. The plan reserved within the National Master Plan 34B sites for eight desalination facilities plus an upgrading of the Eilat facility, which would come on line in an incremental manner, for a total capacity of 775 million m<sup>3</sup>/year.

These plans crossed the threshold to execution at the end of the 1990s, with the combination of a sense of crisis, perceived exhaustion of demand-side and reallocation solutions, and an opened window of pricing feasibility. A prolonged drought and increasing urban water demand caused water levels in natural storage reservoirs to fall below their "red lines," notwithstanding meaningful reductions in per capita domestic, agricultural, and industrial uses of water. At the same time, technology advances brought down the price of seawater desalination dramatically. These circumstances led to the approval and budgeting in 1999 of a range of new water projects, including large scale seawater desalination. On April 4, 2002 Government decision 1682 formally adopted a schedule for establishment of four desalination facilities with a combined capacity of 400 million cubic meters / year. The Water Commission was instructed to prepare tenders for the immediate private sector financing, construction, and operation of desalination facilities to provide 200 million m<sup>3</sup>. In July 2007 the desalination master plan was updated so that the five coastal plants are projected to provide over 500 MCM by 2013.

These five plants are now in various stages. A BOT (build, operate, and transfer) tender was issued for the most readily available of the Master Plan sites, at Israel's southern coastal town of Ashkelon, and a contract for the production of 50 million m<sup>3</sup>/year was signed with the winning consortium. The contracted capacity was doubled to 100 million m<sup>3</sup>/year a year later, and in 2003 financial closure was reached and notice to proceed with construction was issued. The facility, which cost \$250 million, began operation at 50% capacity in August 2005, and 100% capacity in December of the same year, with proven daily production of 348,000 m<sup>3</sup>/day.

In 2002 a 25 year BOO (Build, Own, Operate) concession agreement was signed by the special purpose company Via Maris Desalination, for the provision of 30 million m<sup>3</sup> a year at a facility in *Palmachim* (north of the port city of Ashdod) though

a request to double capacity was, reportedly, denied. (In a BOO scheme, as opposed to a BOT, the operator owns the site.) Financial closure on the Palmachim plant was reached effective on January 1, 2005, and began operation in September of 2007. In November 2006, Housing & Construction Holdings Ltd. and IDE Technologies Ltd. (through the special purpose company H<sub>2</sub>ID) signed an agreement to build and operate a 100 million m<sup>3</sup>/year desalination plant in Hadera for about \$389 million, and it is expected to come on line at the end of 2009. A 45 million m<sup>3</sup> plant at Ashdod is now being readied for tender, while the Shafdan 100 million m<sup>3</sup> wastewater desalination plant is under longer term planning. In addition, an additional 125 MCM will be bid for by plant owners-operators by 2015. Figure 6 in chapter 1 provides a graphic description of the anticipated Israeli desalination network.

In addition to this chain of 5 large coastal desalination plants, Mekorot (Israel's national water company) operates 31 small plants, mainly in the south of the country, and maintains an extensive desalination research program on sea (Eilat, Ashdod), brackish (Eilat, Kziot, Neve Zohar), and wastewater (Shafdan). The Mekorot facilities have a strong emphasis on tailoring the RO process to site-specific conditions, and on best use of brackish water sources, which are limited but much cheaper to desalinate than seawater. Similarly, Mekorot is active in research on desalination of wastewater, which has a specific energy cost 1/3 to 1/4 that of seawater, but the technology is less mature and, obviously, faces cultural stigmas when it comes to household use.

Finally, while this is nowadays often couched, perhaps misleadingly, as a project designed to "save the Dead Sea," the Red-Dead canal megaproject whose feasibility is now under review under World Bank sponsorship, was initially conceived, and is still largely, a desalination project. The Harza Group prefeasibility study of 1996 projected fresh water production of 850 MCM/year, with the elevation difference being used to generate 550 MW of electricity, part of which would be used for the desalination plant, and pumping the water back up to consumers in Amman. This project will not be discussed in the chapter, nor will the additional important issue of the possibilities of, promises for, and fate of plans for sharing of desalinated water with the Palestinian Authority.

## **Environmental and health considerations in Israeli desalination**

Since the Mediterranean is commonly regarded as oligotrophic (offering little support for life), some of the desalination impacts that might apply in other contexts (thermal impacts, for example), are seen to be less critical. At the same time, there are still large gaps in knowledge regarding this relatively new scale of operation of desalination technology, so caution is in order. Similarly, large scale desalination for drinking water raises novel regulatory and human health issues both internationally (for example, the WHO), and in Israel (for the Ministry of Health and the Ministry of Environment. Additionally, initial results from Israeli experience with the use of desalinated water for agriculture has shown some surprising, negative results due to the altered elemental profile of water, with implications for water management and a revision of desalination standards (Yermiyahu et al, 2007). Some of these, as well as energy related issues, are listed briefly below.

**Energy demands.** Energy demands in desalination facilities are mostly for pushing water through the membranes. (In the Ashkelon plant, for example, there are 32 reverse osmosis treatment trains, containing over 40,000 membrane elements.) This process constitutes 30-40% of the water cost. The theoretical minimum amount of energy needed for RO desalination from seawater is around a kilowatt-hour per cubic meter, though even the most efficient actual plants do not drop below about 4 times this theoretical minimum. For example, the Ashkelon plant has a contractual specific energy of 3.9 KWh/m<sup>3</sup>, and actual performance was 10-15% below this. In Ashkelon, the facility is to be powered by two redundant sources: a natural dedicated power plant fueled by natural gas located adjacent to the desalination plant, and high voltage linkage to the national electricity grid.

**Boron concentrations.** While boron is found in very low levels in drinking water (on the order of 0.03 mg/l), it is present at much higher levels (more than two orders of magnitude greater) in sea water (4-7 mg/l). Since boron at these levels can cause reproductive and developmental toxicity in animals as well as effecting crops additional boron removal processes must be added to desalination plants. Israel was forced to address this issue as a result of damage to sensitive crops when the Eilat

plant went on line without boron removal. It was the first country to set a boron limit of 0.04 mg/l for the first generation of desalination plants, and stringent limits (lower than WHO standards) were written into the requirements for the current generation of plants recently tendered. At the Ashkelon plant, for example, the Boron Polishing System installed demands 10% of overall plant energy.

**Overly pure produced water.** Desalinated water is remarkably pure H<sub>2</sub>O. This is largely a boon, but may also be a hazard in some respects. Reverse osmosis lowers calcium and carbonate concentrations, which make the product water acidic enough to corrode the distribution system. This reduces the useful life of the system, and can also introduce iron and other toxic metals (copper, lead, cadmium, zinc, nickel) into water. Post-treatment of desalinated water with lime or limestone corrects this problem. In addition, since the desalting process largely removes a range of ions normally found in drinking water, and which may have a supplementary dietary role, especially in certain high risk populations, blending or chemical addition may be necessary (Cotruvo, 15). Additional consequences for agriculture of the altered chemical profile of desalinated water have also received wider attention for the first time due to research on Israeli experiences with water from the Ashkelon and Eilat facilities (Yermiyahu, et al, 2007)

**Purity of the intake water.** Some toxic materials in source water, such as arsenic and small petroleum molecules can pass through RO membranes. Others can be filtered but may compromise the efficiency of the desalination process. For example, during the first 15 months of operation of the Ashkelon plant there was a summer deterioration in seawater quality, most likely from organic load (particularly sewage) from Gaza entering the plant inlet, causing reduction in production. In wastewater desalination, such as that conceived for the Shafdan facility, a broader suite of contaminants may be present, including metals, other chemicals, as well as pharmaceuticals (as mundane as caffeine and as worrying as endocrine disruptors).

**Introduced impurities and brine discharge.** The RO process can introduce a variety of substances into the discharged water (backwash liquids containing chemicals used to prevent scaling, corrosion, and fouling of the filters, as well as for pretreatment processes), in addition to the intrinsic production of saline brine that is 2-

3 times saltier than seawater. In the Ashkelon plant, for example, the most notable effect observed so far is from ferric sulfate coagulant, which, even at levels of 28 ppm, adds about 450 tons of iron a year to the sea. Even when mixed with the cooling water of the Ashkelon power station, the discharge discolors the sea with a red plume, a situation now being monitored and presumably managed. It is unclear whether this is simply an aesthetic blight or will have more significant effects on the marine environment. While there is still too little known about the marine impacts of discharges from desalination plants, precautionary suggestions to reduce these include use of more environmentally friendly antiscalants, reduction of iron content, pretreatment of brine for nitrogen so as to avoid eutrophication, and the release of organic cleaning solutions.

**Microbes.** Many microbial organisms, include bacteria, protozoa, and viruses in sea water may be pathogenic. Not all of these are removed by the desalination process. An additional concern are brominated and chlorinated organic byproducts of disinfection.

### **Social and institutional considerations in Israeli desalination**

One of the more valuable aspects of desalination in the Israeli-Palestinian context that is the subject of this volume, is the additional options and loosening of constraint that it affords. Desalination can, at least temporarily relieve, what Professor Hillel Shoval has termed “hydro-hysteria,” that is, a fearful inflexibility regarding territorial concessions and the future management of the West Bank because of its criticality as a source of Israeli drinking water. It also may help avoid irreversible overdraw of aquifers, or other consequential decisions made during a time of hydro-crisis. Thus, even the extra 15% of domestic water now being supplied by desalination is valuable for this buffering—both imaginative and actual.

At the same time, we must consider the lessening of options that desalination might entail. These stem from the fact that, for the foreseeable future, desalination plants will tend to be **large, private, and draw intensively on nonrenewable and, possibly, polluting energy sources.** Large -- because the unit cost of water drops

with the size of the plant. Private -- because governments worldwide prefer “off budget” means of building new infrastructure. Drawing on the expertise of the private sector, and the risk profile of desalination projects is well suited to the risk-sharing arrangements of private-public partnerships. (Pankratz reports that every large seawater RO plant in the world over the last 5 years involves some type of public-private partnership; Pankratz, 2005) Energy intensive - because of the inherent demand of the negentropic desalination process, which can only be feasibly met by non-renewable sources in the short and medium term. Thus, desalination ties Israel’s future more tightly into dependency on variability in the price of energy and to the incentive structures of the private sector.

Thus, ironically, in creating a stable source of pure water, not subject to the climatic variations of our region, Israel has buffered itself to one source of vulnerability, but exposed itself to several others. With desalination, Israel is increasingly dependent on water quality in the Mediterranean, the terms of decade-long contracts, and, above all, to energy price variability. To the extent that a larger portion of the cost of desalinated water is a variable cost dependent on rising energy costs, the relative advantage of desalination with respect to other forms of water source augmentation with lower variable costs, for the short run, can be expected to decline.

Desalination allows Israel to avoid hydrological constraints now, through a technological solution for meeting the inelastic demands for potable water; but it may introduce future energy constraints, as the world enters an era where limitations in energy supply and carbon emissions reach the forefront of the policy agenda. In such an era, it is unclear whether alternative energy sources (Qiblawey and Banat, 2008) will be able to meet the needs of a locked in desalination-based water economy, making the nuclear powered desalination plants a compelling option; there are certainly historical precedents for nuclear-powered desalination in the thinking of Israeli technologists and politicians.

While the public private partnerships (PPP) at the core of all Israel’s large and new desalination facilities offer many opportunities, they also can challenge those concerned with the best use of public monies and with the transfer of assets and

public services from public to private hands. For example, while they can allocate financial risks to the sectors best able to accommodate them, and harness expertise for the public good, BOT arrangements can also cloud accountability, avoid current crises by deferring liabilities to the future, and raise costs by introducing an additional layer of profit margins. The water community in Israel must consider these aspects of the shift toward desalination as well.

In short, desalination is changing the profile of Israel's water resources and perceptions of scarcity among government and business interests. Yet, this burgeoning technology must be considered systemically, with an eye to how it facilitates certain trajectories of development of an integrated energy-fiscal-hydrological system over the time horizon of decades.

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