World Water Congress 2017
Water Security in a Changing World

Planning for desalination: A comparative case study

Adriana Zuniga, America Nallely Lutz, Janaina Pasqual, Rodolfo Peon, Yulia Peralta,

Abstract

Population growth combined with climate change impacts have pushed many countries to invest in desalination technologies as a way to increase water supply and, in some cases, to improve water quality. Water managers have often considered this "hard-path" approach as a "panacea" that can solve many problems. However, research has shown that desalination may have negative impacts for both social and ecological systems. The purpose of this project is to examine the mechanisms used by existing desalination plants to alleviate the negative impacts of this technology in both social and ecological systems.
Methods include the analysis of three case studies: (i) Carlsbad Desalination Plant, in California, United States; (ii) Los Cabos Desalination Plant, in Baja California Sur, Mexico; and (iii) Hadera Desalination Plant, in Haifa District, Israel. These three plants were selected because they utilize the same desalination process, represent different scales, are currently active, and experience different political and socio-economic contexts.
Results. Although all plants use the same technology - reverse osmosis - we found that Hadera and Carlsbad have made important engineering variations to decrease the negative impacts on marine ecosystems. In addition, we found that water users in Hadera and Carlsbad accept desalinated water for every use, but it is combined with other water sources. In Los Cabos, however, desalinated water is the main water source and people still buy bottled water for drinking. Furthermore, the three plants use energy from fossil fuels, but Carlsbad has significantly improved energy efficiency, and therefore, decreased their carbon emissions. Finally, having planned the introduction of desalination in Israel for more than a decade, and having exhausted all the available soft-path approaches, the integration of desalination into their overall water management has been smooth and effective. Likewise, the opening of the Carlsbad plant was combined with other soft-path approaches that allowed desalination fit easily into their whole water management, and not be a "bandage" solution to urgent problems. Los Cabos, on the other hand, has no clear environmental assessment, and is heavily subsidized, which threatens the sustainability of the plant. In addition, the opening of Los Cabos plant has promoted population growth and incentivized the tourism industry, exacerbating the problem in the long-term. We conclude that planning for desalination by having exhausted soft-path approaches prior to adopting this technology is critical for the sustainability of water resources.

1. Introduction

Providing freshwater to people living along the coast has been possible within the last decades through desalination processes – or by removing salt and other minerals from seawater and brackish water. Initially, desalination was extremely expensive, but new technologies, including reverse osmosis, have lowered the cost and this has allowed some nations to invest in desalination infrastructure. Nowadays, we can find more than 18,400 desalination plants in 120 countries throughout all inhabited continents (Ocasio 2015; Wilder et al. 2016). Because desalination processes use a lot of energy, it is not surprising to find the highest concentration of desalination plants in the Middle East – a region rich in oil – with more than half of the desalination plants in the world (Ocasio 2015). In terms of percent of desalination plants in the world, the Middle East is followed by North America (17%) and Europe (10%) (Ocasio 2015). But even though wealthy nations are more prone to invest in desalination plants, some developing countries are also turning their attention toward this still expensive method to provide freshwater to their people. For example, in 2015, the first desalination plant in West Africa started operations in Ghana ("First Desalination Plant in West Africa Officially Inaugurated" 2017).

An important aspect to consider when thinking of desalination is energy use. Half of the operating costs of desalination are attributed to energy (Ocasio 2015). This high use of energy requires desalination plants to be located close to a power plant. The energy source of the power plant plays a big role not only in the cost, but also in carbon dioxide emissions and related impacts on climate change. Another aspect to consider is the damage to marine ecosystems. Desalination processes absorb water from the ocean and this intake affects marine ecosystems because fish get caught in this process (Ocasio 2015; Wilder et al. 2016). Furthermore, a by-product of desalination processes is a brine (or water with a high concentration of salt) that is discharged back to the ocean. This brine negatively affects marine ecosystems and all the people that depend on these resources (Ocasio 2015; Wilder et al. 2016).

In spite of the negative effects of desalination, many government officials and water professionals consider desalination as a "panacea" that can solve our water challenges and provide freshwater to a growing population living in coastal areas. Scientists are concerned that this hard-path approach has not fully been examined yet and that there are several environmental and social impacts that need to be considered before investing in desalination (Wilder et al. 2016). Furthermore, researchers recommend to seek soft-path approaches to achieving water security before turning toward desalination (Eden 2011; Wilder et al. 2016). Therefore, it becomes critical to study the effects that current desalination plants have on both social and ecological systems so we can extract important lessons for future plants. The purpose of this study is to examine and compare the impacts of three operating desalination plants that have different scales in both developing and developed nations. Lessons from these case studies have the potential to inform current and future plants and guide them toward more sustainable solutions.

2. **Methods**

We selected three desalination plants for this study that have different scales and are located in wealthy and poor countries. Our case studies include: (1) Carlsbad Desalination Plant in Carlsbad, California; (2) Los Cabos Municipal Desalination Plant in Los Cabos, Baja California Sur, Mexico; and (3) Hadera Desalination Plant in Haifa District, Israel.

2.1. Carlsbad Desalination Plant

The Claude "Bud" Lewis Carlsbad Desalination Plant - or Carlsbad Plant - is located in Carlsbad in Southern California, adjacent to the Encina Power Station. Carlsbad is a small town along the coast of Southern California with a population of 109,318 (Heck et al. 2016a) (Figure 1). But this plant provides freshwater not only to Carlsbad but to the region that includes the City of San Diego, located 35 miles south of Carlsbad. Southern California is highly dependent on imported water. The Colorado River provides 64% of the water supply for the San Diego Water District (Heck et al. 2016a). The rest is provided by the state water project in Northern California, and only 16 % of the water supply comes from local sources (Heck et al. 2016a). The Carlsbad plant increased water supply by 26 % (Heck et al. 2016a).

XVI World Water Congress
International Water Resources Association (IWRA)
Cancun, Quintana Roo. Mexico. 29 May- 3 June, 2017

Figure 1. Location of Carlsbad Desalination Plant (from (Heck et al. 2016a)

After three years of construction, the Carlsbad plant started operations on December 14, 2015. The plant is supported by San Diego County Water Authority (SDCWA) and Poseidon Water; a private company. This public-private partnership made it possible for Carlsbad Desalination Plant to be the largest in the Western Hemisphere (Ocasio 2015).

Water supply to this region has been threatened by reduced snowpack in the Nevada Mountains, and changing weather patterns that basically include less precipitation (Heck et al. 2016b). During the last years, California has experienced a severe water crisis triggered by a prolonged drought. In 2014, the U.S. Drought Monitor stated that California was experiencing an “extreme” drought for the past three years, negatively affecting agricultural activities, increasing pumping costs, and resulting in the loss of many agricultural jobs (Ocasio 2015). Because California is expected to experience prolonged droughts in the future, and population growth increases demand, the government of California has authorized funding to increase water supply via desalination (Ocasio 2015).

In addition to increasing water supply, local governments have mandated water conservation initiatives to reduce water use. Water conservation measures are accompanied by economic incentives that together have successfully reduced water use in this region by 6% (Ocasio 2015). Nevertheless, the SDCWA is concerned for the dire dry future and has invested resources to enhance water supply, and the Carlsbad Desalination Plant is an example (Ocasio 2015).

2.2. Los Cabos Municipal Desalination Plant

The municipality of Los Cabos is located in the southernmost area of Baja California Sur (BCS), Mexico. BCS is the state with the least amount of annual precipitation in the country (174 mm per year) together with the most extensive coastal line (2,131 km) (Bermudez-Contreras, Thomson, and Infield 2008) (Figure 2). Los Cabos municipality accounted for 238,487 people in 2010 (INEGI 2010), the majority of which live in the cities of San José del Cabo, Cabo San Lucas, or along the 18-mile touristic corridor existing between these two localities. Contrary to what happens in the rest of Mexico – where agriculture is the main water user, in this municipality the largest consumer sector of water is the municipality (McEvoy 2014).

Figure 2. Desalination plants in Northwest Mexico (from Wilder et al. 2016).

BCS is one of the most arid and fastest growing states in Mexico. Due to the booming tourism industry directed to high-end consumers (Pombo, Breceda, and Valdez Aragón 2008), the state's population has been growing at rates much higher than the national average, especially in the 1990s (McEvoy 2014). Migrants have been attracted by employments created by hotels and touristic services, but the local government has been unable to cope with the demand for public services, such as water and sanitation, as well as electricity. It is estimated that each new hotel room built in Los Cabos attracts, on average, 19.1 migrants to the area (McEvoy 2014). In 2003, virtually all the water came from underground sources, and the main aquifers supplying the cities were overexploited, had saline intrusion, or both (Bermudez-Contreras, Thomson, and Infield 2008), and this situation continues in more recent years (McEvoy 2014). By 2008, around 70,000 people had no access to the main water networks, and 20,000 did not have access to electricity networks (Bermudez-Contreras, Thomson, and Infield 2008).

Considering the water scarcity as consequence of socio-economic growth, inadequate management, and low efficiency (McEvoy 2014) nowadays one of the biggest problems of BCS in general, and Los Cabos in particular, is water scarcity. Around a decade ago, estimations indicated that the state's freshwater supplies will only cope for five more years considering the business-as-usual scenario (Bermudez-Contreras, Thomson, and Infield 2008). The incapacity of the local government to provide reliable and continuous water supply for all the inhabitants promoted the passing of legislation to ban water purchases from the public network by new tourism and hotel developments. This, in turn, drove the building and operation of many public and private small-scale desalination plants (the latter for serving the tourism businesses). Bermudez-Contreras et al. (2008) reported the existence of 67 desalination plants operating through private and state-managed systems, with capacities ranging between 2 to 1998 cubic meters per day (m^3/day).

Desalination is seen in the long-term water plan of BCS as the principal mean by which they can overcome future water deficits (McEvoy 2014). In 2006 a large scale desalination plant started operations in Los Cabos, becoming the Mexico's "first ever, municipal-scale desalination plant for public water supply" (McEvoy 2014: 524). The Los Cabos Desalination plant (henceforth Los Cabos plant) operates under a 20-year scheme of Public-Private Partnership (PPP or P3), in which the municipal water utility (OOMAPASLC), the state and federal water authorities, and INIMA, a private Spanish firm, share responsibilities, costs, and benefits of building, operating, and maintaining the plant (McEvoy 2014). While the appropriateness of this plant as a strategy for increase water security has been discussed (McEvoy 2014), and its ecological impacts are still unknown, by 2016 further negotiations and meetings were occurring towards the building of a second municipal desalination plant in Los Cabos to provide additional 400 liters per second (lps) for domestic consumption in the *colonias* of the municipality (H. XII Ayuntamiento de Los Cabos 2016).

2.3. Hadera Desalination Plant

Since the 1990s, Israel has invested a considerable amount of resources into building and operating several desalination plants in order to increase water quantity and quality (Dreizin, Tenne, and Hoffman 2008). But this decision to move toward hard-path approaches was taken only after exhausting multiple other soft-path options. Israel has a highly developed water system that combines hard-path solutions such as interbasin-transfers, with soft-path approaches including demand management (Feitelson and Rosenthal 2012). Since the 1950s, Israel has studied the possibility of large-scale desalination, but has actually built only small desalination plants used for brackish waters (Dreizin, Tenne, and Hoffman 2008). The government gave priority to water conservation measures and an important conveyance system – the National Water Carrier (NWC) – that transports water from the Sea of Galilee in the north to southern cities with multiple pumping stations along the way. The government also opened a web of wells providing the users with a blend of surface water and groundwater through regional grids (Dreizin, Tenne, and Hoffman 2008). Other measures included water use efficiency in agriculture combined with the partial use of wastewater effluent for irrigation (Dreizin, Tenne, and Hoffman 2008). All these measures allowed Israel to postpone large-scale desalination for several decades (Dreizin, Tenne, and Hoffman 2008).

But in the 1990s, all the water conservation measures were not enough to overcome a multi-year drought. During this difficult period, the official government agency that manages water resources – the Israeli Water Commission (IWC) – decided that it was time to introduce large-scale desalination to the country including half a dozen plants along the coast (Dreizin, Tenne, and Hoffman 2008). Planning for this dramatic investment and for the location of the desalination plants was carefully studied based on several factors that include (1) distance to nearest junction with the NWC, (2) distance to power stations, (3) proximity to urban centers, (4) distance to NWC's pumping station to minimize energy used for pumping, (5) distance to seawater contamination sources (e.g., oil spills, wastewater), (6) land availability (including future expansions) (Dreizin, Tenne, and Hoffman 2008). In 2004, a national master plan was approved for seem desalination plants and Hadera was one of the selected locations (Feitelson and Rosenthal 2012) (Figure 3). By the year 2020, it is expected that desalination processes will supply almost half of the water used in this country (Feitelson and Rosenthal 2012).

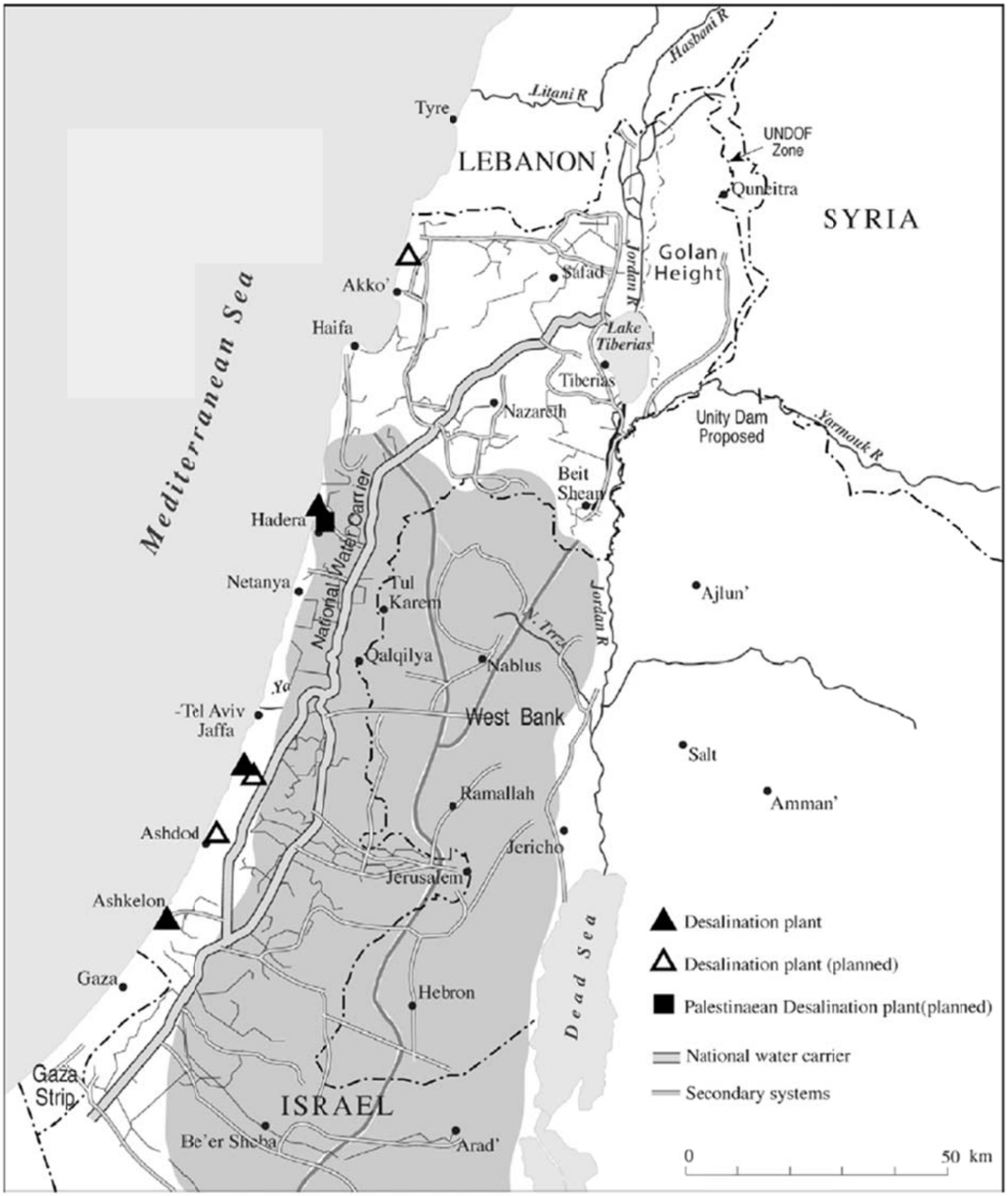

Figure 3. Desalinations plants in Israel (from Feitelson and Rosenthal 2012)

Hadera Desalination Plant (henceforth Hadera plant) was completed in May 2010 and is considered one of the largest desalination plants in the world (Faigon et al. 2013). This plant is located in Hadera, by the Mediterranean Sea, and is part of the Orot Rabin Power Station. Private capital built this plant through build-operate-transfer (BOT) tenders and shareholders include IDE Technologies Ltd. and H&C (Faigon et al. 2013; Feitelson and Rosenthal 2012).

2.4. Analyzing factors

We seek to understand the social and ecological impacts of these desalination plants and its overall sustainability. For this purpose we explore five dimensions of a sustainable desalination plant that include technological, economic, political, environmental, and social (Figure 4).

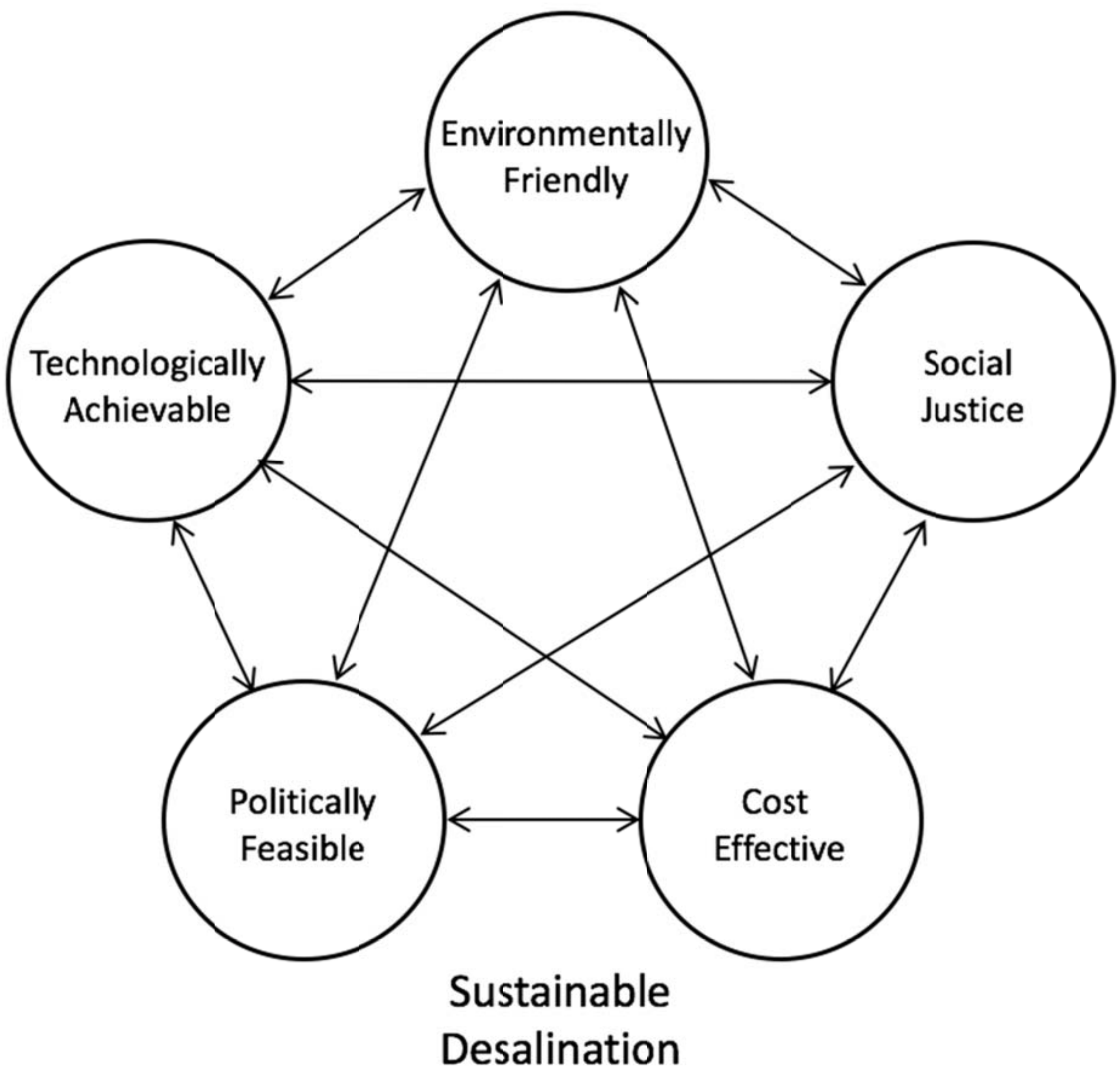

Figure 4. The five dimensions of a sustainable desalination plant analyzed in this paper.

3. Results

3.1. Technological factors

The three desalination plants studied here utilize the same type of technology for desalination – reverse osmosis. This process is the most popular technology used nowadays because it considerable reduces operating costs by using cheaper and more durable filters (Barringer 2013). Reverse osmosis consists of five steps: (1) intake of seawater or brackish water, (2) removal of suspended solids and pre-treatment, (3) removal of dissolved solids by reverse osmosis, (4) post-treatment to prevent corrosion in pipes, and (5) handling and disposal (or reuse) of concentrated brine (Wilder et al. 2016). About half of the seawater taken into the plant is converted into potable water and the rest is discharged back into the ocean as concentrated brine (Ocasio 2015).

The reverse osmosis systems in both, Hadera and Carlsbad plants, was designed by IDE Technologies Ltd. (Faigon et al. 2013; "Seawater Desalination | San Diego County Water Authority" 2015). The Carslbad plant was developed by the private company Poseidon Water, and IDE Technologies operates the plant ("Seawater Desalination | San Diego County Water Authority" 2015).

Compared to Carlsbad and Los Cabos plants, Hadera plant has several engineering variations that are aimed to reduce the negative impacts on marine ecosystems and lower production and maintenance costs (Tal 2011). These variations include an open submerged intake system that consists of three 1 km - long plastic pipelines (Tal 2011). By having a parallel intake system (three pipes instead of one) turbulence is reduced and less fish are caught in the intake process. The purpose of building the intake pipes of plastic material is to facilitate maintenance by inhibiting bio-growth (Tal 2011). In order to reduce the effects of the brine, Hadera discharges its brine at a distance of one kilometer and dilutes the brine with water emitted from the contiguous power plant, achieving a salinity ratio of 1:10 (Tal 2011). But even though the salinity levels of the brine are reduced to a minimum, the temperature of the brine is still higher than seawater, so in order to ensure dispersion and dilution, the Israel's Ministry of Environment mandated the installation of diffusers located two meters above the seabed (Tal 2011). The results of monitoring systems suggest that marine water quality has not been altered significantly (Tal 2011).

Another important modification in the Hadera plant is the removal of boron, which is essential for plant growth in wastewater treatment processes (Tal 2011). Because Israel treats 75 percent of its wastewater, removing boron from desalinated water makes wastewater treatment – at the end of its cycle – more efficient (Tal 2011).

3.2. Economic factors

The Carlsbad plant cost $1 billion USD to build and was financed by two bond offerings that sum $734 million, an equity investment of $189 million, and about $80 million provided by the water authority (Barringer 2013). Construction costs had to be combined with the cost of a 10-mile pipe that would deliver water to the City of San Diego (Barringer 2013). Operating costs of this plant are projected to increase by $3.6 million per year in order to finance upgrades of the intake process needed to comply with environmental regulations ("Seawater Desalination | San Diego County Water Authority" 2015). At the household level, the addition of the Carlsbad plant to the water supply portfolio in this region results in a $5 USD increase per month (Heck et al. 2016a).

Similar to the Carlsbad plant, the construction costs of Los Cabos plant was split between public (34%) and private investments (64%) (McEvoy 2014). McEvoy (2014) found that the market cost to domestic users is highly subsidized. The public local water utility company buys desalinated water from the private operator INIMA at a rate of $12.50/m³ pesos (of 2013) and resells the water at a rate of $3.3/m³ to the public. According to this calculation, the desalinated water in Los Cabos is subsidized at the rate of $9.2/m³ (Gámez Vázquez, 2009, cited in McEvoy 2014). Desalination in BCS was adopted before implementing other less cost-intensive strategies based on improving efficiency or conservation (McEvoy 2014).

3.3. Political factors

Desalination has opened the dialogue for reducing burden on transboundary streams and aquifers in Israel and neighboring countries. Israel has reserved land for the implementation of a Palestinian Desalination plant, near Hadera, and allowing a pipeline to transverse its territory, from Hadera to the West Bank (Feitelson and Rosenthal 2012).

3.4. Environmental factors

Environmental concerns of desalination processes are two fold, marine ecosystems and carbon emissions from energy use.

Marine ecosystems

The Carlsbad plant utilizes an open ocean intake technology to absorb 300 million gallons of seawater a day (mgd) (Heck et al. 2016a). From these 300 mgd, 50 mgd are converted into potable water and another 50 mgd are a concentrated brine (Heck et al. 2016a). The remaining 200 mgd are used to dilute the brine before it is discharged into the Pacific ocean (Heck et al. 2016a). The infrastructure used to absorb and discharge the water is shared with the adjacent Encina Power Plant (Heck et al. 2016a). The plant is located on Agua Hedionda Lagoon in Carlsbad – a lagoon used for aquaculture and recreational activities ("Seawater Desalination | San Diego County Water Authority" 2015; Heck et al. 2016b). However, this power plant will be shut down by the end of 2017 and is planned to be replaced by a new plant located inland ("Seawater Desalination | San Diego County Water Authority" 2015).

In the case of Los Cabos plant, we found that environmental impacts are not evaluated. For a desalination plant to operate, the Mexican National Water Commission (CONAGUA) should issue a discharge permit for the brine water. Also the plant's operator needs to complete an environmental impact assessment and obtain a separate concession from the Ministry of Natural Resources and the Environment (SEMARNAT). However, beyond these simple regulation-like measurements, there are no specific federal or state-level laws for regulating these brine discharges (McEvoy 2015). Unfortunately, "… there is a lack of long-term research and considerable uncertainty about the environmental impacts of desalination" (McEvoy 2014: 519). "Studies of the effects of the discharge on the environment have not been performed in Los Cabos" (Pombo, Breceda, and Valdez Aragón 2008: 203). There is an absence of monitoring, and systematic studies of the ecological effects of brine water discharged into the sea are "urgently needed" (Pombo, Breceda, and Valdez Aragón 2008).

Energy use

The Carlsbad plant utilizes energy from the San Diego County power supply network, even though it is adjacently located to the Encina Power Station (Heck et al. 2016b). The Carlsbad plant requires 40 MW to operate and utilizes state-of-the-art pressure exchanger devices made by Energy Recovery, Inc. Because the device consumes no electricity and recycles otherwise lost energy, much like a hybrid car, the overall energy consumption of the reverse osmosis process is reduced by nearly 46 percent ("Seawater Desalination | San Diego County Water Authority" 2015). Therefore, carbon dioxide emissions are reduced if compared to conventional desalination plants that use energy from fossil fuels.

3.5. Social factors

The dramatic situation in California has stimulated the proliferation of desalination plants along the coast (Heck et al. 2016b). People are accepting more and more this new type of water supply. Some factors influencing social acceptance of desalination include reduced reliability of imported water sources, a rise in taxes of aquifers along the coast, and an increase in demand (Heck et al. 2016b). In a study on the predictors of social support for desalination processes in California,

The people in Los Cabos have accepted desalinated water and they use it regularly for domestic purposes (cleaning, landscaping) but not for drinking water, even though it meets water quality standards (McEvoy 2014). McEvoy (2014) reports that the plant serves around 40,000 people in popular, low socio-economic strata neighborhoods. Additionally, Bermudez-Contreras et al. (2008) found that, due to the growing number of private small-scale desalination plants in resorts and tourism enterprises, there is an emergence of local businesses serving the maintenance of these installations, opening a new economic opportunity for the locality.

4. Discussion and conclusion

In these cases, desalination has been considered a long-term solution for water shortages in the context of a growing population, increasing socio-economic development, and climate change. However, the five dimensions of analysis in this paper illuminate several aspects that confront the benefits of these plants with frequently unknown aspects and impacts. Maybe the biggest concern of policy makers regarding desalination so far has been an economic one: who is going to pay for the investment in building, operation, and maintenance of such installation? Governments have developed partnerships between private and public sectors as an innovation to cover the usually high costs of desalination process. However, even in those cases, the riskiest part of the investment, or the social costs of desalination have to be covered by public funds. In cases where economic issues mix with political factors (e.g. Los Cabos in Mexico, where water tariff increases are seen as unpopular strategies), the local governments partially subsidize the total cost of water production. In the long term this could represent important sources of debt for localities with low revenue capacity. On the other hand, an alternative is to charge the higher costs to those sectors that produce the externalities in terms of water and sustainability (i.e. the tourism sector, as authorities have tried to do in BCS). A second aspect to consider is the ecological impacts of desalination. In the case of Mexico, these effects are not totally understood, and the Mexican legislation has not accommodated yet specific regulations beyond the studies of environmental impact required for water infrastructure in general. Additionally, in all the cases the interactions between these environmental impacts and changing water resources (e.g. changing oceans because of global warming) are not systematically analyzed either. This may become a focus of future research as desalination becomes a preferred (or the only) alternative for water supply. In this endeavor, the importance of scale of operations is critical since this defines not only the price of the water produced, but also the degree of ecological impacts that can be expected, although technological innovations (e.g. the Hadera plant structure) can overcome, at least partially, some of these potential environmental impacts.

In connection to environmental issues, one of the problems we found is the lack of other policy strategies or measures in parallel to desalination. Since desalination is a supply-oriented strategy, other regulations regarding changes in consumption behavior and conservation may be required to enhance the sustainability of this strategy. Desalination plants, as other types of water hard-path solutions (infrastructure) sometimes produce adaptation pathways that are inflexible and lead the urban management systems to traps (Scott and Lutz-Ley 2016). They also draw the attention of policy-makers away of other more environmentally sounding alternatives (Pombo, Breceda and Valdez Aragón 2008).

Beyond these impacts, desalination -when adequately considered- can actually solve development problems that otherwise would be very difficult to address. The decentralized, small to mid-scale desalination plants existing in resorts of BCS have given autonomy to the tourism businesses and shifted the responsibility from the public services' providers to the actual private users that finally benefit from it. This autonomy has allowed the private sector of Los Cabos to be more economically and resilient when extreme events, such as hurricanes, have hit the area and affected the public services of water supply. However, the ecological impacts of these small but multiple plants on the coastal ecosystems remain unknown. Desalination can achieve sustainable goals more easily if combined with other low-energy solutions, such as solar energy. In places with restricted access to standard electric networks, but enough solar radiation, small-scale desalination can become the best alternative to solve water shortages.

References

Barringer, Felicity. 2013. “In California, What Price Water?” *The New York Times. New York, NY* 28. http://nanohydrophobics.com/app/download/582161404/A+Costly+California+Desalination+Plant+Bets+on+Future+Affordability+-+NYTimes.pdf.

Bermudez-Contreras, Alfredo, Murray Thomson, and David G. Infield. 2008. “Renewable Energy Powered Desalination in Baja California Sur, Mexico.” *Desalination* 220 (1-3): 431–40. doi:10.1016/j.desal.2007.01.046.

Dreizin, Y., A. Tenne, and D. Hoffman. 2008. “Integrating Large Scale Seawater Desalination Plants within Israel’s Water Supply System.” *Desalination* 220 (1-3): 132–49. doi:10.1016/j.desal.2007.01.028.

Eden, Susanna. 2011. “Lessons on the Generation of Usable Science from an Assessment of Decision Support Practices.” *Environmental Science & Policy* 14 (1): 11–19. doi:10.1016/j.envsci.2010.09.011.

Faigon, Miriam, Yaron Egozy, David Hefer, Maya Ilevicky, and Yossi Pinhas. 2013. “Hadera Desalination Plant Two Years of Operation.” *Desalination and Water Treatment* 51 (1-3): 132–39. doi:10.1080/19443994.2012.701414.

Feitelson, Eran, and Gad Rosenthal. 2012. “Desalination, Space and Power: The Ramifications of Israel’s Changing Water Geography.” *Geoforum* 43 (2): 272–84. doi:10.1016/j.geoforum.2011.08.011.

“First Desalination Plant in West Africa Officially Inaugurated.” 2017. Accessed February 1. http://www.waterworld.com/articles/2015/04/abengoa-inaugurates-the-first-desalination-plant-in-west-africa-at-accra-ghana.html.

Heck, Nadine, Adina Paytan, Donald C. Potts, and Brent Haddad. 2016a. “Coastal Residents’ Literacy about Seawater Desalination and Its Impacts on Marine Ecosystems in California.” *Marine Policy* 68 (June): 178–86. doi:10.1016/j.marpol.2016.03.004.

———. 2016b. “Predictors of Local Support for a Seawater Desalination Plant in a Small Coastal Community.” *Environmental Science & Policy* 66 (December): 101–11. doi:10.1016/j.envsci.2016.08.009.

H. XII Ayuntamiento de Los Cabos. 2016. “Avanza Proyecto de Nueva Planta Desaladora Para Los Cabos – H. XII Ayuntamiento de Los Cabos.” May 22. http://loscabos.gob.mx/2016/05/avanza-proyecto-de-nueva-planta-desaladora-para-los-cabos/.

(INEGI), Instituto Nacional de Estadística y Geografía. 2010. “México en cifras.Baja California Sur.” http://www.beta.inegi.org.mx/app/areasgeograficas/?ag=03.

McEvoy, Jamie. 2014. “Desalination and Water Security: The Promise and Perils of a Technological Fix to the Water Crisis in Baja California Sur, Mexico.” *Water Alternatives* 7 (3): 518–41.

———. 2015. “Can the Adoption of Desalination Technology Lead to Aquifer Preservation? A Case Study of a Sociotechnical Water System in Baja California Sur, Mexico.” *Water* 7 (10): 5224–38. doi:10.3390/w7105224.

Ocasio, Karen MO’Neill. 2015. “Feeling Salty: Regulating Desalination Plants in the United States and Spain.” *Cornell Int’l LJ* 48: 451.

Pombo, Alberto, Aurora Breceda, and Alva Valdez Aragón. 2008. “Desalinization and Wastewater Reuse as Technological Alternatives in an Arid, Tourism Booming Region of Mexico.” *Frontera Norte* 20 (39): 191–216.

"Seawater Desalination | San Diego County Water Authority." 2015. Accessed July 9. http://sdcwa.org/seawater-desalination.

Tal, Alon. 2011. "The Desalination Debate—Lessons Learned Thus Far." *Environment: Science and Policy for Sustainable Development* 53 (5): 34–48. doi:10.1080/00139157.2011.604009.

Wilder, Margaret O., Ismael Aguilar-Barajas, Nicolás Pineda-Pablos, Robert G. Varady, Sharon B. Megdal, Jamie McEvoy, Robert Merideth, Adriana A. Zúñiga-Terán, and Christopher A. Scott. 2016. "Desalination and Water Security in the US–Mexico Border Region: Assessing the Social, Environmental and Political Impacts." *Water International*, April, 1–20. doi:10.1080/02508060.2016.1166416.