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Desalination: Status and Federal Issues

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Summary

In the United States, desalination is increasingly investigated as an option for meeting municipal water demands, particularly for coastal communities that can desalinate seawater or estuarine water, interior communities above brackish groundwater aquifers, and communities with contaminated water supplies. Adoption of desalination, however, remains constrained by financial, environmental, regulatory, and other factors. At issue is what role Congress establishes for the federal government in desalination research and development, and in construction and operational costs of desalination demonstration projects and full-scale facilities.

Desalination processes generally treat seawater or brackish water to produce a stream of freshwater, and a separate, saltier stream of water that has to be disposed (often called waste concentrate). Desalination's attractions are that it can create a new source of freshwater from otherwise unusable waters, and that this source may be more dependable than freshwater sources that rely on annual or multi-year precipitation, runoff, and recharge rates. Many states (most notably Florida, California, and Texas) and cities are actively researching and investigating the feasibility of large-scale desalination plants for municipal water supplies.

Desalination and its different applications, however, come with their own sets of risks and concerns. Although the costs of desalination dropped steadily in recent decades, making it more competitive with other water supply augmentation options, the declining trend may not continue if energy costs rise. Electricity expenses vary from one-third to one-half of the operating cost of desalination facilities. Reducing the energy requirements of desalination would decrease its cost uncertainties. Substantial uncertainty also remains about the technology's environmental impacts, in particular management of the saline waste concentrate and the effect of intake facilities on aquatic organisms. Moreover, there are few federal health and environmental guidelines, regulations, and policies specific to desalination as a municipal water supply source. Social acceptance and regulatory processes also affect desalination's adoption and perceived risks. Research and public education may help to resolve some uncertainties, develop methods to mitigate impacts, reduce the costs of desalination, and improve public understanding of the risks.

To date, the federal government has been involved primarily in desalination research and development (including military applications), some demonstration projects, and select full-scale facilities. For the most part, local governments, sometimes with state-level involvement, have been responsible for planning, testing, building, and operating desalination facilities, similar to their responsibility for freshwater treatment for municipal drinking water supply. Bills in the 111th Congress (e.g., H.R. 88, H.R. 469, S. 1462, S. 1731, S. 1733, and P.L. 111-11) represent a range of federal authorizations for desalination research, demonstration and full-scale facilities, and planning and financing. H.R. 1145 would formally establish a federal interagency committee to coordinate federal water research, including desalination research.

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Desalination: The Federal Policy Context

Interest in desalination of seawater, brackish water, and contaminated freshwater has increased in the United States as the technology's costs have fallen and pressure to develop new water supplies has grown. Adoption of desalination, however, remains constrained by financial, environmental, and regulatory and social factors. At issue is what role Congress establishes for the federal government in desalination research and development, and in construction and operational costs of desalination demonstration projects and full-scale plants.

Desalination processes generally treat seawater or brackish water to produce a stream of freshwater, and a separate, saltier stream of wastewater, often called *waste concentrate* or *brine*. There are a number of desalination methods. Two processes, thermal (e.g., distillation) and membrane processes (e.g., reverse osmosis), are the most commonly used, with reverse osmosis dominating in the United States. For more information on desalination technologies, see the **Appendix**.

Although desalination costs dropped steadily in recent decades, making it more competitive with other water supply augmentation options, a rise in energy costs could reverse the trend. Electricity expenses vary from one-third to one-half of the cost of operating desalination facilities.[1] Substantial uncertainty also remains about the technology's environmental impacts. Social acceptance and regulatory processes also affect its adoption and perceived risks. Research may help to resolve uncertainties and develop methods to mitigate impacts as well as reduce the costs of desalination.

Questions that may confront the 111th Congress in its consideration of the federal role in desalination include:

- What is the appropriate level and nature of federal investment in desalination research and development? For example, will Congress fund research aimed at reducing the environmental impacts of desalination, or reducing the energy requirements for desalination, or both?
- Should the federal government participate in and provide incentives for the construction and/or operation of desalination facilities to address local water supply needs? If so, should federal involvement be decided on a case-by-case basis, or should Congress authorize a program to define the level and type of federal involvement?

To date, the federal government has been involved primarily in research and development, some demonstration projects, and select full-scale facilities. For the most part, local governments, sometimes with state-level involvement, have been responsible for planning, testing, building, and operating desalination facilities, similar to their responsibility for freshwater treatment for municipal drinking water supply.

[1] S. Chaudry, "Unit cost of desalination," California Desalination Task Force, California Energy Commission, 2003.

Legislation in the 111th Congress

During recent Congresses, legislative proposals have identified a range of different potential federal roles in desalination, including creation of a water research program within the national laboratories of the Department of Energy (to include numerous desalination-related research areas); authorization of desalination demonstration, research, and full-scale facilities; and authorization of payments to offset the energy costs of desalination operations. Bills introduced in the 111th Congress also represent a range of federal authorizations for desalination research, facilities, and planning; below are some examples of desalination-related legislation in the 111th Congress.

Examples of Research Legislation

H.R. 469, the Produced Water Utilization Act of 2009, would authorize a Department of Energy program for research, development, and demonstration of technologies (including desalination) for environmentally sustainable utilization of groundwater produced during energy development (i.e., groundwater brought to the surface as part of exploration or development of coalbed methane, oil, natural gas, or any other substance to be used as an energy source) for agricultural, irrigational, municipal, and industrial uses, or other environmentally sustainable purposes.

H.R. 1145, the National Water Research and Development Initiative Act of 2009, would formally establish a federal interagency committee to coordinate federal water research, including desalination research. The committee, with input from an advisory committee, would develop a four-year plan for priority federal research topics and annually report on progress on the plan. Among the outcomes the plan is to promote is development of technologies for enhancing reliable water supply (e.g., desalination). The bill also would establish a National Water Initiative Coordination Office that would function as a clearinghouse for technical and programmatic information, support the interagency committee, and disseminate the findings and recommendations of the interagency committee. A version of the committee, the Subcommittee on Water Availability and Quality (SWAQ), which was not created by statute, has been operating since 2003 within the Office of Science and Technology Policy (OSTP) as part of the National Science and Technology Council (NSTC).

S. 1462, the American Clean Energy Leadership Act of 2009, includes a provision directing the Secretary of the Interior to operate, maintain, and manage the Brackish Groundwater National Desalination Research Facility.[2] The facility is directed to conduct research, development, and demonstration activities to promote brackish groundwater desalination, including the integration of desalination and renewable energy technologies, and outreach programs with public and private entities and for public education. The facility's mission also includes managing the waste concentrated from desalination, desalinating waters produced during oil and gas production, and small-scale desalination systems.

[2] The Brackish Groundwater National Desalination Research Facility is a federally constructed research facility focused on developing desalination technologies for brackish and impaired groundwater found in the inland states. It is located in Alamogordo, Otero County, NM. The facility opened in August 2007 and is integrated into Department of the Interior's existing desalination research and development program at the Bureau of Reclamation. It brings together researchers from other federal agencies, universities, the private sector, research organizations, and state and local agencies.

S. 1733, Clean Energy Jobs and American Power Act, includes a provision requiring the U.S. Environmental Protection Agency (EPA) to establish a research program on the effects of climate change on drinking water utilities, and authorizing $25 million annually for program funding for FY2010 through FY2020. The research program is required to address alternative water supply technology issues, including desalination, brine management, and environmental impacts of intakes for seawater desalination.

Examples of Planning, Construction, and Financing Legislation

P.L. 111-11, the Omnibus Public Land Management Act of 2009, includes provisions authorizing federal funding to be used for design, planning, and construction costs for facilities with desalination and brine disposal components—$20 million for the Rancho California Water District (CA)[3] and $46 million in the Santa Ana watershed (CA)[4]—as part of the Bureau of Reclamation's Title XVI water reuse program. The bill also authorizes the Secretary of the Interior to financially assist the California Water Institute to conduct a study coordinating and integrating subregional water management plans, including desalinated water supplies, for the San Joaquin and Tulare Lake regions.

H.R. 88, the City of Oxnard Water Recycling and Desalination Act of 2009, would authorize federal funding to be used for up to 25% of the design, planning, and construction costs ($15 million of a total $60 million) of the Groundwater Recovery Enhancement and Treatment (GREAT) project in Ventura County (CA). The bill would authorize the project as part of the Bureau of Reclamation's Title XVI water reuse program. The project combines wastewater recycling and reuse and groundwater management and desalination to provide regional water supply solutions to the Oxnard Plain.

S. 1731, Clean Renewable Water Supply Bond Act of 2009, would have facilities desalinating seawater, groundwater, or surface water among the types of projects eligible for accessing the federal bonds mechanism created by the bill.

In addition to the research provision previously described, S. 1733, Clean Energy Jobs and American Power Act, includes investigating, designing, or constructing desalination facilities among the eligible uses of grants provided to states as part of the bill's climate change adaptation provisions.

Desalination Adoption in the United States

Desalination is increasingly investigated as an option for meeting water demands, particularly for coastal communities that can desalinate seawater or estuarine water, interior communities above brackish aquifers, and communities with contaminated water supplies. Globally, seawater desalination represents 60% of the installed desalination capacity.[5] In the United States, however,

[3] The project is also the subject of H.R. 371, Rancho California Water District Recycled Water Reclamation Facility Act of 2009.

[4] These activities and additional regional conveyance infrastructure for the waste brine are also the subject of H.R. 530, Santa Ana River Water Supply Enhancement Act of 2009.

[5] Data in this paragraph is from H. Cooley et al., *Desalination, With a Grain of Salt: A California Perspective*, Pacific Institute (June 2006).

only 7% of the existing capacity uses seawater as its source. More than half of the water desalinated in the United States is brackish water. Another 25% is river water desalinated for use in industrial facilities, power plants, and some commercial uses.

Desalination's attractions are that it can create a new source of freshwater from otherwise unusable waters, and that this source may be more dependable than freshwater sources that rely on annual or multi-year precipitation, runoff, and recharge rates. Many states—most notably Florida, California, and Texas—and cities are actively researching and investigating the feasibility of large-scale desalination plants for municipal water supplies. Desalination and its different applications, however, come with their own sets of risks and concerns. The growing use of desalination in the United States and related concerns are discussed below.

Adoption Growing in States Searching for Municipal Water Supplies

The nation's installed desalination capacity has increased in recent years. As of 2005, approximately 2,000 desalination plants larger than 0.3 million gallons per day (MGD) were operating in the United States, with a total capacity of 1,600 MGD (less than 0.4% of total U.S. water use).[6] Florida, California, Texas, and Arizona have the greatest installed desalination capacity. Florida dominates the U.S. capacity, with the facility in Tampa being a prime example (see box); however, Texas and California are bringing plants online or are in advanced planning stages. Several other efforts also are preliminarily investigating desalination for particular communities, such as Albuquerque. Two-thirds of the U.S. desalination capacity is used for municipal water supply; industry uses about 18% of the total capacity.[7]

Tampa's Desalination Experience and Lessons

Tampa's planning of the first large-scale (25 MGD) desalination plant in the late 1990s ignited interest in large-scale desalination as a municipal water supply source elsewhere in the United States. The facility was thought of as a signal of desalination becoming a cost-effective supply option, However, the Tampa plant, a facility to desalinate heavily brackish estuarine water, encountered technical and economic problems (e.g., less freshwater produced than anticipated, fouling of reverse osmosis membranes, financing issues) during construction and start-up, driving up the cost of the freshwater produced. For some observers, a lesson from the Tampa plant experience is one of caution; before proceeding to full-scale implementation, large-scale desalination requires careful investigation. In the view of industry observers, the lessons to be learned from Tampa are that (1) good design suited to the local conditions and (2) a thorough pilot-study are critical for a desalination facility to function properly. For other observers, the Tampa project illustrates some of the risks of working with private water developers and lowest-bid contracts without sufficient external review and accountability mechanisms. Private developers, however, remain attractive for some communities because of their role in financing the capital cost of constructing a large-scale desalination facility.

Energy Intensity Creates Cost Uncertainties

The cost of desalination remains a barrier to adoption of the technology. Like nearly all new freshwater sources, desalinated water comes at substantially higher costs than today's existing sources. Much of the cost for seawater desalination is for the energy required to operate the plant; in particular, the competitiveness of reverse osmosis seawater desalination is highly dependent on the price of electricity, which has driven many of the facilities currently being planned to

[6] Ibid.

[7] Ibid.

investigate renewable energy supplies and co-location with power plants.[8] As energy becomes more expensive, less energy-intensive options (such as conservation, water purchases, and changes in water pricing) increase in competitiveness relative to desalination.

Reverse osmosis pushes water through a membrane to separate the freshwater from the salts; this requires a considerable energy input. Currently the typical energy intensity for seawater desalination with energy recovery devices is 3-7 kilowatt-hours of electricity per cubic meter of water (kWh/m^3).[9] The typical energy intensity of brackish desalination is less than seawater desalination, at 0.5-3 kWh/m^3. This range exists and is lower than seawater requirements because the energy required for desalination is proportional to the salinity of the source water.[10] Uncertainty in energy prices, therefore, creates significant uncertainty in the operating costs of desalination facilities, which decreases the technology's attractiveness as a water supply. Reducing the technology's energy requirements would decrease its cost uncertainties.

Substantial further cost savings are unlikely to be achieved through incremental advances in the commonly used technologies, like reverse osmosis. The National Research Council (NRC) in a 2008 report, *Desalination: A National Perspective*, recommended that federal desalination research funding be targeted at long-term, high-risk research not likely to be attempted by the private sector that could significantly reduce desalination costs.

Health and Environmental Concerns

From a regulatory, oversight, and monitoring standpoint, desalination as a significant source of water supply is new in the United States, which means the health and environmental regulations, guidelines, and policies regarding its use are still being developed. Existing laws and policies often do not address the unique issues raised by desalinated water as a drinking water supply. Similarly, the implications of integrating desalination into existing water distribution infrastructure have not been tested in a wide range of applications (e.g., corrosion of distribution facilities by desalinated water). This creates uncertainty for those considering investing millions in constructing a full-scale facility. Addressing these concerns will reduce potential risks and improve the information available for decision-making.

Evolving Drinking Water Guidelines

While the quality of desalinated water is typically very high, some health concerns remain regarding its use as a drinking water supply. For example, the source water used in desalination may introduce biological and chemical contaminants to drinking water supplies that are hazardous to human health, or desalination may remove minerals essential for human health. For example, a health concern about boron has been raised in relation to seawater desalination; this is an uncommon concern for traditional water sources. Boron is know to cause reproductive and developmental toxicity in animals and irritation of the digestive tract, and it accumulates in

[8] A major benefit of co-location is using the cooling water from the power plant for desalination; this water has been warmed up by the power plant which reduces the energy requirements for desalinating it. Also, the desalination facility may avoid construction costs for some intake and discharge facilities.

[9] National Research Council, *Desalination: A National Perspective*, 2008, pp. 74-75, and 77. Hereafter referred to as NRC *Desalination: A National Perspective*.

[10] NRC *Desalination: A National Perspective*, p. 77.

plants, which may be a concern for agricultural applications. There are concerns about boron in the freshwater produced from seawater desalination because the boron levels after basic reverse osmosis commonly exceed current World Health Organization health guidelines and the U.S. Environmental Protection Agency (EPA) health reference level. Boron can be removed through treatment optimization, but that treatment could increase the cost of desalted seawater. Boron is one of a number of potential health concerns requiring further attention and investigation as seawater desalination is used in large-scale application for water supply; for example, microorganisms unique to seawater and algal toxins may also pass through reverse osmosis membranes and enter the water supply.

EPA sets federal standards and treatment requirements for public water supplies, and controls disposal of wastes, including concentrate disposal which is discussed later.[11] In 2008, EPA determined that it would not develop a maximum contaminant level for boron because of its rare occurrence in most groundwater and surface water drinking water sources; EPA has encouraged affected states to issue guidance or regulations as appropriate.[12] Most states have not issued such guidance. Therefore, most U.S. utilities lack clear guidance on boron levels in drinking water suitable for protecting public health. The National Research Council recommended development of boron drinking water guidance to support desalination regulatory and operating decisions; it recommended that the guidance be based on an analysis of the human health effects of boron in drinking water and other sources of exposure.

Environmental Effects of Intake Structures and Concentrate Disposal

The environmental concerns that arise in relation to desalination facilities include the effect of intake structures and the disposal of waste concentrate, as well as the potential to open up new coastal areas to development. These concerns are often raised in the context of obtaining the permits required to site, construct, and operate the facility and dispose of the waste concentrate. According to the Pacific Institute's report *Desalination, With a Grain of Salt*, as many as 26 federal, state, and local agencies may be involved in the review or approval of a desalination plant in California. Some stakeholders view these permit requirements as a barrier to adoption of desalination.

The application of desalination in the United States is also challenged by the use of estuarine water in many of the facilities being contemplated. Estuarine water, which is a brackish mixture of seawater and surface water, has the advantage of lower salinity than seawater. Application of desalination to estuarine water is uncommon, with the facility in Tampa being the largest of its kind in the United States. The presence of surface water (which tends to be more contaminated than seawater) in estuarine water may complicate compliance of desalinated estuarine water with federal drinking water standards. For inland brackish desalination, significant constraints on adoption are the uncertainties and the cost of the waste concentrate disposal.

The National Research Council called for further research and development on mitigating environmental impacts of desalination and reducing potential risks relative to other water supply

[11] For more information on EPA's role in protecting drinking water, see CRS Report RL31243, *Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements*, by Mary Tiemann.

[12] EPA, *Regulatory Determinations for Priority Contaminant s on the Second Drinking Water Contaminant Candidate List*, available at http://www.epa.gov/OGWDW/ccl/reg_determine2.html.

alternatives.[13] It identified the following priority research areas to address environmental concerns:

- assess environmental impacts of desalination intake and concentrate management approaches, and synthesize results in a national assessment;
- improve intake methods at coastal facilities to minimize harm to organisms;
- develop cost-effective approaches for concentrate management that minimizes environmental impacts; and
- develop monitoring and assessment protocols for evaluating the potential ecological impacts of surface water concentrate discharge.

Federal Desalination Research

Desalination research represents less than 0.1% of the approximately $130 billion annual federal research and development investment. The optimal level of federal investment in desalination research is inherently a public policy question. Increasing federal funding for desalination research raises questions, such as what should be the respective roles of federal agencies, academic institutions, and the private sector in conducting research and commercializing the results, and should federal research be focused on basic research or promoting the use of technologies?

Most federally supported desalination spending is on research to improve existing technologies, fostering innovations in alternative technologies, and applications in the military. Much of the federal desalination research is managed by the Bureau of Reclamation through its Desalination and Water Purification Research & Development Program. Congress authorized the program in the Water Desalination Act of 1996 (P.L. 104-298) beginning in FY1997 for a six-year period; funding has been extended through FY2011.

The National Research Council recommended a level of funding consistent with the levels in FY2005 and FY2006, roughly $25 million, but recommended that the research be targeted strategically, including being directed at the research activities described above.[14] The level of funding fell after FY2006, when the appropriations process has included less congressionally directed spending. The NRC drew the following conclusion:

> There is no integrated and strategic direction to the federal desalination research and development efforts. Continuation of a federal program of research dominated by congressional earmarks and beset by competition between funding for research and funding for construction will not serve the

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[13] NRC *Desalination: A National Perspective*.

[14] According to the 2004 NRC report, *Confronting the Nation's Water Problems: The Role of Research*, "water supply augmentation and conservation" including desalination research by federal agencies totaled $14.5 million in FY2000. In the past the federal government invested more in this area; in the late 1960s, federal research in desalination and other saline water conversion activities exceeded $100 million (in 2000 dollars) annually. Research alone does not represent all federal spending on and support of desalination. The EPA also may support construction of municipal desalination facilities through loans provided to these facilities through the EPA's Drinking Water State Revolving Loan Funds.

> nation well and will require the expenditure of more funds than necessary to achieve specified goals.[15]

Although not directly addressing desalination research, H.R. 1145, the National Water Research and Development Initiative Act of 2009, would require greater coordination of federal water research and funding, which would include technologies such as desalination. Research cannot address all barriers to adoption of desalination. Efforts to overcome other constraints (e.g., public education and regulatory processes) also are often recommended as part of an overall strategy for reducing adoption barriers.

[15] NRC *Desalination: A National Perspective*, p. 228.

Appendix. Desalination Technologies

There are a number of methods for removing salts from seawater or brackish groundwater to provide water for municipal and agricultural purposes. The two most common processes, thermal (e.g., distillation) and membrane processes (e.g., reverse osmosis), are described below; their descriptions are followed by descriptions of some of the more innovative and alternative desalination technologies. The earliest commercial plants used thermal techniques. Improvements in membrane technology have reduced costs, and membrane technology is less energy-intense than thermal desalination (although it is more energy-intense than most other water supply options). Reverse osmosis and other membrane systems account for nearly 96% of the total U.S. desalination capacity and 100% of the municipal desalination capacity.

Distillation and Reverse Osmosis

In distillation, saline water is heated, separating out dissolved minerals, and the purified vapor is condensed. Reverse osmosis forces salty water through a semipermeable membrane that traps salt on one side and lets purified water through. Reverse osmosis plants have fewer problems with corrosion and usually have lower energy requirements than thermal processes. Distillation plants, however, require less maintenance and pretreatment before the desalination process.

Innovative and Alternative Desalination Processes

Forward Osmosis

Forward osmosis is a relatively new membrane-based separation process that uses an osmotic pressure difference between a concentrated "draw" solution and the saline source water; the osmotic pressure drives the water to be treated across a semipermeable membrane into the draw solution. The level of salt removal can be competitive with reverse osmosis. A main challenge is in the selection of a draw solute; the solute needs to either be desirable in the water supply, or be easily and economically removed. Research is being conducted on whether a combination of ammonia and carbon dioxide gases can be used as the draw solution. The attractiveness of forward osmosis is that its energy costs can be significantly less than for reverse osmosis when combined with industrial or power production processes.[16]

Electrodialysis[17]

Electrodialysis depends on the ability of electrically charged ions in saline water to migrate to positive or negative poles in an electrolytic cell. Two different types of ion-selective membranes are used—one that allows passage of positive ions and one that allows negative ions to pass between the electrodes of the cell. When an electric current is applied to drive the ions, fresh water is left between the membranes. The amount of electricity required for electrodialysis, and

[16] R. L. McGinnis, and M. Elimelech. "Energy requirements of ammonia carbon dioxide forward osmosis desalination," *Desalination* (2007) 207, pp. 370-382.

[17] The description of the remaining technologies was written by Peter Folger, Specialist in Energy and Natural Resources Policy.

therefore its cost, increase with increasing salinity of feed water. Thus, electrodialysis is less economically competitive for desalting seawater compared to less saline, brackish water.

Ion Exchange

In ion exchange, resins substitute hydrogen and hydroxide ions for salt ions. For example, cation exchange resins are commonly used in home water softeners to remove calcium and magnesium from "hard" water. A number of municipalities use ion exchange for water softening, and industries requiring extremely pure water commonly use ion exchange resins as a final treatment following reverse osmosis or electrodialysis. The primary cost associated with ion exchange is in regenerating or replacing the resins. The higher the concentration of dissolved salts in the water, the more often the resins need to be renewed. In general, ion exchange is rarely used for salt removal on a large scale.

Freezing Processes

Freezing processes involve three basic steps: (1) partial freezing of the feed water in which ice crystals of fresh water form an ice-brine slurry; (2) separating the ice crystals from the brine; and (3) melting the ice. Freezing has some inherent advantages over distillation in that less energy is required and there is a minimum of corrosion and scale formation problems because of the low temperatures involved. Freezing processes have the potential to concentrate waste streams to higher concentration than other processes, and the energy requirements are comparable to reverse osmosis. While the feasibility of freeze desalination has been demonstrated, further research and development remains before the technology will be widely available.

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