Study on the Demand Response Potential for Seawater Desalination Projects

Executive Summary

In 2015, the 84th Texas Legislature enacted House Bill (HB) 4097, which included several provisions relating to seawater desalination projects, including a requirement that the Public Utility Commission of Texas (PUC) and Electric Reliability Council of Texas (ERCOT) study the potential for seawater desalination projects to participate in existing demand response opportunities in ERCOT. There are several demand response products in which demand-side resources (i.e., consumers of electricity) can participate. These programs help to preserve system reliability, and provide economic benefits to participating demand-side resources. Seawater desalination is an energy-intensive process that removes salt and other minerals from salt water to produce fresh water for municipal consumption, industrial use or irrigation. Participation in demand response could help mitigate electricity costs for future seawater desalination projects in Texas and provide reliability benefits to the grid.

There are two main demand response reliability-based services administered by ERCOT: participation by demand-side resources in the Ancillary Services market and the Emergency Response Service (ERS). Within the Ancillary Services market, the most common service provided by demand-side resources is Responsive Reserve Service (RRS), which requires resources to respond either instantaneously or within 10 minutes in response to unplanned system emergencies. ERS is separate from ERCOT's Ancillary Services market, and allows demand-side resources and distributed generation to provide reliability services in the event of an energy emergency. Resources can qualify for either the 10-minute or 30-minute response time ERS programs.

There are several key considerations that will impact a demand-side resource's ability to participate in different demand response opportunities: response time, recovery time, predictability of electrical demand, and flexibility of operations. Considering these factors together, it appears that seawater desalination plants could be designed to meet the requirements for participation in demand response. Because the ability to meet the qualification requirements is dependent on the plant design, demand response opportunities should be considered early in a project's development if participation is desirable.

Whether project developers will choose to address these requirements will depend on the economic benefits of participation. There may be additional costs to design seawater desalination plants to operate in the manner required in order to participate in demand response. These include costs associated with additional plant design specifications, need for excess capacity and storage to make up for lost production during demand response deployment, operational costs resulting from interruptions to plant processes, and potential financial penalties if demand response deployment results in failure to meet contract demands. The interplay of the benefits of participation and these costs will determine whether it would be beneficial for a future seawater desalination plant to participate in demand response in ERCOT.

To date, participation of seawater desalination plants in demand response programs has been limited. Because the process of seawater desalination is energy-intensive, participation in demand response could help to reduce electricity costs while posing a relatively low risk to plant operations. As stakeholders in Texas continue to plan for possible future droughts in the region and identify water management strategies, consideration of demand response could play a role in mitigating some costs associated with seawater desalination, and allow seawater desalination plants to assist with maintaining electric reliability in the region.

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1. Introduction

In 2015, the 84th Texas Legislature enacted House Bill (HB) 4097, which included several provisions relating to seawater desalination projects, including a requirement that the Public Utility Commission of Texas (PUC) and Electric Reliability Council of Texas (ERCOT) study the potential for seawater desalination projects to participate in existing demand response opportunities in ERCOT. ERCOT and the PUC initiated this study to fulfill that requirement, and evaluated the operational and economic characteristics of seawater desalination plants in light of ERCOT's primary demand response products.[1]

ERCOT is the independent system operator (ISO) for the ERCOT Interconnection, which encompasses approximately 90% of demand for electricity in Texas. ERCOT is the independent organization established by the Texas Legislature to be responsible for the reliable planning and operation of the electric grid for the ERCOT Interconnection. ERCOT also administers and maintains a forward-looking open market to provide affordable and reliable electricity to consumers in Texas. In collaboration with market participants, ERCOT has developed demand response products and services for customers that have the ability to reduce or modify electricity use in response to instructions or signals. These programs help preserve system reliability, and provide economic benefits to participating demand-side resources.

The process of seawater desalination removes salt and other minerals from salt water to produce fresh water for consumption, industrial processes, or irrigation. The drought-prone Texas climate, coupled with projections for increasing water demand in the state, has created interest in seawater desalination as a future water source. The 2017 Texas State Water Plan includes seawater desalination as a future water management strategy for water users in the state. However, the seawater desalination process is energy intensive, and electricity consumption can be a significant cost driver for these projects. To the extent that these plants could participate in demand response, it would help to defray these costs. Thus, there is a potential nexus between seawater desalination projects built in Texas to mitigate drought, but which have large electricity requirements, and ERCOT demand response opportunities, which could help to reduce their electricity costs and provide reliability benefits.

This study evaluates the demand response potential of seawater desalination plants based on their operational characteristics and economic drivers. The report is organized as follows:

- **Section 2** provides background on typical seawater desalination plant operations and economics;
- **Section 3** describes the current demand response opportunities in ERCOT;
- **Section 4** evaluates the characteristics of seawater desalination plants to determine their potential to participate in demand response opportunities in ERCOT; and,
- **Section 5** provides a summary of the conclusions of this study.

[1] In the course of developing this report, ERCOT consulted with several desalination experts with experience with existing or planned seawater desalination plants in the U.S. The technical experts consulted included Jorge Arroyo (Water Management Consultant), Andrew Chastain-Howley (Black & Veatch), Jonathan Loveland (Black & Veatch), Ron Parker (Black & Veatch), John Wolfhope (Freese and Nichols), and Srinivas Veerapaneni (Black & Veatch).

2. Seawater Desalination

There are two primary methods for seawater desalination: distillation (also referred to as "thermal") and reverse osmosis. Distillation uses heat to remove salts and minerals from seawater by boiling water at high pressures. In contrast, reverse osmosis technology forces saline water through a membrane to separate water from the salts and minerals. While both distillation and reverse osmosis are energy intensive, distillation requires thermal energy to heat the water and overall has a higher energy requirement, whereas reverse osmosis requires primarily electrical energy and overall is less energy intensive – though still with significant electricity requirements.

Globally most thermal desalination plants are located in the Middle East due to low energy prices in the region. Plants located elsewhere, including in the U.S., typically use reverse osmosis technology.[2] There are two large existing seawater desalination plants in the U.S.: one in Carlsbad, California, providing water to the San Diego area, and one in Gibsonton, Florida, providing water to the Tampa Bay area. Both plants use reverse osmosis technology. In addition, there are several desalination projects currently in the planning stages or under development in Texas in the Corpus Christi area that would use reverse osmosis technology. For that reason, this report focuses on reverse osmosis technology in the evaluation of demand response potential of seawater desalination plants.

While there are currently no existing seawater desalination plants in Texas, there are several municipal and industrial brackish water desalination plants in the state. According to the Texas Water Development Board (TWDB), there are 46 municipal brackish water desalination plants with capacities greater than 0.025 million gallons per day (MGD) in Texas, representing a total of 123 MGD of capacity.[3] The desalination of brackish water is typically less expensive compared to seawater, due to the lower relative salinity of brackish water. This study focuses exclusively on seawater desalination, consistent with the requirements of HB 4097, but it should be noted that conclusions may also apply to brackish water desalination, though at a different cost and scale.

This section provides high-level information on the operations (Section 2.1) and economics (Section 2.2) of seawater desalination plants, to inform the discussion of their demand response potential in Section 4.

2.1. Seawater Desalination Plant Operations

Seawater desalination plants typically range in capacity from less than 5 MGD up to 165 MGD. For example, the Carlsbad seawater desalination plant has a capacity of approximately 50 MGD, and the plant in Tampa Bay has a capacity of approximately 25 MGD. The associated electricity consumption ranges between 10 and 15 kWh/1,000 gallons produced, depending on the salinity of the water being processed.[4,5,6] More saline water (e.g., seawater) requires larger amounts of electricity for desalination. Thus, a seawater desalination plant would have larger electricity consumption requirements compared to a similarly sized brackish water desalination plant.

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[2] American Water. "Innovation Solutions within the Water Industry: Desalination." Available at http://www.amwater.com/files/InnovationsSolutionsWithinTheWaterIndustryDesalination.pdf.

[3] Texas Water Development Board. "Desalination Facts." Available at https://www.twdb.texas.gov/innovativewater/desal/facts.asp

[4] American Membrane Technology Association. April 2016. "Membrane Desalination Power Usage Put in Perspective." Available at http://www.amtaorg.com/wp-content/uploads/7_MembraneDesalinationPowerUsagePutInPerspective.pdf.

[5] Water Reuse Association. November 2011. "Seawater Desalination Power Consumption." Available at https://watereuse.org/wp-content/uploads/2015/10/Power_consumption_white_paper.pdf.

[6] Ghaffour, N., T.M. Missimer, and G. Amy. January 2013. "Technical review and evaluation of the economics of water desalination: Current and future challenges for better water supply sustainability." *Desalination* 309, pp197-207. Available at https://www.researchgate.net/publication/256693140_Technical_review_and_evaluation_of_the_economics_of_water_desalination_Current_and_future_challenges_for_better_water_supply_sustainability.

While the two existing seawater desalination plants in the U.S. were co-located with power plants to ease compliance with regulations on water intake and discharge structures and reduce costs, many other reverse osmosis desalination plants receive their electricity from the grid. However, plants may have on-site backup generation in case of a power outage. This will vary depending on the size and design of the plant and other factors. For example, the Carlsbad plant in California does have diesel backup generation to power control systems and flushing systems in the case of a power outage. The plant in Tampa Bay was not built with backup power due to potential storm surge risks from hurricanes and other storms. The plant does use uninterruptible power supply (UPS) backup to power control systems during power outages.

Reverse osmosis plants are typically designed with several "trains", which consists of a high-pressure pump, turbine, and reverse osmosis membrane. Desalination plants are turned on or off one train at a time in a highly controlled process. The process of ramping up or down an individual train under normal operations typically takes one to two hours. While plants can be designed to handle immediate shutdowns (i.e., in a power outage), re-starting a system after an interruption would take this amount of time. In addition, the saline water must be pretreated (i.e., filtered) before going through the reverse osmosis train, and this can sometimes pose constraints on the flexibility of operations.

Demand for water is the key factor driving the level of production at seawater desalination plants. Typically, the plant will have a contract or contracts with municipal or other water users to deliver desalinated water, and is operated to meet that demand. Alternatively, if the plant is municipally owned, it would similarly be operated to meet the level of water demand, in conjunction with other available water sources. If water demands are close to a plant's full capacity, the operator's flexibility to adjust its electricity consumption as part of demand response may be limited. However, this does mean that plant operations are fairly predictable on a day-to-day basis, which is necessary for participation in demand response.

The amount of flexibility in plant operations will also be impacted by the amount of water storage available. For example, if a plant has sufficient water storage on-site, or storage within the customer's distribution system, it could provide flexibility for the plant to reduce its operations during peak hours when electricity prices are likely to be highest. It would also mitigate the impacts of interruptions to production from demand response deployments.

2.2. Seawater Desalination Plant Economics

Seawater desalination is typically more expensive than other sources of water, and a major driver of the overall cost is energy costs. In 2016, the Carlsbad plant charged rates at between $2,131 and $2,367 per acre-foot.[7,8] This charge is intended to cover both the fixed costs of the plant and the variable costs to produce a unit volume of water. Typically, half to two thirds of the cost of providing desalinated seawater are accounted for by capital cost recovery, with the remainder accounted for by operations and maintenance costs, including electricity costs. Electricity costs can account for 20-25% of the total costs of seawater desalination with reverse osmosis technology.[9]

Factors affecting the capital cost of a seawater desalination plant include plant size, type of desalination process and pre-/post-treatment technologies, plant infrastructure (e.g., piping, water storage, backup power), and compliance with applicable regulations (e.g., regulations on intake structures, brine byproduct disposal). A significant driver of operating and maintenance costs is membrane replacement. Reverse osmosis membranes need to be replaced every few years, and

[7] Source: San Diego County Water Authority. "Seawater Desalination." Available at http://www.sdcwa.org/seawater-desalination.
[8] Note that 1 acre-foot is approximately 325,851 gallons.
[9] Based on technical input from Black & Veatch.

the rate at which they are replaced will depend on the salinity of the feedwater and how the plant is operated. Treatment and disposal of the salty brine byproduct from desalination may also incur operating costs.

Electricity costs will vary depending on a range of factors, including the size of the plant, type of desalination technology, source of electricity, and quality of the feedwater. As previously noted, more saline water requires higher amounts of electricity in desalination, and thus the amount of electricity consumption is a key difference between brackish water and seawater desalination. As a result, electricity costs comprise a significant share of the costs of seawater desalination. These costs could potentially be defrayed in part by participation in demand response initiatives.

3. Demand Response Opportunities in ERCOT

Broadly speaking, demand response can be broken down into two major categories: dispatchable or non-dispatchable. For purposes of this report, we will define dispatchable as those demand response events that are initiated by ERCOT and non-dispatchable as an event not specifically initiated by ERCOT. These non-dispatchable events may include decisions made by the end-use customer to alter its consumption pattern or may include contractual obligations with another entity, such as the end-use customer's retail electric provider ("REP"), to alter consumption patterns.

ERCOT's wholesale market is open to several types of dispatchable demand response, which are deployed to maintain system reliability. Demand-side resources providing Emergency Response Service (ERS) may offer based on either a 10 or 30-minute response time, commonly referred to as the "ramp period." Alternatively, demand-side resources may register and qualify as a Load Resource that can provide Reserves in the Ancillary Services market. The most common service provided by demand-side resources is Responsive Reserve Service which requires an under-frequency relay that can instantaneously interrupt the load during certain system reliability events. Some demand-side resources can also participate in other Ancillary Services as Controllable Load Resources that require sophisticated control systems that allow them to be deployed in a more incremental, proportional manner.

Non-dispatchable demand response in ERCOT can include a response to avoid transmission costs, where rates are based on Four Coincident Peak Pricing (4CP), response to wholesale energy prices initiated by the customer or by a REP or other load-serving entity ("LSE"), or utility-managed Load Management programs (LM).

The sections that follow provide a description of both ERCOT-dispatched (Section 3.1) and non-ERCOT-dispatched (Section 3.2) demand response. For a more detailed description of opportunities for demand-side resources to participate in demand response in ERCOT, see ERCOT's guide, *Load Participation in the ERCOT Nodal Market.*[10]

3.1. ERCOT-Dispatched Demand Response

There are two main demand response reliability-based services administered by ERCOT: participation by demand-side resources in the Ancillary Services market and participation in ERS. These services are dispatched by ERCOT during system emergencies.

[10] Available at http://www.ercot.com/content/services/programs/load/Load%20Participation%20in%20the%20ERCOT%20Nodal%20Market_3.02.doc.

3.1.1. Ancillary Services Markets

Demand-side resources with demand response capability that can meet a set of performance requirements can be qualified to provide Ancillary Services as Load Resources in the Ancillary Services Market. The value of having a Load Resource available to reduce load is equal to the value of having a generator available to increase its generation at a generating plant. The providers of operating reserves selected to provide Ancillary Services are eligible for capacity payments regardless of whether the Resource is actually deployed (or curtailed, in the case of the Load Resource).

ERCOT holds auctions on a daily basis for each of the following Ancillary Services: Regulation Up, Regulation Down, Responsive Reserve, and Non-Spinning Reserve.[11] Table 1 describes the various Load Resource types and their qualification requirements and eligible services.

Table 1: Load Resource Types and Ancillary Services

Service	Load Resource Type [a]	Qualification
Responsive Reserves (≤50% of total Reserve requirement)	Non Controllable	Under-Frequency Relay and 10-minute ramp to manual dispatch instruction
Responsive Reserves	Controllable	Primary Frequency Response and follow 5-minute dispatch instructions
Regulation-Up Regulation-Down	Controllable	Primary Frequency Response and respond to Regulation deployments
Non-Spin Reserves	Controllable	Follow 5-minute dispatch instructions

[a] A Controllable Load Resource is a Load Resource capable of controllably reducing or increasing consumption under dispatch control by ERCOT.

Demand-side resources that agree to reduce load when directed by ERCOT, and that meet other metering and operational requirements as specified in the ERCOT Protocols, may participate in Ancillary Services market auctions. As noted in Table 1, the type of Ancillary Service that a Load Resource may provide will depend upon the demand-side resource's response time and metering system, as well as other requirements described in the Protocols. In the Responsive Reserve and Non-Spin Reserve markets, the Load Resource will receive capacity payments regardless of whether or not the load was actually deployed, but the load must be available for deployment at any time while providing the service.

3.1.2. Emergency Response Service (ERS)

ERCOT procures ERS to maintain grid reliability during emergency conditions and reduce the likelihood of the need for rotating outages. ERS participants may offer to provide demand response with either a 10-minute ramp period requirement (similar to Load Resources providing Responsive Reserve Service) or a 30-minute ramp period requirement. ERS Resources do not have the same telemetry and under-frequency relay requirements as Load Resources.

[11] Regulation Up and Regulation Down service respond to signals from ERCOT every 4 seconds to respond to changes in system frequency, full response has to be provided within 5 minutes. Responsive reserves must provide their committed capacity either instantaneously in an under-frequency event (e.g. due to a generator outage) or in energy scarcity conditions within ten minutes following an instruction from ERCOT. Non-spinning reserves must provide their committed capacity within 30 minutes based on economic dispatch instructions. Non-spinning reserve is used as replacement reserve to replenish other ancillary services and during energy scarcity.

ERS is procured through a request for proposal (RFP) process three times per year, for four-month contract terms, each of which is further split into smaller time periods based on business cycles and other factors. Demand-side resources may choose to submit offers in all time periods or only in those that best fit their unique circumstances, and may vary both the price and demand response capacity offers by time period.

Payments for ERS are performed up to 80 days after each four month contract term has ended and are subject to downward revision based upon delivered demand response capacity, and the demand-side resource's availability during the contract term.

3.2. Non-ERCOT-Dispatched Demand Response

The options listed below are not dispatched by ERCOT but they either are controlled directly by a customer or are dispatchable by another entity such as a demand response provider ("DR Provider"), REP, or a transmission and distribution utility.

3.2.1. Four Coincident Peak (4CP)

Many industrial customers are subject to transmission charges based upon a Four Coincident Peak (4CP) demand. The 4CP demand is determined by averaging the consumer's actual demand during the 15-minute settlement interval with the highest ERCOT demand during each of the four summer months (June through September). This measured 4CP demand serves as the basis for the customer's transmission tariff charges for the following year. By correctly predicting the ERCOT system peaks during the summer and curtailing load during those intervals, a consumer can help reduce the stress imposed on the electric system during peak periods of consumption and reduce its transmission charges for the following calendar year.

3.2.2. LSE or DR Provider Contracted Price Response

In the competitive areas of ERCOT, consumers can contract with their REP or a DR Provider to have their load respond to the REP's or DR Provider's instructions. The contract will usually outline the parameters of this response – at what times and frequency demand response events can be called, ramp periods, sustained response periods, compensation, etc. Because this response is a contractual matter between the REP or DR Provider and the consumer, a great deal of variety can be present in these arrangements. For example, a consumer's response may be voluntary or required; compensation could come in the form of reduced energy prices or rebate payments for each curtailment event; consumers might be notified up to a day in advance, or could have no notification at all (for automated curtailment).

In areas of ERCOT not open to competition, interruptible tariffs may be available. These tariffs will usually offer a reduced energy price for defined curtailment obligations.

3.2.3. Self-Directed Price Response

REPs may offer dynamic pricing options, or consumers within a municipality or cooperative may have their energy prices determined by a published tariff, which also may be structured based upon Time-of-Use (TOU) or have a Critical Peak Pricing (CPP) or Peak Time Rebate (PTR) component. Self-directed price response refers to consumers making an independent decision to respond to energy prices contained in a governing tariff or in either the ERCOT Day Ahead or Real Time energy markets.

TOU offerings will typically have higher energy prices during normal peak periods – for example, a TOU tariff may charge one price during Monday through Friday from 2 p.m. through 8 p.m. and another price during all other times. Customers may choose to reduce consumption during these high priced periods. Load reduction can be accomplished by load shifting (loads can be shifted by rescheduling certain processes or by utilizing thermal storage), ending certain processes that are no longer economic, or through energy efficiency measures.

Offerings that incorporate CPP usually have prescribed high prices only during certain defined periods – for example, when load or prices are expected to reach a certain level. Response to CPP may be similar to those employed under TOU tariffs, especially if CPP is reached frequently. More often, CPP is infrequent and as such, short-term load curtailment may be the more appropriate response to meet economic objectives.

4. Demand Response Potential for Seawater Desalination

This section evaluates whether the operational characteristics and economics of seawater desalination plants would enable them to participate in one or more of the various demand response opportunities in the ERCOT Region. To date, participation of seawater desalination plants in demand response programs has been limited. Neither the plant in Carlsbad nor the plant in Tampa Bay participate in demand response programs in California or Florida, respectively. However, as will be described below, it appears that these plants can be designed and operated to meet the requirements for participation in demand response and receive economic benefit from participation in these programs.

Section 4.1 describes the operational parameters that must be met for a demand-side resource to provide ERCOT-dispatched demand response and evaluates the ability of seawater desalination plants to meet these criteria. Section 4.2 discusses the tradeoffs between payments for participation in ERCOT-dispatched demand response and potential additional costs posed to seawater desalination plants. Finally, Section 4.3 presents other opportunities for seawater desalination plants to reduce their electricity costs outside of ERCOT's reliability-based services that are open to demand response assets.

4.1. Operational Considerations for ERCOT-Dispatched Demand Response

There are several key operational parameters that impact a demand-side resource's ability to participate in different demand response services: response time, recovery time, predictability of electrical demand, and flexibility of operations. This section discusses each of these considerations as they apply to seawater desalination plants.

As discussed in Section 3.1, one of the differentiating factors between ERCOT's demand response products is the amount of time within which a demand-side resource must respond to a deployment instruction to reduce electricity consumption during an event. Participation in RRS requires an automatic response within either half a second (i.e., instantaneous) based on grid frequency, or within 10 minutes via a manual instruction. ERS requires a response time of either 10 or 30 minutes. As noted in Section 2.1, the typical time to take a reverse osmosis train on- or off-line is 1-2 hours under normal, controlled, operations. To comply with the response time requirements of RRS or ERS, a seawater desalination plant would need to be able to reduce its electricity consumption far more quickly than in normal operations. This is an element of plant design that would need to be accounted for in the specifications of the project. Considerations include the potential need for on-site backup generation including uninterruptible power supply, potential impacts to plant infrastructure (e.g., piping), reverse osmosis membranes, and pretreatment systems.

The two large U.S. desalination plants provide illustrative counterpoints in this respect. The Carlsbad plant was designed to withstand instantaneous power interruptions, and has on-site backup generation, including uninterruptible power supply to provide the ability to power control systems and flush the membranes in the event of a power loss. In contrast, the Tampa Bay plant was not designed with on-site backup generation, and a loss of power would result in a plant shutdown and may require several days to bring the plant back on-line. Thus, it appears that it is technically possible for a seawater desalination plant to meet the response time requirements for participation in demand response, so long as this factor is considered in the design of the facility.

The time it takes a desalination train to return to operations after an event is also a consideration. Demand-side resources participating in RRS must be able to come back on-line within three hours, and those participating in ERS must return within 10 hours. Again, it appears that it is technically feasible for desalination plants to meet this requirement, so long as this requirement is considered in the plant design.

An additional consideration is the predictability of a demand-side resource's electricity consumption. Participation in the responsive reserves ancillary service market requires bidding in the day-ahead market, and thus a demand-side resource must know with great accuracy (within 95%) its electrical demand at least a day ahead of time. For ERS, auctions are held three times a year for four-month contract periods. Thus, to participate in ERS, a resource must know its forecasted electrical demand several months in advance. Because seawater desalination plant operations are driven by contracted demand for water, it is likely that a plant operator would have a good idea of the plant's electrical demand days or even weeks/months in advance, especially for summer months when demand is likely to be relatively steady. An important consideration, however, is the salinity of the water, which drives the electrical requirements, and which can be impacted by recent weather events. Similarly, reductions in demand for water during non-summer months, or wet summer days where demand may be reduced, could also impact a plant's ability to predict its electricity demand.

Finally, a seawater desalination plant must have sufficient flexibility in its day-to-day operations so that it can afford to lose several hours of production when deployed for demand response. It should be noted that demand-side resources participating in RRS and ERS are called infrequently: demand-side resources providing responsive reserves were deployed one time in 2015, and ERS was not deployed that year. However, this is an important factor to consider if a plant is operating at close to full capacity and would incur financial penalties if it fails to meet its contract obligations due to a demand response event. Including additional storage and building a plant with extra capacity could help to mitigate this risk. It should also be noted that a plant operator does not need to commit the full plant capacity to these services, but rather can specify an amount of MW that will be committed. Thus, a plant operator could mitigate issues both with predictability and flexibility of plant operations by committing only a portion of its predicted electrical demand to participate in demand response.

Considering these factors together, it appears that seawater desalination plants could be designed to meet the operational requirements for participation in ERCOT's demand response services (both RRS and ERS). Because the ability to meet the requirements is dependent on the plant design, demand response would need to be considered early in a project's development if participation is desirable. Whether project developers will choose to address these requirements will depend on the economic benefits of participation in demand response, which will be discussed in the next section.

4.2. Economic Considerations for ERCOT-Dispatched Demand Response

This section describes the economic benefits to demand-side resources from participation in ERCOT-dispatched demand response programs. The average price paid for a demand-side resource participating in RRS in 2015 was $10.87 per MW per hour, and for ERS was $6.45 per MW per hour for the contract periods during the 2015 program year. These payments could provide a significant financial benefit to seawater desalination plants. To give a simplified example, for a plant with an electrical demand of 10 MW operating at a 100% annual load factor (10 MW × 24 hours × 365 days), the annual benefit would be on the order of $500,000 for ERS or $1 million for RRS.

In 2015, demand-side resources providing responsive reserves were deployed one time for a duration of 10 minutes, and ERS was not deployed.[12] The most ERS was ever deployed in a single year was two times in 2011. Thus, participation in either program could result in a substantial payment to a seawater desalination plant with a relatively low risk of deployment and associated disruption of plant operations, although it is important to note that participation in either ERCOT service subjects demand response resources to annual unannounced testing. Other than testing, the frequency of deployment will depend on grid conditions and is a risk that should be considered.

The financial benefits of participation must be weighed against the costs of designing facilities with the capabilities to operate in this manner. These include:

- The costs to design the plant to reduce electrical demand within the required timeframes for demand response and to withstand an instantaneous interruption, if not already part of the plant design. For example, a plant may need to be designed to have backup power generation on-site. In addition, there could also be costs to restart the system after an interruption.
- The costs to build a plant with excess capacity and/or storage to make up for lost production hours when demand response is deployed. This will add to the total capital costs of the project. Land area constraints should also be considered when considering additional storage, as the space requirements for the necessary storage capacity could be significant.
- Costs associated with the impact of interruptions on plant processes (e.g., more frequent replacement of membranes, impacts to pretreatment system or plant infrastructure).
- Potential financial penalties that would be incurred if deployment as part of demand response were to result in failure to meet contract obligations to supply water.
- The loss of potential benefits in the form of cost avoidance from participation in non-ERCOT-dispatched demand response opportunities (see Section 4.3). If a plant is committed to RRS or ERS, the plant operator would lose the flexibility to take advantage of these other opportunities to reduce their electricity costs.

The interplay of these benefits and costs will determine whether it would be beneficial for a future seawater desalination plant to participate in demand response in ERCOT.

4.3. Considerations for Non-ERCOT-Dispatched Demand Response

Outside of the reliability-based services administered by ERCOT, there are other opportunities for seawater desalination plants to reduce their electricity costs. As described in Section 3.2.1, seawater desalination plants may be able to reduce the demand charges on their electricity bills through curtailing load during 4CP intervals. In addition, plant operators may adjust operations in response to real-time electricity prices to take advantage of lower off-peak prices and avoid price spikes (see Sections 3.2.2 and 3.2.3). All of these opportunities require that the plant have flexibility to reduce production during certain times of the day.

In the ERCOT region, as noted above, a portion of transmission and distribution charges are set based on the peak systemwide 15-minute interval of the four summer months (June through September), referred to as the four coincident peaks (4CP). Large customers can reduce or avoid this charge by reducing electrical consumption during these four peak intervals. AEP Central Texas and CenterPoint are the transmission providers covering the majority of the Gulf Coast in Texas.[13]

[12] ERCOT. June 2016. "Load Resource Deployment Update." Available at http://www.ercot.com/content/wcm/key_documents_lists/87098/5._RRS_Load_Resource_Deployment_Update.pdf.
[13] It is also possible that a seawater desalination plant could be located in an area that as not opted in to competition, in which case the plant owner would need to negotiate its electricity charges bilaterally with the Non Opt-In Entity (NOIE).

Assuming a future seawater desalination plant would be connected at transmission-level voltages, the relevant 4CP charges based on the 2016 tariffs, accounting for both transmission charges and transmission cost recovery factors, would be $4.1425 per 4CP kW for AEP Central Texas and $4.1870 per 4CP kVA for CenterPoint.[14] If a seawater desalination plant has 10 MW of load and is capable of interrupting all of it, and successfully does so for all four 4CP intervals, the savings based on the 2016 tariffs would be approximately $500,000 per year ($4.1425 × 1,000 (kW to MW) × 10 MW × 12 months). Thus, a seawater desalination plant that reduces its electricity use during the 4CP intervals could avert some or all of these charges.

Another opportunity for seawater desalination plants to reduce their electricity costs is through adjusting operations in response to real-time electricity prices. In 2015, the average electricity price in ERCOT was $26.77/MWh. However, prices exceeded $50/MWh in 254 hours (3% of all hours), $100/MWh in 88 hours (1%), $200/MWh in 40 hours (0.5%), and $300/MWh in 21 hours (0.2%). Prices exceeded $3,000/MWh for 0.21 hours.[15] Depending on the desalination plant's exposure to real-time wholesale market prices (via its retail contract), the degree of high prices the plant owner is willing to avoid, and grid conditions in a given year, reducing unit operations in order to avoid high electricity prices could impact operators for anywhere between a few and several hundred hours out of the year. In addition, a plant can plan its operations to take advantage of lower electricity prices during off-peak periods (e.g., at night when generation from wind is high). For example, at least one company is marketing a modular desalination unit design intended to take advantage of low prices during periods of high renewables generation and to provide grid reliability services through demand response.[16]

There are several factors to consider regarding these opportunities to reduce electricity costs. The plant would need to monitor the ERCOT market, or hire a contractor to do so, in order to know when to reduce demand for electricity. These programs do not impose any requirements on response time as with RRS or ERS, and there may be sufficient warning of 4CP intervals or peak pricing to allow the plant operator to plan its operations earlier in the day with sufficient time to ramp down production under controlled conditions. However, quicker ramping capability may be desirable to respond to electricity price fluctuations.

For 4CP, because the four intervals used to set demand charges are not known ahead of time, it is likely that the plant would need to reduce its demand multiple times per summer to ensure the 4CP intervals are hit, impacting production at the facility. Timing operations to coincide with off-peak pricing or to avoid price spikes would similarly result in reduced operations during certain hours. To offset the lost production hours, the plant may need to be designed with extra capacity and water storage capability to maintain the ability to meet its contractual obligations for freshwater delivery. Because the period of reduced operations is greater than with ERCOT-dispatched demand response services, this need would be greater for a seawater desalination plant reducing load during 4CP intervals or in response to real-time electricity prices, and would increase the capital costs of the project. It should also be noted that high prices in the ERCOT Region typically, but not always, occur in summer months, when drought conditions are more likely to develop and demand for desalinated water is likely to be highest. This may limit the flexibility of the plant to time its electricity consumption to avoid high-priced hours.

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[14] Public Utility Commission of Texas. "Transmission and Distribution Rates for Investor Owned Utilities." Available at http://www.puc.texas.gov/industry/electric/rates/tdr.aspx.

[15] Potomac Economics. June 2016. *2015 State of the Market Report for the ERCOT Wholesale Electricity Markets*. Available at https://www.potomaceconomics.com/index.php/markets_monitored/ERCOT.

[16] Sisyan LLC. "Demand Response Desalination." Available at http://renewabledesalination.com/wp-content/uploads/2015/06/Demand-Response-Desalination.pdf.

In addition, the plant's ability to participate in demand response would also be limited for those hours it is reducing load as part of 4CP response or in response to real-time prices, because the plant would not be able to reduce its electricity consumption if that demand is already committed to another demand response service. Thus, participating in demand response versus taking advantage of these other opportunities may be, to some extent, mutually exclusive.

5. Conclusion

Based on this analysis, it appears that the operational characteristics of seawater desalination plants would allow them to participate in demand response opportunities in ERCOT, so long as the necessary operational requirements are considered in the design specifications of the plant. Project developers should consider the necessary requirements early in the plant design. Whether the economic benefits of participation would provide a sufficient incentive for them to do so will depend on the costs of accommodating those operational requirements, and whether there is the flexibility available to operate the plant as necessary under these programs. Though most existing seawater desalination plants do not participate in demand response programs, it does appear that participation by these plants is possible and could result in a financial benefit. Table 2 compares the different demand response opportunities available to demand-side resources in ERCOT.

Table 2: Comparison of Demand Response Opportunities

Demand Response Opportunity	Requirements for Participation	Impacts to Plant Operations	Financial Benefit
Ancillary Services – Responsive Reserve Service (RRS)	• Under-Frequency Relay • Instantaneous or 10 minute response time • Recover load within 3 hours • Bid in day-ahead market	• Deployed once in 2015 for 10 minutes • Subject to annual unannounced testing	• $10.87 per MW per hour (based on 2015 prices)
Emergency Response Service (ERS)	• 10 or 30 minute response time • Recover load within 10 hours • Four-month contract term	• Not deployed in 2015; the most times ever deployed in a single year was twice in 2011 • Subject to annual unannounced testing	• $6.45 per MW per hour (based on 2015 prices)
Four Coincident Peak (4CP)	• Interval Data Recorder (IDR) meter • Ability to predict system-wide peak demand hours during summer months	• Likely plant will need to reduce load multiple times per summer to hit 4CP intervals • Likely to be able to predict possible 4CP intervals earlier in day	• Avoid ~$48,000 per 4CP MW per year (based on 2016 tariffs) if successful in reducing during all four summer months
LSE or DR Provider Contracted Price Response	• Varies based on contractual arrangements	• Varies based on contractual arrangements	• Varies based on contractual arrangements
Self-Directed Price Response	• Retail contract with exposure to real-time market prices • Ability to monitor real-time prices in ERCOT wholesale market	• Varies depending on number and severity of pricing events • May be able to predict peak pricing events earlier in day	• Varies depending on number and severity of pricing events

Demand response programs in ERCOT provide opportunities for demand-side resources to defray their electricity costs and provide reliability benefits to the ERCOT electric grid. Because the process of seawater desalination is energy intensive, participation in demand response could help to reduce electricity costs while posing a relatively low risk to plant operations if demand response participation is factored into plant design.

Participation in non-ERCOT-dispatched demand response opportunities, such as reducing load during 4CP intervals or in response to real-time electricity prices, may also help to reduce electricity costs for seawater desalination plants in Texas. As stakeholders in Texas continue to plan for possible future droughts in the region and identify water management strategies, consideration of demand response could play a role in mitigating some costs associated with seawater desalination, and allow seawater desalination plants to assist with maintaining electric reliability in the region.