California North Coast Offshore Wind Studies

Electricity Market Options for Offshore Wind

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1. OVERVIEW

The purpose of this document is to describe electricity markets operated by the California Independent System Operator (CAISO)[1] and the opportunity for offshore wind to participate. Offshore wind power plant operators may or may not participate directly in these markets, depending on the individual plant attributes and business plan (e.g., they may have a power purchase agreement with a third party). An overview of the different CAISO concepts covered in this report are given in Table 1, along with their relevance to offshore wind power. Details of the CAISO concepts in this document came from CAISO's Business Practice Manual (Delparte, 2020a,b), which provides an excellent reference for further details.

Table 1. Overview of CAISO electricity market concepts and relevance to offshore wind.

CAISO Concept	*Description*	*Relevance to Offshore Wind*
Day Ahead Market	Market where energy is bought and sold to address demand for the next day after market closure, guided by load and generation forecasts	The day-ahead market accounts for most of the energy transactions, and offshore wind will likely participate and influence prices in this market.
Real Time Market	Market to address the shortfall between the energy bought/sold on the day-ahead market and the real-time energy demand	Though smaller than the day-ahead market, the real-time market is still a key area for participation.
Ancillary Services	Frequency regulation and operating reserves procurement providing grid stability and supporting reliability	New technology can allow offshore wind to provide ancillary services.
Resource Adequacy	Capacity product designed to ensure enough peak power supply is available at all times	Offshore wind's qualification for capacity payments will depend on the probability of generation at system peak times, and will require analysis since it is a new resource.
Congestion Revenue Rights	The tradable rights to costs and revenues generated by grid congestion	While offshore wind is not required to obtain Congestion Revenue Rights, given the local grid constraints additional study is recommended.
Convergence Bidding	A system similar to commodity options markets designed to minimize the price difference between day-ahead and real-time energy prices, allowing virtual bids to be placed without requiring physical capabilities to generate.	Virtual bidding traders will incorporate the influence of offshore wind in their bidding strategies. Offshore wind plant operators may also participate, though there will be less utility in doing so than a non-intermittent resource.
Hybrid Resources	Resources combining multiple forms of generation, which are subject to special constraints	Offshore wind may qualify if combined with other generation and/or energy storage, but many policy details have yet to be finalized.

[1] The California Independent System Operator (CAISO) is an independent Balancing Authority responsible for operating a portion of the Western US electric power system. CAISO manages 26,000 circuit miles of transmission lines and coordinates generation resources through competitive electricity markets. CAISO's jurisdiction covers most of California, as well as small areas of Nevada.

2. CAISO ENERGY MARKET

The main tool used by the CAISO to manage energy generation resources is the integrated energy market. The market operates in two phases: the day-ahead market, used to serve the expected energy demand, and the real-time market to serve more immediate demand fluctuations. These markets include serving energy demand and also ancillary services; for the sake of simplicity the day-ahead and real time markets are discussed in terms of energy in this section.

2.1 Day Ahead

The Day Ahead Market (DAM) is a process for organizing generation resources to meet hourly demand for the next day after market bidding closes. Despite the name, the day-ahead market for any given day opens seven days prior, and closes at 1 p.m. the afternoon before the day in question. The CAISO then processes all bids, balancing active generation and load throughout their authority area to determine which bids are successful and result in the least cost option for reliably serving load, given the constraints on the system.

There are two pathways to participate in this area of the CAISO market: self-scheduling, and competitive bidding. Under self-scheduling, a scheduling coordinator can submit a schedule to the CAISO describing the amount of energy that a resource will generate during each trading hour regardless of participation in the competitive bidding process. Resources which participate in self-scheduling are known as "price takers," as they will accept the final energy price (determined by a combination of market forces and possible adjustments by the CAISO), which can in some cases be negative.[2]

In contrast, resources in the competitive market offer energy at a specified price interval, constructing a "bid stack" with prices based upon given market circumstances and plant operating characteristics.[3] In its simplest form, a bid will offer increasing operating capacity for increasing prices. A simple example of a competitive market bid is shown in Table 2; actual bid stacks contain up to 10 increments describing a resource's willingness to participate in the various CAISO market products.

Table 2. Simplified example market bid.

Operating Capacity	Energy Price
50 MW (min capacity)	$15/MWh
75 MW	$20/MWh
100 MW	$25/MWh
150 MW (max capacity)	$40/MWh

The competitive market often generates higher profits since bids can be designed in a way to prevent producing during times when the market clearing price is lower than the marginal cost of operation for a resource. There is some risk of a poorly constructed bid stack failing – if the lowest energy price falls above the closing market energy price, the bid will not be awarded.

In tandem with those selling energy supply into the DAM, scheduling coordinators representing load serving entities (such as utilities or community choice aggregators) are placing bids to purchase the energy being provided. The demand bidding process is very similar to the supply bidding structure: bids can either be self-scheduled, or entered competitively. Competitive demand bids mirror their supply counterparts, with the maximum purchase quantity at the lowest cost, and the lowest purchase quantity at

[2] If the market experiences an energy glut, it is possible that the market price would be negative - forcing self-schedulers to pay money to generate electricity. Alternately, power plants utilizing energy storage may purchase energy to charge energy storage.

[3] Characteristics such as start-up time and cost to run would be entered into the bid; there is often a desire to select plants already running, or with lower operating costs, if energy bid prices are equal.

the highest cost. At a certain price/supply point, the day-ahead supply meets the day-ahead demand, and the market energy price (and the price offered to self-schedulers) is set to that value. This energy price is not uniform throughout the entire Balancing Authority Area, but will vary from locality to locality based upon available demand, load, and transmission constraints. The day-ahead market awards generally account for approximately 90% of the energy demand that will be required the next day.

2.1.1 Relevance to Offshore Wind

Offshore wind can participate in the DAM similar to existing land-based wind facilities. Self-scheduling presents far less risk for wind plants over conventional plants: whereas conventional plants have significant marginal costs (reflected in the increasing price tiers of a competitive bid stack), wind plants have essentially zero marginal cost (a wind turbine will produce minimum power at the cut-in wind speed for the same cost as its rated power at higher wind speeds). As long as the market clearing price is positive, a self-scheduling wind plant can make money without needing a more complex bidding strategy. While there is the long-term risk that market clearing price will be insufficient to reimburse initial investment in a wind farm, there is no market bidding mechanism to address that concern.

2.2 Real Time Market

As mentioned earlier, approximately 90% of demand is covered in the DAM. The Real Time Market (RTM) is designed to procure any products needed to correct for the difference between the demand forecasted in the DAM and the actual need on the grid during each interval in the RTM. There are two markets time intervals within the RTM: the fifteen-minute market and the five-minute market (also known as the real time dispatch).

Similar to the day-ahead market, scheduling coordinators can either self-schedule or competitively bid into the real-time market. A self-scheduling resource will still simply provide their scheduled product to the CAISO, and receive the final price determined at the end of the real time dispatch. A resource can also submit a competitive bid stack into the real-time market, which provides the most control of the final product price, but is more complex and riskier than competitive bids in the day-ahead market.

A resource can also competitively bid into the DAM, but abstain from doing so in the RTM. Bids which have been awarded in the DAM are automatically passed into the RTM, however these awards are still subject to real-time mitigation and fluctuations. Without a competitive real-time bid, a resource will have no impact on how the mitigation and fluctuation will impact their final award. This is not the same as price-taking, rather there are adjustments made to the day ahead award following the RTM closely.

2.2.1 Relevance to Offshore Wind

Nothing would prevent an offshore wind installation from actively bidding into the RTM, although it can be riskier given the variable nature of the resource. However, a variable energy resource (such as a wind installation) has protections built into the market to mitigate some of these risks. For example, the CAISO requires all resources participating as a variable energy resource to provide (or purchase from the CAISO) a meteorological forecast specific to the likely output capability of the resource. The CAISO takes this forecast into account when reviewing bids, and will mitigate any bid promising a product which cannot be provided according to the forecast and resource characteristics. This reduces the risk of penalties for a resource failing to honor their award - penalties which can be significant, and also result in a resource being removed from market participation.

Even with the protections available, a very cautious bid strategy would need to be developed to limit the risk of unfulfillable awards. As with the day-ahead market opportunities, self-scheduling and competitive markets offer a trade-off between stability and potential profits. There is likely considerable value in a prototype offshore wind project exploring these issues as a blueprint for future projects. One option is to integrate energy storage as discussed in Section 3.5 about Hybrid Resources further below.

3. OTHER ASPECTS OF CAISO OPERATIONS

There are several other aspects of operations beyond simply matching energy demand with generation, as discussed in the day-ahead and real-time markets above. The more advanced products, discussed below, provide grid stability and resiliency over just meeting demand.

3.1 Ancillary Services (AS)

Ancillary Services are a market mechanism that values the different ways a generator can support a reliable grid through frequency and voltage support or dispatchable reserve power. These services provide a way for generators to generate revenue while providing the CAISO assurance that the stable grid operation can be maintained during unexpected demand or supply issues. There are two components of ancillary services: Regulation Up/Down and Spinning/Non-Spinning Reserves, which are described below.

3.1.1 Regulation Up/Down

Regulation Up/Down are methods of frequency control, where generators can increase (Regulation Up) or decrease (Regulation Down) the power output to adjust power supply to control grid frequency and stabilize any fluctuations. Depending on the resource type, regulation services must be dispatched nearly instantaneously so any plant providing this service must be connected to the CAISO Automatic Generation Control (AGC), which sends dispatch instructions every four seconds.

There are two ways to participate in the Regulation service within the CAISO market: bidding into the DAM and RTM as discussed above, or participating in the Regulation Energy Management market. In the Regulation Energy Management market, the CAISO is given full control of dispatching the resource, and the resource becomes unauthorized to participate in bidding.

3.1.2 Spinning/Non-Spinning Reserves

Similar to Regulation, Spinning and Non-Spinning Reserves provide dispatchable power to compensate when demand suddenly outpaces supply, for example if an operating plant goes offline. Spinning Reserves refer to capacity that can be sent to the grid from currently-operational (“spinning”) generators, whereas Non-Spinning Reserves refer to capacity that can be brought online in various time frames.

3.1.3 Relevance to Offshore Wind

The most reliable way for any wind installation to participate in the Ancillary Services market is with integrated, dispatchable energy storage. Without energy storage, the variable nature of wind resources brings added risks, but new technology and system management strategies enable wind power plants to provide AS.

Land-based wind systems have been able to provide Regulation Up frequency modulation using energy stored in rotor momentum, although this can only provide short-term regulation before the rotors lose enough energy to seriously curtail energy production (Morren, Pierik and de Haan 2006). A more versatile strategy to quickly dispatch energy is to deliberately shift normal turbine operations from maximum power point tracking (MPPT) to a less productive level, leaving unused capacity. When Ancillary Services are required, turbine operations can shift closer to the MPPT and dispatch additional energy. The unused capacity level can be set to a constant, or with sufficient forecasting and planning, a variable capacity. Recent tests at Tule Wind Farm demonstrated this concept. With advanced power plant controllers and slight curtailment, the wind farm was able to respond to the 4-second AGC signals, and provide regulation services (Loutan et al., 2020).

3.2 Resource Adequacy (RA)

Resource Adequacy is an organizational tool mandated by the California Public Utilities Commission (CPUC) to ensure an adequate level of energy resource is available at all times to meet expected peak demand. Load serving entities are required to provide a certain amount of RA, determined by rules developed by the CPUC and through agreements with the CAISO. Qualified energy providers may then contract to provide RA; if successful, they will be assigned a period of time and a set quantity of capacity they must be able to provide, regardless of other commitments. For example, a plant could be required to have 10 MW of available capacity from 12 p.m. - 4 p.m. on October 4th. An RA contractor may not necessarily end up providing this resource, but they must offer it into the CAISO market through a bid called a Must Offer Obligation.

If enough capacity is available and provides a better value, then the contractor will not need to provide the RA capacity they were assigned. RA can be thought of as a kind of insurance: RA resources provide a stable power supply for load-serving entities when normal operations cannot, and regardless of whether the extra capacity is actually needed, the RA provider will still be paid for reserving resources. However, if these obligations are not met when called on, payments can be revoked – even for times when they were not called.

3.2.1 Relevance to Offshore Wind

As a variable energy resource, offshore wind would have the RA capacity determined by the Effective Load Carrying Capacity method. Currently this method looks at historical production of a variable energy resource and sets the RA Qualifying Capacity at 70% of its historical output. As newly developed variable energy resources have no historical output, they often must wait to provide RA for at least one year. Offshore wind may fall into this category, and clarification should be sought before attempting to provide Resource Adequacy.

3.3 Congestion Revenue Rights

Congestion occurs when transmission lines are not rated to meet the load demand in a given local area. This can cause local fluctuations in energy prices, as generators that were otherwise not competitive are utilized to meet their local demand. These additional energy costs, referred to as Congestion Revenues, can be paid out through a variety of mechanisms. Which entities are responsible for these costs and which are entitled to these revenues are determined through Congestion Revenue Rights.

Congestion Revenue Rights can be purchased at a specific percentage of the congestion costs over specific time intervals, and they can be purchased between two nodes only, or between multiple nodes in specific arrangements. Purchasing these rights provide a way for a resource to hedge against profit losses due to congestion in the grid, but it is also another avenue to simply bring in revenues. Participants in the Congestion Revenue Rights market do not have to be a scheduling coordinator, and they do not have to be a resource in the CAISO energy or AS markets.

3.3.1 Relevance to Offshore Wind

An offshore wind installation could participate in Congestion Revenue Rights trading, and it may be particularly valuable in a transmission constrained area like Humboldt County. Recognizing that the implementation of a new resource would almost certainly impact congestion, it would be highly advantageous to develop a strategy to trading Congestion Revenue Rights in such a way as to make a profit.

3.4 Convergence Bidding

Convergence Bidding, also known as Virtual Bidding, is a market for participants to take a financial position by placing day-ahead market bids to be liquidated in the real time market – energy demand is bought at day-ahead prices and sold at real-time prices, and energy supply is sold at day-ahead prices and "purchased back" at real-time prices. But while virtual bids compete in the market alongside traditional supply and demand bids, they do not involve the buying or selling of actual energy, and do not affect any physical generation or load. Neither scheduling coordinators nor load serving entities are required to participate, and importantly, virtual bidding is not involved in grid reliability.

Given that Convergence Bidding is not linked with the production or consumption of energy, it is natural to wonder why it exists. While the simplest reason is legal (Convergence Bidding is required by the Federal Energy Regulatory Commission), Convergence Bidding also closes the gap between day-ahead and real-time prices, which prevents scheduling coordinators and load serving entities from withholding participation in one market to pursue better prices in the other. This balancing is competition based: virtual demand makes money if the energy price increases between the day-ahead and real-time market, while virtual supply makes money if the energy price decreases between day-ahead and real-time, so competition between these two positions will shrink the price gap. Convergence Bidding also provides a means for market actors to hedge risk based on the knowledge of their own operations.

3.4.1 Relevance to Offshore Wind

Assuming participation in the CAISO markets, any offshore wind development would be able to participate in convergence bidding. The relevance to wind generators would largely be the same for any other resource, to reduce risk, increase profit, and influence physical supply commitment in its favor.

3.5 Hybrid Resources

Hybrid Resources, broadly, are any combination of multiple generation technologies controlled by the same owner/operator, behind a single point of interconnection, and operating in the CAISO markets under a single resource ID. A common hybrid resource is a combination generation and battery storage resource. CAISO is in the process of completing the Hybrid Resource Initiative, which will implement the regulatory framework to allow hybrid resource projects to fairly participate in the markets. As this policy development is ongoing, the exact requirements of a hybrid resource are not yet finalized.

While the market products and instruments noted above do not change for hybrid resources, Hybrid Resources participate in different ways – for example, protections for variable energy resources may no longer apply. How Hybrid Resources can be profitable and what barriers they present will depend on the Hybrid Resource Initiative, set to be fully implemented by the fall of 2021.

3.5.1 Relevance to Offshore Wind

The most likely way for an offshore wind installation to become a hybrid resource would be to include integrated battery storage. Newer technology may enable other means of becoming a Hybrid Resource, such as floating platforms hosting both wave energy converters and wind turbines. Currently 40% of projects in the CAISO queue are Hybrid Resources, (CAISO, 2019) and it would be worthwhile for offshore wind developers to follow the Hybrid Resource Initiative.

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