SPP Southwest Power Pool
MARKET MONITORING UNIT

Self-committing in SPP markets: Overview, impacts, and recommendations

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Market Monitoring Unit

Self-committing in SPP markets
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1 OVERVIEW AND RECOMMENDATIONS

In this report, we examine self-commitment offer behavior in SPP's Integrated Marketplace, and describe how self-commitment can affect market participants and market outcomes.

Towards that end, we conducted an empirical study analyzing offer behavior over the period of March 2014 to August 2019, and ran two simulation series of a week per month from September 2018 to August 2019 where we re-solved past market cases. The simulations included the following assumptions: (1) all generation is offered in market status, and (2) all generation offered in market status can be started economically by the day-ahead market.

Key takeaways from our analysis include:

- The volume of self-committed megawatts has declined over time, but remains nearly half of the total megawatt volume generated from March 2014 through August 2019.
- Prices and production costs were systematically lower when at least one self-committed unit was marginal.
- In almost all cases, self-committed generators had lower revenues because of negative congestion prices; whereas, market-committed generators typically had a more balanced congestion profile.
- Resources with long lead times and/or high start-up costs tend to be self-committed instead of market-committed.
- Units that are self-committed generally have much higher capacity factors than those that are market-committed. However, these results differ substantially by fuel type.

Key takeaways from the simulations include:

- When the market made unit commitment decisions, and lead times remained unchanged, both market-wide production costs and market clearing prices for energy increased.

- When the market made unit commitment decisions and lead times were modified to allow the day-ahead market to commit the resources with long lead times, market-wide production costs were essentially unchanged and market clearing prices for energy increased.
    - System prices increased by about $2/MWh (seven percent) on average.
    - Congestion prices changed by about –$1/MWh to $1/MWh on average.
- To optimize long-lead time resources' participation in the market, the economic commitment process would need to solve over a longer market window (e.g., over a two-day period rather than just one day).

1.1 RECOMMENDATIONS

- In order to improve price formation and market efficiency, we recommend SPP and stakeholders work to reduce the incidence of self-commitments.
- We recommend modifying SPP's market design by adding one additional day to the market optimization period.[1]

1.2 OUTLINE

The paper is organized as follows. In chapter 2, we cover the mechanics of self-commitment in the SPP market, how this impacts the supply curve, and identify reasons participants may choose to self-commit their generation. Chapter 3 covers the theoretical underpinnings of the market and efficient price formation. Chapter 4 presents empirical observations over the study period comparing market and self-commitment behavior. Chapter 5 covers self-commitment behavior and price formation. Chapter 6 presents two simulation scenarios estimating how market results

[1] SPP has found in its multi-day forecasting study, the accuracy of forecasts (load and wind) remain at acceptable levels for a second day but decline sharply afterwards.

would change if participants market-committed versus self-committed. Chapter 7 highlights our conclusions.

The empirical study period spans from March 2014 through August 2019 and covers all resources and fuel types. However, in our presentation of offer and generation related metrics, we exclude nuclear resources because of the limited number of resources with this fuel type.[2]

Readers of this report may note that the analysis of self-commitment differs from what we have presented in our previous reports. In our annual and quarterly state of the markets reports, we have presented self-commitment information in the form of offers and unit starts. In this report, we focus instead on the megawatts produced from self-committed units.

The re-run (simulations) study period covers the first week of each month from September 2018 through August 2019.[3] We believe that this provides a significant enough sample of re-runs to capture seasonality in the market.

[2] Many of the charts and analysis that follows presents offer behavior by fuel type. As there are a limited number of nuclear resources, any charts that show this as a fuel type could potentially expose specific market offer data. All other resources have a sufficient number of resources to mask any specific offer behavior.

[3] Additional information regarding the sample set can be found in chapter 6.

2 SELF-COMMITMENT MECHANICS

In the broadest terms, and similar to other auction-based electricity markets, the Integrated Marketplace attempts to minimize the cost to serve load[4] subject to transmission and generator constraints. The day-ahead market does this by using two main tools: centralized unit commitment[5] and economic dispatch.[6]

Centralized unit commitment sorts the available generators from least expensive to most expensive and then selects the least expensive units that can achieve the objective without violating the constraints of the optimization.

Economic dispatch then uses the results of the unit commitment process as inputs to its own separate optimization. The results of which produce two key, time-based outputs: the megawatts each generator should produce at the corresponding locational prices.

Centralized unit commitment and economic dispatch processes are designed to work together to make the market more efficient. For instance, FERC stated that "…the unit commitment process an essential part of least-cost operation" when discussing price formation in organized wholesale electricity markets.[7]

The idea behind centralized unit commitment is essentially this: In the same way a team will likely realize better outcomes when the coach selects both the players and plays, the Integrated

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[4] The cost to serve load is also referred to as production cost.

[5] The Integrated Marketplace Protocols define Security Constrained Unit Commitment as an algorithm capable of committing Resources to supply Energy and/or Operating Reserve on a co-optimized basis that minimizes commitment costs while enforcing multiple security constraints. Integrated Marketplace Protocols, Section 1 Glossary

[6] The Integrated Marketplace Protocols define Security Constrained Economic Dispatch as an algorithm capable of clearing, dispatching, and pricing Energy and Operating Reserve on a co-optimized basis that minimizes overall cost while enforcing multiple security constraints. Integrated Marketplace Protocols, Section 1 Glossary

[7] Price Formation in Organized Wholesale Electricity Markets, Docket No. AD14-14-000

Marketplace will also probably realize better outcomes, for the collective, when it commits units in addition to dispatching them. While the team's record might be the same regardless of who is on the field, it is unlikely that the plays called, points scored, or yards gained would be the same.

Much like players choosing when to play, the SPP market allows participants to self-commit resources rather than have the market choose which units to run. While there may be good reasons for this (see Section 2.2 below), the practice can distort prices and investment signals.

2.1 TYPES OF COMMITMENT STATUS

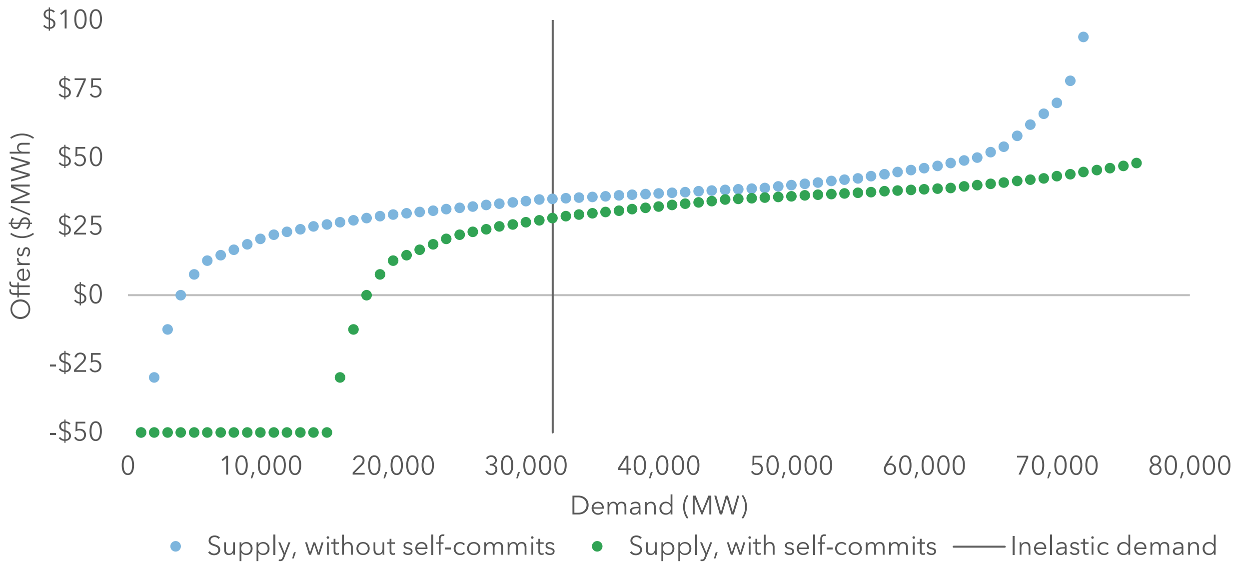
Including self-commitment, the Integrated Marketplace permits five different commitment statuses. The statuses convey information to the centralized unit commitment process. Each status and its accompanying description can be found below:

1. Market – the resource is available for centralized unit commitment through its price sensitive (merit-based) price quantity offers.
2. Self – the market participant is committing the resource through price insensitive offers outside of centralized unit commitment.
3. Reliability – the resource is off-line and is only available for centralized unit commitment if there is an anticipated reliability issue.
4. Outage – the resource is unavailable due to a planned, forced, maintenance, or other approved outage.
5. Not participating – the resource is otherwise available but has elected not to participate in the day-ahead market.

Because the day-ahead market cannot dispatch resources with commitment statuses of outage and not participating, we included market, self, and reliability commitment statuses in our empirical study. However, due to the extremely low megawatt volumes[8] dispatched from reliability-committed units, we present and discuss only market and self statuses in the report.

Mechanically, self-commitment can affect the construction of supply curves by altering the generators selected to serve the demand. Self-commitment shifts the merit order of the supply curve by treating the self-committed generators as price insensitive, which shifts the supply curve to the right.[9] This relationship is shown in Figure 2–1.

Figure 2–1 Rightward shift in market supply curve



The blue supply curve represents supply without self-committed megawatts, whereas the green supply curve represents supply including self-committed megawatts. When participants self-commit resources, the commitment algorithm does not make the decision to commit those units based on their cost. Participants make their own commitment decisions without regard to the optimization of total costs. Said another way, these resources effectively move themselves to the bottom of the cost curve. The result of a rightward shift in supply, all else equal, likely

[8] Over the study period, less than 0.004 percent of dispatched megawatts sourced from units committed in reliability status.

[9] Moreover, the supply curve itself can be reordered as resources whose commitment costs are high can also change the order of dispatch of incremental energy.

reduces the market's marginal clearing price.[10] In addition to shifting the supply curve to the right, the slope of the supply curve also changes when generators self-commit. The change in slope reflects the re-ordering of suppliers in least cost merit order for market dispatch based on the set of resources from the commitment process.[11]

Along with shifting and reordering the supply curve, when participants self-commit resources, their economic minimums essentially create a resource specific dispatch megawatt floor. These floors in turn, create additional constraints to which the economic dispatch optimization must solve around. Self-committed resources also carry the lowest curtailment priority, which means they are generally the last producers instructed to reduce output.[12] Because these self-committed units are deemed "must run", the dispatch engine cannot take them off-line for economic reasons.[13]

2.2 REASONS FOR SELF-COMMITMENT

We have worked with market participants to understand the reasons that participants self-commit generators. Market participants have stated the following reasons for self-commitment:

- Testing – NERC requirement
- Public Utilities Regulatory Policy Act (PURPA)
- Federal service exemptions
- Started by a different market
- Weather
- Long lead times

[10] This is also known as the system marginal price.

[11] Under certain circumstances, this type of reordering could cause a price increase, but this has not been observed. Typically, the reordering has resulted in price declines.

[12] Integrated Marketplace Protocols, Section 4.3.2.2 Day-Ahead RUC Execution

[13] Integrated Marketplace Protocols, Section 4.4.2.5 Out-of-Merit Energy (OOME) Dispatch

- Fuel contracts
- Other contracts
- Long minimum run times
- Commitment bridging
- Desire to reduce thermal damage to the unit due to starts and stops
- High startup costs

Some of these reasons are unavoidable and can require the resource to be offered in self-status. Testing the output of a plant, as periodically required by regulatory agencies, is a frequent justification. A few generators in SPP are classified as qualifying facilities under the Public Utilities Regulatory Policy Act, and the commitment of those resources cannot be separated from other uses, such as cogeneration processes. Additionally, a small group of SPP resources qualifies for Federal service exemptions. Finally, a participant may need to self-commit a resource during very cold weather for reliability reasons.

Some of the reasons, such as high start-up costs, fuel contracts, or commitment bridging are economic in nature and can be handled within the market offer through dollar-based offer parameters. Thermal damage due to start-ups and shut-downs and resulting major maintenance could be included in mitigated offers starting in April 2019.[14] As we show later in the report, we have seen a general decline in self-committed generation over time and it is possible that perceptions of economic justifications have changed over time.

To the extent that a long lead time[15] is reflective of operating or environmental limitations, there may be a software limitation. To the extent that there are limitations to the software, these can be addressed through market design changes.

[14] Revision Request 245.

[15] Based on August 2019 offers, 7 percent of resources (or MWs) had lead times longer than 32 hours and 10 percent had between 24 and 32 hours.

3 MARKET FEEDBACK LOOP

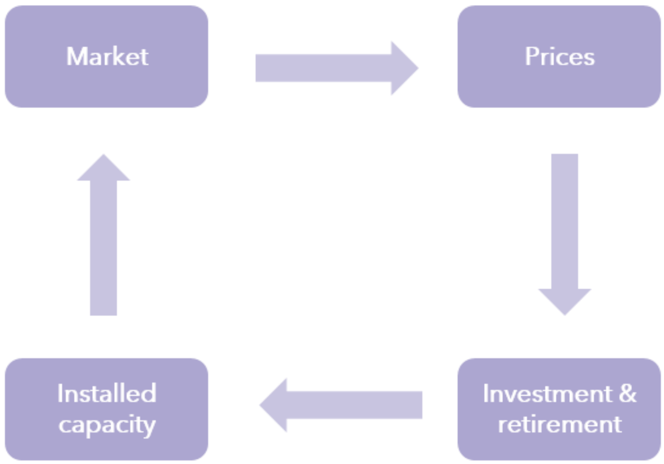
As we showed in the previous section, self-commitment of generation can put downward pressure on the marginal clearing price of energy. In this section, we discuss how the marginal clearing price drives the market feedback loop to bring about equilibrium and efficiency.

A central theory in economics is that competition leads to efficiency.[16] If the market design effectively fosters competition, a competitive equilibrium is possible, and by extension, efficiency may be gained. In electricity markets, a primary source of efficiency gain stems from the minimization of system production cost through centralized clearing. When this occurs, resulting prices are based on marginal costs and the level of production and consumption is optimal – the result is an efficient market at competitive equilibrium.

Market equilibrium generally has two time dimensions: the short-run and the long-run. In the short-run, market participants profit maximize by asking themselves, "What is the best we can do with our current set of resources?" They submit their best answers in the form of market offers. The market provides feedback in the form of commitment, dispatch, and prices. Market participants then use this information to adjust their short-run profit maximizing behavior. Concurrently, participants ask themselves, "What is the best we could do if we had something different?" This question relates to long-run market equilibrium and decision-making to include investment (or retirement) in installed capacity. The search for short-run and long-run equilibriums creates the market feedback loop. In the following sections, we will examine how self-commitment can affect this process and, by extension, market efficiency.

[16] Perfectly competitive markets attain both *productive efficiency*—where output is produced at the least possible cost—and *allocative efficiency*—where output produced is the one that consumers value most.

Figure 3–1 The market feedback loop



3.1 THE MARKET

For competition to flourish, several conditions must exist including having the lack of market power by market participants,[17] the necessary cost information,[18] and non-convex operating costs.[19] Good market design, along with effective regulation and monitoring, helps bring about the first two requirements. The third requirement, however, is unlike the first two. Convexity or lack thereof, is inherent to the characteristics of the resources that participate in the market. Non-convex costs occur when it is cheaper to produce two units than to produce one. Generator start-up and no-load operating costs have this property and are non-convex. As such, when non-convex cost elements exist, designing a competitive market with an efficient pricing mechanism is difficult. However, when suppliers lack market power and have necessary cost information, the improved, if not perfect, level of competition can still bring about efficiency improvements.

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[17] A lack of market power implies being a price taker.

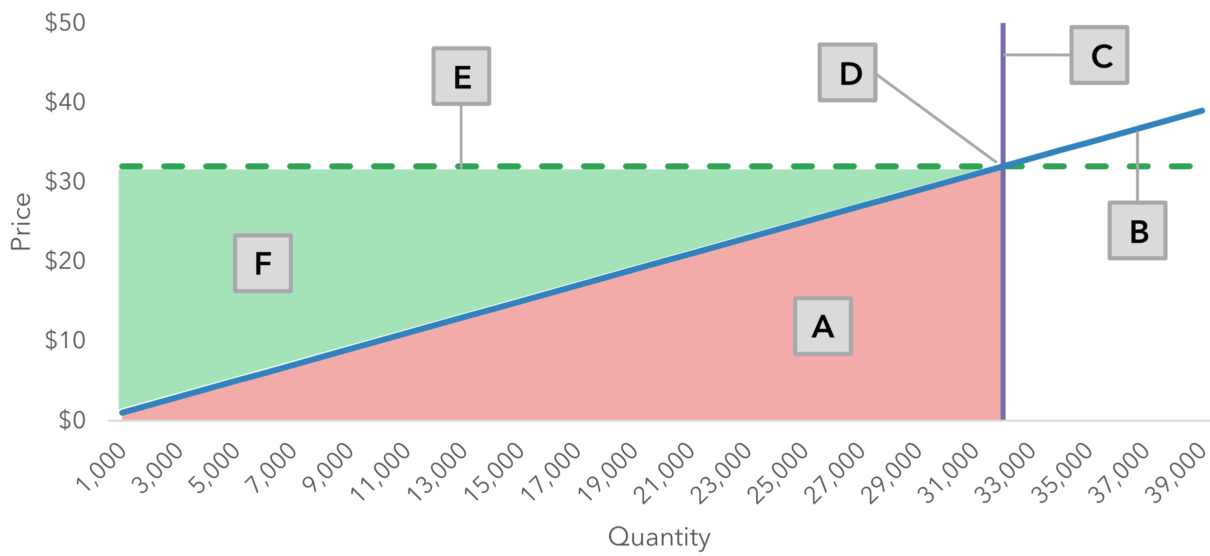
[18] All production costs are known.

[19] The shape of the cost curve is a critical input to the supply function. Classical economics assumes that costs are convex. In practice, some costs are nonconvex.

3.2 LINKING THE MARKET TO PRICES

Economics has concepts that are very precise and have specific meanings. For example, accountants and economists both use the term profit. However, the idea each intends to convey can differ materially.[20] For this reason, we provide the following simplified figure[21] and associated terms to help convey the appropriate intention.

Figure 3–2 Market supply and demand



A. The red shaded region is the production cost,[22] more specifically the energy portion of total production cost.[23] This region is also referred to as the area under the supply (or marginal cost) curve, which gives *total* variable cost, or *total* marginal cost.

B. The supply curve is the blue line. In electricity markets, the supply curve is created by summing the offers of market participants. These offers are submitted in price/quantity

[20] For instance, the IRS expects income tax even when economic profit is zero.

[21] In order to facilitate illustration we use a linearized approximation (of a stepwise line) under a continuous function assumption.

[22] Corresponding to "mitigated offers" in SPP tariff terms.

[23] Production cost is generally presented as the sum of energy, start-up, no-load, and ancillary service costs.

pairs each indicating minimum price levels the supplier is willing to offer for the corresponding quantity. The price the supplier wants to be paid is plotted on the y-axis, and the quantity the supplier is willing to produce for that price is plotted on the x-axis.

C. The demand curve is the purple vertical line.[24] The demand curve shows price/quantity pairs each indicating maximum price levels the consumer is willing to demand for the corresponding quantity. Electricity is mostly a non-storable product and must be supplied instantly upon demand. Further, when there is no competition at the retail end, price elasticity is very low. As such, we represent demand as a vertical line.

D. The market-clearing price is the point where the supply meets the demand. When this occurs, all buyer orders have been filled and the market is said to have cleared. In an organized wholesale electricity market setting, the market clearing price is also called the spot price.

E. The dark green dotted line reflects the price each supplier is paid and is equivalent to the market-clearing price. This equilibrium price multiplied by the total quantity produced is the revenue received by all suppliers.

F. The light green shaded region is the producer surplus. Generally, when economists refer to profit, they are referring to the producer surplus. Short-run profits for individual producers can be calculated by subtracting variable costs from revenue where revenue equals market clearing price multiplied by the quantity produced.[25]

[24] This represents perfectly inelastic demand. Under that assumption, demand is not responsive to price. In practice, the line may not be vertical, having a certain degree of downward slope depending on the degree of price responsiveness in the market, particularly in the day-ahead market.

[25] In electricity markets, start-up and no load costs, in addition to incremental energy costs, need to be included in the short-run profit calculation.

3.3 PRODUCTION COST MINIMIZED, NOT PRICE

The objective function of the market clearing software, stated generally, is to minimize production cost, not the marginal clearing price.[26] Broadly, production cost is the sum of energy,[27] ancillary services,[28] start-up,[29] and no-load[30] costs. Efficiency occurs by serving the same level of demand, while at the same time minimizing the sum of these costs. The clearing price is an output of the optimization and a component of the total production cost. Because the clearing price only relates to a component of the production cost (i.e., the incremental energy component), there is no guarantee that an increase in energy prices will translate to an increase in total production cost.

3.4 PRICE TO INVESTMENT SIGNALS

In the long run producers are incented to invest in projects that minimize their costs.[31] When current prices reflect the true marginal cost of the current set of producers at the margin, participants can better determine the cost structure of the market. When participants have better information, they will likely better optimize their existing generation portfolio. However, in the long run some market participants may not be able to use their existing fleet to achieve their desired level of profitability or recover their cost of capital. When participants find themselves in this situation, they consider entry and exit decisions. Typically, this means

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[26] In this cost minimization problem, prices are discovered by identifying the marginal cost of serving the next increment of load during a specific interval and location.

[27] Energy is a power flow for a time period.

[28] Ancillary services are needed to maintain reliability of the system, often by forgoing the opportunity to sell energy.

[29] Start-up is the cost associated with preparing a generator to produce (and stop producing) energy or ancillary services.

[30] No-load is the theoretical cost of running a generator while producing no output.

[31] In a competitive market, the market price is given to individual suppliers and all they can do is to adjust their production amount that minimizes cost.

generators whose long run costs exceed projected revenues retire.[32] Then suppliers either permanently exit the market, focus on reducing maintenance costs, place the unit in reserve shutdown (i.e., mothball),[33] or invest in new lower cost generators.

3.5 INVESTMENT SIGNALS TO INSTALLED CAPACITY

Spot prices are an input to forward price projections and bilateral contract prices. Therefore, a spot price that does not reflect the true cost structure of the market can send an incorrect entry and exit signal. In addition to potentially sending distorted investment signals, generators that self-commit may displace other generators who would have otherwise been committed and earned energy market revenue. This could cause generators that should have earned profits to mount losses. These losses may subsequently incent more generators to self-commit, or cause a generator to retire who would have otherwise been profitable—either case results in a distorted investment signal. In short, sending the right price signal is critical, but so too is ensuring those who warrant the revenue—receive it.

[32] Projected revenues would be based on estimated forward prices.

[33] Mothballed generators are not used to produce electricity currently but could produce electricity in the future. Additionally, generators can be made available for reliability only.

4 UNIT COMMITMENT AND DISPATCH PROCESSES: EMPIRICAL FINDINGS

This section includes information and analysis regarding the pervasiveness of self-commitment, and then discusses generator start-up parameters and capacity factors.

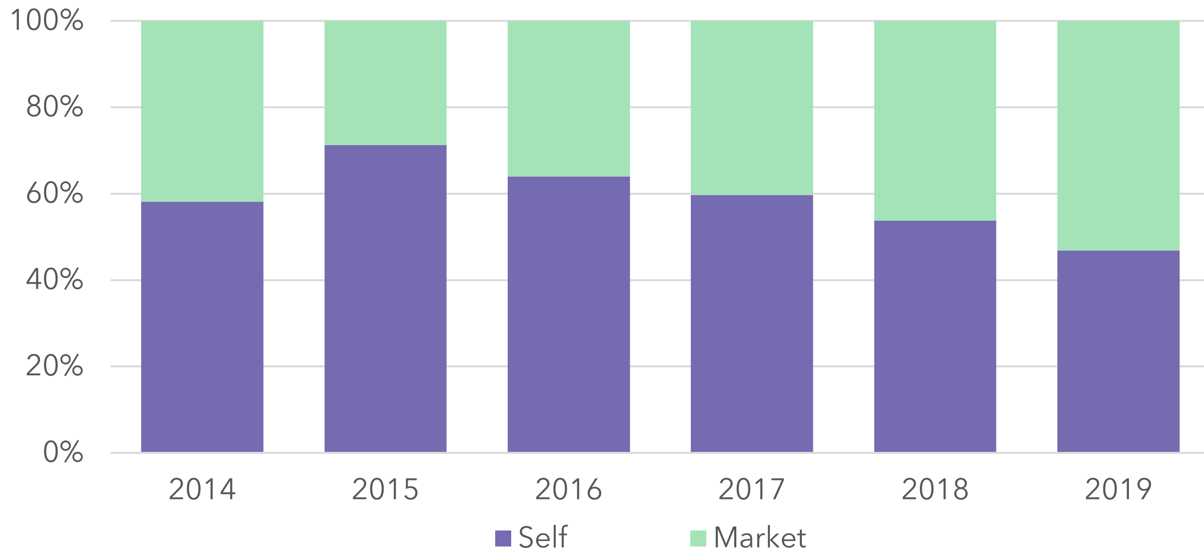
Key takeaways from this section include:

- The volume of self-committed megawatts declined over the study period, but remains nearly half of the total megawatt volume produced in the day-ahead market.
- Resources with long lead times and/or high start-up costs tend to self-commit instead of market-commit.
- Units that self-commit generally have much higher capacity-factors than those who market-commit. However, capacity factors by commitment status differ substantially by fuel type.

4.1 UNIT COMMITMENT – COMMITMENT STATUS

Figure 4–1 shows the percentage of day-ahead economic dispatch megawatts by commitment type over the study period.

Figure 4–1 Percentage of megawatts dispatched by commitment status



The volume of self-committed megawatts has declined over the last several years, but remains nearly half of the total dispatch megawatt volumes. In other words, nearly half of the energy produced was from a resource that was not selected by the day-ahead market's centralized unit commitment process.

While a relatively small percentage[34] of the self-committed megawatts were block-loaded,[35] many self-committed resources have operating parameters that include non-zero economic minimums.[36]

Even though resources are self-committed in the market, there also tends to be economic capacity above minimum that the market can dispatch. Figure 4–2 shows the percentage of self-committed dispatch megawatts above economic minimums.

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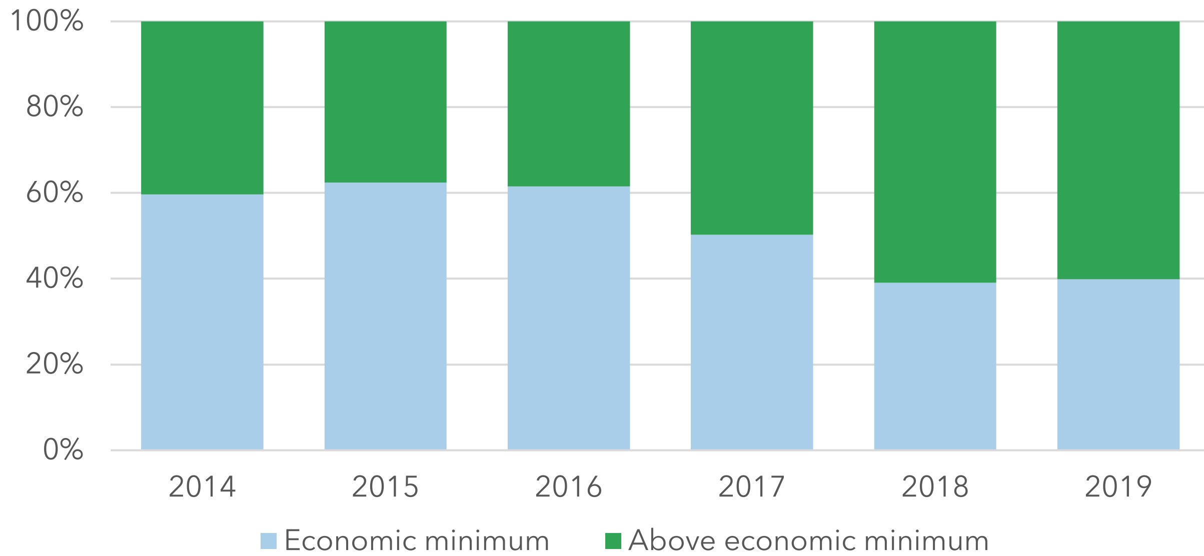
[34] Over the study period, block loaded self-committed resources averaged about six percent of total self-committed volume.

[35] Block-loaded resources self-schedule by submitting one point offer curves, where economic dispatch range is zero, i.e. where economic minimum and economic maximum values are identical.

[36] Integrated Marketplace Protocols, Exhibit 4-6: Resource Limit Relationships, "Minimum Economic Capacity Operating Limit"

Figure 4–2 Percentage of self-committed megawatts dispatched above economic minimum



While the trend is decreasing, economic minimums amount to roughly forty percent of all self-committed dispatch megawatts.

4.2 UNIT COMMITMENT – FUEL TYPE

Resource fuel type is a useful classification of resources. Generally, the operating parameters and economics tend to be similar among units of the same fuel type. Operating parameters tend to be physical or time-based and include items like ramp rate, minimum run time, and lead time. Economic parameters include operating cost. In auction based ISO/RTO markets, the capital/fixed cost[37] portion is generally recovered through market revenues and public service commission rate cases, whereas allowable fuel and short-term maintenance cost[38] is incorporated directly into energy market offers.

In the absence of market power, the centralized unit commitment optimization uses the suite of unmitigated offers when it chooses the lowest cost generators. In general, a low (operating)

[37] Capital cost is also referred to as fixed cost (there is also fixed overhead & maintenance).

[38] Operating cost is also referred to as variable cost.

cost position on the supply curve comes at the expense of high fixed costs. Because fossil fuel generators tend to be quite levered to the price of fuel, the tradeoff between capital cost and operating cost can change if fuel prices decline significantly. This means that each generator's cost position can change, perhaps dramatically, based on fuel prices.

Figure 4–3 shows the percentage of self-committed dispatch megawatts by fuel type by year. Over the study period, the largest portion of self-committed dispatch megawatts sourced from coal units. Coal self-committed megawatts generally exceed the size of the second largest fuel type by a factor of more than four to one.

Figure 4–3 Percentage of self-committed megawatts by fuel type

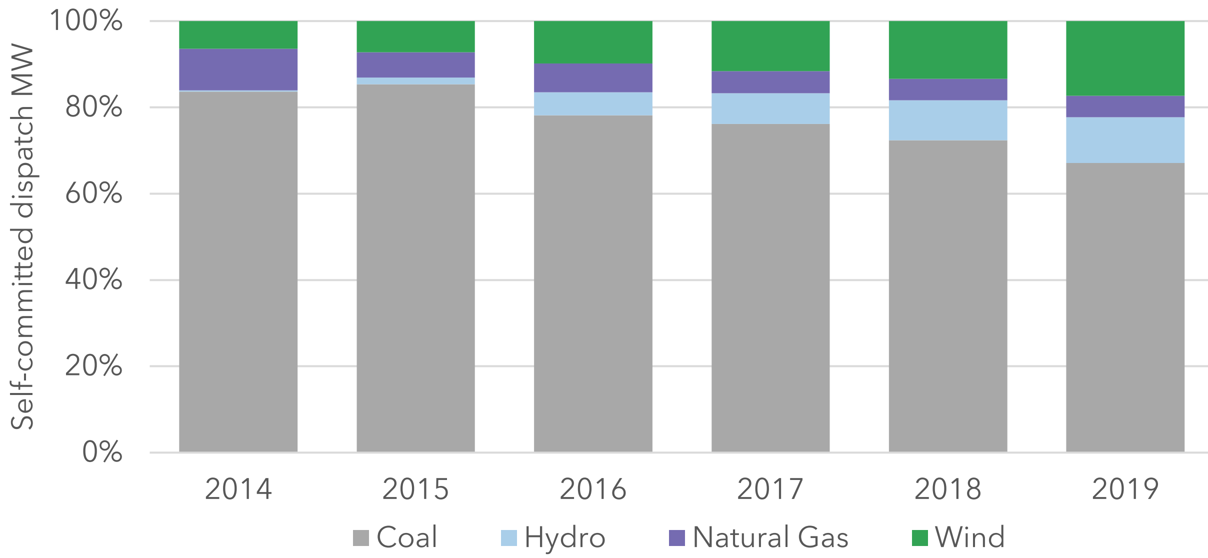


Figure 4–4 shows the percentage of market-committed dispatch megawatts by fuel type by year. Over the study period, the largest portion of market-committed dispatch megawatts sourced from natural gas units. However during the first year of market operation, coal units made up the largest share of market-committed megawatts.

Figure 4–4 Percentage of market-committed megawatts by fuel type

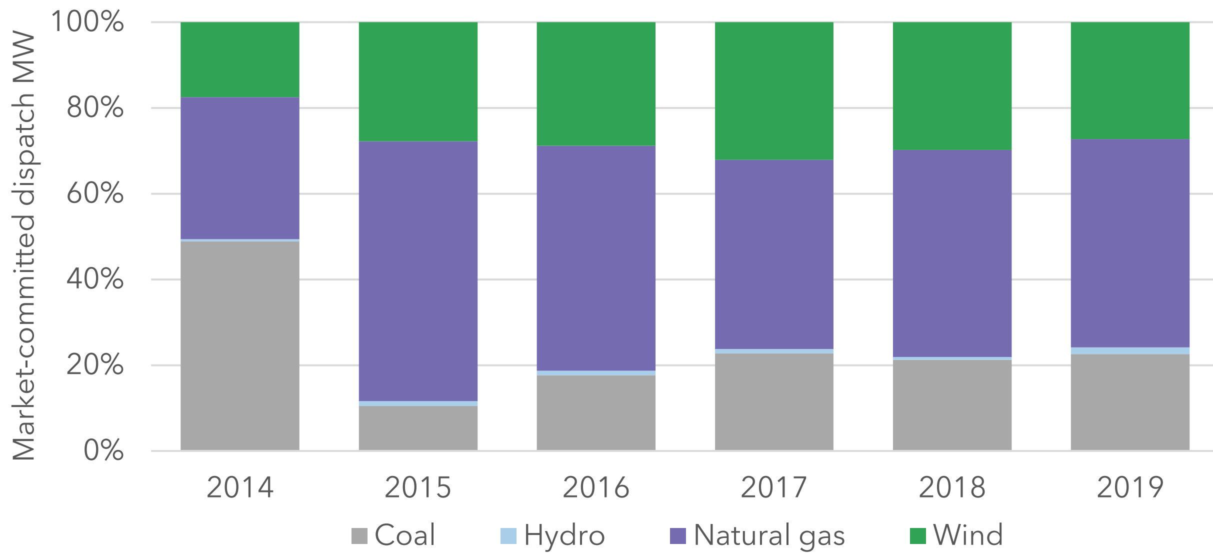
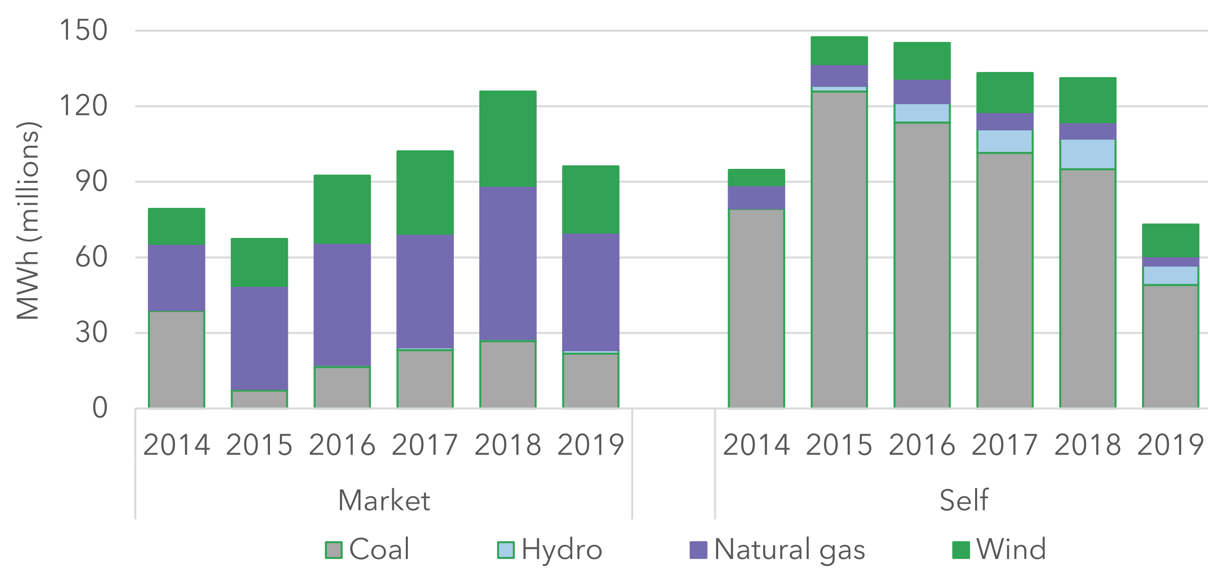


Figure 4–5 shows dispatch megawatts by fuel type by commitment type for each year of the study period.

Figure 4–5 Dispatch megawatt hours by fuel type by commitment type



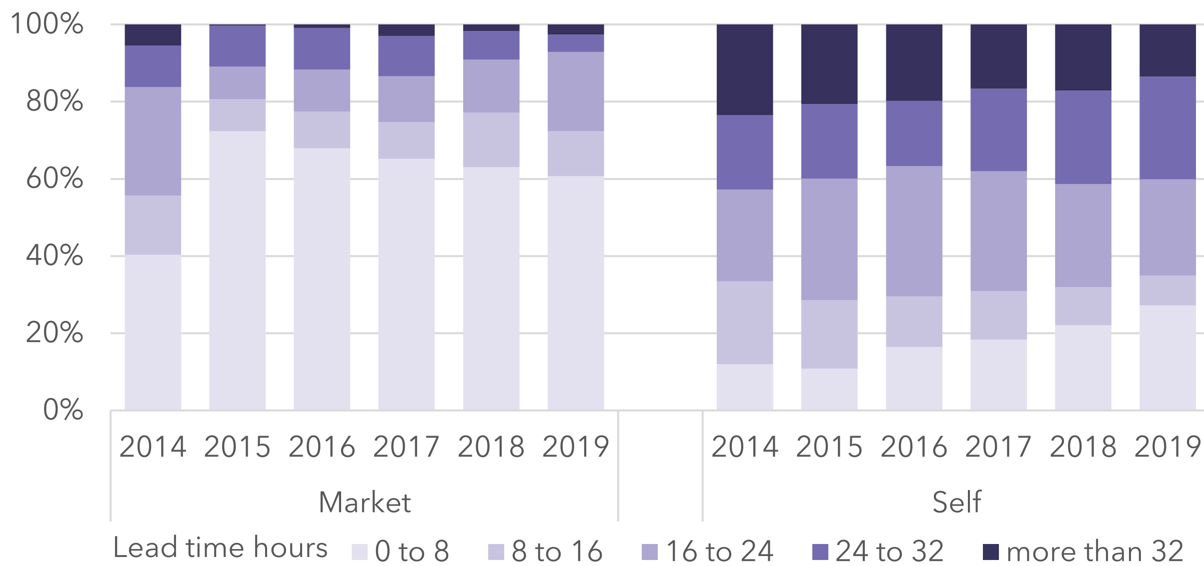
For the total period of March 2014 to August 2019, the magnitude of coal self-committed dispatch megawatts essentially equaled the total dispatch megawatts from all market-committed resources over the same period. In 2015 and 2016, self-committed coal greatly exceeded market commitments. However, as seen in 2019, self-committed coal megawatt hours, while still quite large, do not exceed market committed megawatt hours.

4.3 UNIT COMMITMENT – START-UP TIME

Resource lead times, also called start-up times, are time based operational parameters that vary widely by fuel type. In the Integrated Marketplace, resources can submit three different lead times: cold, intermediate, and hot. Thermal resources generally have longer lead times when they are cold as opposed to when they are hot. In the following section, we examine lead times by commitment status and fuel type.

Figure 4–6 shows the relationship between commitment status and start-up time.

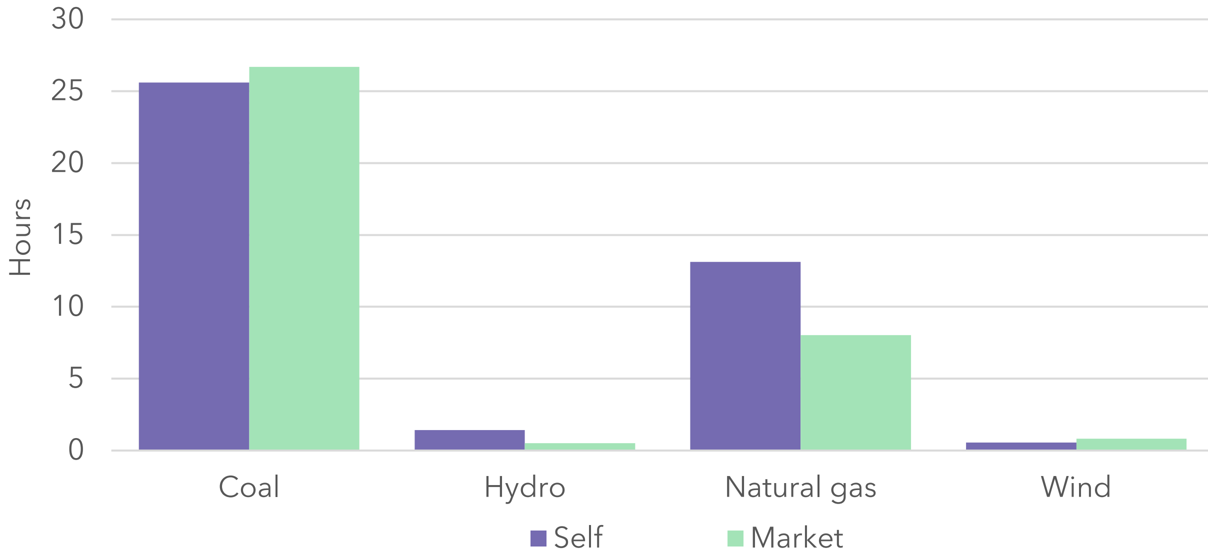
Figure 4–6 Lead time hours by commitment status



Self-committed resources tend to have longer lead times than market-committed resources. Because centralized unit commitment must observe constraints other than cost, it may not select a unit even if that unit's offer falls below the marginal resource.

Coal units have the longest cold start-up time, followed by natural gas. Figure 4–7 shows the dispatch megawatt weighted cold start-up time by fuel type by commitment type

Figure 4–7 Dispatch megawatt weighted lead time by fuel type by commitment status



Natural gas generators have the largest difference in start-up times between self-committed and market committed resources compared to other resources. Coal resources show relatively little deviation in their cold start-up time.

4.4 UNIT COMMITMENT – START-UP COST

Start-up cost is submitted in terms of dollars per start.[39] These parameters also vary widely by fuel type. Like start-up time, resources can submit three different start-up costs: cold, intermediate, and hot. Thermal resources generally have more expensive start-up costs when they are cold, as opposed to when they are hot. Additionally, start-up costs are non-convex which makes it hard for the market clearing algorithm to achieve an optimum solution.[40] However, when price taking behavior combines with good information, the market's efficiency can be improved.[41] In the following section, we examine start-up cost by commitment status and fuel type.

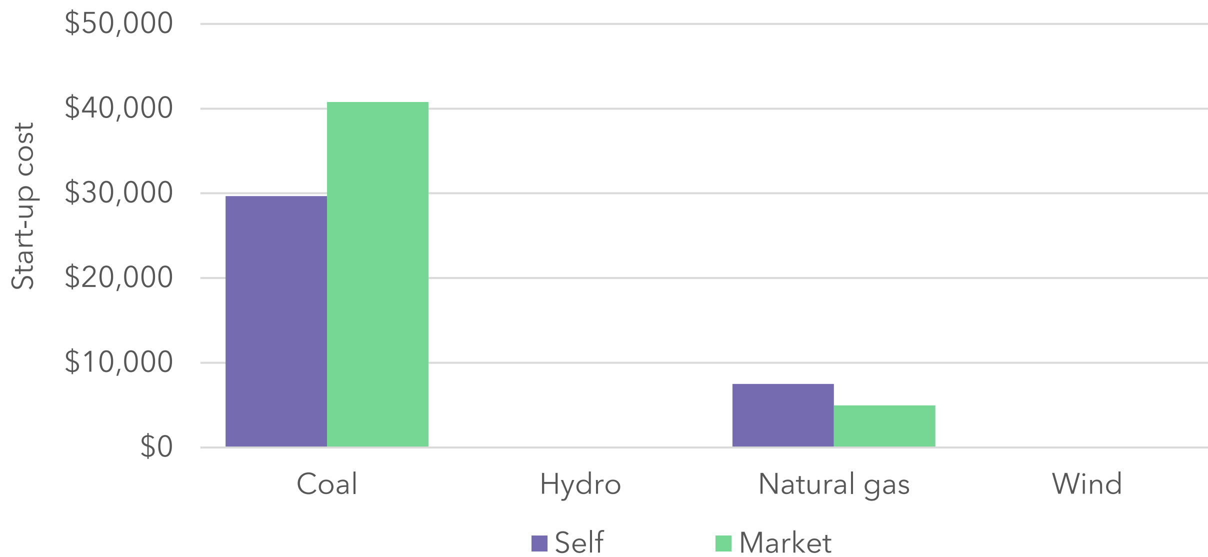
[39] Integrated Marketplace protocols, G.2.6.1 Start- Up Offer Definitions

[40] https://www.ferc.gov/legal/staff-reports/2014/AD14-14-operator-actions.pdf

[41] Steven Stoft, Power System Economics, p.55

Coal units have the highest cold start-up cost by more than a factor of five over the next highest start-up cost fuel type as seen in Figure 4–8. Coal start-up costs and gas start-up costs correlate strongly with gas prices.[42]

Figure 4–8 Dispatch megawatt weighted start-up cost by fuel type by commit status



Unlike start-up time, start-up cost differs materially for both coal and natural gas resources by commitment type. The difference between the market-committed cold start-up cost of coal and natural gas is even more significant than the relationship called out in Figure 4—7. Interestingly, market status based coal start-up costs exceed the start-up costs of self-committed resources. In market status, the cold start-up cost of coal exceeds that of natural gas by a factor of more than eight to one.

4.5 UNIT COMMITMENT – START-UP OFFERS

Start-up offers are generally representative of the cost that a market participant incurs when starting a generating unit from an off-line state to its economic minimum as well as the cost to eventually shut the unit down. These offers are submitted in terms of dollars per start.

[42] Over the study period, the correlation between natural gas start-up costs and Henry Hub gas prices is 78 percent, whereas the correlation between coal start-up costs and Henry Hub gas prices is 65 percent.

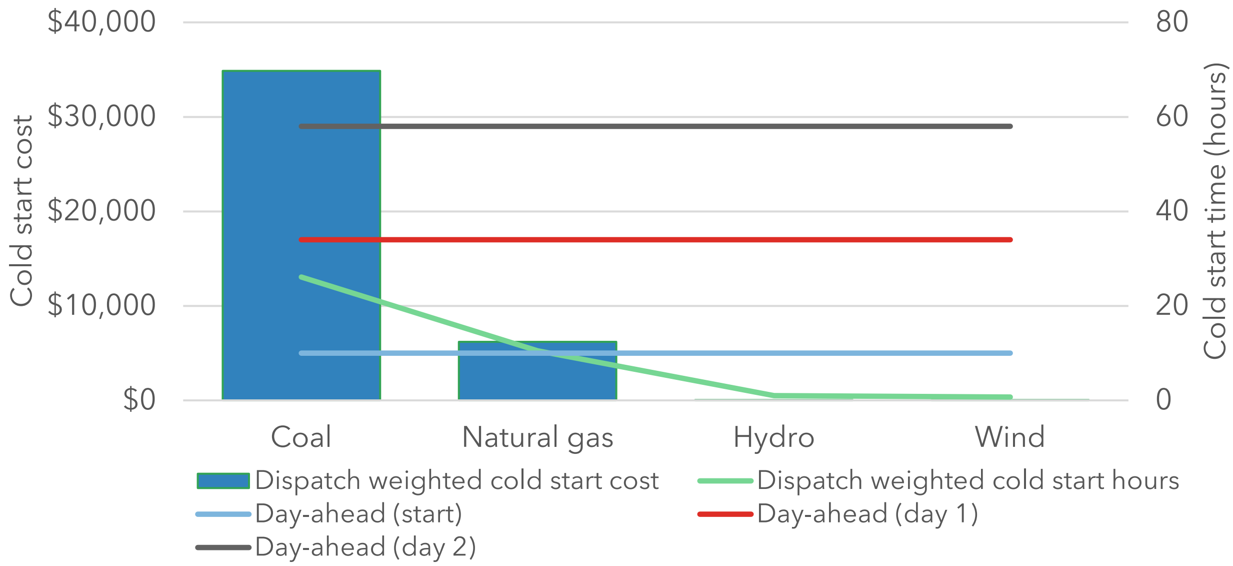
However, the optimization evaluates the offer in dollars per start per hour. The start-up cost is optimized and later amortized over the lesser of the resource's minimum run time or the number of hours from start time through the end of the day-ahead market window.[43]

While the financially binding day-ahead market covers only one operating day, the day-ahead market optimizes over a two-day window – the operating day and the next operating day. However, only the results from day one of the unit commitment solution feed forward to the economic dispatch algorithm. The results from the second day of the optimization are non-binding and are not used for commitment purposes. The two-day optimization helps prepare for the following day's morning ramp and attempts to prevent any unnecessary starting and stopping of units from one day to the next.

Figure 4–9 compares cold start time and cold start cost (y-axes) by resource fuel type (x-axis). The horizontal reference lines (blue, red, black) call out various periods in the day-ahead market window. Hour 10 represents the time from the posting of day-ahead market results to the beginning of the day-ahead market day. The second line at hour 34 represents the end of the first day-ahead market day and the beginning of the second day-ahead market day. The third line at hour 58 represents the end of the second day-ahead market day. The blue bars relate to the left axis and the lines relate to the right axis. These two inputs are used in the construction of the start-up offer.

[43] The day-ahead market window covers two days.

Figure 4–9 Cold start time and cold start cost by resource fuel type



Many of the units with high start-up costs have minimum run times that extend past the day-ahead market window. If the optimization evaluated start-up costs over each resource's full minimum run time, their start-up offers would be more competitive with shorter lead-time resources. This issue compounds for those resources with long lead times and high start-up costs. Because these units cannot come online until much later than the first hour of the day-ahead market day, their start-up cost is optimized over even fewer hours.

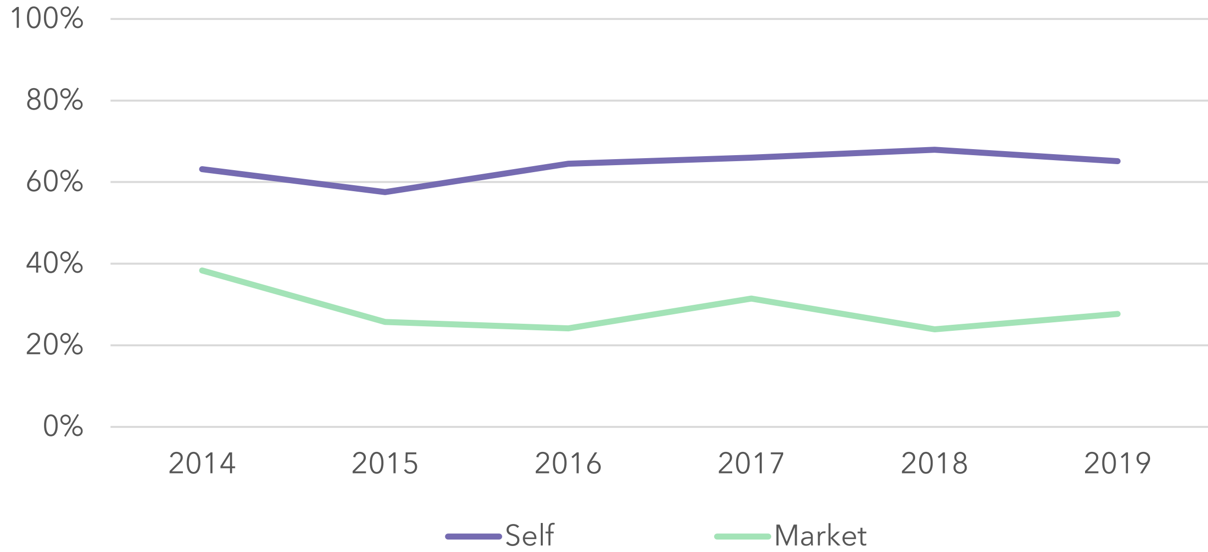
4.6 UNIT COMMITMENT – THE CAPACITY FACTOR

Because of the relationship between fixed cost and variable cost inherent in power generation, capacity factors are a central input when calculating a generator's long run average cost and by extension their long run economic viability.

A capacity factor is the ratio of energy output for a given period (usually a year) to the maximum possible energy output over the same period. The more energy a resource produces, the lower its fixed cost per unit of production. The relationship between fixed cost and marginal cost is often referred in other industries as operating leverage. If fixed costs are significantly larger than variable costs, a firm will exhibit high operating leverage.

The higher the operating leverage the more profit earned from an incremental sale and the more lost from a lost sale. The capacity factor is effectively the ratio of sales to potential sales for power plants.

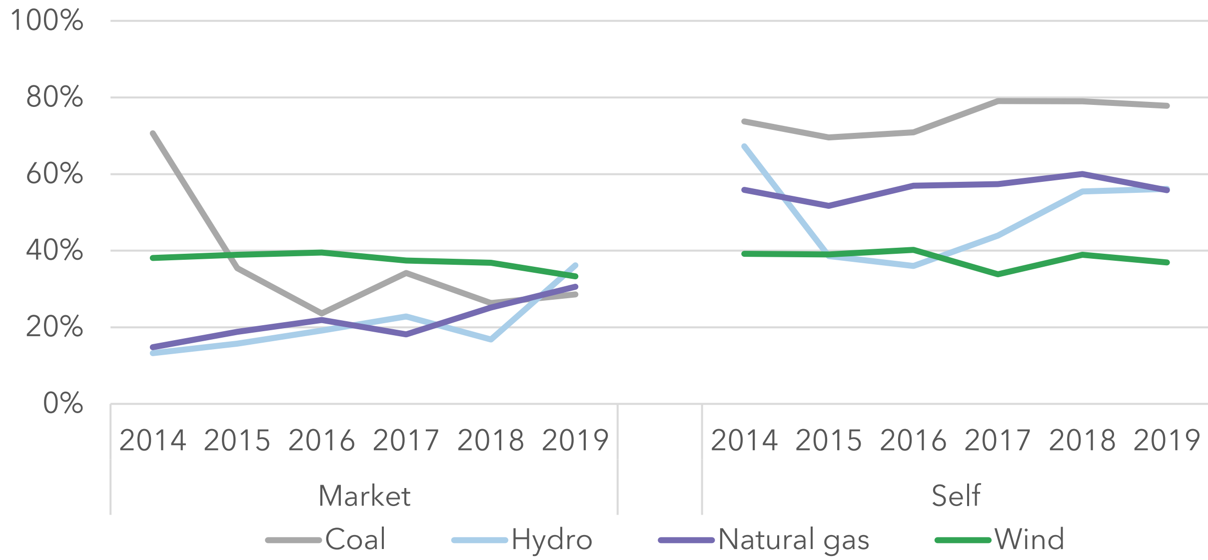
Figure 4–10 Capacity factors by commitment type



Over all resource fuel types, capacity factors roughly double when resources offer in self-status, as opposed to market-status.

Figure 4–11 shows the capacity factors by commitment type by fuel type. This figure shows that some fuel types (such as wind) have comparatively similar capacity factors irrespective of their offer status. However, some fuel types (such as coal and natural gas) have vastly different capacity factors when they are committed in market or self.

Figure 4–11 Capacity factors by fuel type by commitment type



Similar to capacity factors by fuel type, some turbine types have quite similar capacity factors when they are committed in market or self-status.

5 PRICE FORMATION

In this section, we build upon the price portion of the market feedback loop discussed earlier. Specifically, we provide empirical information and analysis reflecting the prices and production costs over the study period.

Key points from this section include:

- Over the study period, at least one self-committed unit was marginal in roughly 75 percent of the day-ahead market hours.[44]
- Over the study period, prices were systematically lower when at least one self-committed unit was marginal.
- In almost all cases, self-committed generators had lower revenues than market-committed generators because of negative congestion prices.
- In SPP's case, consumers and producers are not necessarily two distinct, organically separated groups.[45] This dynamic makes the impact of price levels and production costs less clear.

5.1 IMPACT OF SELF-COMMITMENT ON PRICE FORMATION

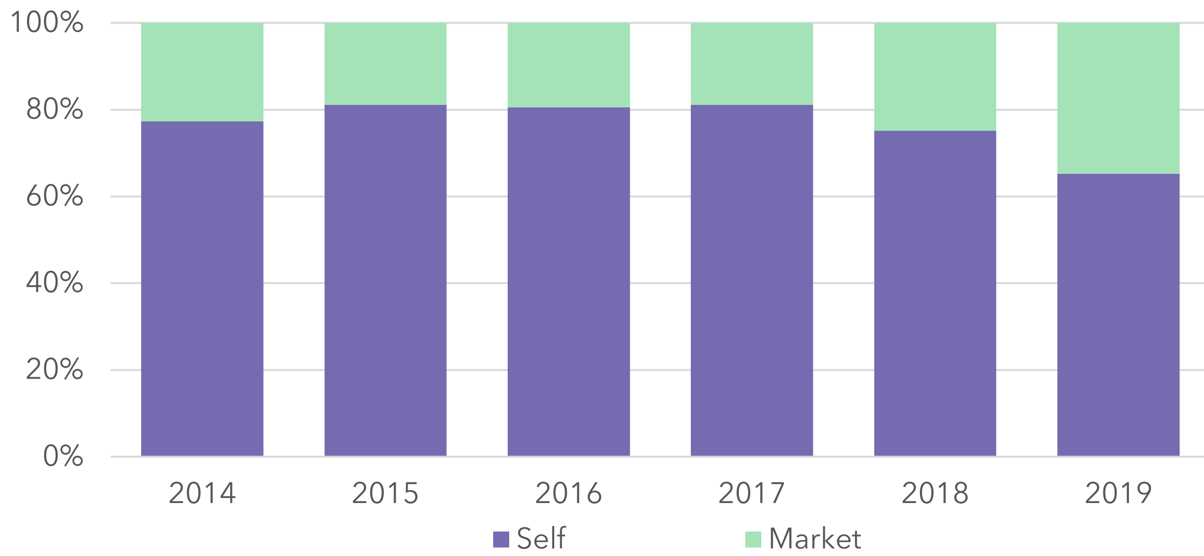
To quantify the impact of self-commitment on prices and price formation, we evaluate the frequency and magnitude of self-commitment in addition to the time it sets price. Self-committed resources can set price as many self-committed generators offer their incremental

[44] More than one resource can be marginal during a given period.

[45] The participants—primarily the investor owned utilities—who serve load may also own or control both generation and transmission assets. In fact, in 2018 investor owned utilities owned 53 percent of the total nameplate generation capacity in the SPP market.

energy into the market. Self-dispatched resources are resources that do not allow the market to choose their incremental energy output.[46]

Figure 5–1 Percentage of day-ahead hours by marginal resource by commitment type



Over the study period, at least one self-committed resource was marginal in substantially more than half of the day-ahead market hours. For the purposes of Figure 5–1, if during an hour, a single marginal generator was self-committed, that hour is classified as self. If only market committed generators were marginal during the hour, that hour is classified as market.

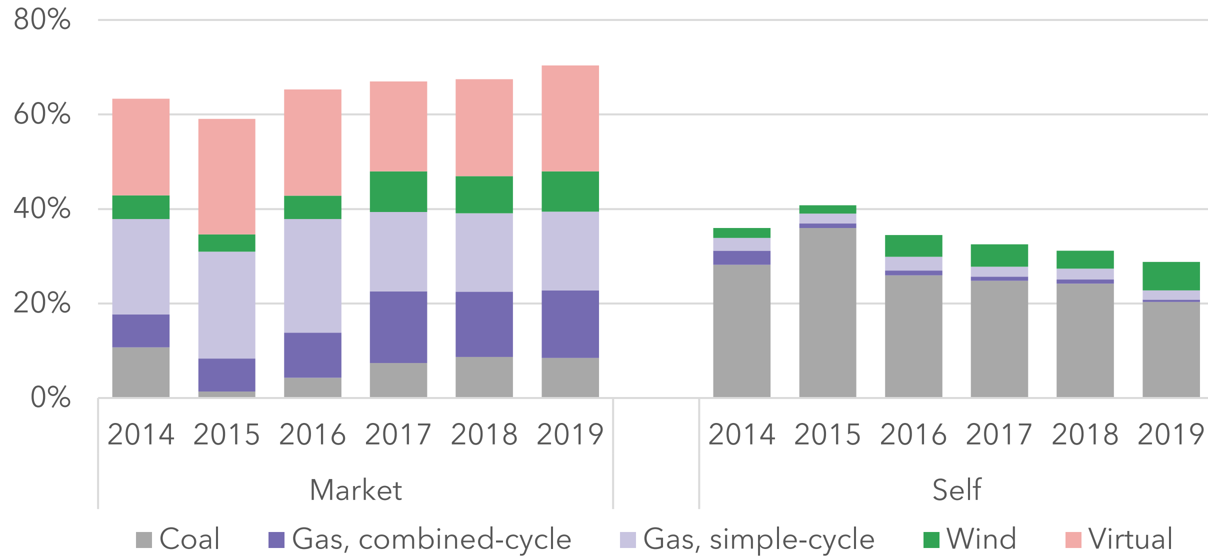
Even though self-committed generators are treated as price insensitive suppliers in the unit commitment process, these same generators can set the marginal clearing price if they provide the marginal unit of supply when dispatched above their economic minimum. These units may not have been committed by the centralized unit commitment had they been offered in market-status, and by extension, may not have otherwise been marginal. This is one of the reasons market participant's unit commitment decisions can affect price formation.

However, in any given hour, there is likely to be more than one marginal price setting resource because of the effects of transmission congestion. Figure 5–2 captures this effect. It looks at all

[46] For example, non-dispatchable variable energy resources (NDVERs) are self-scheduled as opposed to self-committed. However, for the purposes of this analysis, we have including NDVER as self-committed.

the marginal resources in the market and finds that over the study period, market-committed resources[47] were on the margin setting prices during roughly two-thirds of all instances in the day-ahead market whereas self-committed resources set prices during roughly one-third of all instances day-ahead.

Figure 5–2 Percentage of marginal hours by fuel type

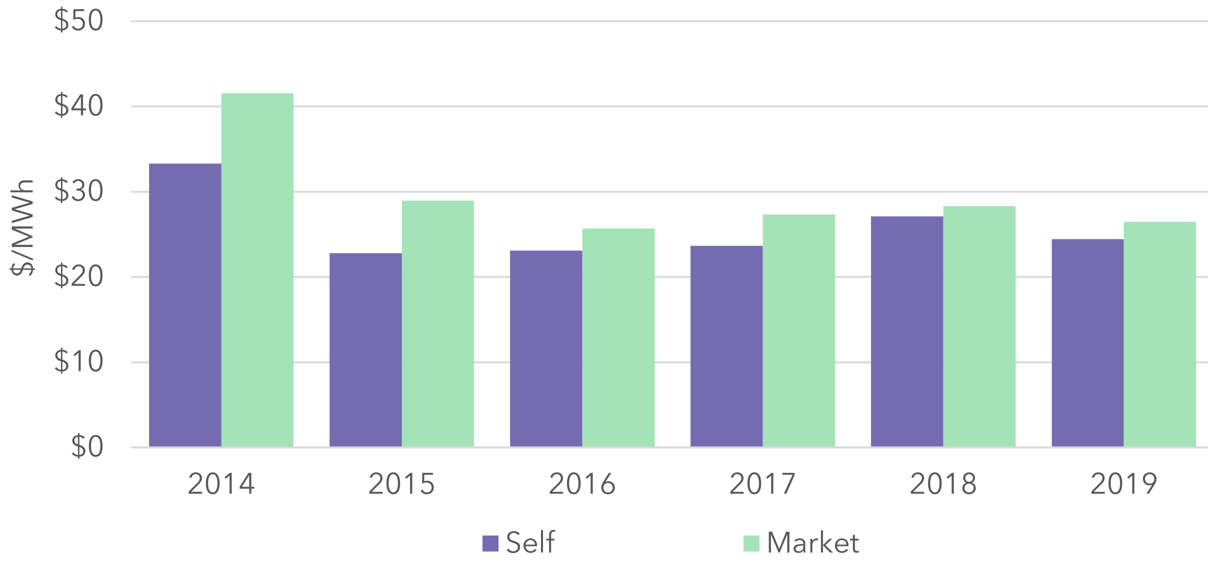


Of the market committed-units, wind, virtual, and combined-cycle gas resource types have increased their time setting prices on the margin, while simple-cycle gas and coal generators have decreased their time setting prices on the margin.

Of the self committed-units, coal dominates the time on the margin compared to all other fuel types. Wind on the margin continues to grow, whereas the frequency of coal on the margin, while still quite large, continues to decline.

[47] We have classified virtual transactions as market committed for the purpose of this analysis.

Figure 5–3 Average day-ahead system marginal prices by marginal unit commitment type



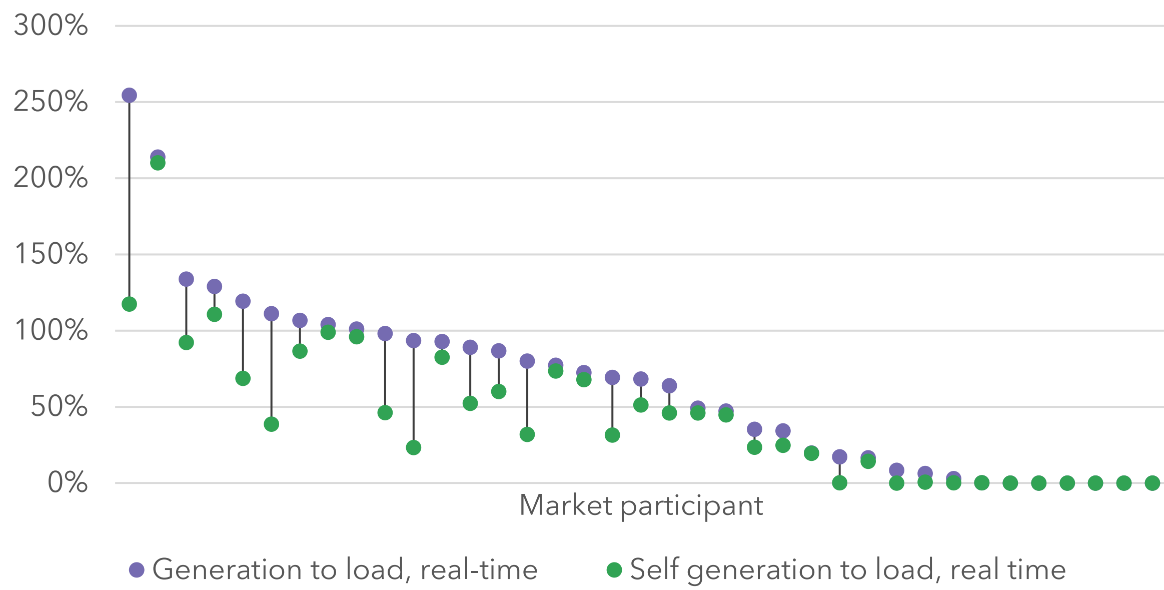
Over the study period, prices were systematically lower when at least one self-committed unit was marginal.

5.2 WHO PAYS?

SPP market participants have indicated in stakeholder meetings, that in a cost-of-service regulated market, when participants are vertically integrated, the load ultimately pays and therefore will benefit from lower prices and production costs. However, when participants are vertically integrated, the load is also the generation in terms of integrated ownership. Low prices do indeed benefit load, but they do not benefit generation. Because these entities are not distinct, and must carry generation capacity to meet their capacity obligation, the "who benefits" question with respect to the level of prices is nuanced.

Figure 5–4 highlights two things. First, it shows the level of generation produced by a participant relative to its load. Second, the figure shows the level of self-committed generation relative to its load.

Figure 5–4 Generation megawatts to load megawatts by commitment type



The purple dots above 100 percent line denote a market participant who produced energy in excess of its real-time load obligation. The inverse indicates a market participant who produced less than their real-time load. In a competitive market, it would be expected that some would produce more than their load and some would produce less, as lower cost resources would displace higher cost resources.

The green dots show the self-committed generation relative to load. The green dots above the 100 percent line denote a market participant whose self-committed energy production exceeded their corresponding real-time load. The inverse indicates a market participant whose self-committed units produced less than their real-time load.

The figure shows that there are three participants that self-committed more generation than their load. In this case, the participant would be selling self-committed generation to the market. Furthermore, the chart shows that some participants self-committed almost all of their generation (purple and green dot the same or very close) and that the majority of participants self-committed some generation. This highlights how difficult it is to determine who benefits from higher or lower prices.

5.3 CONGESTION

Congestion price signals incentivize the behavior of market participants. When locational marginal prices are elevated, generators in that particular pricing node earn more. Because every node in the system includes the system marginal price, the difference in locational marginal prices stems mostly from the marginal congestion component of the locational marginal price.

Congestion affects all resources. However, in the SPP market, it tends to affect resources differently as seen in Figure 5–5. Natural gas resources tend to have higher prices as a result of congestion, while coal and wind resources tend to have dramatically lower prices. The congestion profile is more balanced for units that market-commit. Some market generators earn more than the system marginal price and some earn less, whereas generators who self-commit almost always earn less than the system marginal price.

Figure 5–5 Congestion dollars by fuel type, by commitment status

Additionally, Figure 5–5 brings to light an additional price signal. Congestion prices, similar to energy prices, provide feedback to market participants. When congestion reduces generator revenues, the market's general message is twofold: generators are incented to do less of what they are doing in the short-run and generators are incented not to build additional generation in the long run. The market also uses congestion to convey information to transmission owners.

In this case, if participant behavior does not change, transmission owners will likely be incented to build additional transmission infrastructure. When generator congestion is positive, the market generally conveys the opposite information to market participants. As an extension of our message in Section 3, self-commitment also blurs the congestion price signal.

In Figure 5–5, the green bars represent the market commitments and is more desirable than the purple bars because the unit commitment process committed that resource, not the market participant. What we do not know, however, is if the market-committed unit earned its commitment to offset a constraint created or enhanced by a self-committed unit. The purple bars below zero might also represent the market software attempting to incent different commitment behavior.

Both generators and loads are assessed congestion costs. Generators pay congestion through reductions in the locational marginal price. Loads pay congestion through increases in the locational marginal price. On balance, we observe that generation has been assessed more congestion than load in the Integrated Marketplace.[48]

Because self-commitment affects congestion, it also affects SPP's congestion hedging market. One way of scaling this impact is to compare average transmission congestion right (TCR) profitability by marginal unit commitment type by hour, which is the same classification methodology used in Figure 5–1.

[48] MMU Quarterly State of the Market Report, Spring 2019, Special Issues

Figure 5–6 Transmission congestion right revenue per megawatt by marginal unit commitment status

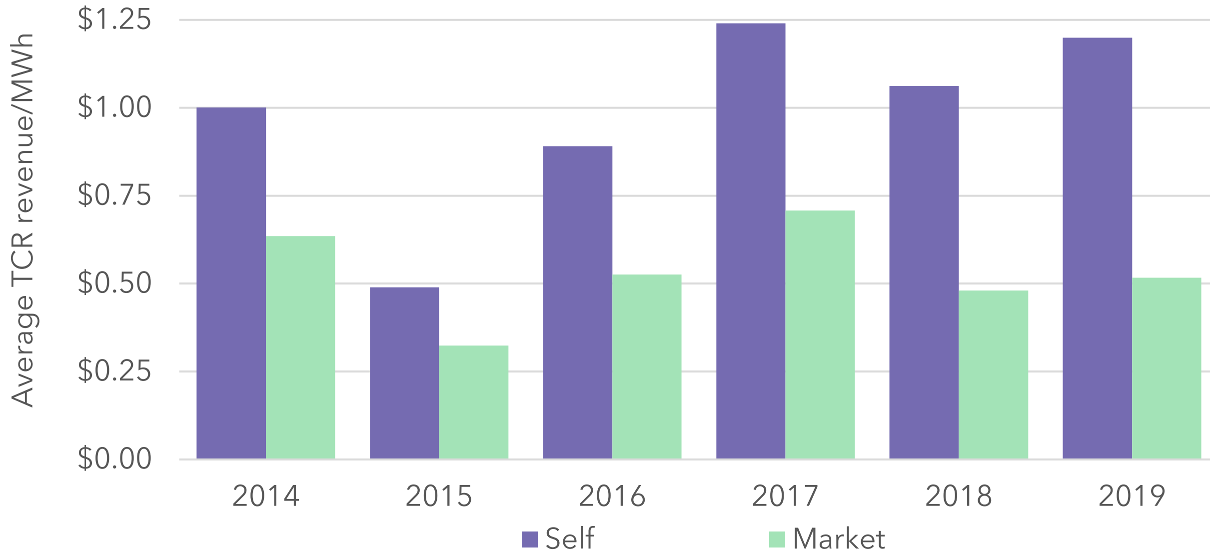


Figure 5–6 shows the revenue per megawatt of transmission congestion rights[49] was significantly higher when at least one self-committed unit was marginal. Our general takeaway is that in hours when at least one self-commit unit is marginal the system is more congested when compared to hours where only market-committed units are marginal. By extension, the congestion revenues from congestion hedges increase during hours where at least one self-committed unit is marginal.

[49] Figure 5—6 includes self-converted transmission congestion rights, long-term transmission congestion rights, and the positions purchased and sold in the various auctions.

6 SELF-COMMITMENT SIMULATIONS

In this section, we perform three simulations to study the effect of market committing resources that participants currently self-commit in the day ahead market.

6.1 OVERVIEW

To study the impact of self-commitment on market results, we re-solved the Integrated Marketplace's day-ahead market. In our study, we executed three scenarios using the effective version of the actual Integrated Marketplace software associated with each operating day. In each of the scenarios, we simulated the centralized unit commitment and economic dispatch optimizations.

In our first scenario, we validated our process by rerunning the original day-ahead market and compared the validation results to the original results. The validation cases were then used as the base inputs to scenarios two and three.

In scenario two, we changed the offer status from self to market for all resources that originally elected self-status. We also turned off all resources, so the market could make all unit commitment and dispatch decisions without optimizing the generators already producing power. Scenario three builds on scenario two, and includes the same input modifications in addition to reducing lead times to simulate extending the day-ahead market optimization window.

Findings from the simulations include:

- The key to reducing self-commitment while not increasing costs is multi-day economic unit commitment.[50]

[50] Our position supports the findings of The Holistic Integrated Tariff Team's Reliability Recommendation #3 – Implement Marketplace enhancements. Specifically, Multi-day market.

- Increasing the optimization window by another 24 hours allows the market to more effectively optimize resources with long start-up times. This enhancement combined with a reduction in self-commitment, would likely benefit ratepayers by reducing production costs in addition to sending more clear investment signals.
- If the optimization window is not lengthened, and self-commitment is eliminated, investment signals would be more clear, but production costs would likely increase.

6.2 STUDY DETAILS

6.2.1 SCENARIO 1 – VALIDATION SCENARIO

The purpose of the validation scenario is to determine the legitimacy of our testing framework. As with many electricity markets, SPP's software uses a mixed-integer optimization program that solves for optimal commitment and dispatch. Because of the nature of this type of software, it is not always possible to reproduce the original results even with identical inputs. For this reason, we rejected several market days from our study where the hourly production costs fell outside our tolerance when compared to the original market solution.[51]

Because of simulation run-time constraints, the study period includes one week of each month from September 2018 through August 2019. In addition to the data being readily available, this period also includes the different annual seasons and a wide variety of market conditions. The testing criteria, sample size, and results of our validation scenario gives us confidence in our process.

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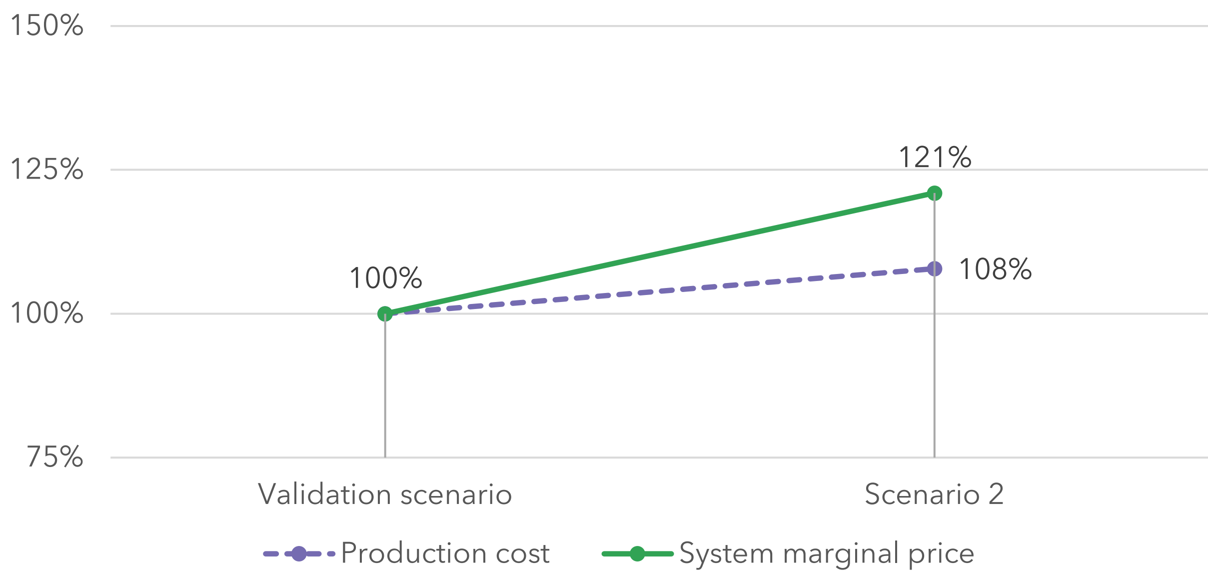
[51] We discarded market days for which the coefficient of determination of hourly production costs between the original market solution and the validation solution were less than 95 percent, representing about eight percent of market periods simulated. The remaining days averaged 99.5 percent coefficient of determination between the original solution and the validation solution. When simulating a market day, small differences in the calculation of hourly commitment or dispatch levels can compound in subsequent hourly solutions, leaving the final solution set for a day significantly different from the original market solutions.

6.2.2 SCENARIO 2 – UNITS CHOOSE "MARKET"

A number of changes were made to the validation data set prior to executing scenario two. Resources that were originally offered to the day-ahead market in self-status were set to market-status, de-committed at the start of each study period, and treated as having met their minimum down time before each continuous study period to allow for immediate commitment by the market engine.

Figure 6–1 shows the results of scenario two in terms of change in prices and production cost relative to the validation scenario.

Figure 6–1 Scenario 1 vs Scenario 2, system marginal price and production cost



In scenario two, marginal energy prices increased in excess of twenty percent, which was more than $6/MWh. Also in scenario two, production costs increased roughly eight percent, or more than $22,000 per hour. The results suggest that the current market software cannot more efficiently commit and dispatch all available units in the absence of self-commitment. As we discussed earlier in this report, the length of the optimization period is one of the software's limitations. As such, scenario two represents the market software's optimal solution given the current market structure if all resources did not self-commit.

6.2.3 SCENARIO 3 – UNITS CHOOSE "MARKET" AND OPTIMIZE LONG LEAD TIMES

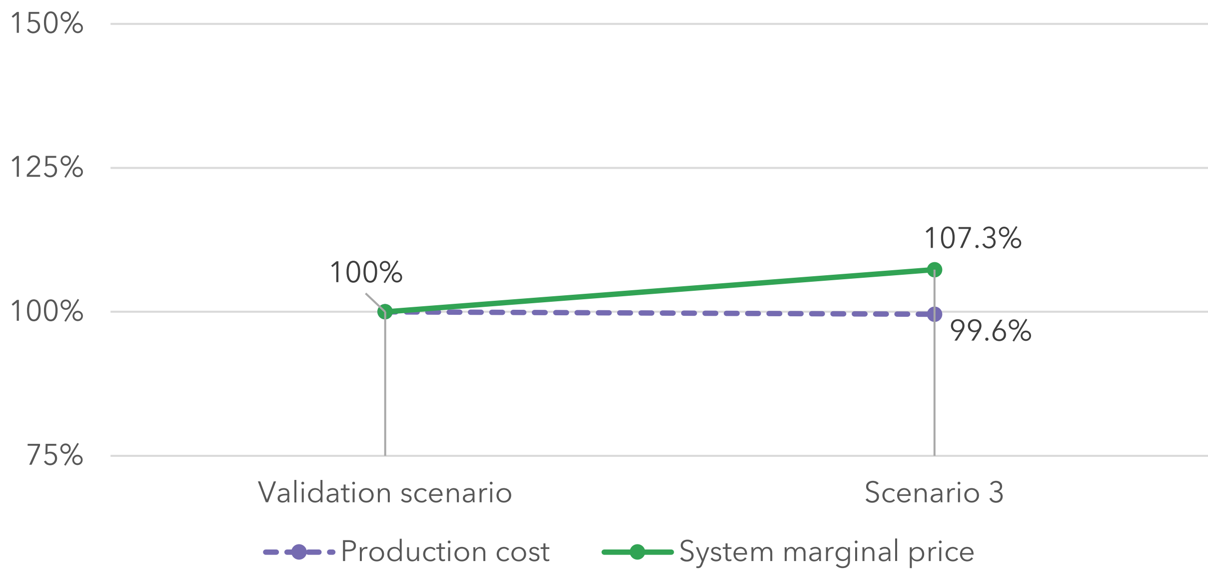
Scenario three expands on scenario two by simulating the lengthening of the optimization period of the day-ahead market. Effectively, this scenario attempted to create a multi-day economic unit commitment. This enhancement directly addresses one of the current limitations of the market software – optimizing long-lead time resources. As we mentioned in the unit-commitment section, long-lead time resources, especially those with high start-up costs, tend to be uncompetitive, in part, because of the duration of the current market optimization window.

Lengthening the optimization window includes long-lead resources that would otherwise be excluded from the optimization and decreases the hourly-amortized start-up amount, making these resources more competitive. Lengthening the optimization window by an additional day resolves the majority of these cases.

The length of the optimization window is not configurable in the current software. Therefore, to simulate an increased optimization window, we decreased the start-up times of resources with startup times greater than 23 hours to 12 hours. This change allows the current day-ahead market software to commit the resource in a manner which simulates the presence of a lengthened economic commitment mechanism.

Figure 6–2 shows that in this scenario prices increased, but production cost decreased when compared to the validation scenario.

Figure 6–2 Scenario 1 vs Scenario 3, system marginal price and production cost

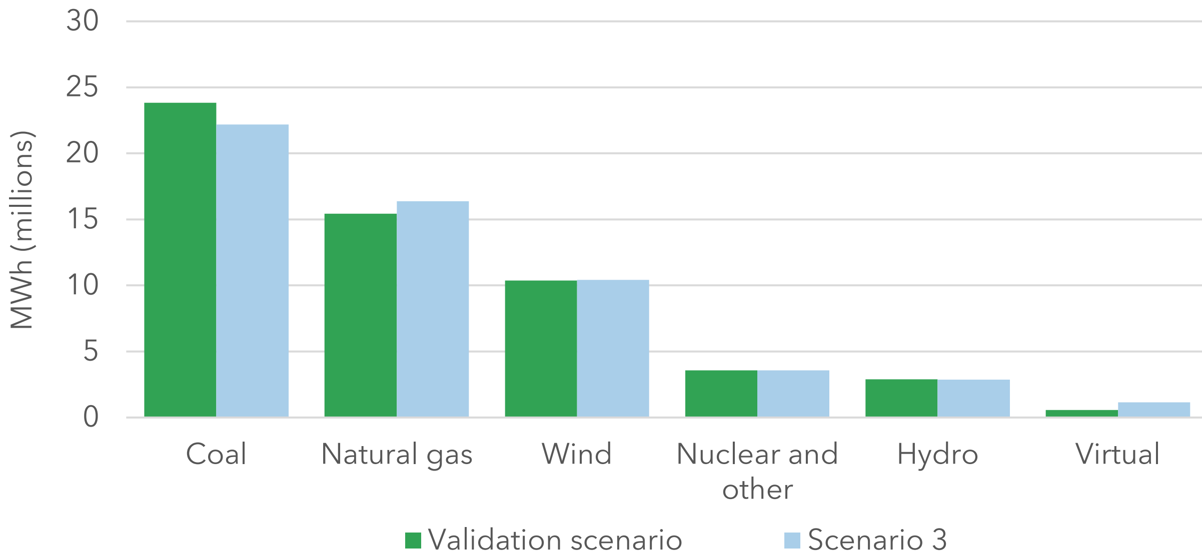


On average in every hour of the study period, system marginal prices were higher when all units market-committed. This is the same directional result as in scenario two and a predicted result based on the change in the supply curve as discussed in section two. The average system marginal price over all hours increased more than seven percent, about $2/MWh on average. The average production cost change over all hours decreased roughly one-half of one percent, or $1,750 per hour.

These results suggest that a purely economic commitment model, if able to consider and commit long lead-time resources, would lead to somewhat higher market prices and potentially more accurate investment signals while potentially reducing production costs. Given this result, we would prefer scenario three to scenario two.

Not only did the optimization change prices, it also changed dispatch quantities. Figure 6–3 shows the change in dispatch megawatts between scenario three and the validation scenario.

Figure 6–3 Scenario 1 vs Scenario 3, dispatch megawatts by fuel type



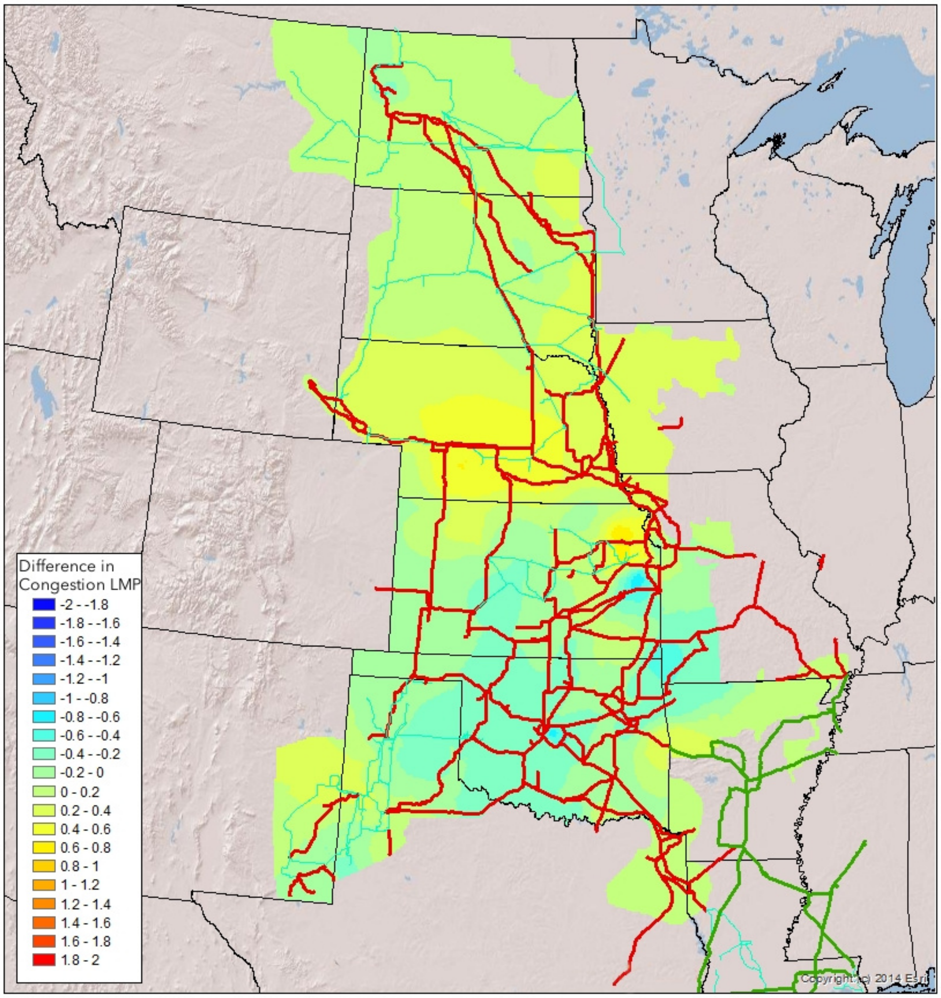
In scenario three, coal energy awards decreased seven percent, when compared against the validation scenario. Natural gas and virtual supply replaced the majority of the reduction in coal. Because changes in self-commitment affect prices, and virtual participation is based on projected prices, we expect virtual trading behavior would also change. However, we are unable to simulate how virtual participants might change their behavior in this analysis.

Any structural change to the SPP markets would likely cause a redistribution of marginal generation that can have far-reaching impacts on congestion, local pricing, and congestion hedging products. In order to visualize the net congestion differences between the original market solution and this scenario, we graphed the difference in the marginal congestion component (MCC) of the locational marginal price over the study period.

Generally, congestion reflects supply and demand relationships between producers and consumers in a given area. When an area is oversupplied with generation, congestion prices tend to be lower. Likewise, an area undersupplied with generation will tend to have higher congestion prices. This framework translates into the figure below.

Figure 6–4 shows the change in congestion between scenario three and the validation scenario. Higher congestion prices (yellow and orange) indicate increase in prices from the validation scenario to scenario three, and lower prices (green and blue) reflect price reductions in scenario three relative to the validation scenario. Ultimately, changes in congestion prices ranged between a decrease of approximately $1/MWh and an increase of approximately $1/MWh over the study period.

Figure 6–4 Scenario 1 and Scenario 3 comparison, difference in congestion costs



The majority of the supply reductions are in the coal-dominated regions of the footprint, which leads to a slight increase in congestion pricing in those areas. Accordingly, much of the replacement energy committed and dispatched to serve the day-ahead demand comes from gas-fired generation in the southern portion of the footprint, leading to a slight reduction in congestion pricing around those units.

7 CONCLUSION

Self-commitment represents a significant portion of the transaction volume in the Integrated Marketplace, and while it cannot be eliminated completely, the practice can likely be reduced substantially. By reducing self-commitment, prices and investment signals will likely be less distorted. A smaller distortion will likely help market participants make better short-run and long run decisions, which tends to coincide with improved profit maximization. Enhanced profit maximization combined with effective regulation and monitoring will likely lead to ratepayer benefits in the form of cost reduction.

While we have seen gradual reductions in self-commitments over the last few years, generation from self-committed generators still represent about half of the generation in the SPP market. Given our results, we recommend that the SPP and its stakeholders continue to find ways to further reduce self-commitments. Many resources have switched from self-commitment to market status over the past few years, and it is possible that many more could switch without any market enhancements.

However, as we presented in our simulations, simply eliminating self-commitment without any additional changes could result in an increase in total production costs. This would not necessarily be an improvement when compared to today's results. However, when lead times were shortened to reflect an additional day in the market optimization and self-commitment was eliminated, producers were paid more and production costs declined.

The efficiency gain stems largely from an improvement in the optimization of nonconvex costs, specifically start-up costs. In the current construct, units with long lead times, high start-up costs, and long minimum run times may be uneconomic over a single day, but economic over a longer period. Extending the optimization period helps bridge this gap. However, as the optimization period lengthens, it must solve for variables further into the future where there is more uncertainty. However, empirical evidence suggests that the accuracy of wind and load forecasts remain acceptable over a two-day optimization window.[52]

For these reasons, and others covered throughout this report, we support the HITT recommendation of evaluating a multi-day optimization,[53] and see this as an enhancement that can improve market efficiency and help further reduce the incidence of self-commitment. Specifically, we recommend that SPP and its stakeholders consider a multi-day commitment period of two days to allow units to commit long lead time resources.

[52] Market Working Group Meeting Materials – February 2019 – 10.b.i.MultiDay Forecast_021919

[53] See footnote 50.