



California ISO

# Exploring Commitment Cost Inclusion in Fast-Start Pricing

California ISO Staff Presentation

Price Formation Working Group  
February 12, 2024


## Housekeeping reminders

- This call is being recorded for informational and convenience purposes only. Any related transcriptions should not be reprinted without ISO's permission.
- These collaborative working groups are intended to stimulate open dialogue and engage different perspectives.
- Please keep comments professional and respectful.
- Note: The ISO encourages any verbal or written agreements to comments made during this working group session.
- You may also send your question via chat to either Brenda Corona or to all panelists.

## Great news with Intellor platform, specifically around audio while joining meetings

- The “call me” feature now enabled when joining Operator assisted meetings.
- I have a very positive update regarding the Webex Webinar(s) you have scheduled with us for January 2024. Integrated Webex telephone audio is now enabled for these webinars – meaning, speakers and attendees can join Webex and then use the call-me feature for the best experience. (We will still open the separate teleconference in case any of your attendees choose to use it.)

## Instructions for WebEx

- The “raise hand” icon is located in the lower tool bar. You will hear a beep tone when you are un-muted; at that time please state your name, and question. Attendees dialed in on the phone only press #2 will hear a notification when you are un-muted; at that time please state your name and question. 
- WebEx platform will **LOCK** and mute you if you mute yourself once you have finished your question. Do not mute yourself until you have completed your question or comment.

# Purpose of the workshop

- On December 12, 2023, the CAISO presented draft results from analyzing potential market impacts of fast-start pricing.
- This workshop aims to educate stakeholders about the methods used in the analysis to incorporate commitment costs into the price, as well as explore methods used in other markets.
- Understanding this topic is crucial for stakeholders to grasp CAISOs ongoing analysis of fast-start pricing's potential impact on the Western Energy Imbalance Market.

# Fast-start pricing

- Fast-start pricing methods vary across markets but intend to “recognize that fast-start resources are...the marginal resource used to meet the next increment of energy or operating reserves demand.”
- Two common features:
  - Relaxing the minimum output constraint in the pricing run
  - **Including commitment costs in the price calculation**

← Today's focus

# Fast-start pricing

## Scheduling Run

- Does not change resource parameters
- Establishes dispatch points
- Does not determine prices

## Pricing Run

- Changes resource parameters
- Determines prices

## Why does fast-start pricing incorporate commitment costs into Locational Marginal Pricing (LMP)?

- The market can commit fast-start resources in real time, close to when they are needed to serve load.
- Consequently, the market incurs the costs of committing these resources around the same time as the incremental energy costs.
- Therefore, fast-start pricing suggests including commitment costs in the LMP to more accurately reflect the cost of serving load.



## How does fast-start pricing incorporate commitment costs in LMP?

- It integrates commitment costs into the variable bid range.
  - As a result, LMPs will include these commitment costs.
- There are two common methods for this integration:
  - Modified offer curves (used by NYISO, ISO-NE, SPP)
  - Integer relaxation (used by PJM, MISO)
  - We discuss these methods at a high level and do not intend to include every detail from other market designs. We exercised diligence to ensure the information's accuracy but take full responsibility for any misrepresentations of other market designs.

\*CAISO uses a modified offer curve methodology for pricing of Constrained Output Generators (COGs)

# Modified Offer Curves

- The market adds the amortized commitment cost to a resource's incremental cost before solving
  - Commitment costs include start-up costs, minimum load costs, and transition costs\*
- We will explore three variations

\*To keep things simple, today's discussion will exclude transition costs.

# Modified Offer Curves

- Incremental offer curves are in units of \$/MWh
- To construct modified offer curves, we must convert start up costs and minimum load costs to \$/MWh units
  - Start up costs are in \$ units
  - Minimum load costs are in \$/hour units

## Start-up costs

- Amortize start-up costs across the resource's maximum output and minimum up time.

$$\frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\}} P_{max} \frac{\Delta t}{60}$$

### Where:

*MUT*: Minimum up time (minutes)

*SUC*: Startup cost in (\$ per start)

$\Delta t$ : Market interval; FMM=15 min

$P_{max}$ : Maximum output (MW)

Note: Alternatives to amortizing SUC over the MUT exist, and we will revisit the question of amortizing these costs later in developing any fast-start pricing proposal.

# Start-up costs

- Amortize start-up costs across the resource's maximum output and minimum up time.

$$\frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max} \frac{\Delta t}{60}}$$

## Where:

- MUT*: Minimum up time (minutes)  
*SUC*: Startup cost in (\$ per start)  
 $\Delta t$ : Market interval; FMM=15 min  
 $P_{max}$ : Maximum output (MW)

You first determine how many time intervals  $\Delta t$  fit into the minimum up time *MUT*. Since  $\Delta t$  is 15 minutes, if the *MUT* is, say, 1 hour (60 minutes), that would be 4 intervals.

The ceiling function, denoted by  $\lceil x \rceil$ , means rounding up to the nearest whole number.

# Start-up costs

- Amortize start-up costs across the resource's maximum output and minimum up time.

$$\frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max} \frac{\Delta t}{60}}$$

The "max" function ensures that you always consider at least one time interval, even if the *MUT* is less than  $\Delta t$ .

## Where:

- MUT*: Minimum up time (minutes)  
*SUC*: Startup cost in (\$ per start)  
 $\Delta t$ : Market interval; FMM=15 min  
 $P_{max}$ : Maximum output (MW)

# Start-up costs

- Amortize start-up costs across the resource's maximum output and minimum up time.

$$\frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max} \frac{\Delta t}{60}}$$

Then, you multiply this number by  $P_{max}$  and scale it to an hourly rate by dividing by 60 (since  $\Delta t$  is given in minutes and there are 60 minutes in an hour).

## Where:

- $MUT$ : Minimum up time (minutes)  
 $SUC$ : Startup cost in (\$ per start)  
 $\Delta t$ : Market interval; FMM=15 min  
 $P_{max}$ : Maximum output (MW)

## Simple example

- 450MW resource
- \$2,000 start-up cost
- 1 hour minimum up time

$$\frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max} \frac{\Delta t}{60}}$$

$$\frac{\$2000}{\max\left\{1, \left\lceil \frac{60min}{15min} \right\rceil\right\} * 450MW * \frac{15min}{60}}$$

= \$4.44/MWh



# Minimum load costs

- Minimum load costs are amortized across the resource's maximum output

$$\frac{MLC}{P_{max}}$$

**Where:**

*MLC*: Minimum load cost (\$/hour)

*P<sub>max</sub>*: Maximum output (MW)

# Minimum load costs

- Minimum load costs are amortized across the resource's maximum output

$$\frac{MLC}{P_{max}}$$

By dividing the minimum load cost by the generator's  $P_{max}$ , you get the cost per megawatt-hour (\$/MWh) when the generator is operating at its minimum load.

## Where:

$MLC$ : Minimum load cost (\$/hour)

$P_{max}$ : Maximum output (MW)

## Simple example

- $MLC = \$5000/\text{hour}$
- $P_{max} = 450\text{MW}$

$$\frac{MLC}{P_{max}} = \frac{\$5000/\text{hour}}{450\text{MW}} = \$11.11/\text{MWh}$$

# Variant 1: Constant amortization derives a single adder that applies to each segment of the variable-cost bid

Given:

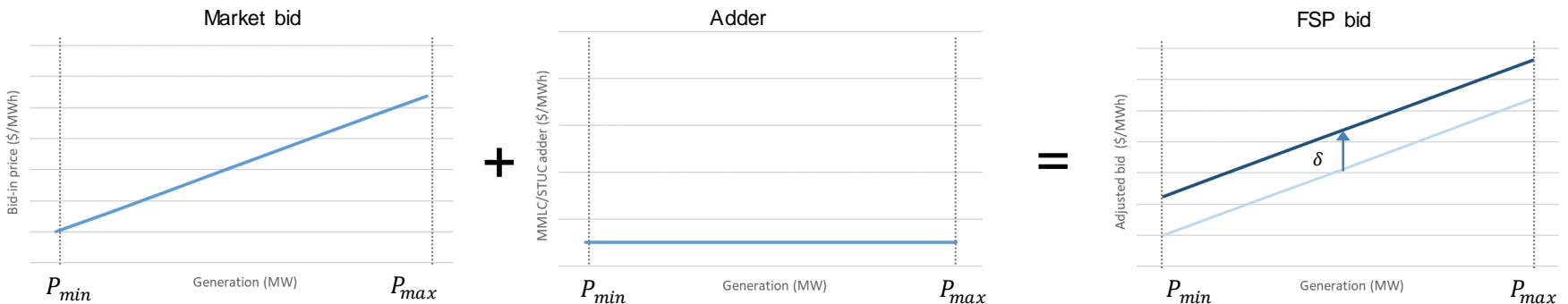
- MUT*: Minimum up time (minutes)
- SUC*: Startup cost in (\$ per start)
- MLC*: Minimum load cost (\$/MWh)
- $\Delta t$ : Market interval; FMM=15 min
- $P_{max}$ : Maximum output (MW)

All elements are parameters and therefore the adder  $\delta$  is a constant

MUT is rounded up to # of intervals  
 If MUT=0 then SUC is amortized in 1 interval

The FSP adder is

$$\delta = \frac{MLC}{P_{max}} + \frac{SUC}{\max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max} \frac{\Delta t}{60}}$$



# Illustration: Simplest amortization scenario is a constant adder through the variable range

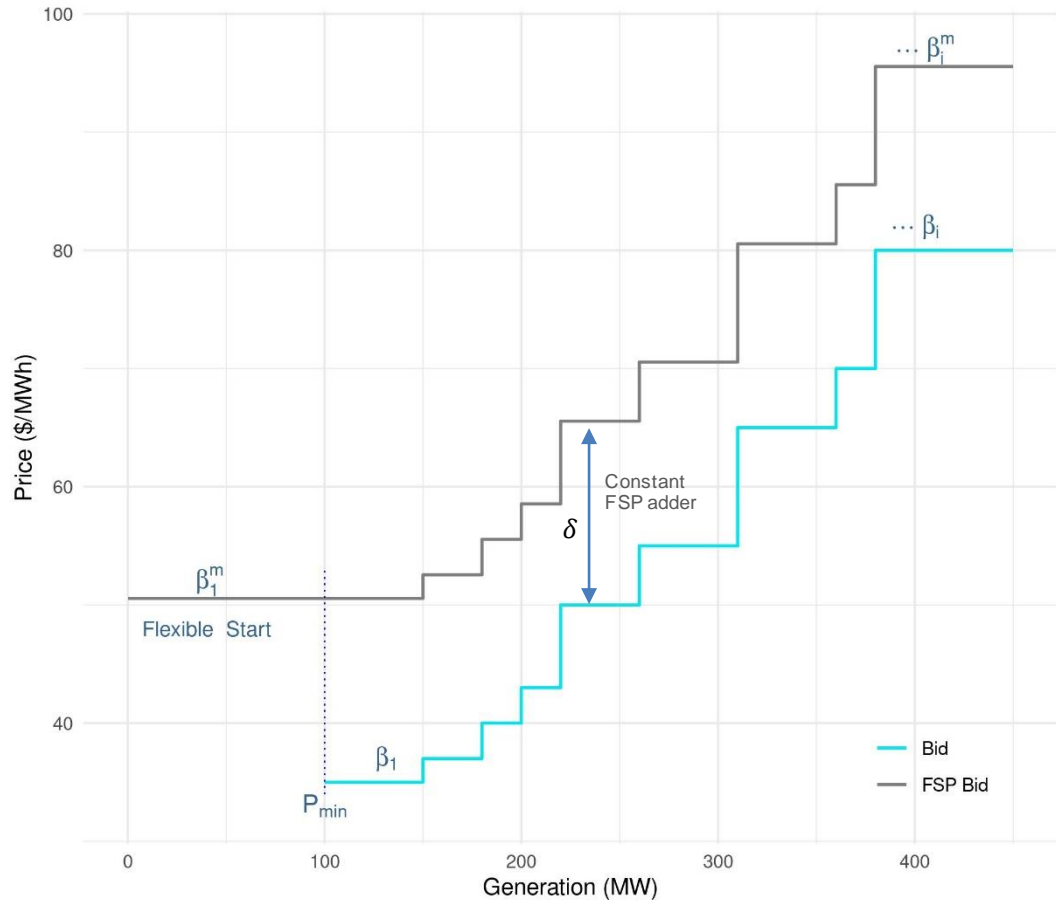
MLC=\$5,000/hr  
 STUC=\$2000 per start  
 MUT= 1 hr  
 PMAX = 450MW

A constant adder is estimated to reflect Both MLC and STUC

$$\delta^e = \frac{\$2000 + \$5000}{450 \text{ MW}} = \$15.55/\text{MWh}$$

This adder applies to each segment of the bid

First segment is extended to 0 MW to model a flexible start



# Variant 2: Constant amortization with an adjustment to MLC

Given:

$MUT$ : Minimum up time (minutes)

$SUC$ : Startup cost in (\$ per start)

$MLC$ : Minimum load cost (\$/MWh)

$\Delta t$ : Market interval; FMM=15 min

$P_{max}$ : Maximum output (MW)

$P_{min}$ : Minimum output (MW)

$\beta_1$ : Offer price of 1<sup>st</sup> incremental segment (\$)

All elements are parameters and therefore the adder  $\delta$  is a constant

$MUT$  is rounded up to # of intervals

If  $MUT=0$  then  $SUC$  is amortized in 1 interval

The FSP adder is

$$\delta = \frac{MLC - P_{min}\beta_1}{P_{max}} + \frac{SUC}{\frac{\Delta t}{60} \max\left\{1, \left\lceil \frac{MUT}{\Delta t} \right\rceil\right\} P_{max}}$$

# Minimum load costs

- Minimum load costs are amortized across the resource's maximum output

$$\frac{MLC - P_{min}\beta_1}{P_{max}}$$

## Where:

- MLC*: Minimum load cost (\$/hour)  
*P<sub>max</sub>*: Maximum output (MW)  
*P<sub>min</sub>*: Minimum output (MW)  
*β<sub>1</sub>*: Offer price of 1<sup>st</sup> incremental segment (\$)

By subtracting  $P_{min}\beta_1$  from  $MLC$ , the formula accounts for the variable cost already covered in the first bid segment. This reflects the additional cost per megawatt-hour of operating the generator at its minimum load above the incremental cost already bid for  $P_{min}$ .

# Illustration: Constant amortization with an adjustment to MLC

MLC=\$5,000/hr  
 SUC=\$2000 per start  
 MUT= 1 hr  
 PMAX = 450MW  
 $\beta_1$ : \$35/MWh  
 PMIN = 100MW

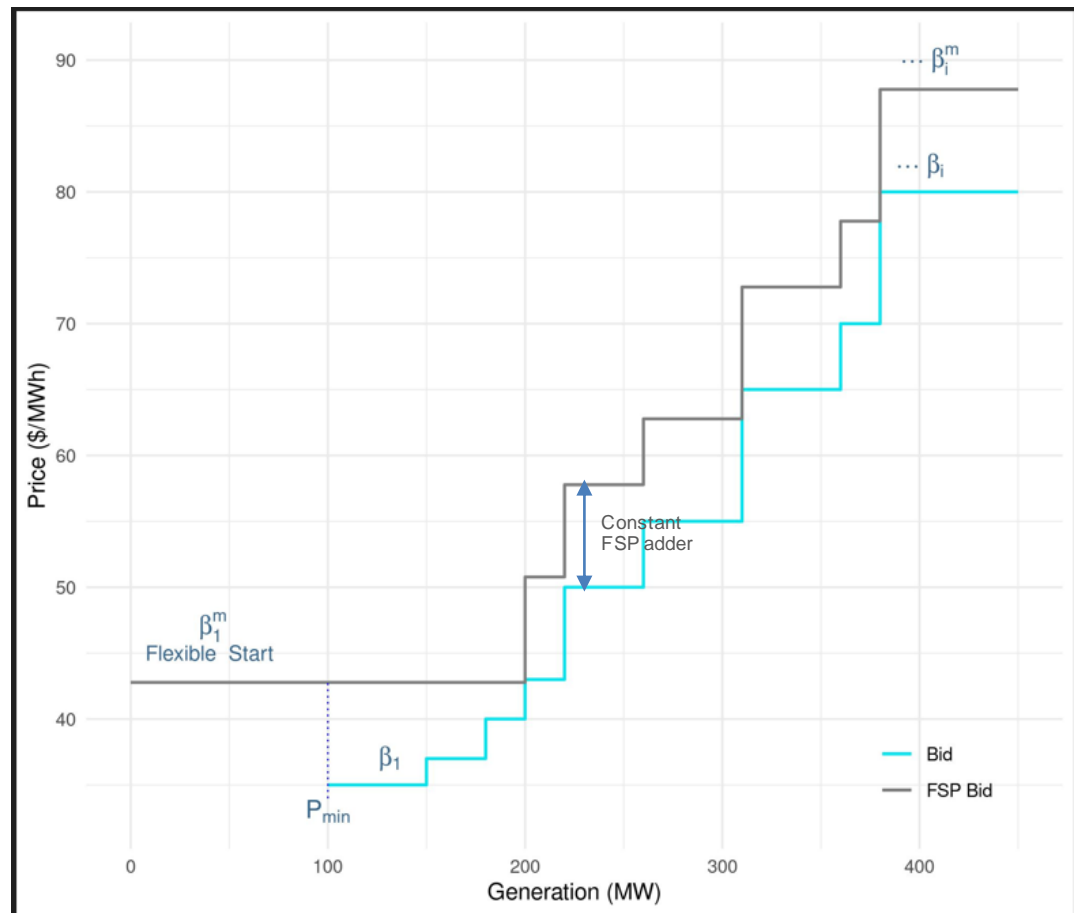
A constant adder is estimated to reflect Both MLC and SUC

$$\delta^e = \frac{\$2000 + \left[ \frac{\$5000}{hr} - (100MW * \$35/MWh) \right]}{450 MW}$$

$$= \$7.78/MWh$$

This adder applies to each segment of the bid

First segment is extended to 0 MW to model a flexible start





# Example from Mike Cadwalader's comments

|       | Capacity<br>(MW) | Actual Offer      |                  |                | Constant Adder         |                  |                |
|-------|------------------|-------------------|------------------|----------------|------------------------|------------------|----------------|
|       |                  | Offer<br>(\$/MWh) | Cost of<br>Block | Cumul.<br>Cost | Adj. Offer<br>(\$/MWh) | Cost of<br>Block | Cumul.<br>Cost |
| Pmin  | 100              |                   | \$ 7,000         | \$ 7,000       | \$ 75.00               | \$ 7,500         | \$ 7,500       |
| Inc 1 | 50               | \$ 40.00          | \$ 2,000         | \$ 9,000       | \$ 75.00               | \$ 3,750         | \$11,250       |
| Inc 2 | 50               | \$ 80.00          | \$ 4,000         | \$13,000       | \$ 115.00              | \$ 5,750         | \$17,000       |

Cumulative costs  $\neq$

|       | Capacity<br>(MW) | Actual Offer      |                  |                | Alt. Constant Adder    |                  |                |
|-------|------------------|-------------------|------------------|----------------|------------------------|------------------|----------------|
|       |                  | Offer<br>(\$/MWh) | Cost of<br>Block | Cumul.<br>Cost | Adj. Offer<br>(\$/MWh) | Cost of<br>Block | Cumul.<br>Cost |
| Pmin  | 100              |                   | \$ 7,000         | \$ 7,000       | \$ 55.00               | \$ 5,500         | \$ 5,500       |
| Inc 1 | 50               | \$ 40.00          | \$ 2,000         | \$ 9,000       | \$ 55.00               | \$ 2,750         | \$ 8,250       |
| Inc 2 | 50               | \$ 80.00          | \$ 4,000         | \$13,000       | \$ 95.00               | \$ 4,750         | \$13,000       |

Cumulative costs  $=$

## The following example illustrates the rationale for minimum average cost amortization

- Consider the following unit:
  - $P_{\min} = 100 \text{ MW}$ ,  $SUC = \$2000$ ,  $MLC = \$5000$ ,  $MUT = 1 \text{ hour}$
  - One incremental segment with 50 MW of capacity, at a cost of \$40/MWh.
- The total cost of operating this unit at its 150 MW capacity for one hour is:
  - $(\$2000 + \$5000 + 50 \text{ MW} \times \$40/\text{MWh}) / 150 \text{ MWh} = \$60/\text{MWh}$ .

## The following example illustrates the rationale for minimum average cost amortization

- Now consider another unit, just like the first one, except that it has a second incremental segment with 50 MW of capacity.
  - This capacity is only available at a very high cost, so that it is almost never used.
- The availability of this segment doesn't affect the cost of committing the unit or operating it at levels of 150 MW or lower.
  - So the adjusted offers that are used for the first 150 MW of this unit should be the same as the adjusted offers that are used for the unit that doesn't have this additional segment.

## The following example illustrates the rationale for minimum average cost amortization

- The minimum average cost approach produces this outcome, by not allocating any of the commitment costs to the second incremental segment.
- This also avoids the problem of having the adder depend on the difference between the MLC and the bid for the first incremental segment, as it does under Variant 2
  - This can be manipulated to produce very large adders, which would make the offers that are used in the physical and pricing dispatches differ substantially
  - As a result, resources could be dispatched using one offer, while the prices are set using an offer that incorporates a large adder

## Variant 3: Average amortization relies on the least cost across the variable range

Define  $\psi_i$  as average cost at segment  $i$

$$\psi_i = STUC + \left\{ MLC + \sum_{k=1}^i (p_k - p_{k-1})\beta_k \right\} \frac{\Delta t}{60} \max \left\{ 1, \left\lceil \frac{MUT}{\Delta t} \right\rceil \right\}$$

Where

$\beta_i$  is the bid-in price for segment  $i$

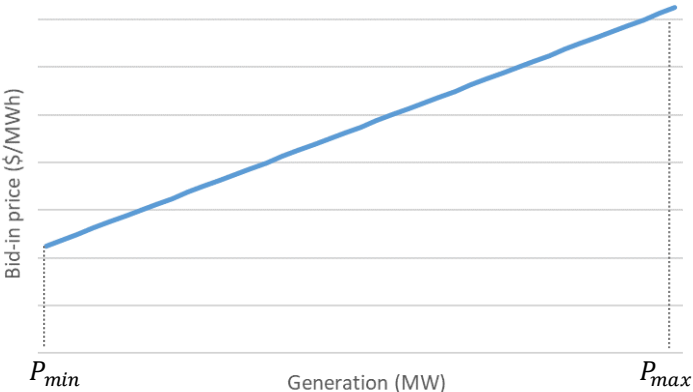
$p_i$  is the  $i$ -th generation break point of the step-wise bid

This yields the minimum average price as

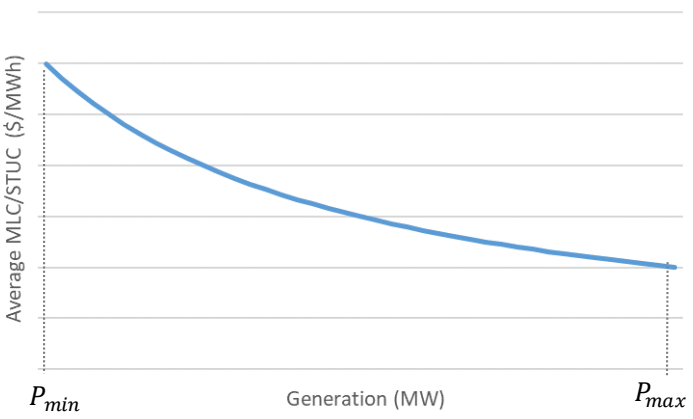
$$\delta^m = \min_{p_i^*} \frac{\psi_i}{\frac{\Delta t}{60} \max \left\{ 1, \left\lceil \frac{MUT}{\Delta t} \right\rceil \right\} p_i}$$

The purpose of these calculations is to find the segment  $i$  that provides the lowest average cost of production, considering both variable and fixed costs.

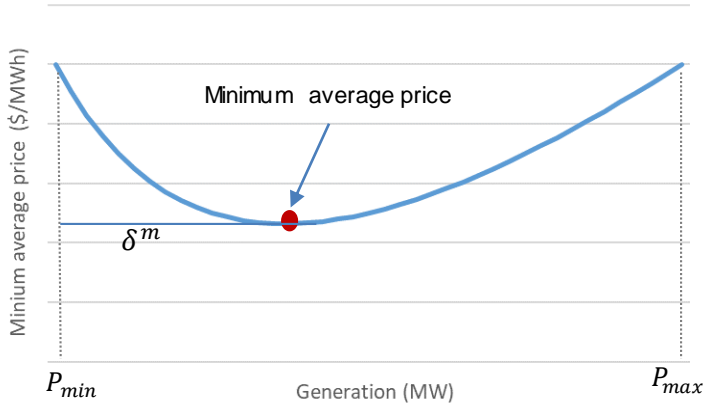
# The minimum average price defines the breaking point for the adjusted bid



+



=



# Illustration: minimum averaged-cost is a different scheme to amortize commitment costs

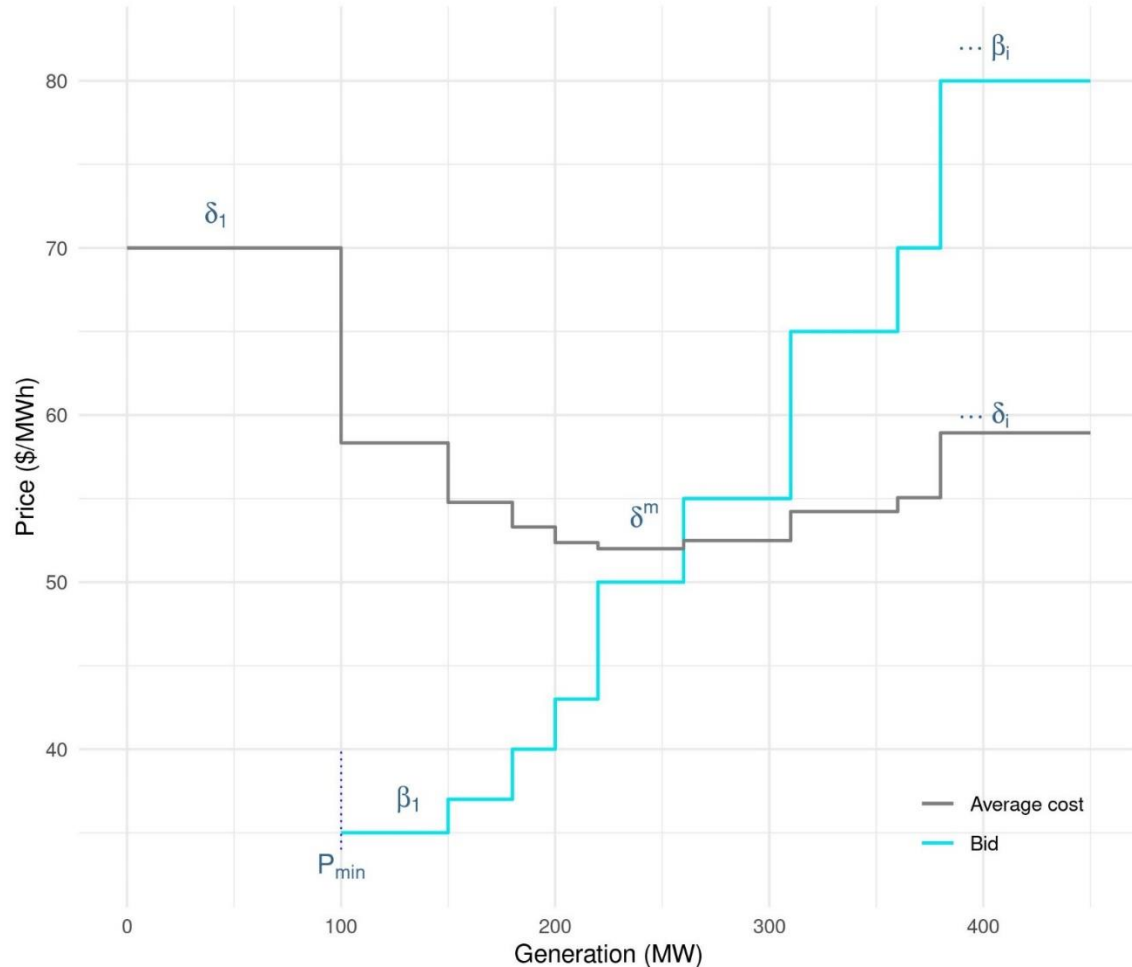
MLC=\$5,000/hr  
 STUC=\$2000per start  
 MUT= 1 hr  
 PMIN = 100MW

Between 0 and 100 MW, MLC and STUC define the average cost at Pmin

$$\delta_0 = \frac{\$2000 + \$5000}{100 \text{ MW}} = \$70/\text{MWh}$$

Subsequent segments incorporate the cumulative variable cost

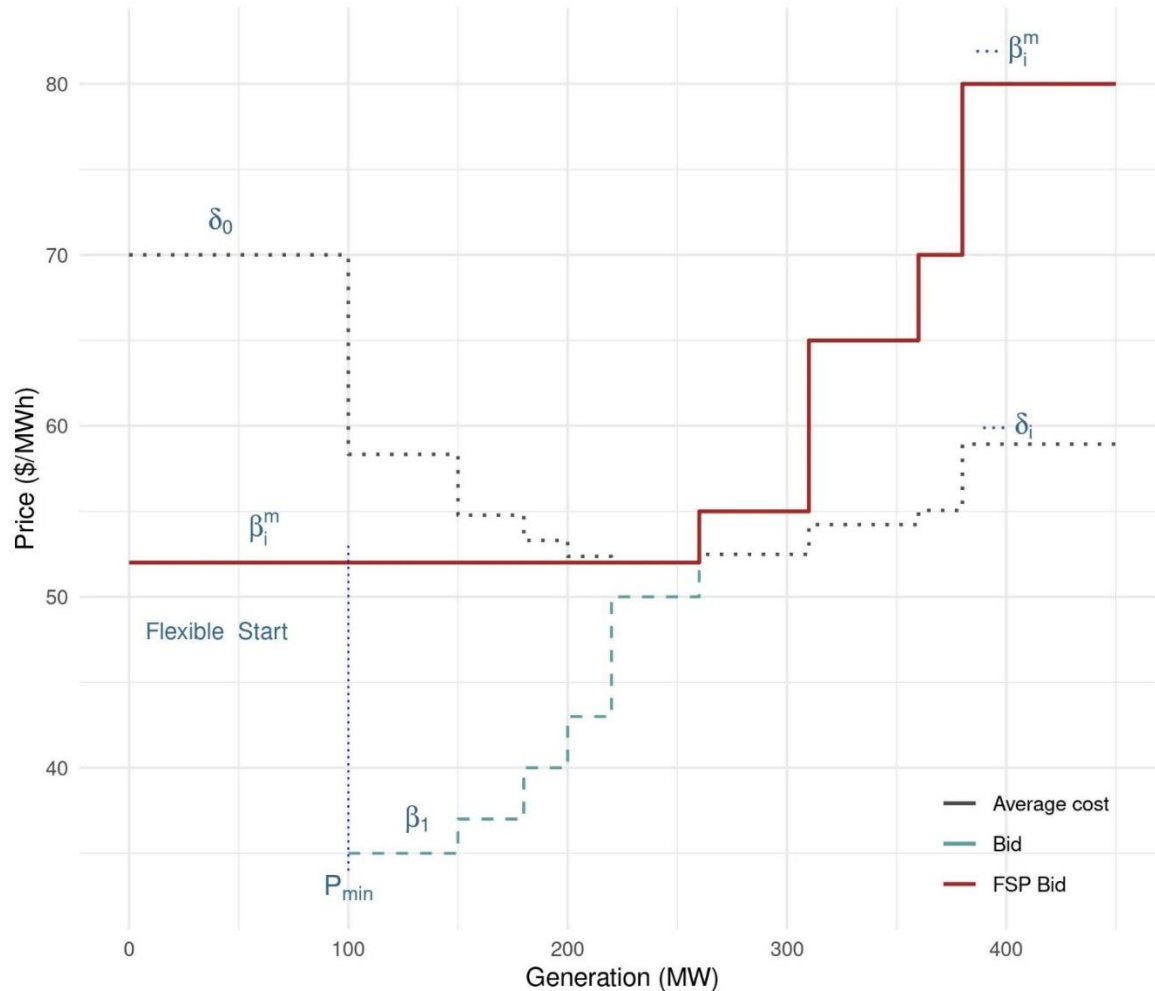
The resulting curve will attain a minimum average cost



# The minimum average cost defines the first segment of the adjusted bid curve

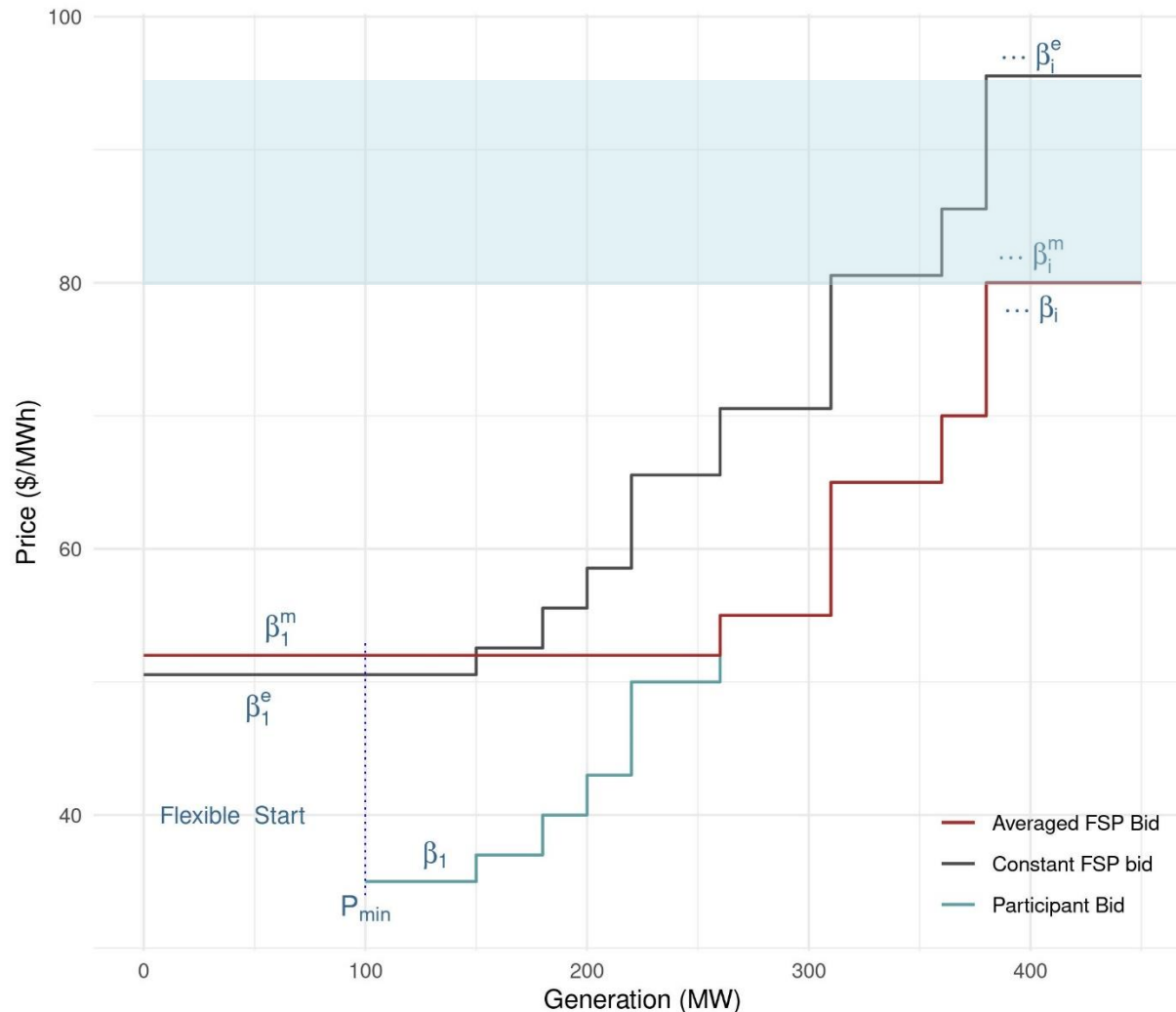
The minimum average cost extends to the left up to 0 MW and covers the flexible startup range up to  $P_{min}$

Segments to the right of the minimum-cost segment use the original bid curve





# Constant amortization may tend to have higher-priced segments towards the end of the range than averaged-cost amortization



# Integer Relaxation

- The market relaxes the integrality constraint for a subset of binary commitment variables.
  - This change allows a resource's commitment status to range between on (1) and off (0), instead of being strictly one or the other (i.e.,  $0 \leq x \leq 1$ )
- Relaxing the binary commitment variables lets the marginal generator's commitment costs, spread over its maximum output, automatically influence the price.

# Integer Relaxation

- At a high-level, the integer relaxation method is a different mathematical process that seems to produce similar pricing results when allocating the same costs are over the same periods.
- PDF page 32 begins a mathematical discussion of the integer relaxation method. <https://www.pjm.com/-/media/library/reports-notice/special-reports/20171115-proposed-enhancements-to-energy-price-formation.ashx>

## For reference

- Visit Price Formation Enhancements Working Group initiative webpage for more information:  
<https://stakeholdercenter.caiso.com/StakeholderInitiatives/Price-formation-enhancements>
- Price Formation Working Group Schedule  
<http://www.caiso.com/InitiativeDocuments/Price-Formation-Enhancements-Working-Group-Schedule-2024.pdf>
- If you have any questions, please contact Brenda Corona at [bcorona@caiso.com](mailto:bcorona@caiso.com) or [isostakeholderaffairs@caiso.com](mailto:isostakeholderaffairs@caiso.com)

# Annual Policy Initiatives Roadmap Process 2024

Please submit potential discretionary initiatives to the 2024 annual policy catalog.

Submission deadline is Wednesday, **February 28, 2024**

- comment template [here](#)
- information on this process [here](#).

Any questions or concerns email us at [ISOStakeholderaffairs@caiso.com](mailto:ISOStakeholderaffairs@caiso.com)

# Save the Date: 2024 Stakeholder Symposium

- The California ISO Stakeholder Symposium to be held Oct. 29-30, 2024
- The Symposium will be held at the Safe Credit Union Convention Center in Sacramento, California
- Welcome reception for all attendees the evening of Oct. 29. Additional information, including event registration and sponsorship opportunities, will be provided in a future notice and on the ISO's website.

| <b>Welcome reception:</b>   | <b>Stakeholder symposium:</b>   |
|---|---|
| Date: Oct. 29, 2024<br>Time: 5:30 p.m. - 7:30 p.m.<br>Location: To be announced | Date: Oct. 30, 2024<br>Time: 8:00 a.m. - 4:30 p.m.<br>Location: <a href="#"><u>Safe Credit Union Convention Center</u></a> , 1400 J St., Sacramento, CA 95814 |

Please contact Symposium Registration at [symposiumreg@caiso.com](mailto:symposiumreg@caiso.com) with any questions.