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Presentation updated **11/04/2024**. Impacted slides are noted.

Energy Market Opportunity Costs

For Oil and Dual-Fuel Resources with Intertemporal Production Limitations

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Topics

- Opportunity Cost Overview
- Opportunity Cost Methodology
- Simple Example
- Key Takeaways
- Opportunity Cost – Internal Market Monitor

Acronyms

| Acronym | Description |
|----------------|---|
| CAMS | Customer Asset Management System |
| DAM | Day-Ahead Market |
| IMM | Internal Market Monitor |
| IMMAC | Internal Market Monitor Asset Characteristics |
| LMP | Locational Marginal Price |
| OC | Opportunity Cost |
| O&M | Operation & Maintenance |

Opportunity Cost Overview

- ❖ *What is an Opportunity Cost?*
- ❖ *Why Calculate Opportunity Cost?*
- ❖ *How Will ISO Calculate an Estimated Opportunity Cost?*
- ❖ *What Input Assumptions Are Used?*

What Are Limited-Fuel Opportunity Costs?

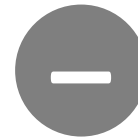
Reduction in maximum **net revenue** over a specific time horizon associated with a 1 MWh reduction in available fuel supply

- Opportunity cost horizon = seven days

Net Revenue



Energy Revenue
(i.e., LMP x MWh)



Cost of Production
(i.e., fuel cost, emission allowance costs, and variable operation & maintenance [O&M])

- Intended audience:
 - Lead participants for oil-fired and dual-fuel generators
 - Back-office personnel responsible for:
 - Formulating offer strategy
 - Submitting generator offers into eMarket

Why Calculate Opportunity Costs?

Generator offer prices that reflect opportunity costs help the market **preserve a limited fuel supply** for the hours when fuel will be:

- Most valuable
- Most useful



How Will ISO Calculate Estimated Opportunity Costs?

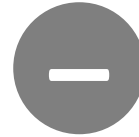
Using a seven-day independent forecast of energy market locational marginal prices (LMPs), estimates of future fuel prices, and generator's current fuel inventory, ISO estimates maximum net revenue that can be produced in two different situations:

- A. With generator's available fuel supply (assuming no replenishment during seven-day horizon)
- B. When fuel supply is reduced by 1 MWh

**Daily
Estimated
Opportunity
Cost**



**A. Max net revenue produced
with generator's available
fuel supply**



**B. Max net revenue produced
when fuel supply is
reduced by 1 MWh**

What Input Assumptions Are Used?

Spanning Rolling Seven-Day Opportunity Cost Horizon

- Hourly (zonal) electricity price projections
 - Seven-day independent forecast of energy market LMPs
- Daily fuel spot-price projections
 - Algonquin (non-G)
 - Oil (#2, #6 1% S, #6 0.3% S, Jet (kerosene))
- Emission allowance prices (SO₂, NOX, and RGGI CO₂)
- Temperature forecast
- Generator operating characteristics
 - (EcoMin, EcoMax, Minimum Run Time, etc.)
- Generator's current fuel inventory



Opportunity Cost Methodology

- ❖ *Methodology*
- ❖ *Initial Roll-Out Limitations*

Methodology

Objective: Find the reduction in maximum net revenue that results from a 1 MWh reduction in fuel supply

Method: Determine the generation schedule that produces the maximum net revenue over a rolling seven-day horizon while accounting for the generator's limitations:

- Fuel supply limitations
- Generator operating characteristics

Simple problems, such as the upcoming example, can be solved by visual inspection; realistic situations are more complex and are solved by the ISO using an optimization model



Simple Example

How Opportunity Costs Are Calculated and Help Find Best Use for Limited Fuel



Examples used in this presentation are for illustrative purposes only.

Example Assumptions

- Example looks at a single two-day horizon
- In actual practice, opportunity costs are:
 - Estimated over seven-day horizon
 - Recalculated daily as seven-day forecast is updated
- In this example, generator:
 - Runs on oil
 - Always dispatched at EcoMax (assuming sufficient fuel)
 - Has eight hours of fuel for next two days
 - Assumed to have no replenishment (even if generator has fuel-delivery planned)
 - Must run at least three hours at a time when dispatched

| Operation and Fuel Inputs | Value |
|---------------------------|----------|
| EcoMax | 100 MW |
| Minimum Run Time | 3 Hours |
| Fuel Replacement Cost | \$57/MWh |
| Initial Fuel Inventory | 800 MWh |

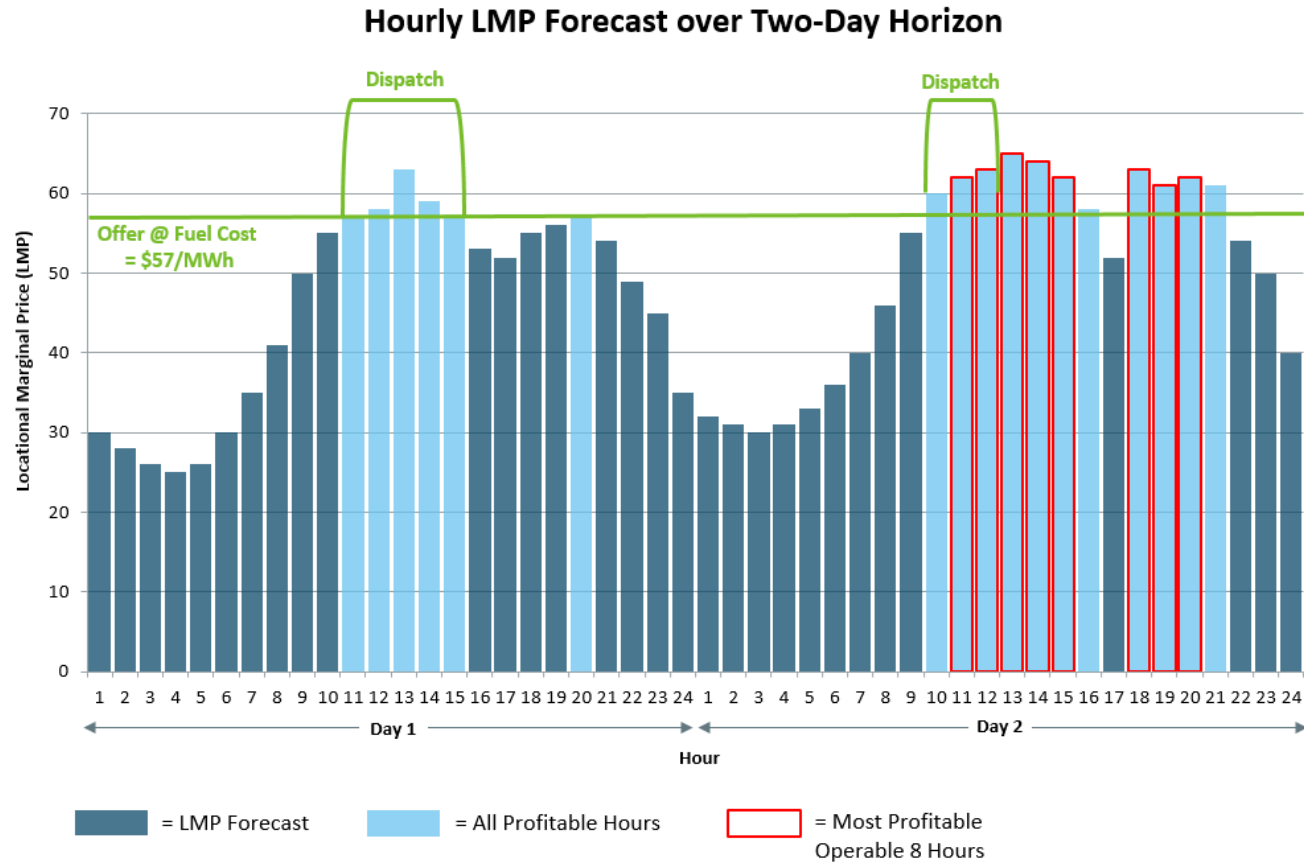
Example: What Happens If Generator Offers on Fuel Costs Only?

Generator is dispatched whenever $LMP \geq$ offer price

At offer of **\$57/MWh** (fuel cost):

- Five hours of dispatch on Day 1; three on Day 2
- Only two hours of dispatch during most profitable period

Result: All fuel is consumed before reaching the most profitable hours in Day 2



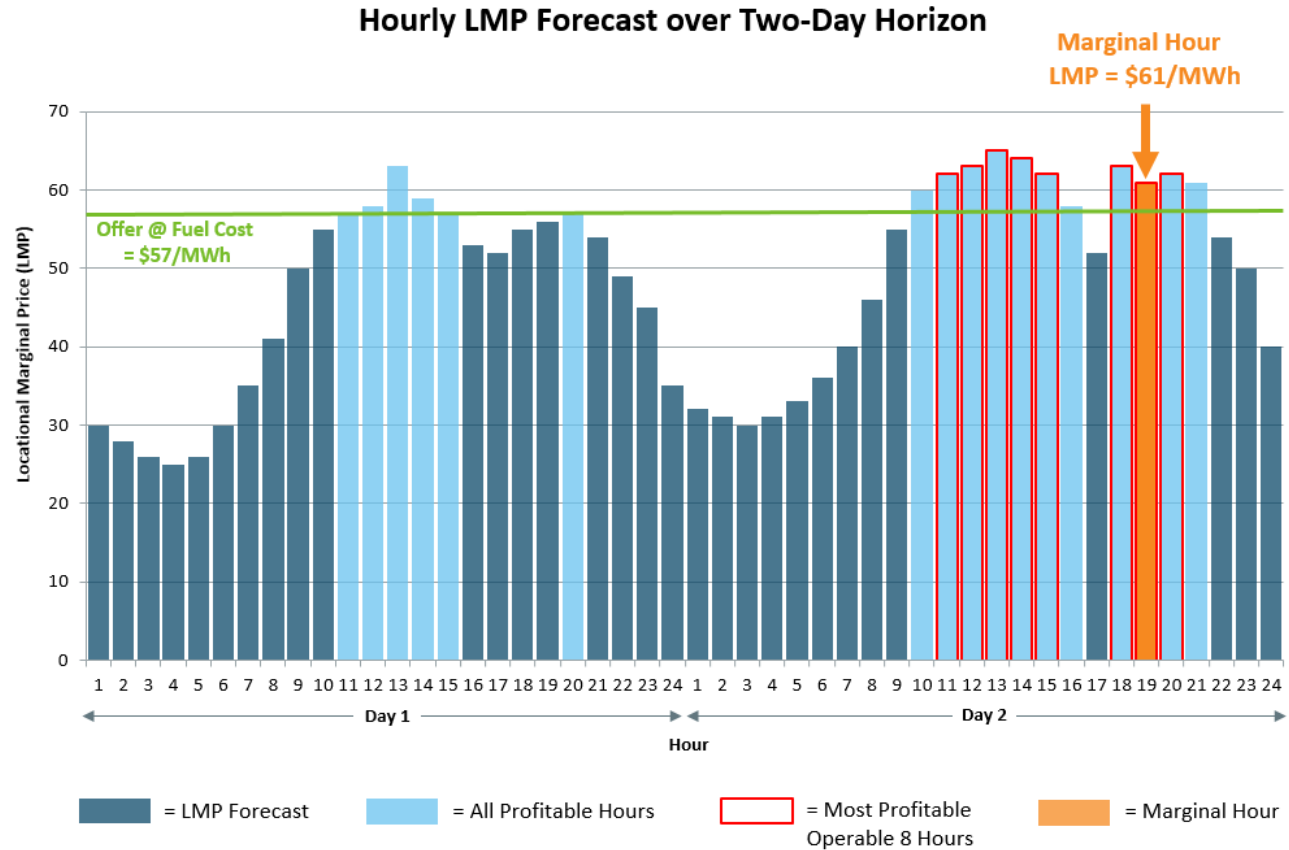
Example: Which Hours Produce Maximum Net Revenue?

Maximum net revenue produced if generator is dispatched to run on most profitable operable eight hours of Day 2

- Recall three-hour min run time

Day 2, Hour 19 is **marginal hour**

- When generator would choose to reduce output if it had 1 MWh less fuel
- Lowest LMP during most profitable period



Example: What is Generator's Opportunity Cost?

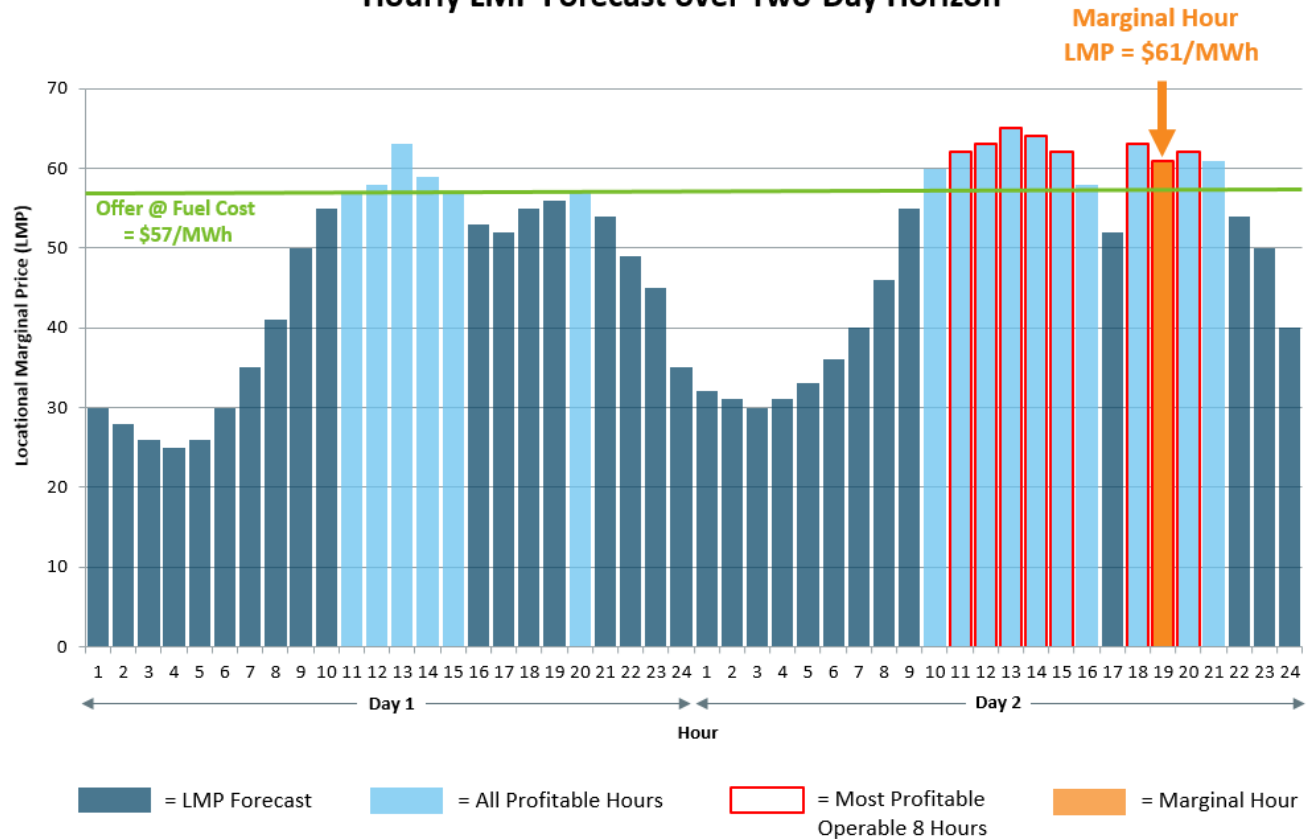
Opportunity cost is reduction in net revenue from 1 MWh less fuel:

Marginal hour LMP = \$61/MWh

Fuel cost = \$57/MWh

Opportunity cost (net revenue change) = \$4/MWh

Hourly LMP Forecast over Two-Day Horizon



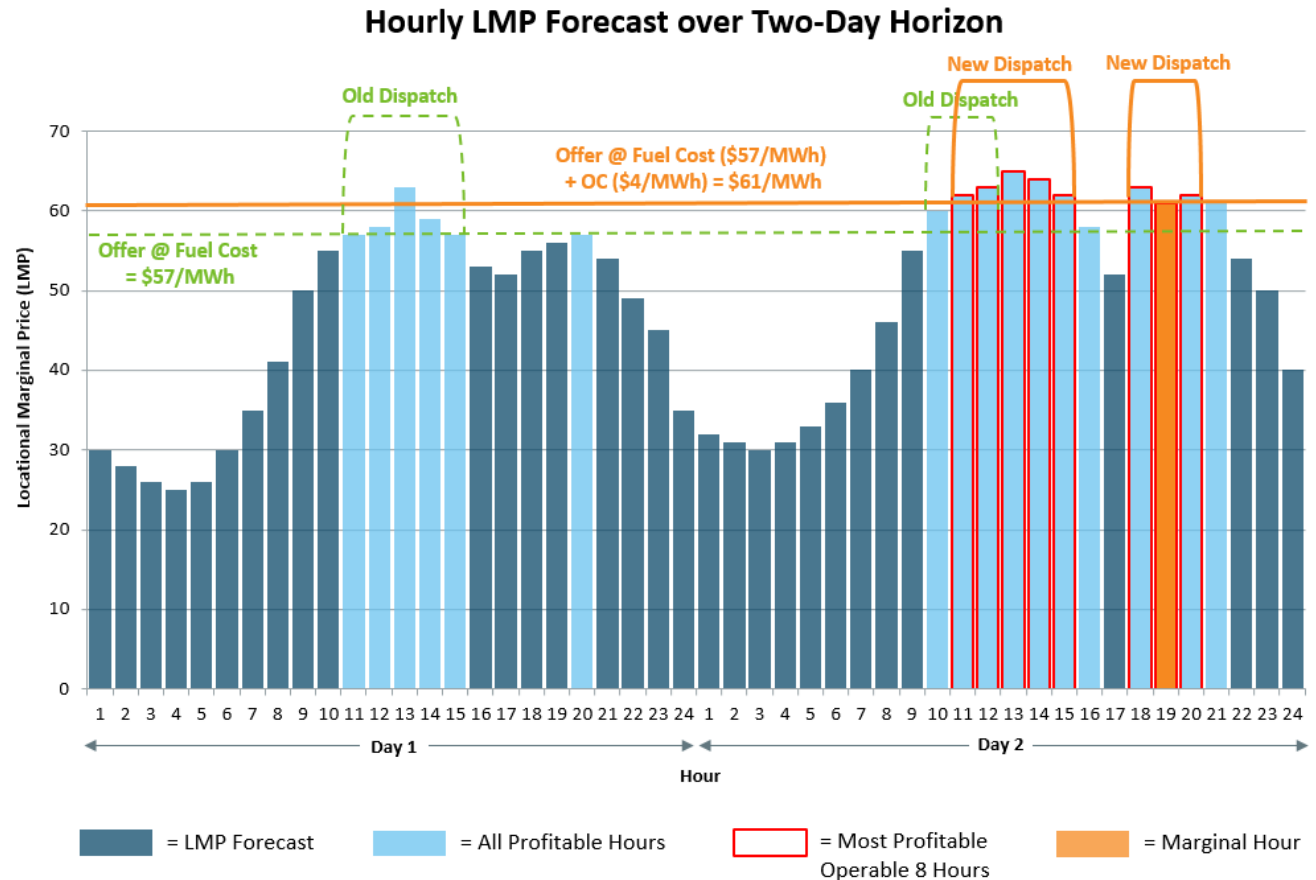
Example: What Happens If Offer Includes Opportunity Cost Adder?

At offer of **\$61/MWh**

(\$57/MWh fuel cost + \$4/MWh opportunity cost):

- Dispatch shifts to higher-priced hours on Day 2
- More profitable overall
 - Despite generator missing out on one high-priced hour
- Helps conserve fuel

Result: Limited fuel preserved for use in more valuable hours



Key Takeaways

Opportunity Cost Adders Make Most Cost-Effective Use of Limited Resources

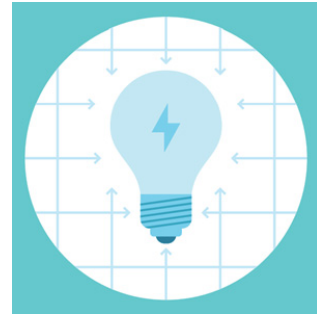
Including fuel costs plus opportunity costs in generator offers tends to preserve limited fuel for dispatch in higher-priced hours

- Higher LMPs typically reflect stressed system conditions and/or higher demand



Points to Keep in Mind

- ISO actually calculates hourly opportunity cost estimates
- ISO publishes a daily opportunity cost estimate = maximum of hourly opportunity cost estimates for the day
 - Hourly opportunity cost estimate will change as real-time hours pass and fuel is consumed
 - Hourly opportunity cost estimates will tend to increase over the course of the day
- Generator will have a \$0/MWh opportunity cost adder if it either:
 - Is never in merit over seven-day horizon
 - Has sufficient fuel inventory to run every profitable hour
 - Has no way to store input energy supply for future use (for example, wind)
- Generator using full opportunity cost adder may not be dispatched during some profitable hours
 - [See simple example on slide 11](#)





Questions?



Opportunity Cost – Internal Market Monitor

- ❖ Tariff Allows for Opportunity Costs – Section III.A.7.5.1
- ❖ Overview
- ❖ Implementation
- ❖ Opportunity Cost Calculation Steps
- ❖ Future Enhancements
- ❖ Frequently Asked Questions (FAQ)
- ❖ Resources on ISO New England Website

Tariff Allows for Opportunity Costs – Section III.A.7.5.1.

III.A.7.5.1. Estimation of Incremental Operating Cost

The Internal Market Monitor's determination of a Resource's marginal costs shall include an assessment of the Resource's incremental operating costs in accordance with the following formulas,

Incremental Energy:

*(incremental heat rate * fuel costs) + (emissions rate * emissions allowance price) + variable operating and maintenance costs + opportunity costs.*

Opportunity costs may include, but are not limited to, economic costs associated with complying with:

- (a) emissions limits;*
- (b) water storage limits; and,*
- (c) other operating permits that limit production of energy.*



Overview

- No requirement for participant to include opportunity cost as part of their three-part offer
 - Used by IMM to calculate reference levels
 - Reference levels are used to evaluate competitiveness of generator's offer
- Participants can use IMM's estimated opportunity costs or determine their own opportunity costs
 - Participant methodology must be analytically supported and vetted ahead of time by IMM
- Other physical/financial parameters changes will continue to be monitored to determine whether the generator's offer is competitive
 - For example, minimum run time and start-up costs
- Introduction of opportunity cost does not change offer submission process



Implementation

Timing

- Opportunity cost are updated and visible by 9:00 a.m. for day-ahead market (DAM)
- Any real-time market (RTM) updates will be posted at 18:30
- A time stamp field will indicate the time and date of the last update
- Implementation date is anticipated to be December 3, 2019, and will run daily

Where to find estimated opportunity costs

- **Customer Asset Management System (CAMS)**
 - > **IMMAC** tab > **Fuel Index** tab
 - Ask your [Security Administrator \(SA\)](#) to assign you rights

Customer and Asset Management System
IMMAC

Asset details as of 11/07/2019

| Fuel Indexes | Premium (\$/mmBTU) ² | Default Premium (\$/mmBTU) ² | Opportunity Cost (\$/MWh) ¹ | Fuel Price Override (\$/mmBTU) ² | Multiplier ¹ | NOX (lbs/mmBTU) ² | SO2 (lbs/mmBTU) ² | CO2 (lbs/mmBTU) ² | Carbon Permit Price: |
|--------------|---------------------------------|---|--|---|-------------------------|------------------------------|------------------------------|------------------------------|----------------------|
| MA_natgas6 | 3.160 | 0.000 | 5.63 | 0.00 | 0.000 | 0.000000 | 0.000000 | 159.436200 | 0.000000 |
| ULSDiesel | | | | | | | | | |
| MA_natgas2 | | | 6.47 | | | | | | |

Calculated Opportunity Cost (\$/MWh): 6.47
Calculated Opportunity Cost Timestamp: 11/21/2019 11:07:34 am

Participant Editable Opportunity Cost

Emission Restrictions: ISO Calculated Opportunity Cost

Internal Market Monitor Asset Characteristics (IMMAC) values are used in the calculation of IMM reference levels

For more guidance on IMMAC please refer to the [Internal Market Monitor Asset Characteristics \(IMMAC\) User Interface](#) training

Slide updated on 11/06/2024.

Opportunity Cost Calculation Steps

1. Calculate opportunity cost

- [Use previous input assumptions](#)
- Inputs into optimization model evaluated to determine marginal hour
- Marginal hour used to evaluate whether an opportunity cost exists
 - Opportunity cost, in many cases, will be equal to the difference (minimum of \$0) between the marginal hour and the variable cost of production for that hour

2. Upload opportunity cost to IMMAC database for viewing by 9:00 a.m.

- For Massachusetts generators, the published opportunity cost will include Massachusetts emissions value as well

3. Reference levels will reflect opportunity cost for DAM



Frequently Asked Questions (FAQ)

| Question | Answer |
|---|--|
| Does opportunity cost apply to day-ahead and real-time reference levels? | Yes |
| Will IMM use a participant's internally-developed methodology to estimate opportunity cost? | Maybe , if the participant's opportunity cost is greater than the ISO calculated value, it will be used in reference level calculations |
| Can I switch between an internally-developed methodology and the ISO's approach? | No , the software selects the higher of the internally developed, or the ISO calculated opportunity cost |
| Do I have to include the calculated opportunity cost when submitting my offers? | No , but be aware when making offers, the ISO calculated opportunity cost may increase the reference level value |
| Do I need special rights to view the opportunity cost in IMM? | No , not if you have viewer rights to IMM |

Summary

- Participants are encouraged to incorporate estimated opportunity costs in energy market offers, but use of opportunity costs is not required
- Opportunity costs for oil and dual fuel units will be updated daily by 9:00 a.m.
- Opportunity costs will be included in reference prices calculated by Internal Market Monitor for each generator
- Future enhancements will allow ISO to estimate opportunity costs for any resource with any inter-temporal limitation on energy production over a 12-month horizon, as long as the limitation can be documented, quantified, tracked and modeled by the ISO



Internal Market Monitor Contact Information

For opportunity cost calculation questions, email the Internal Market Monitor at IMM@ISO-NE.com



Resources on ISO New England Website

- [Opportunity Costs and Energy Market Offers \(Phase 1\): ISO's Proposal to Estimate Opportunity Costs for Oil and Dual-Fuel Resources with Inter-temporal Production Limitations](#)
(September 12-13, 2018, Presentation to NEPOOL Markets Committee)
- [Opportunity Costs and Energy Market Offers \(Phase 1\): ISO's Proposal to Estimate Opportunity Costs for Oil and Dual-Fuel Resources with Inter-temporal Production Limitations](#)
(October 9-10, 2018, Presentation to NEPOOL Markets Committee)
 - Related materials:
 - [Energy Market Opportunity Costs for Oil and Dual-Fuel Resources with Inter-temporal Production Limitations](#)
(October 9, 2018, Memo to NEPOOL Markets Committee)
 - [Natural Gas Price Forecast Method for Energy Market Opportunity Costs](#)
(October 9, 2018, Memo to NEPOOL Markets Committee)



Resources on ISO New England Website, *continued*

- [Opportunity Costs and Energy Market Offers \(Phase 1\): ISO's Proposal to Estimate Opportunity Costs for Oil and Dual-Fuel Resources with Inter-temporal Production Limitations](#)
(November 7-8, 2018, Presentation to NEPOOL Markets Committee)
 - Related materials:
 - [Efficiency and Market Power in Opportunity Cost Modeling](#)
(November 2, 2018, Memo to NEPOOL Markets Committee)
- [Internal Market Monitor Asset Characteristics \(IMMAC\) User Interface](#) (self-paced training)
- [Market Monitoring: Energy Market Mitigation Overview Internal Market Monitor Energy Market Mitigation Overview](#) (e-learning)



Providers of Information Used in Opportunity Cost Model

- Intercontinental Exchange (www.theice.com) – gas price data
- Argus Media (www.argusmedia.com) – oil price data
- PRT, Inc. (<http://www.prt-inc.com/forecast/NE.html>) – LMP forecast

Contact Participant Support and Solutions



Submit a request via Ask ISO *(preferred)*

<https://askiso.iso-ne.com>

Email AskISO@iso-ne.com

Phone

(413) 540-4220 (call center)

(833) 248-4220

Pager *(for emergency inquiries outside of business hours)*

(877) 226-4814

**Business hours and
additional contact details
are available from the
Participant Support page**

[Visit the Participant Support page](#)



Slide updated on 11/06/2024.



Questions?



Evaluation