Unit Commitment and Dispatch

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Module Objective

- Provide an understanding of how Unit Commitment and Economic Dispatch works
  - Objectives
  - Process
  - Factors impacting Unit Commitment
  - How Unit Commitment impacts Economic Dispatch

Three Primary Responsibilities of ISO New England

1 Operate New England's Bulk Electric Power System

- Dispatch New England's resources as a single system to:
  - Maintain reliability throughout the region.
  - Minimize cost of electricity production in New England.
  - Adhere to national, regional, and local operating procedures and policies.

2 Manage New England's Wholesale Electricity Marketplace

Ensure a fair and reasonable marketplace

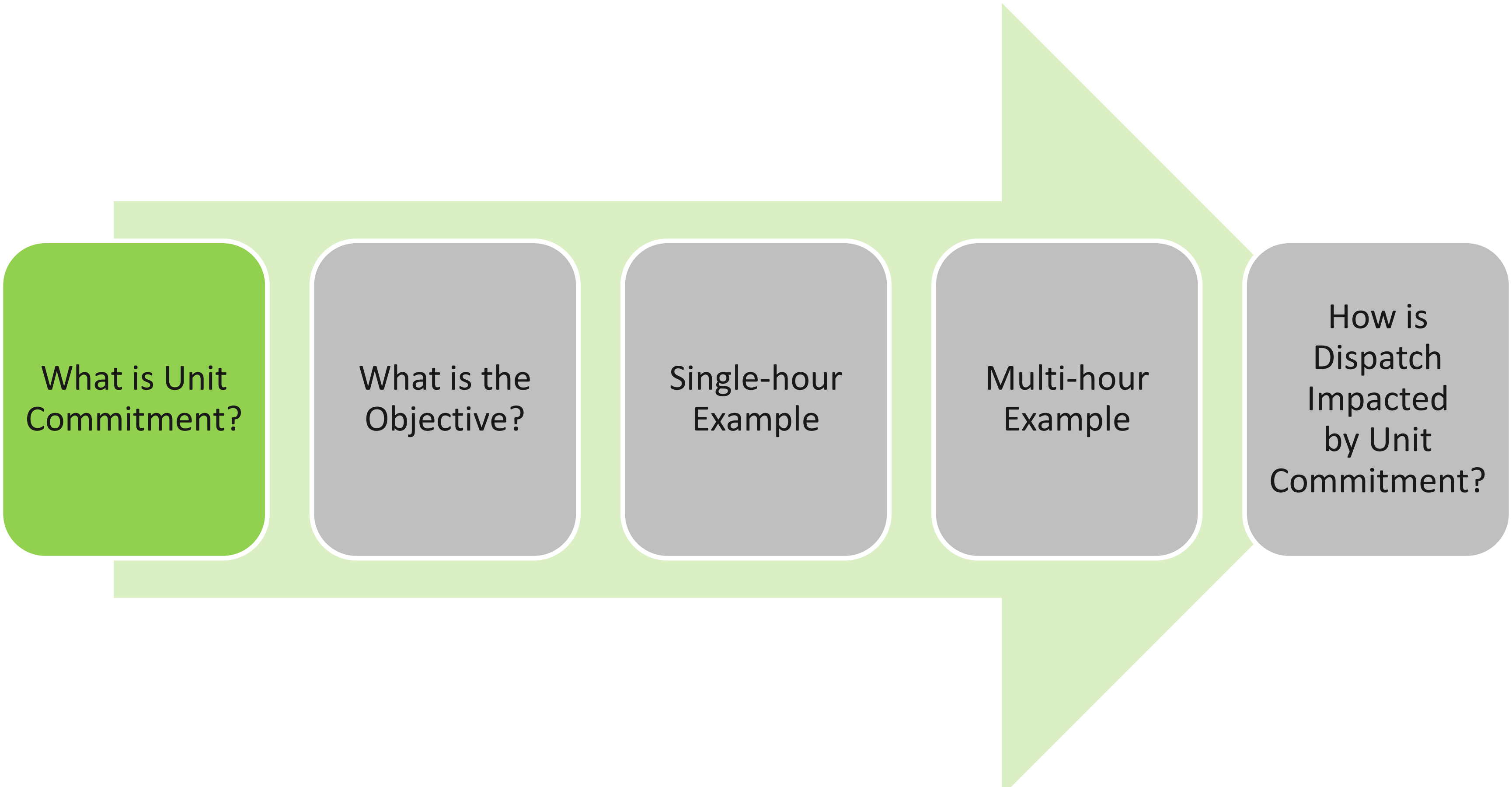
3 Develop and Manage Long-term Planning Process in New England

Application of ISO Responsibilities

- Minimize cost of electricity production in New England
  - The ISO shall determine the least cost security-constrained unit commitment and dispatch
    - Least costly means of serving load at different Locations in the New England Control Area based on:
      - Scheduled or actual conditions existing on the power grid
      - Prices at which Market Participants have offered to supply and consume energy in the New England Markets. [Market Rule 1]

Topics Covered in this Module

- What is Unit Commitment?
- What is the Objective?
- Single-hour Example
- Multi-hour Example
- How is Dispatch Impacted by Unit Commitment?


What is Unit Commitment?
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Single-hour Example
Multi-hour Example
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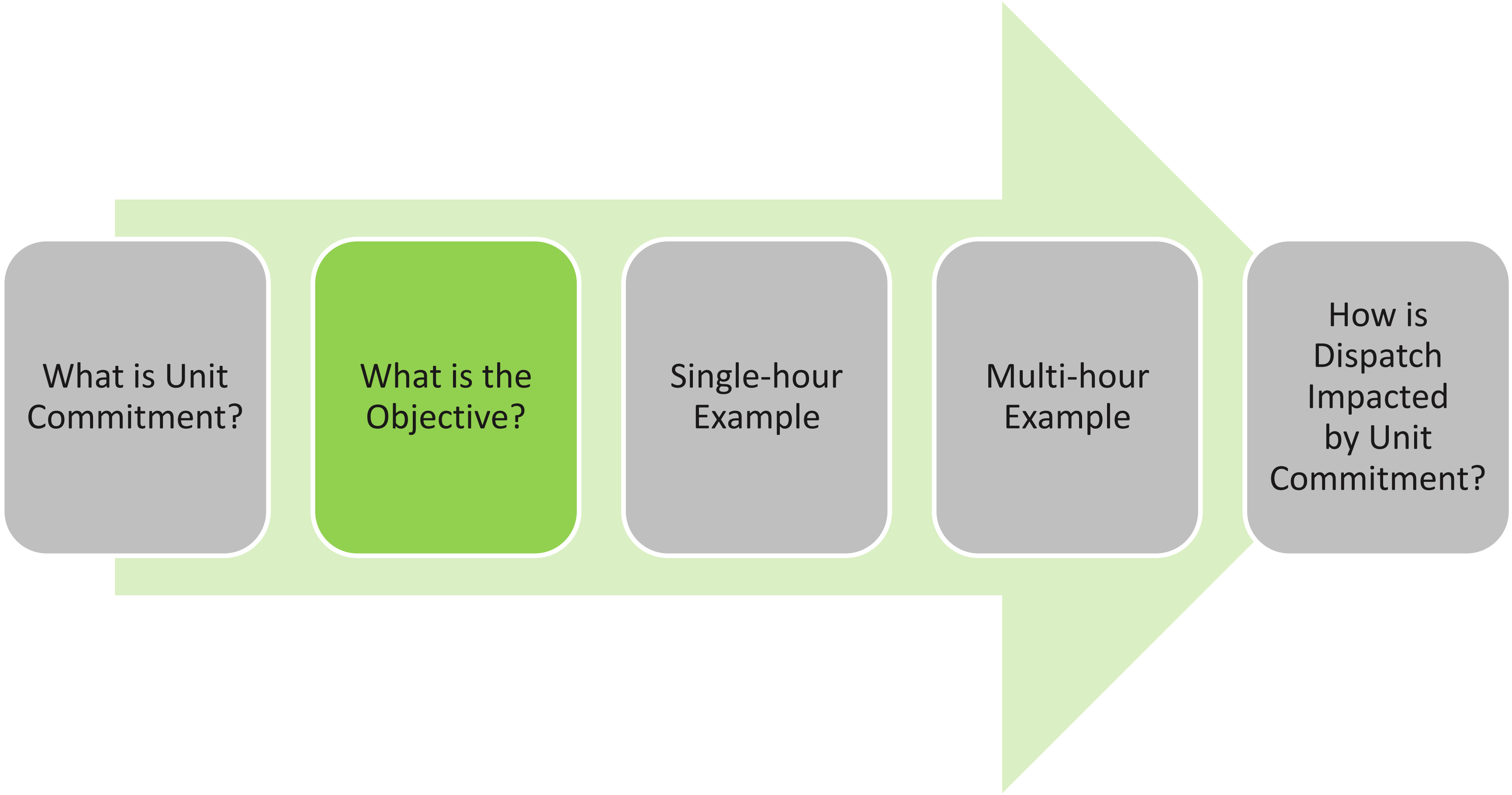
What is Unit Commitment?

- Decision making process by ISO to ensure minimal production cost
- On/off of scheduling resources for a defined period
- System-wide Unit Commitment has been in place in New England well before markets (part of the implementation of NEPOOL in the 70's)
- Techniques and tools for Unit Commitment have changed and been updated over the years.
  - This training is not focused on the techniques for solving the Unit Commitment problem, complex mathematical techniques are used to quickly solve these large problems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What is the Objective of Unit Commitment?

- Without any demand bidding, the objective is to minimize the overall committed cost of the resources needed to meet the load and reserve requirements.
- With demand bidding, the objective is to maximize social welfare (current objective)
- In both cases, UC takes into account all of the costs of producing the energy, including no load costs and startup costs. At the same time, UC respects each resource's characteristics such as, minimum up time, minimum down time, ramp rates, and notification times.

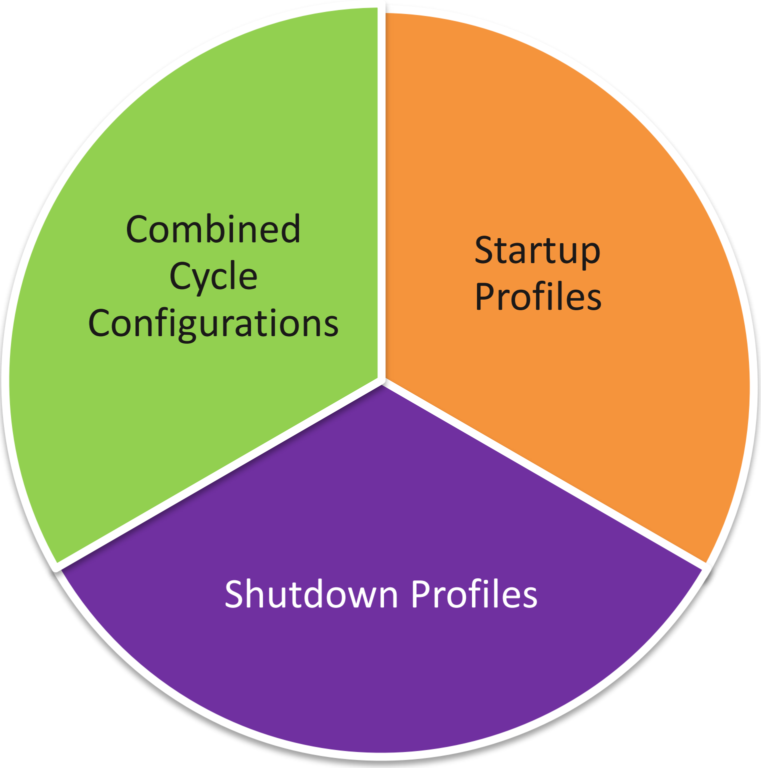
Parameters Used in Unit Commitment

- Incremental Energy Offer Curves
- Startup Costs $ (Hot, Cold, Intermediate)
  - Costs incurred per startup of the resource
  - Type of start is based upon number of hours down since previous run
- No Load Costs $
  - Fixed cost that is incurred every hour the resource is running
- Minimum Run Time (in hours or fractions of hours)
- Minimum Down Time (in hours or fractions of hours)

Parameters Used in Unit Commitment (cont.)

- Ramp Rates (MW/minute, different ramp rates may be submitted for ranges of the resource)
- Notification Time - Time to Start (Hot, Cold, Intermediate)
- Economic Minimum and Economic Maximum

Other Information that Can Be Used to Impact Unit Commitment



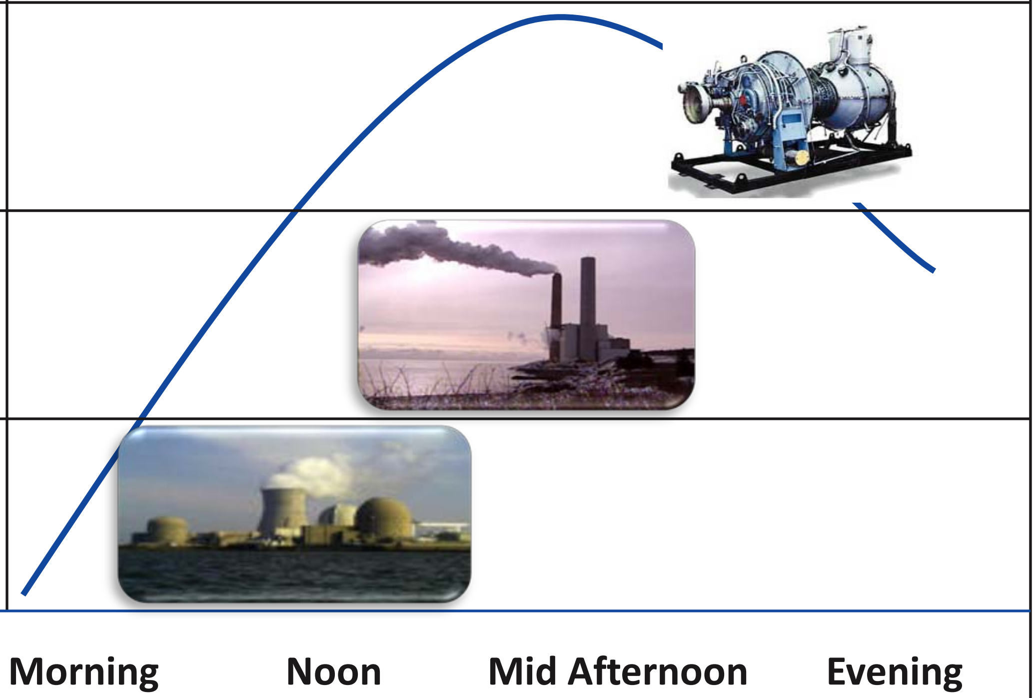
None of these are currently used in the ISO New England systems

Basic Terms and Concepts:
Unit Commitment & Dispatch

- Pool Schedule (Pool Committed)
  - Action by the ISO to schedule a resource for which the Participant submitted supply offers to sell energy. The ISO can schedule these resources in the DA Market as well as commit them to provide energy in the RT dispatch.
- Self Schedule (Self Committed)
  - Action of a Participant in committing and/or scheduling its resource, to provide service in an hour, whether or not in the absence of that action the resource would have been scheduled or dispatched by the ISO to provide the service.

Major Classification of Generators

Type of Asset (need to meet loads of)
Peaking Spring: 17,000 - 31,000 MW Summer: 20,000 - 31,000 MW
Intermediate Spring: 9,500 - 17,000 MW Summer: 10,000 - 20,000 MW
Base-load Spring: up to 9,500 MW Summer: up to 10,000 MW



How Dollar Values Impact Unit Commitment

- Total Production Cost ($)
  - Fixed Costs (not dependent on loading level), if Asset is "ON" cost is incurred
    - Startup Costs are included in the cost calculation for every start (based on Hot, Cold and Intermediate) of the Asset
    - No Load Costs are included in the cost calculation for every hour the Asset is on-line
  - Incremental Energy Costs
    - Based on the hourly Economic Dispatched MWh needed from each resource to meet the demand
- Objective is to minimize the total of the fixed and incremental costs.

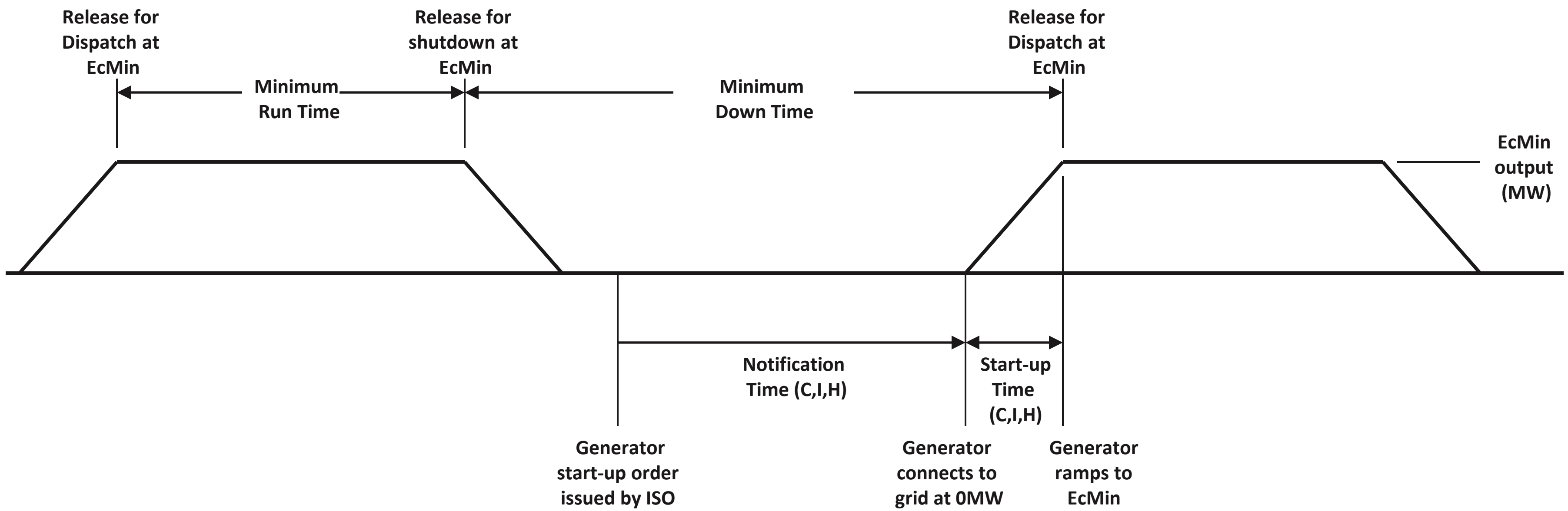
Impacts of Time Data on Unit Commitment

- Generally classified as "Intertemporal Parameters"
- Minimum Run Time
  - When a Asset is Committed it must run for at least this many hours before being shut down
- Minimum Down Time
  - When a Asset is De-committed it must stay down for at least this many hours before starting up again

Graphical Representation of Terms

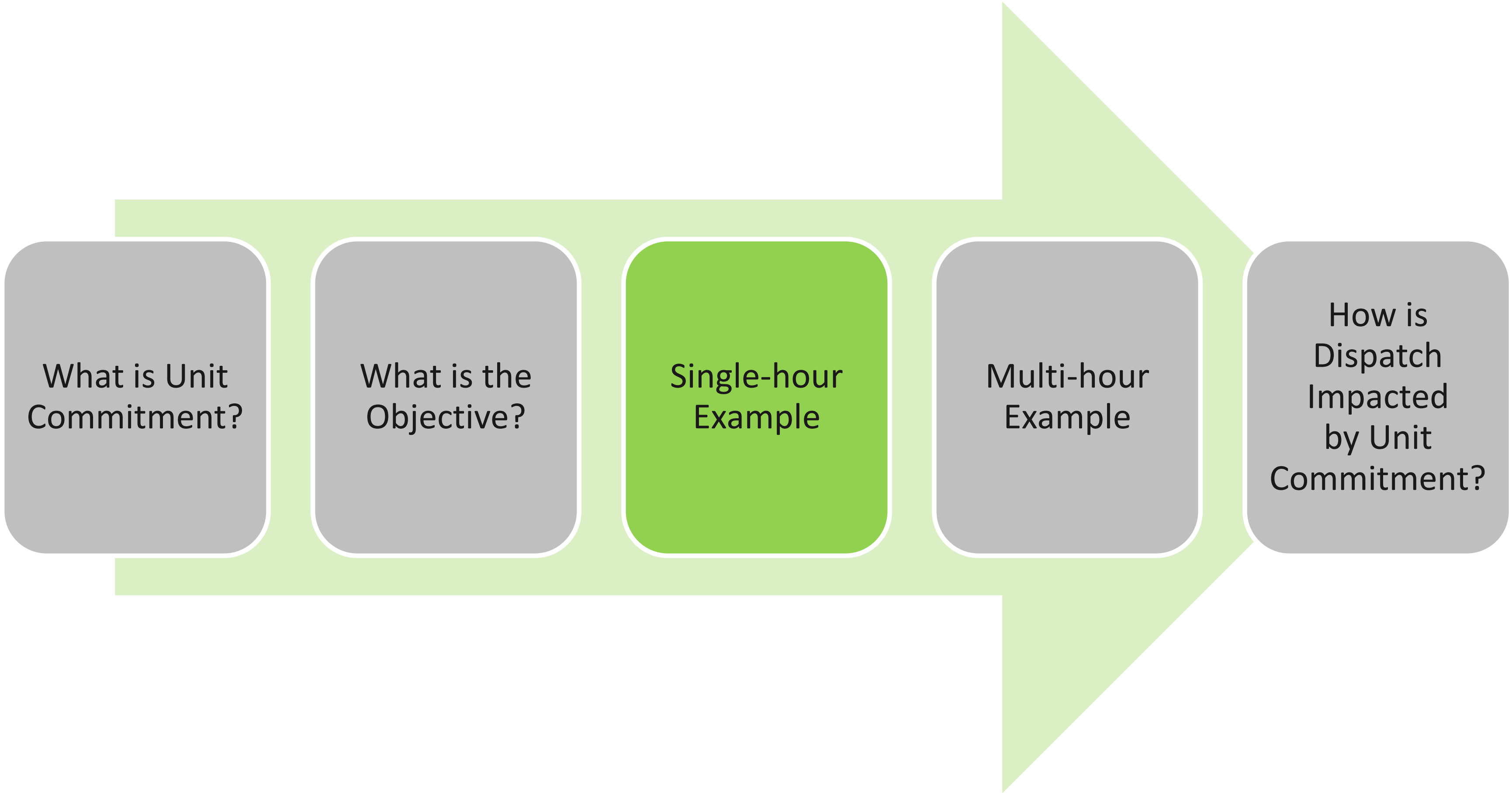
- Notification Time
- Start-up Time
- Minimum Run Time
- Minimum Down Time

What do these terms mean?



Major Points to Remember from this Section

- ✓ Decision Making Process
- ✓ Objective is to Maximize Social Welfare
- ✓ Startup and No-Load Cost impact solution
- ✓ Pool Committed versus Self Committed
- ✓ Intertemporal Parameters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Objectives

- Show how combinations of Asset's are evaluated against the Production Cost Objective Function
- Use a Single Hour for ease of use
- Expand to show Multiple Hours

Single-hour Example

Asset	Cost $/MW	ECO MIN (MW)	ECO MAX (MW)	No Load $/hr
X	$20	300	325	$5000
Y	$30	200	275	$1200
Z	$35	125	400	$700

Single-hour Example (cont.)

- For a single-hour, 8 possible combinations (each asset could be on or off so 2^3 is the number of unique combinations)
- Table shows all combinations possible

Comb.#	X	Y	Z
1	On	On	On
2	On	On	Off
3	On	Off	On
4	Off	On	On
5	On	Off	Off
6	Off	On	Off
7	Off	Off	On
8	Off	Off	Off

Single-hour Example (cont.)

- Each combination has a Minimum and Maximum Output based on the sum of the minimums and maximums of the resources that are on in that combination.
- These Minimum and Maximum values will represent the range of load levels that can be achieved with this combination.

Comb.#	∑Min	∑Max
1	625	1000
2	500	600
3	425	725
4	325	675
5	300	325
6	200	275
7	125	400
8	0	0

Single-hour Examples (cont.)

- Try three different load levels (no reserve requirement)
  - 350 MW
  - 475 MW
  - 525 MW
- Find the Total Dispatch Cost (objective function) for each of the eight combinations at each load level
  - Since we can look at dispatch of all eight solutions rather than just commitment, we are looking at commitment and dispatch.

Single-hour Example – 350 MW Load

Comb	Range MW	X No Load $	X MW & Cost $	Y No Load $	Y MW & Cost $	Z No Load $	Z MW & Cost $	Total Production Cost $
1 [XYZ]	625-1000	$5000	300 MW $6000	$1200	200 $6000	$700	125 $4375	$23,275
2 [XY]	500-600	$5000	300 MW $6000	$1200	200 $6000			$18,200
3 [XZ]	425-725	$5000	300 MW $6000			$700	125 $4375	$16,075
4 [YZ]	**325-675**			$1200	225 $6750	$700	125 $4375	$13,025
5 [X]	300-325	$5000	325 MW $6500					$11,500
6 [Y]	200-275			$1200	275 $8250			$9,450
7 [Z]	**125-400**					$700	350 $12250	$12,950 ✓
8 [ ]	0							$0

Excess Generation (green)   Capacity Deficient (red)

Single-hour Example – 475 MW Load

Comb	Range MW	X No Load $	X MW & Cost $	Y No Load $	Y MW & Cost $	Z No Load $	Z MW & Cost $	Total Production Cost $
1 [XYZ]	625-1000	$5000	300 MW $6000	$1200	200 $6000	$700	125 $4375	$23,275
2 [XY]	500-600	$5000	300 MW $6000	$1200	200 $6000			$18,200
3 [XZ]	425-725	$5000	325 MW $6500			$700	150 $5250	$17,450
4 [YZ]	325-675			$1200	275 $8250	$700	200 $7000	$17,150 ☑
5 [X]	300-325	$5000	325 MW $6500					$11,500
6 [Y]	200-275			$1200	275 $8250			$9,450
7 [Z]	125-400					$700	400 $14000	$14,700
8 [ ]	0							$0

Excess Generation (green) Capacity Deficient (red)

Single-hour Example – 525 MW Load

Comb	Range MW	X No Load $	X MW & Cost $	Y No Load $	Y MW & Cost $	Z No Load $	Z MW & Cost $	Total Production Cost $
1 [XYZ]	625-1000	$5000	300 MW $6000	$1200	200 $6000	$700	125 $4375	**$23,275**
2 [XY]	**500-600**	$5000	325 MW $6500	$1200	200 $6000			$18,700 ✓
3 [XZ]	**425-725**	$5000	325 MW $6500			$700	200 $7000	$19,200
4 [YZ]	**325-675**			$1200	275 $8250	$700	250 $8750	$18,900
5 [X]	300-325	$5000	325 MW $6500					**$11,500**
6 [Y]	200-275			$1200	275 $8250			**$9,450**
7 [Z]	125-400					$700	400 $14000	**$14,700**
8 [ ]	0							**$0**

Excess Generation (green) Capacity Deficient (red)

Single-hour Examples – Summary

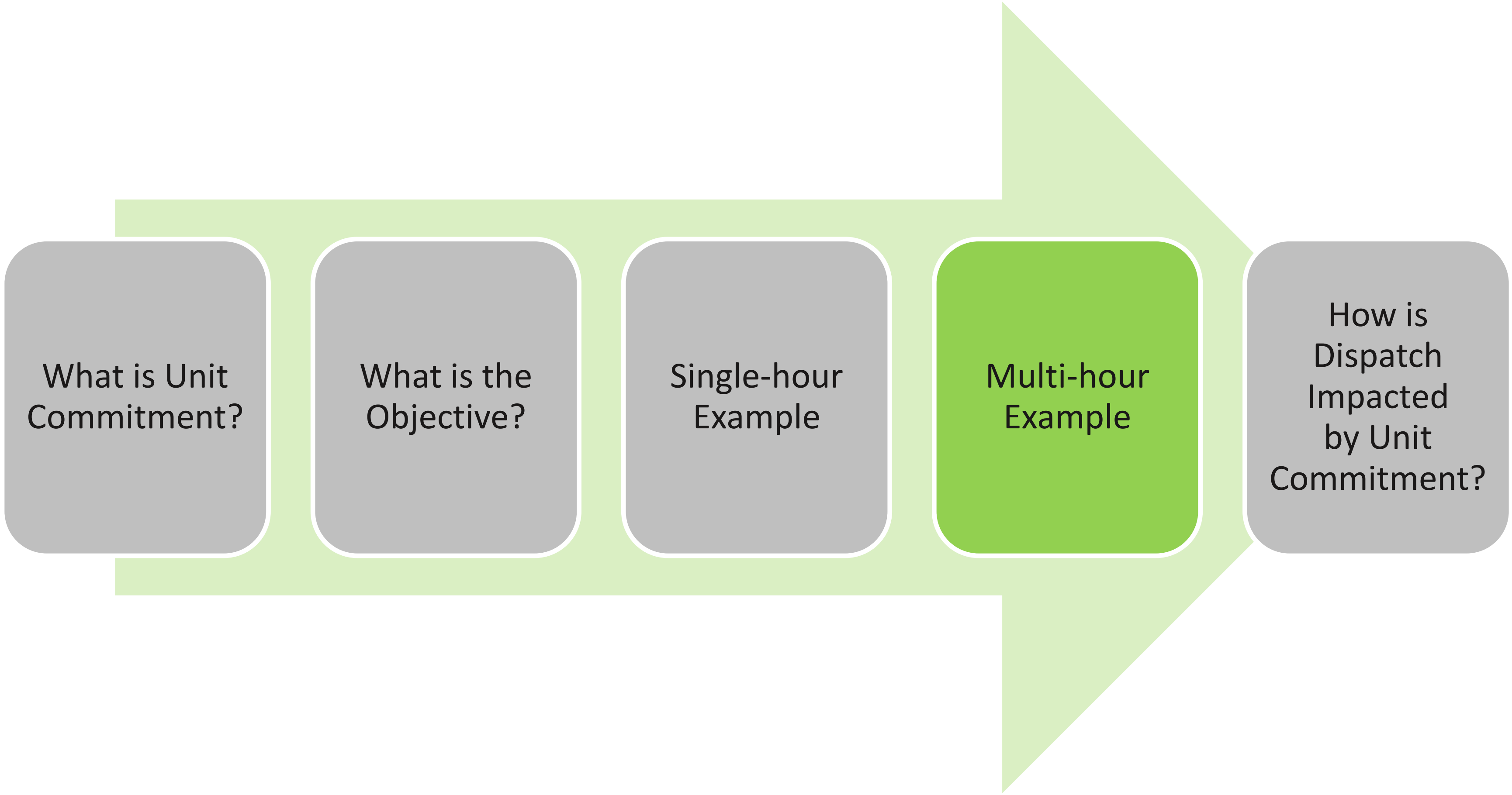
- ✓ Three different load levels – three different best commitment and dispatch solutions
- ✓ Each of the eight combinations may have at least one load level where that combination is the lowest cost
- ✓ These single-hour examples do not take into consideration previously discussed “intertemporal parameters.”

Single-hour Example – 525 MW Load

Comb	Range MW	X No Load $	X MW & Cost $	Y No Load $	Y MW & Cost $	Z No Load $	Z MW & Cost $	Total Production Cost $
1 [XYZ]	625-1000							
2 [XY]	**500-600**	$5000	___ MW $_____	$1200	___ MW $_____			$________
3 [XZ]	**425-725**	$5000	___ MW $_____			$700	___ MW $_____	$________
4 [YZ]	**325-675**			$1200	___ MW $_____	$700	___ MW $_____	$________
5 [X]	300-325							
6 [Y]	200-275							
7 [Z]	125-400							
8 [ ]	0							

Changed energy cost

Asset	Cost[$/MW]
X	20
Y	35
Z	25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Multi-hour Example
How is Dispatch Impacted by Unit Commitment?

Multi-hour Example

- The number of possible combinations that could be evaluated in a multi-hour example increases exponentially
- So, with our previous set of three resources, one hour has eight combinations, if we look at four hours there are 8^4 or 4096 possible combinations of those three assets towards meeting those four hours load
- As we have seen before, many of each hourly eight combinations may not be viable (excess generation or capacity deficient), so the actual number of viable combinations will be much smaller (if three viable each hour then 3^4 or 81 viable combinations).

Multi-hour Example (cont.)

- Example will use the same resources as single-hour examples
- Assume the following loads for the four hours:
  - Hour 12 – 475 MWh
  - Hour 13 – 525 MWh
  - Hour 14 – 525 MWh
  - Hour 15 – 350 MWh
- What are the possible combinations that are viable?
- What is the cost of each of these combinations?

Multi-Hour Example (cont.)

Comb.#	Production Cost $ @ 475 MWh Load Hour 12	Production Cost $ @ 525 MWh Load Hour 13	Production Cost $ @ 525 MWh Load Hour 14	Production Cost $ @ 350 MWh Load Hour 15
1 [XYZ]	$23,275	$23,275	[illegible]	$23,275
2 [XY]	$18,200	$18,700	[illegible]	$18,200
3 [XZ]	$17,450	$19,200	$19,200	$16,075
4 [YZ]	$17,150	$18,900	$18,900	$13,025
5 [X]	$11,500	[illegible]	[illegible]	$11,500
6 [Y]	$9,450	$9,450	$9,450	$9,450
7 [Z]	$14,700	$14,700	$14,700	$12,950
8 [ ]	$0	$0	$0	$0

Combination #1

Combination #2 (4-2-2-4)

2x3x3x2=36 Combinations

Excess Generation   Capacity Deficient

Multi-hour Example – No Intertemporals

Comb.#	Production Cost $ @ 475 MWh Load Hour 12	Production Cost $ @ 525 MWh Load Hour 13	Production Cost $ @ 525 MWh Load Hour 14	Production Cost $ @ 350 MWh Load Hour 15
1 [XYZ]	$23,275	$23,275	$23,275	$23,275
2 [XY]	$18,200	$18,700	$18,700	$18,200
3 [XZ]	$17,450	$19,200	$19,200	$16,075
4 [YZ]	$17,150	$18,900	$18,900	$13,025
5 [X]	$11,500	[illegible]	[illegible]	$11,500
6 [Y]	$9,450	[illegible]	[illegible]	$9,450
7 [Z]	$14,700	$14,700	$14,700	$12,950
8 [ ]	$0	$0	$0	$0

Lowest Cost = $67,500

(17,150+18,700+18,700+12,950)

Excess Generation   Capacity Deficient

Introduction of Intertemporals

- Minimum Run Time
  - Asset X = 3
  - Asset Y = 2
  - Asset Z = 1

Multi-hour Example – Intertemporals

Comb.#	Production Cost $ @ 475 MWh Load Hour 12	Production Cost $ @ 525 MWh Load Hour 13	Production Cost $ @ 525 MWh Load Hour 14	Production Cost $ @ 350 MWh Load Hour 15
1 X,Y,Z	$23,275	$23,275	$23,275	$23,275
2 X,Y	$18,200	$18,700	$18,700	$18,200
3 X, Z	$17,450	$19,200	$19,200	$16,075
4 Y,Z	$17,150	$18,900	$18,900	$13,025
5 X		$11,500		$11,500
6 Y	$9,450	$9,450	$9,450	$9,450
7 Z	$14,700	$14,700	$14,700	$12,950
8	$0	$0	$0	$0

Asset X cannot run for only two hours

Lowest Cost = $67,800

Excess Generation   Capacity Deficient

What If We Change the Intertemporals?

- Minimum Run Time
  - Asset X = 2
  - Asset Y = 1
  - Asset Z = 3

Multi-hour Example – Intertemporals

Comb.#	Production Cost $ @ 475 MWh Load Hour 12	Production Cost $ @ 525 Mwh Load Hour 13	Production Cost $ @ 525 Mwh Load Hour 14	Production Cost $ @ 350 MWh Load Hour 15
1 X,Y,Z	$23,275	$23,275	$23,275	$23,275
2 X,Y	$18,200	$18,700	$18,700	[illegible]
3 X, Z	$17,450	$19,200	$19,200	$16,075
4 Y,Z	$17,150	$18,900	$18,900	$13,025
5 X	$11,500	$11,500	[illegible]	$11,500
6 Y	$9,450	$9,450	$9,450	$9,450
7 Z	$14,700	$14,700	$14,700	$12,950
8	$0	$0	$0	$0

Asset Z must run for at least 3 hours cannot use these

Lowest Cost = $67,900

Green: Excess Generation
Red: Capacity Deficient

Commitment Schedule (Operating Plan)

- Commitment software determines which generators are scheduled to run for which hours.
- It is only an on/off schedule, the MW levels are not used
- In the Day-Ahead Market (DAM), we run the commitment schedule through a dispatch algorithm to determine loading levels and demand clearing as well as final costs and LMPs.
- In the Real-Time Market (RTM), the commitment schedule (also known as Current Operating Plan) is used to determine actual on/off times for resources; actual dispatch of those resources is done on a five-minute basis.

Multi-hour Example – Based on Last Solution Commitment Schedule

Asset	Hour 12	Hour 13	Hour 14	Hour 15
X	Off	Off	Off	Off
Y	On	On	On	Off
Z	On	On	On	On

Major Points to Remember from this Section

- ✓ Multiple Hours solution impacted by minimum run time and minimum down time
- ✓ An hour may not be able to achieve its lowest cost solution
- ✓ Objective is met for the whole period
- ✓ Unit Commitment determines Current Operating Plan
- ✓ Current Operating Plan is on/off schedule

What is Unit Commitment?

What is the Objective?

Single-hour Example

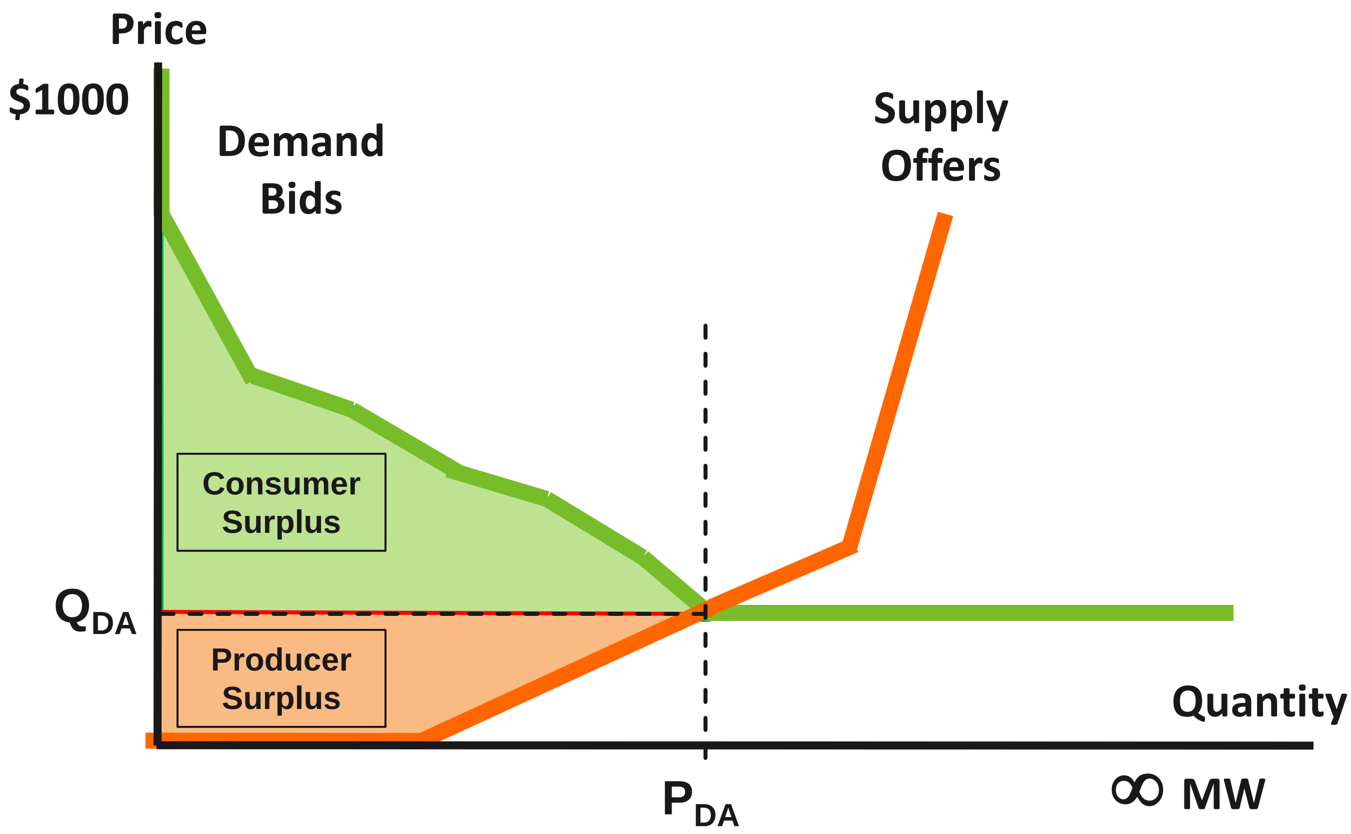
Multi-hour Example

How is Dispatch Impacted by Unit Commitment?

Commitment Impact on Economic Dispatch for a Single Period

- Economic Dispatch is the least-cost usage of the **committed** (as defined by the Operating Plan) assets during a single period to meet the demand
  - Day-Ahead the single period is hourly
  - Real-Time the single period is approximately every five minutes
- Economic Dispatch doesn't need to adhere to inter-temporal parameters, since commitment has respected them
- Both in the DAM and RTMs, the set of resources are dispatched to maximize the social welfare
- Economic Dispatch is what determines the LMPs (not the commitment)

Maximizing Social Welfare



Social Welfare = Producer Surplus + Consumer Surplus

Module Review: Topics Covered

- What is Unit Commitment?
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- How is Dispatch Impacted by Unit Commitment?

Quick Review

Minimum Run Time and Minimum Down Times are this type of parameters? What are ___________________________.

There are two ways to be committed by the ISO. One is Pool Commitment the other is ____________________________.

When evaluating the total cost of a committed set of assets the software will use the Startup Cost, the ______________ and the __________________.

The current _____________ _____________ defines the set of assets that will be on and off for the hours of a period.

The objective function of the Energy Markets (both DA and RT) is to maximize the _____________ ____________.

Questions

Evaluations