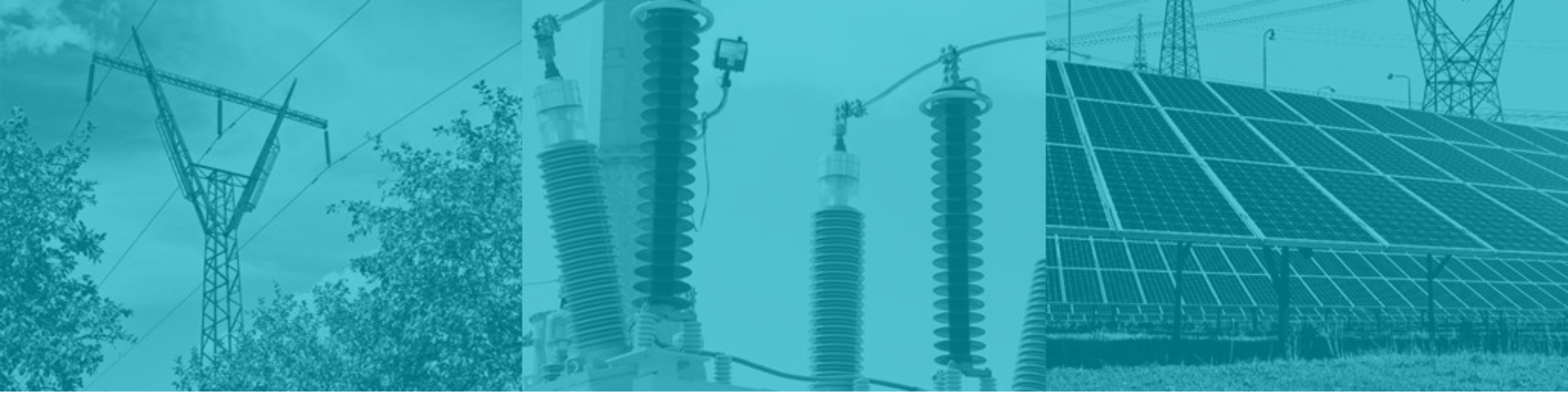
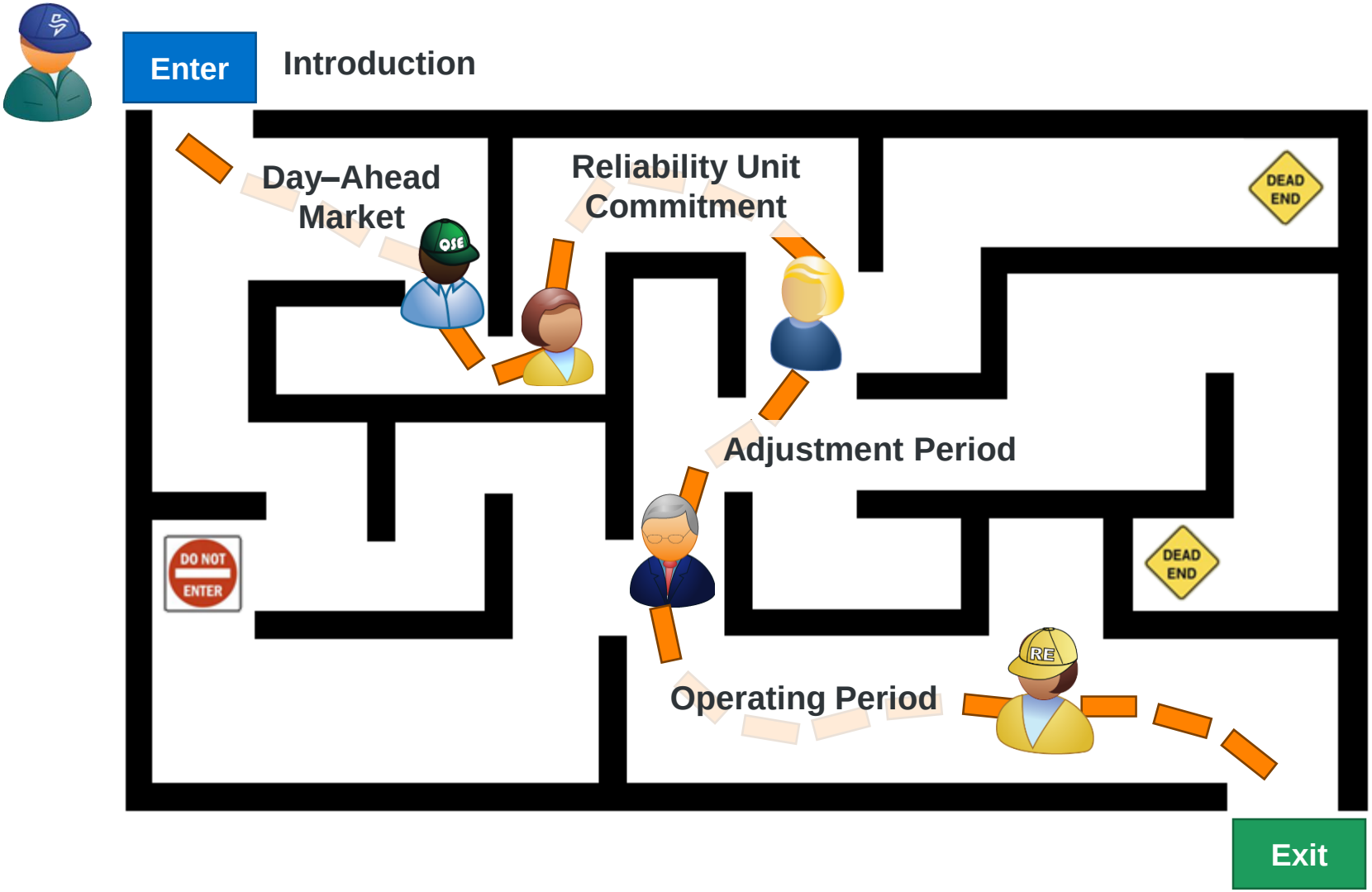


ERCOT MARKET EDUCATION

Wholesale Markets 201

Operating Period

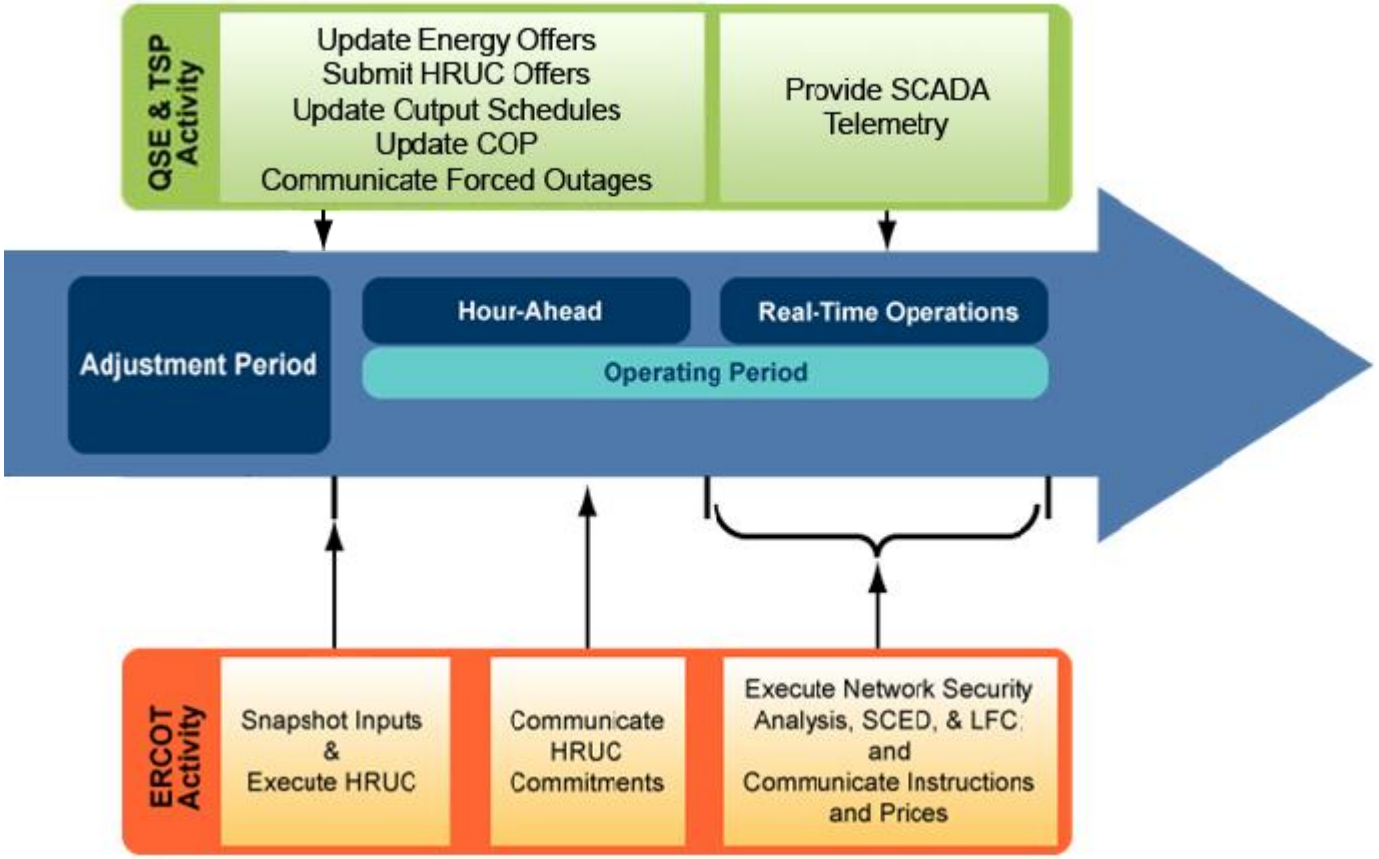
Module Overview



Upon completion of this module, you will be able to:

- Identify the timeline and processes of the Operating Period
- Describe the inputs, processes, and outputs related to Real-Time Energy Dispatch
- Describe the functions of Load Frequency Control
- Illustrate the primary financial impacts associated with the Operating Period

The Operating Period Activity Timeline



Goals of Real-Time Operations

- Manage reliability
  - Match generation with demand
  - Operate transmission system within established limits
- Operate the system at least cost

ERCOT finds the balance between Reliability and Economics

Constraints

- Power Balance
- Transmission constraints
- Resource constraints

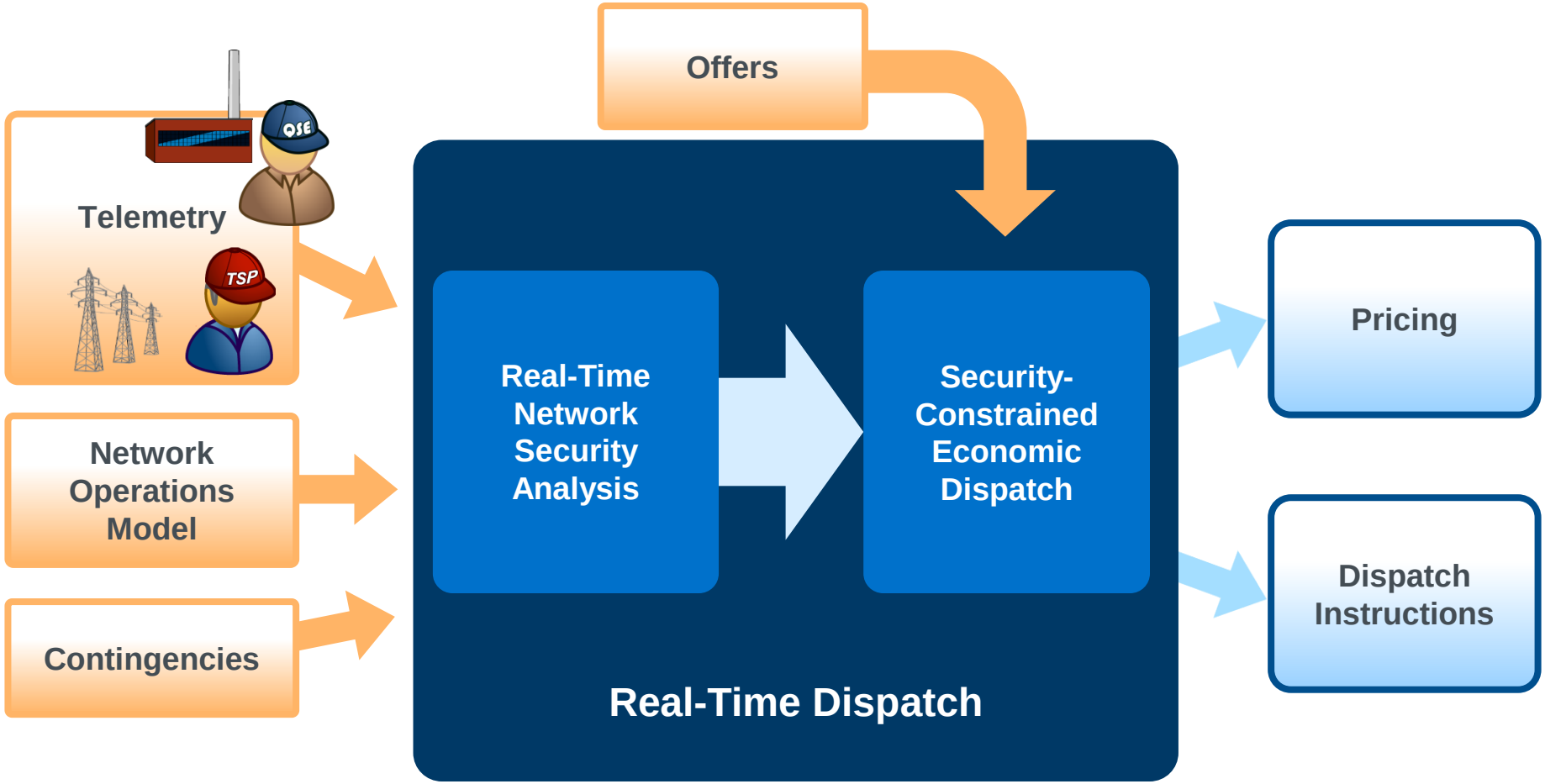
Contributing Factors

- Weather conditions
- Planned and unplanned Outages

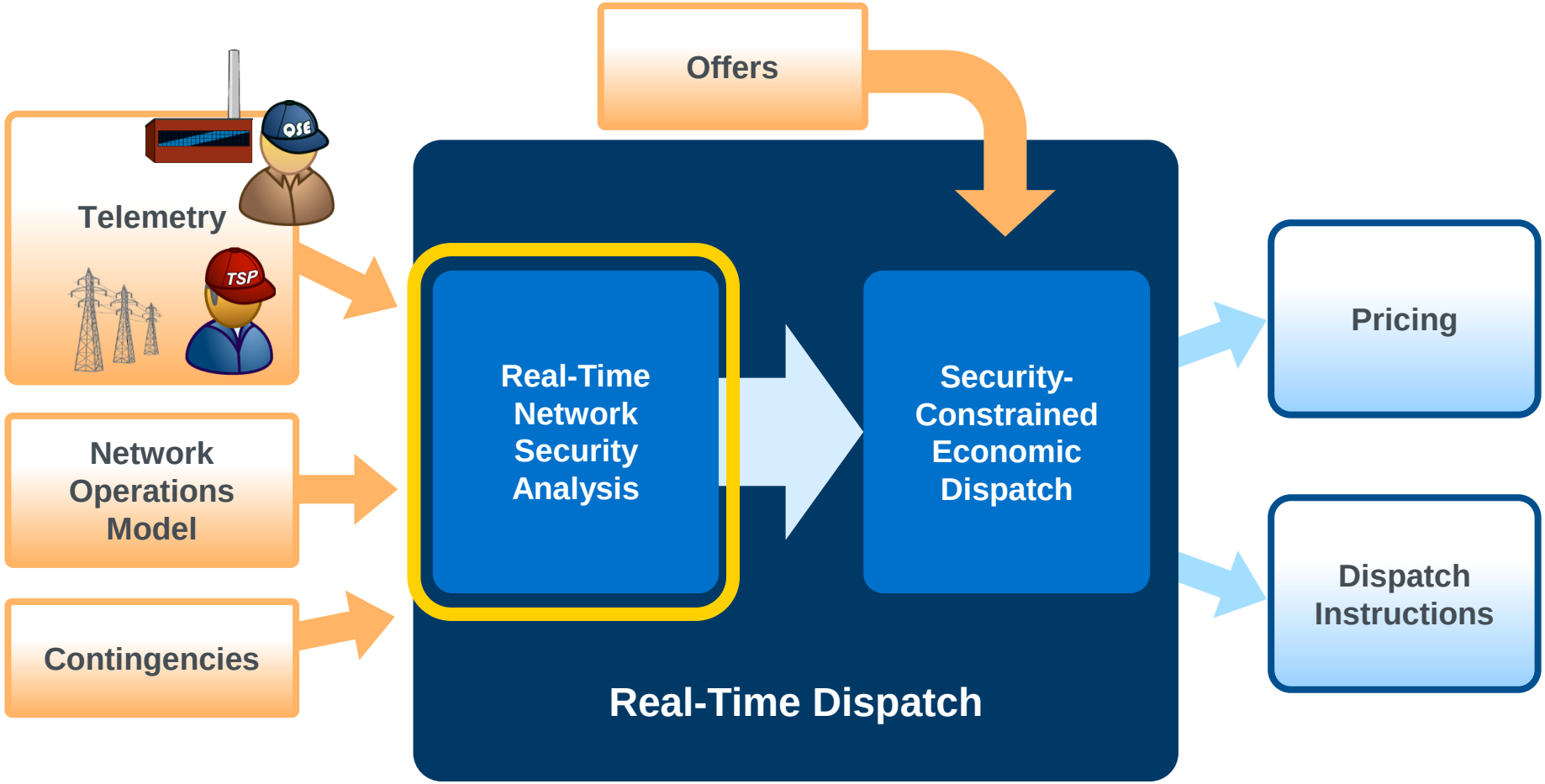
Real Time Processes

- Energy Dispatch
  - Achieve Power Balance
  - Manage Congestion
  - Least Cost Dispatch
- Load Frequency Control
  - Maintain Power Balance

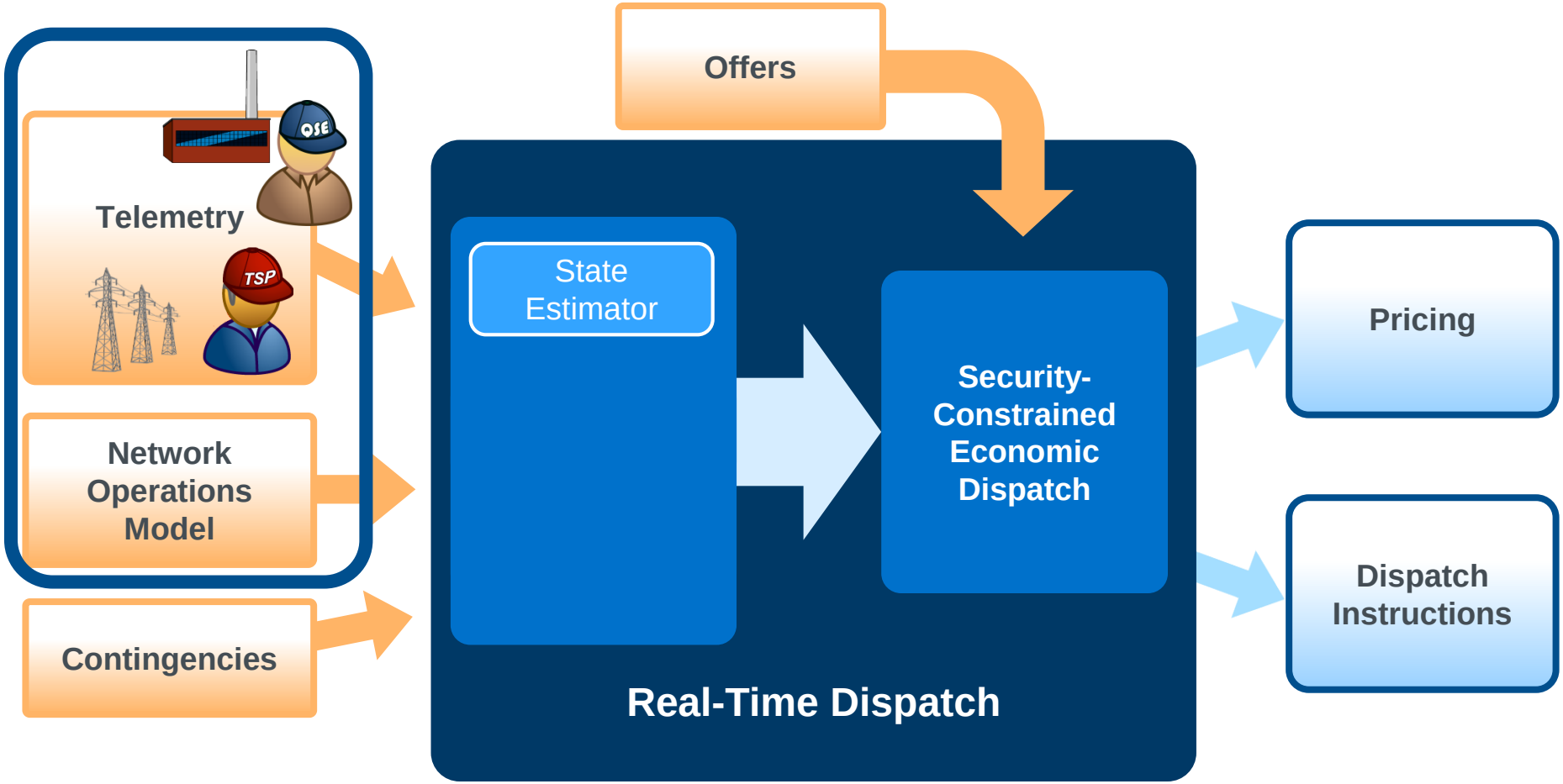
Energy Dispatch Overview



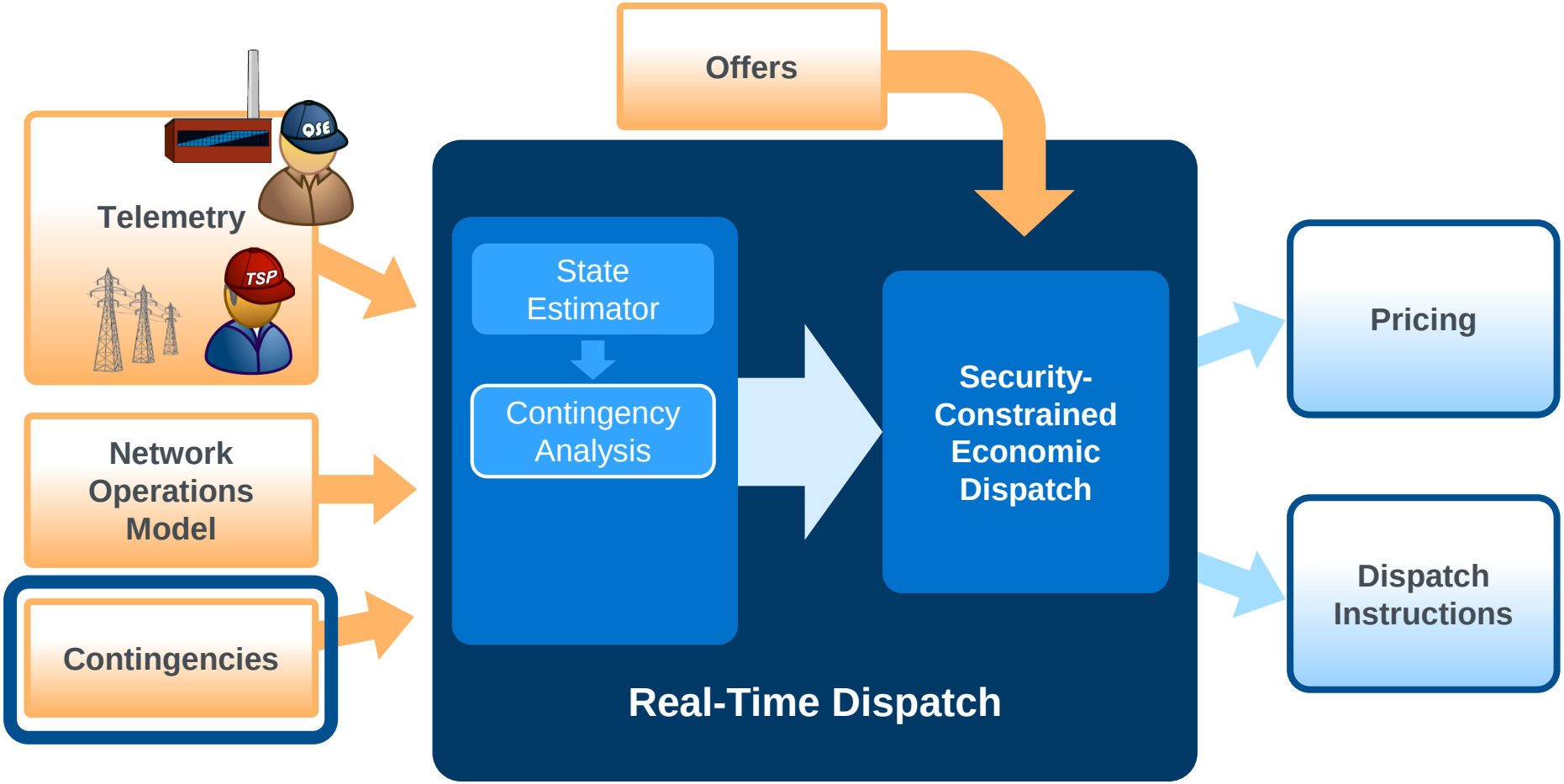
Real-Time Network Security Analysis



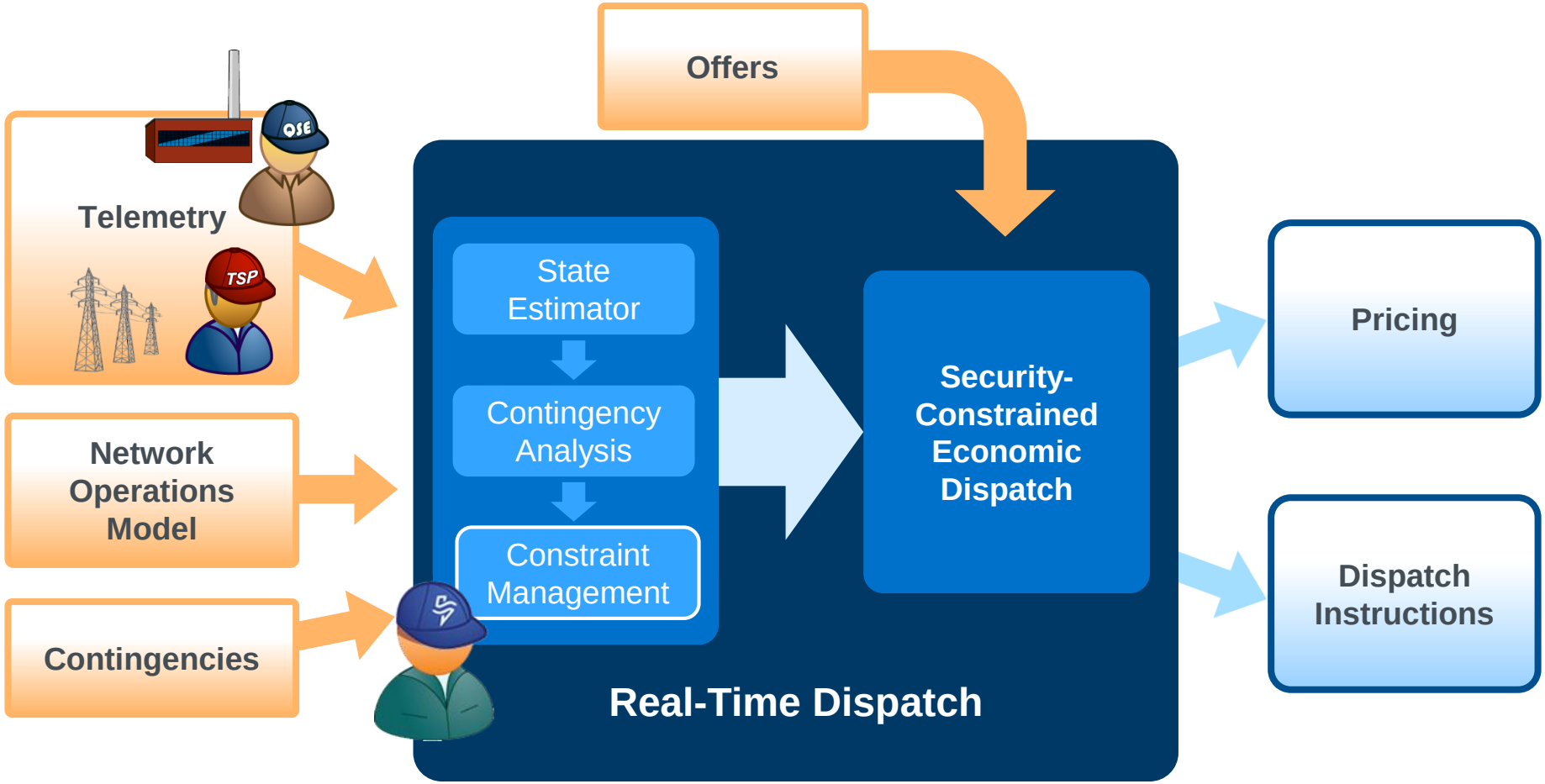
Real-Time Network Security Analysis



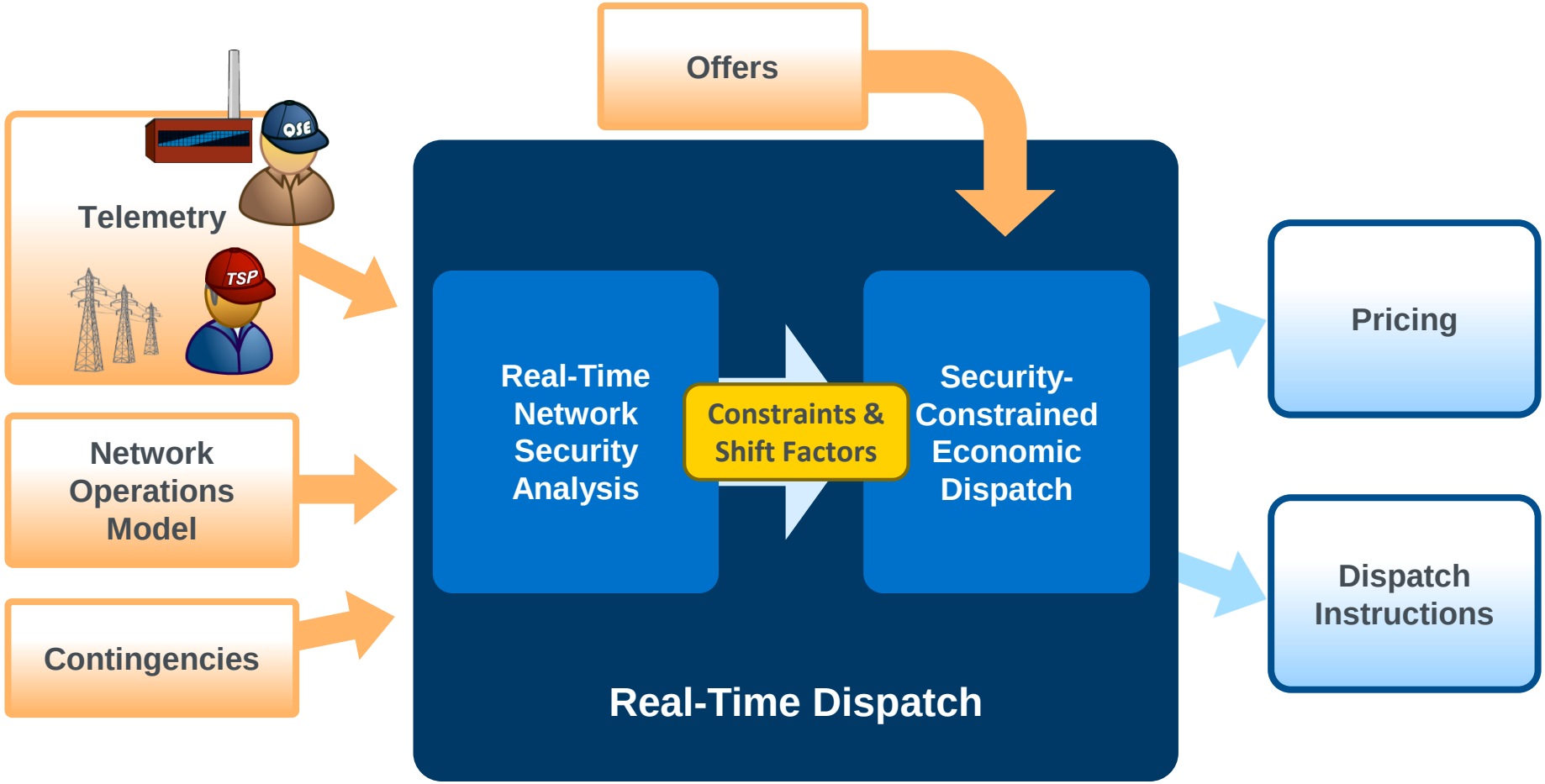
Real-Time Network Security Analysis



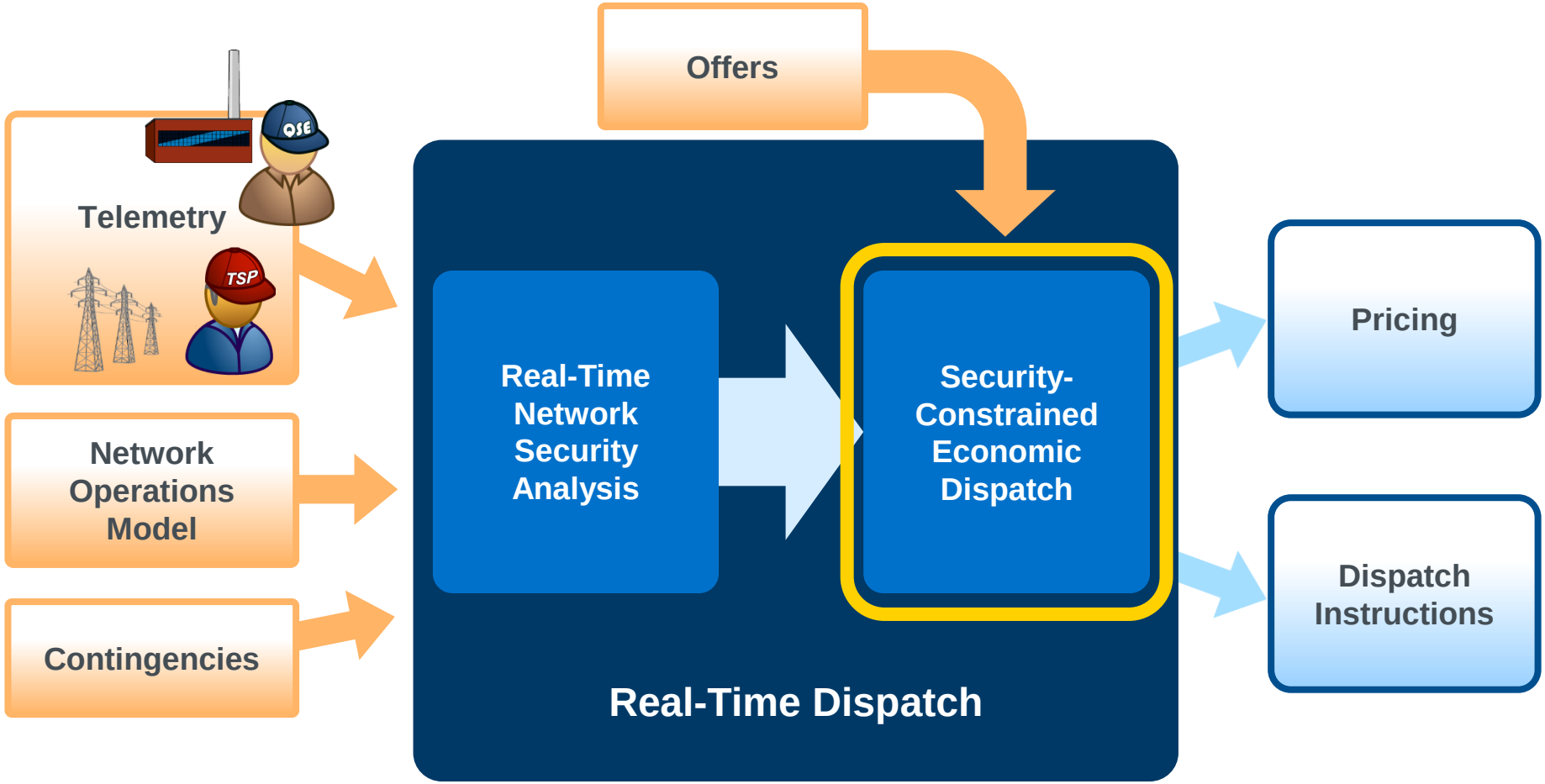
Real-Time Network Security Analysis



Real-Time Network Security Analysis



Real-Time Network Security Analysis



Balancing Reliability and Economics

Network Security Analysis

Energy Offer Curves

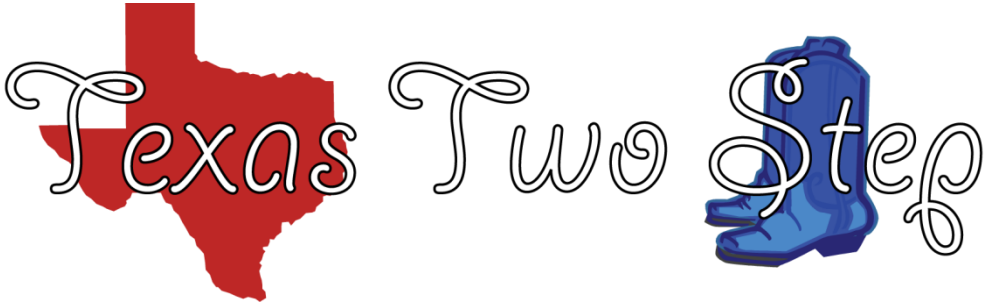
SCED

The Texas Two Step

SCED executes twice each cycle

- Ensures competition
- Reduces Market Power
- Allows high prices under “the right circumstances”

The Texas Two Step



Circumstances for high prices

- All generation is expensive
- Expensive generation needed to resolve constraints
- Scarcity

The Texas Two Step

Constraints are classified* as:

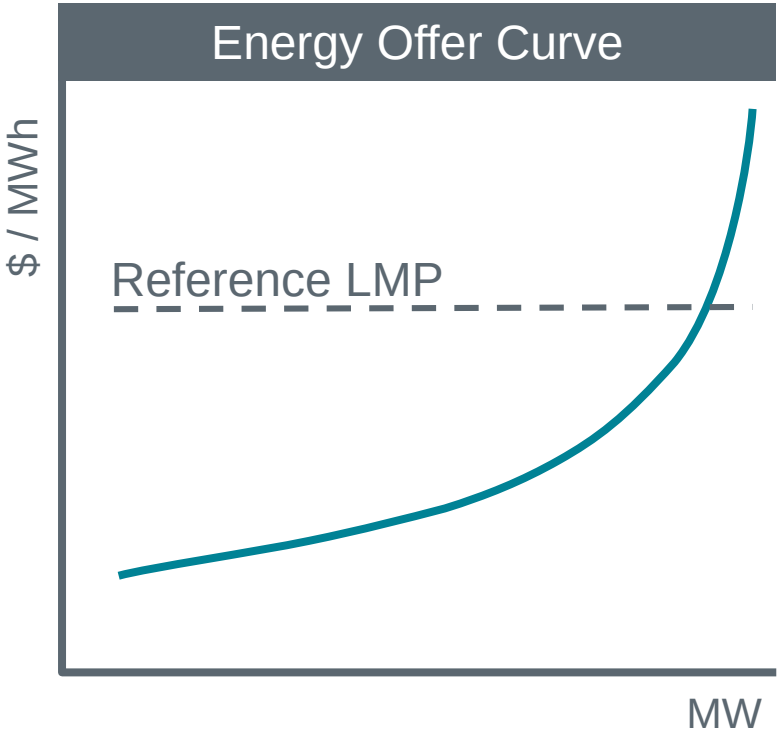
- **Competitive**
- **Non-Competitive**

* See Protocol Section 3.19.4 for details

The Texas Two Step

Step One

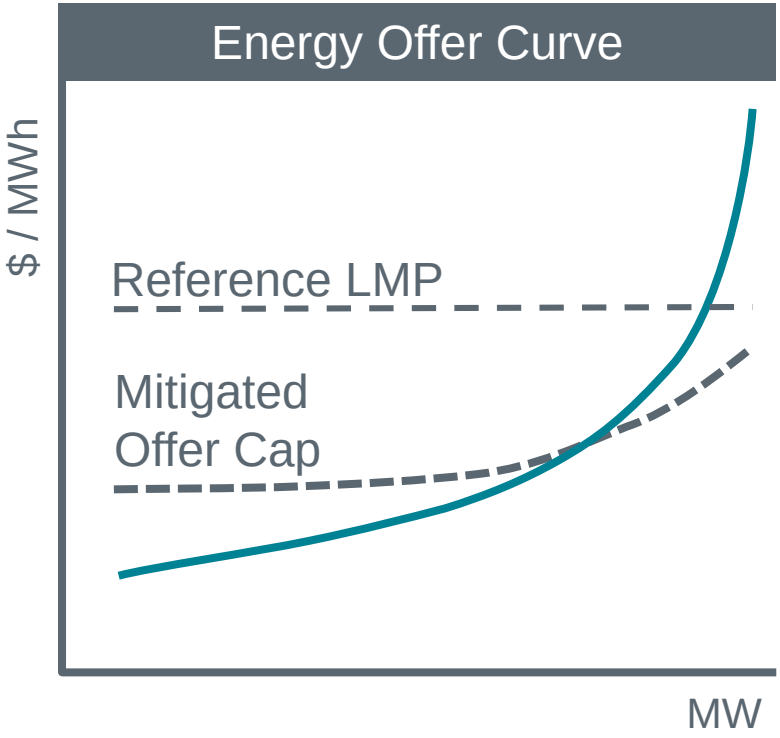
- Uses Energy Offer Curves for all On-Line Resources
- Observes the limits of Competitive Constraints only
- Determines “Reference LMPs”



The Texas Two Step

Step Two

- Observes limits of all Constraints
- Energy Offer Curve for each on-line Generation Resource capped at greater of Reference LMP or Mitigated Offer Cap

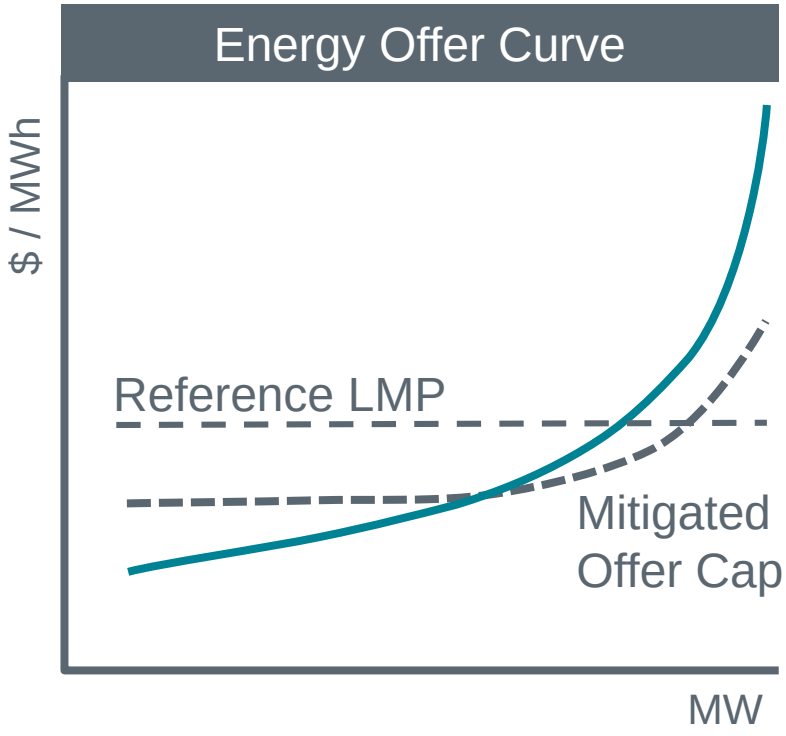


SCED Step Two produces binding LMPs and Dispatch Instructions

Scenario 1

SCED has completed Step One and determined Reference LMPs

How will this Energy Offer Curve look in STEP Two?

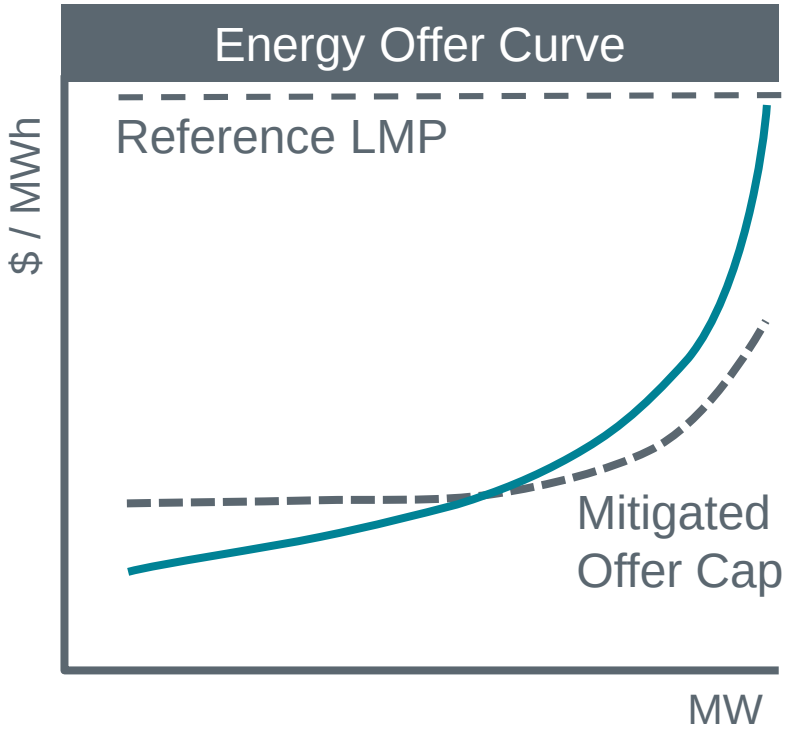


Scenario 2

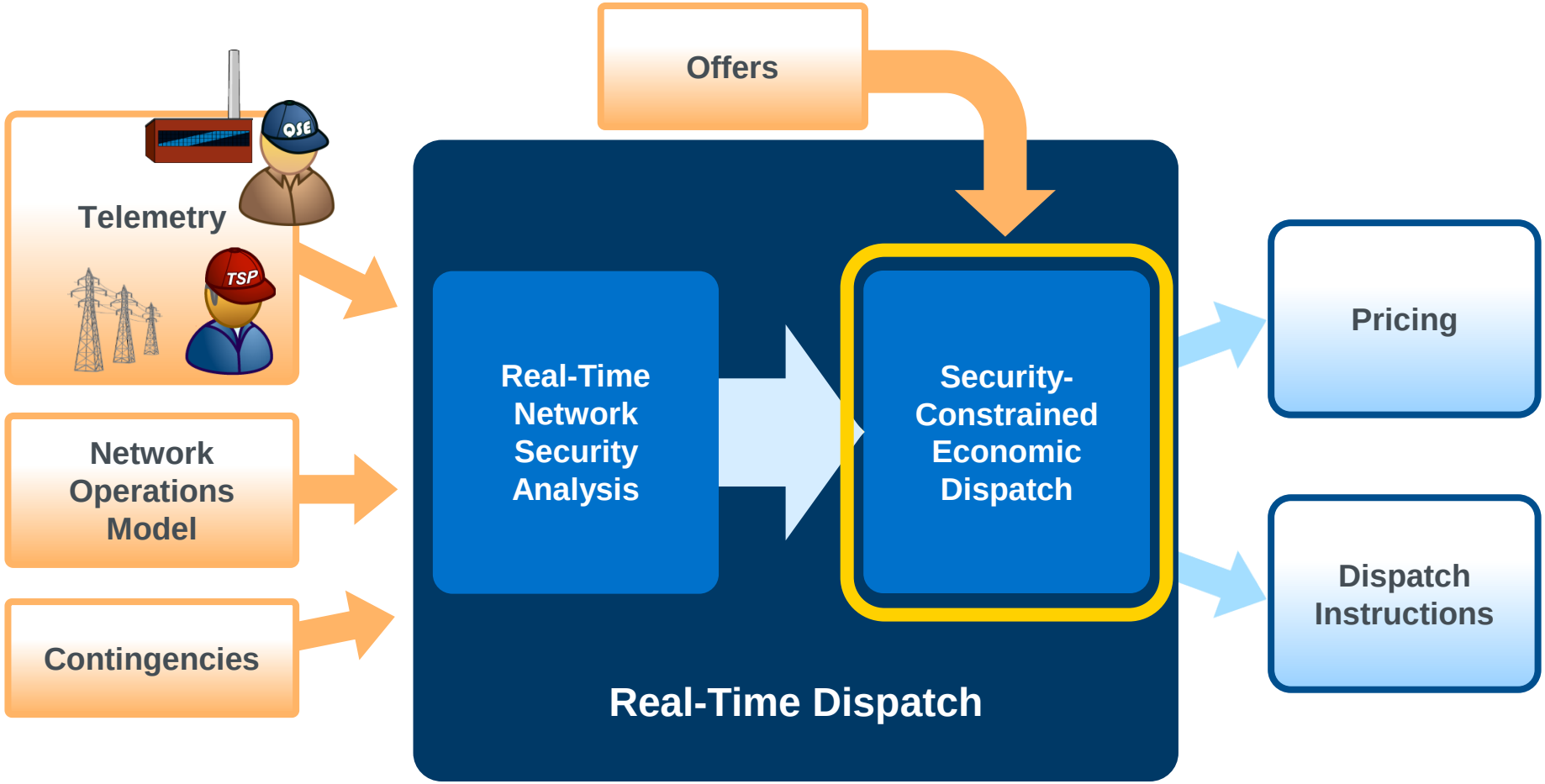
SCED has completed Step One and determined Reference LMPs

1. ***How will this Energy Offer Curve look in STEP Two?***

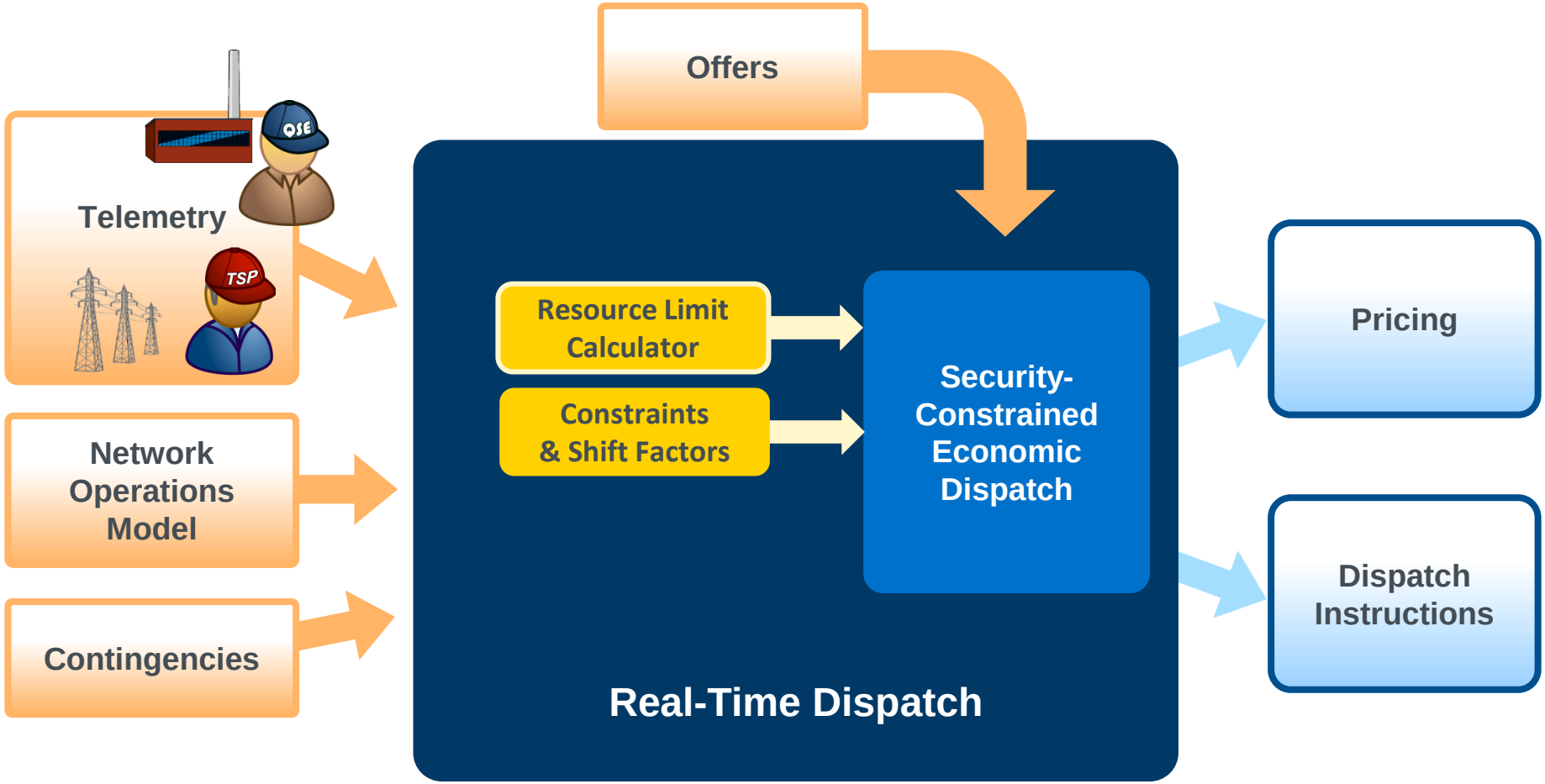
2. ***What will it take for this scenario to occur?***



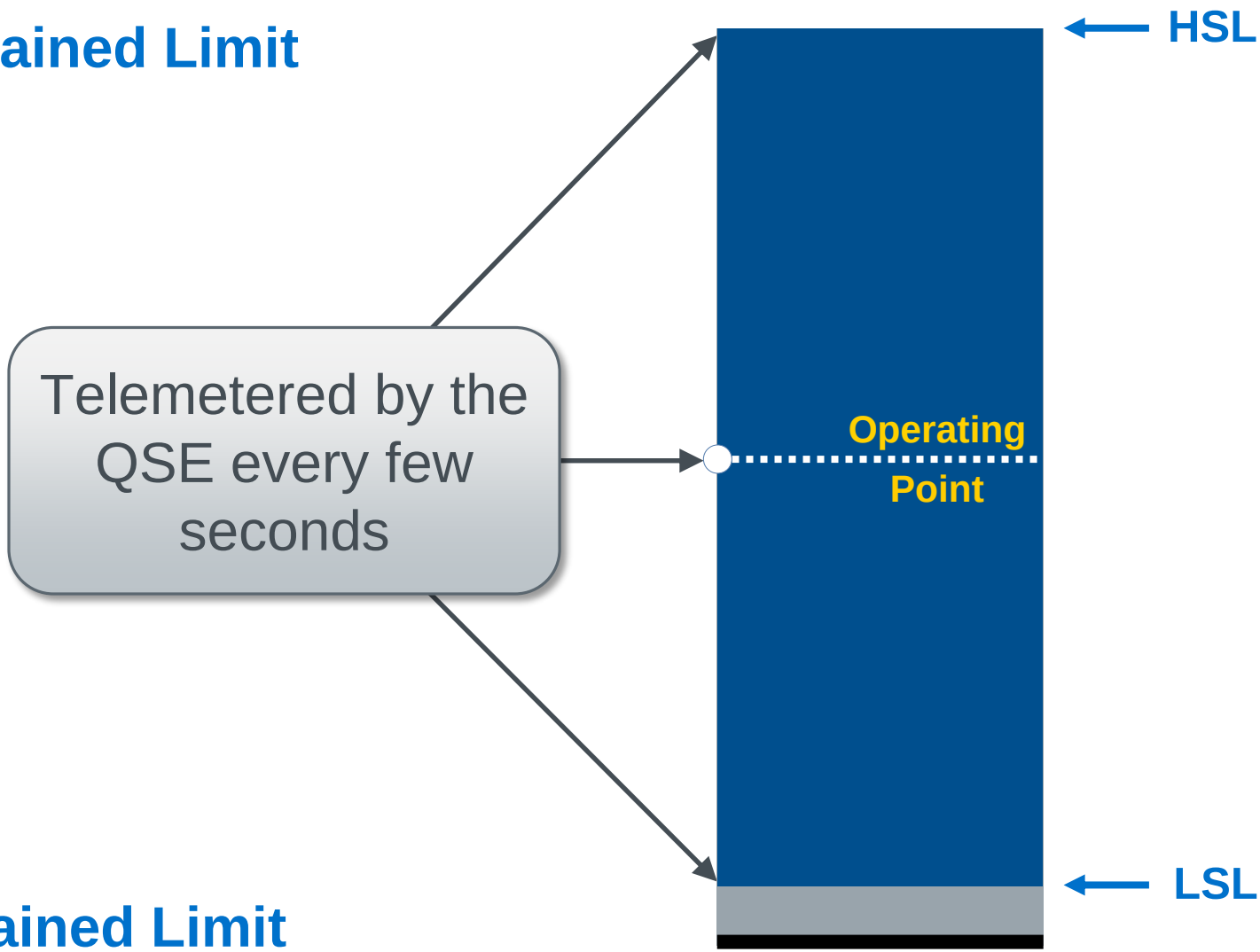
The SCED Process



The SCED Process



High Sustained Limit

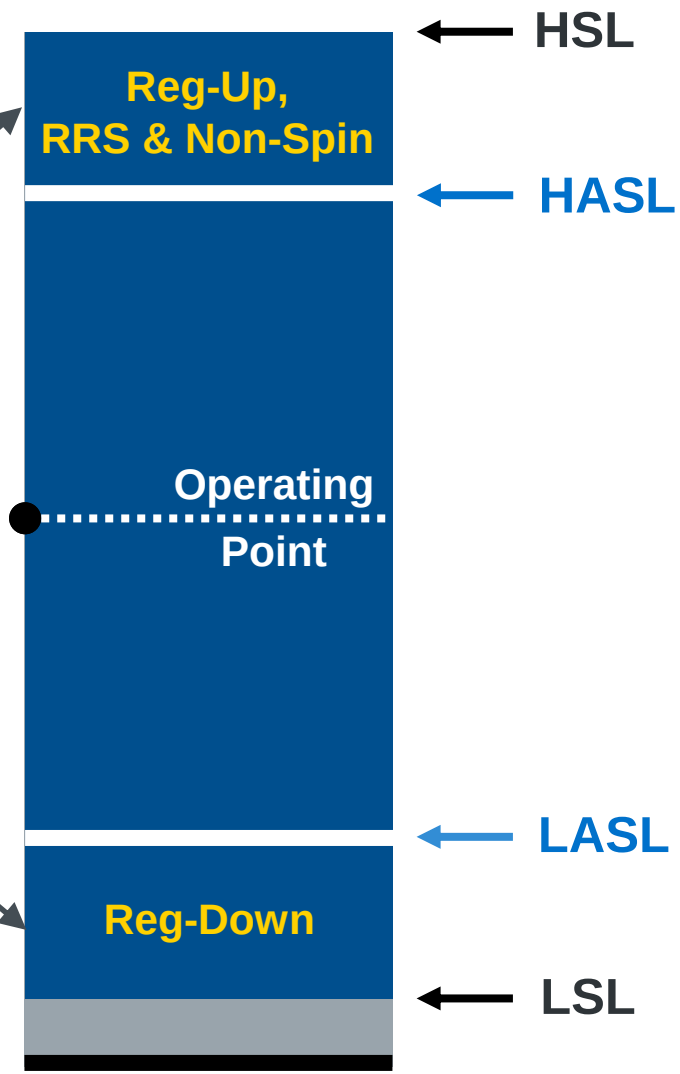


Low Sustained Limit

High Ancillary Service Limit

Also telemetered by QSE

- AS Resource Responsibility (Reg)
- AS Schedule (RRS & Non-Spin)



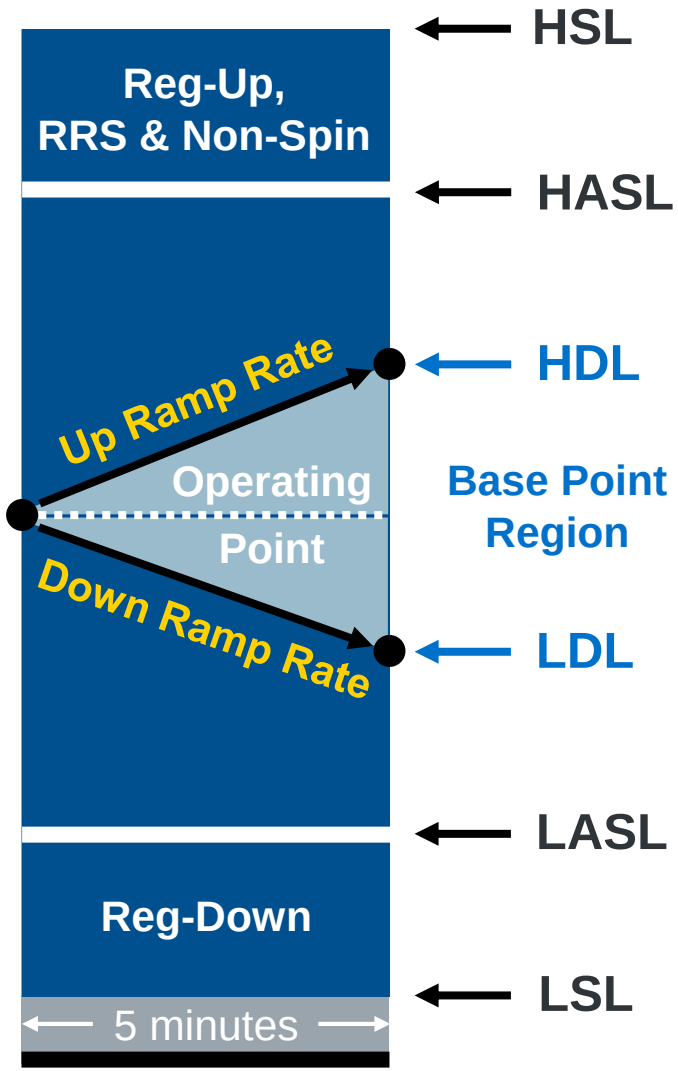
Low Ancillary Service Limit

High Dispatch Limit

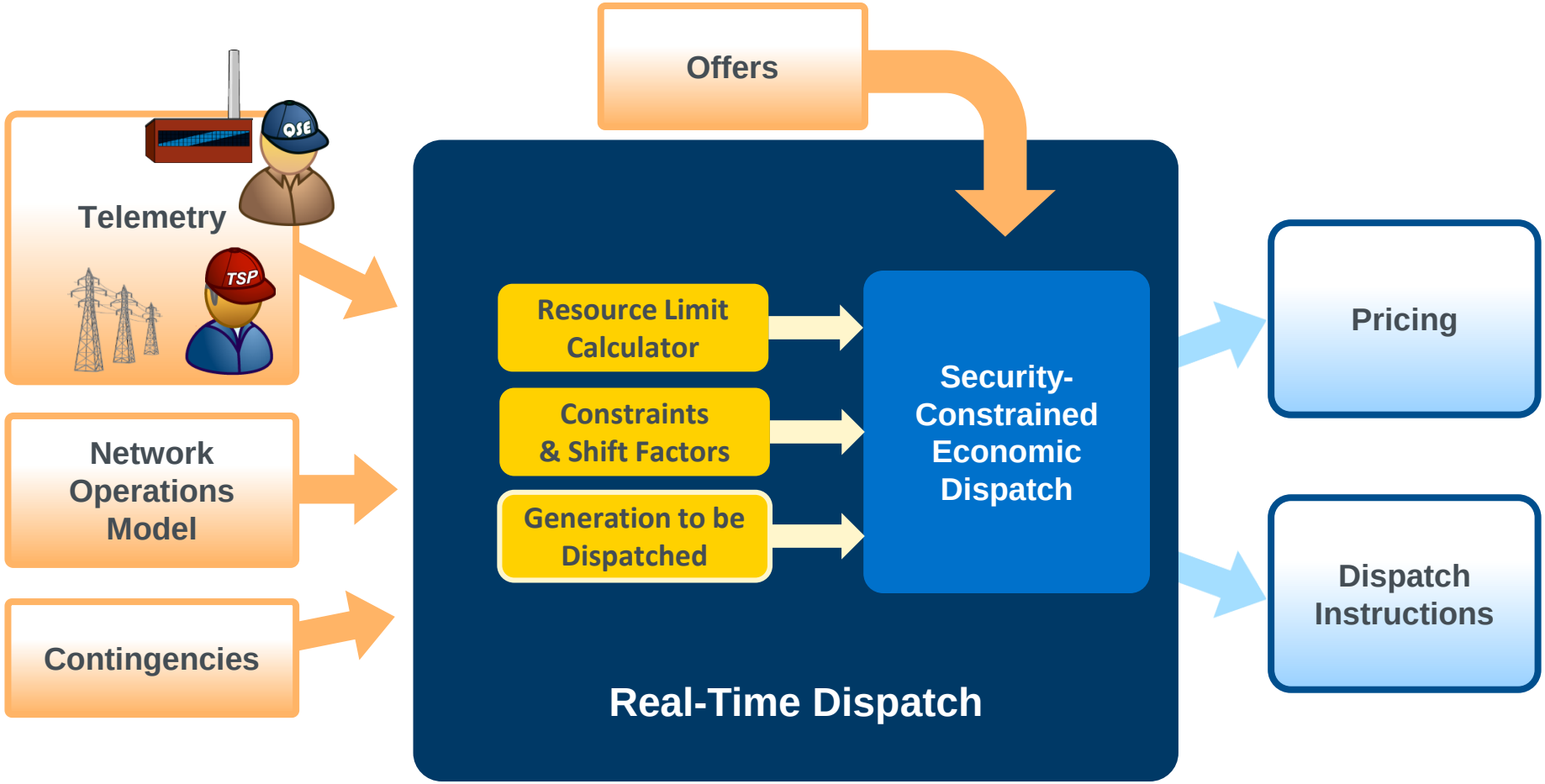
HDL ≤ HASL

LDL ≥ LASL

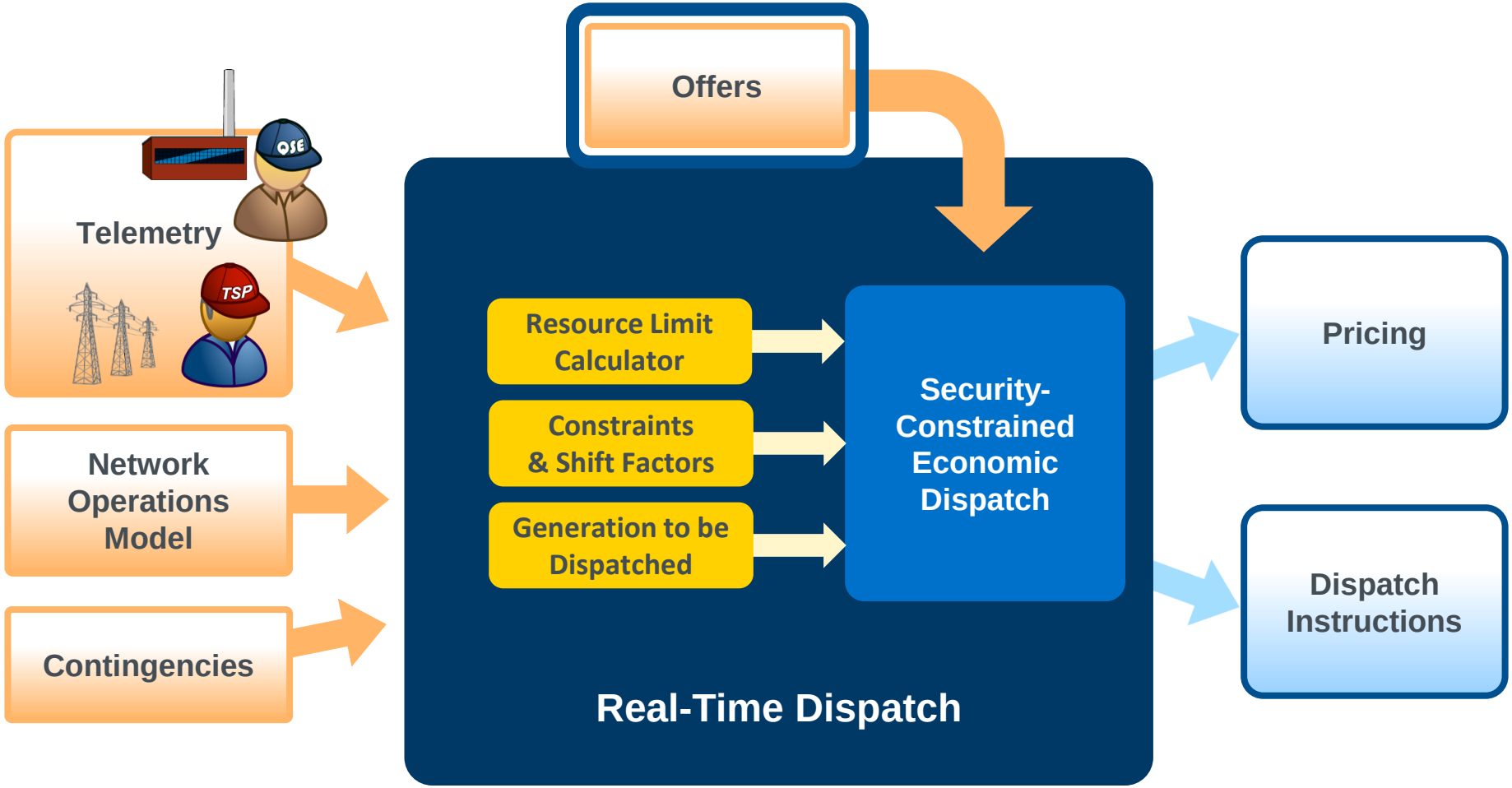
Low Dispatch Limit



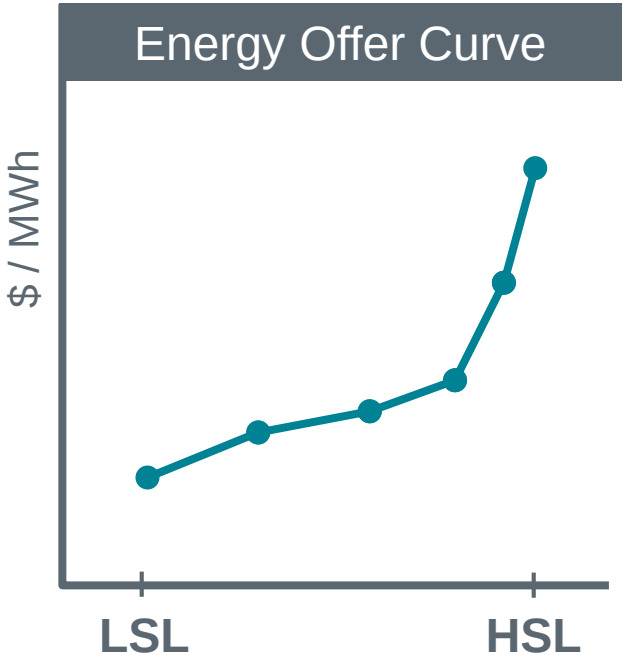
The SCED Process



The SCED Process



Energy Offer Curves for Generation Resources:



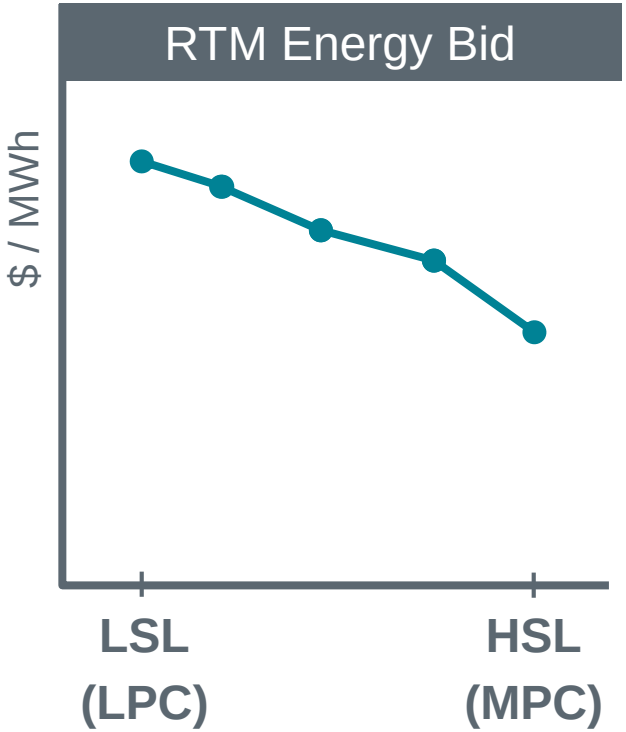
Avenues to Real-Time:

- Awarded offer in DAM
- Committed through RUC
- Committed by QSE

Resource with no Offer Curve:

- Is a price taker at current output
- Is last to be moved

RTM Energy Bid for Load Resources:

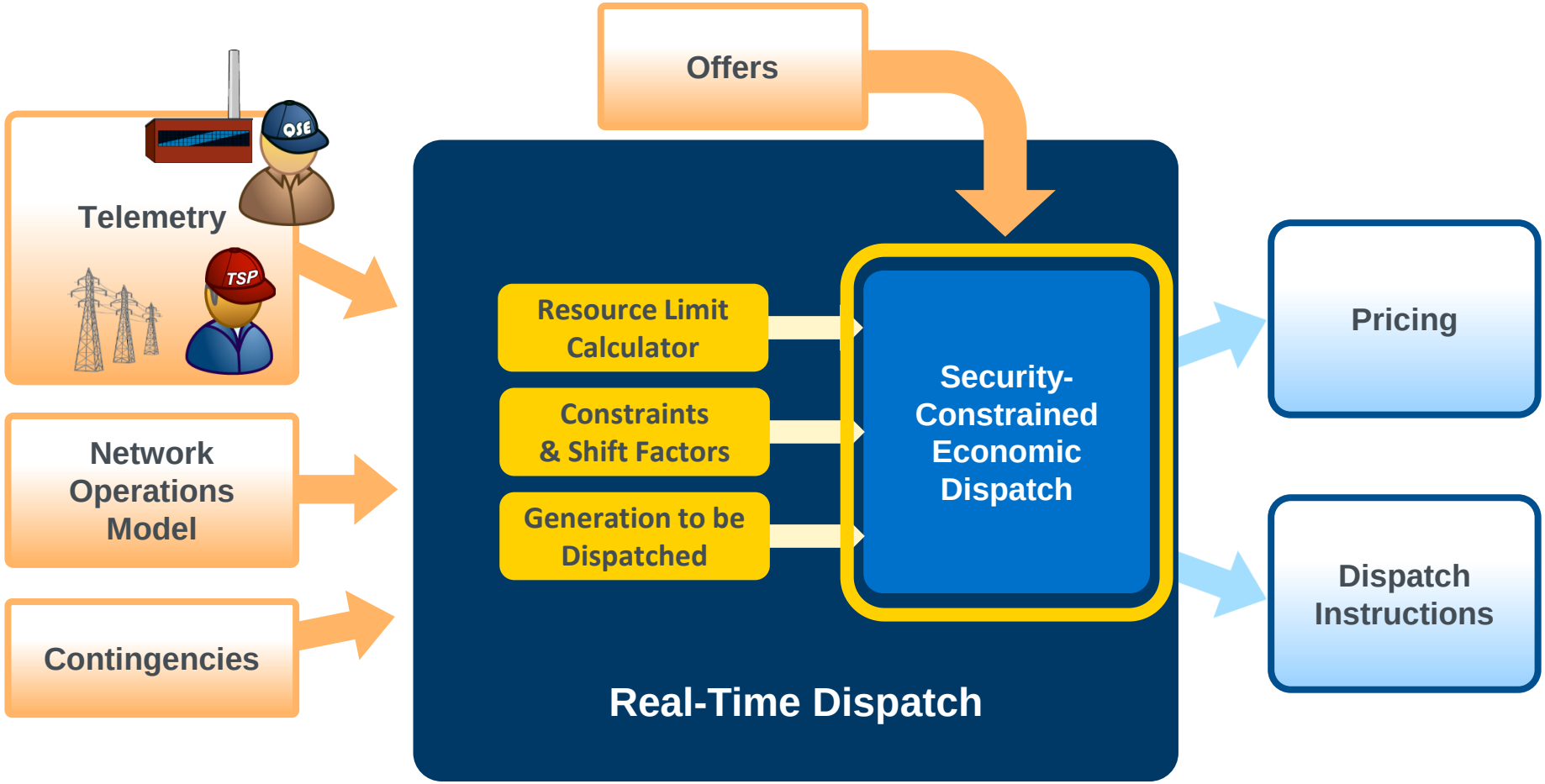


Loads dispatchable by SCED:

- Controllable Load Resources may qualify
- Bid represents price tolerance
- Load curtailed at the right price

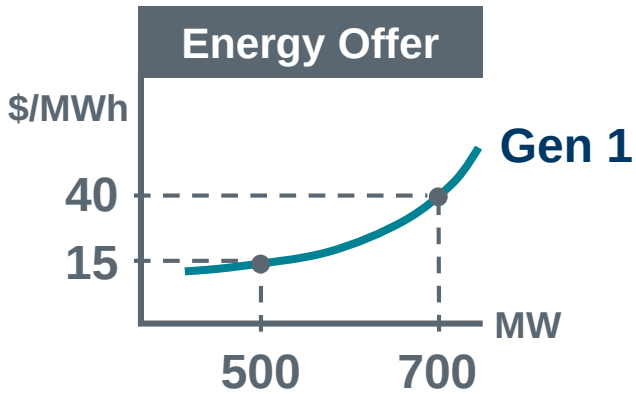
May be an Aggregate Load Resource

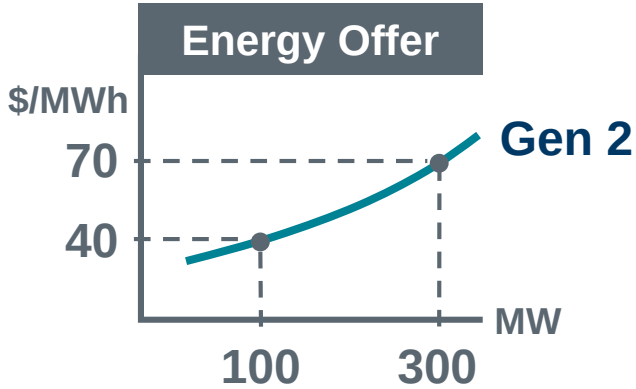
The SCED Process

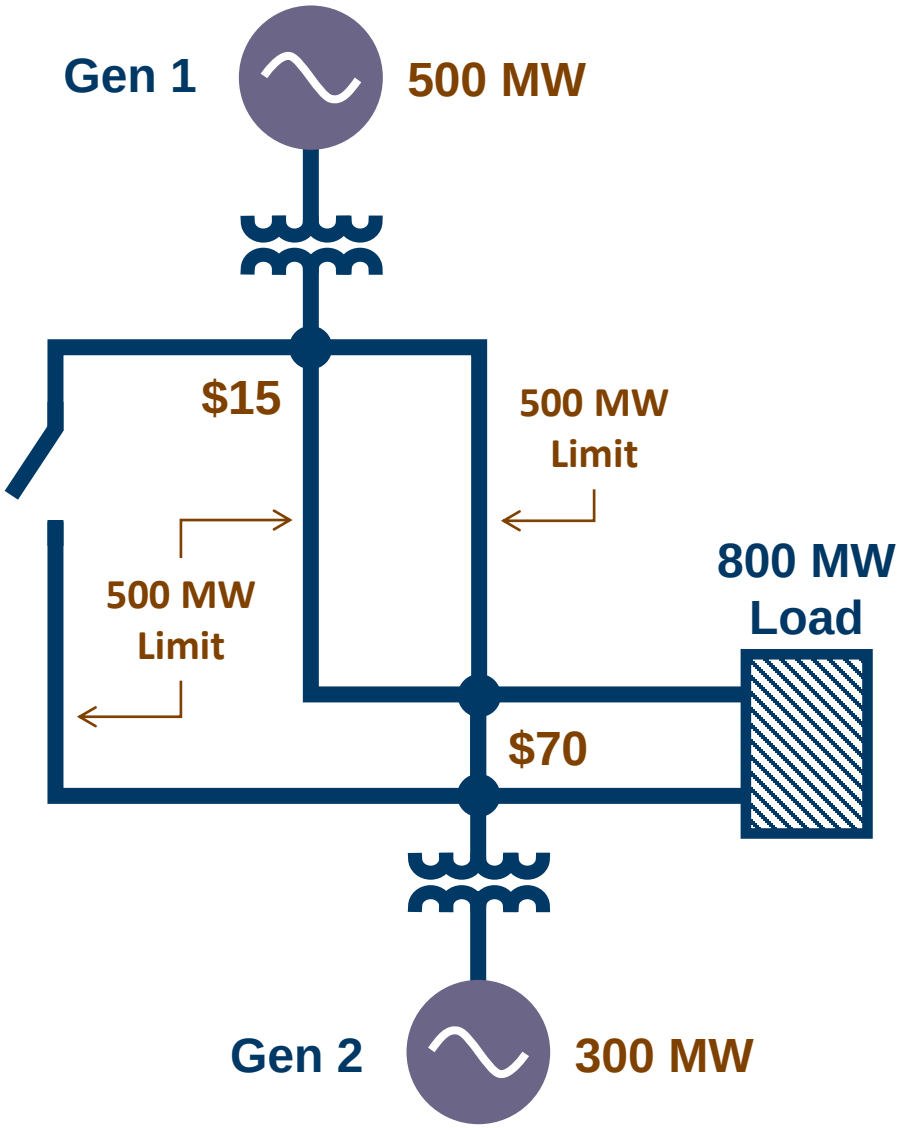


Energy Dispatch – Putting it all together

Scenario 1







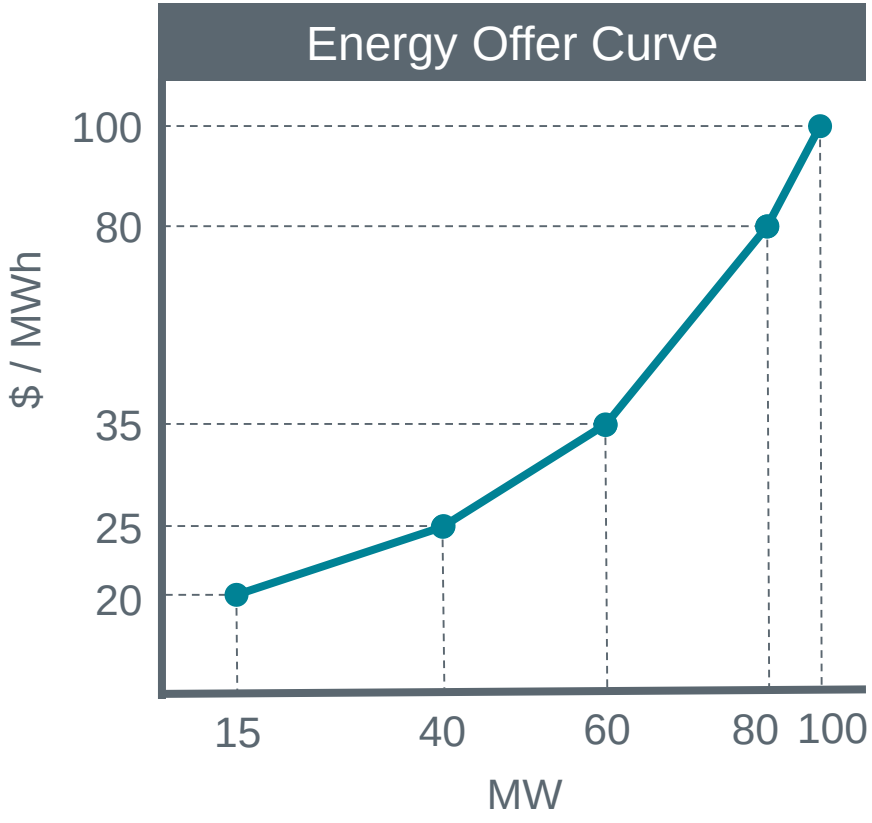
Scenario 2

A Generation Resource is available for SCED dispatch

The QSE has provided the following Energy Offer Curve.

SCED runs at 1100 and dispatches the Resource to 80MW @$40.

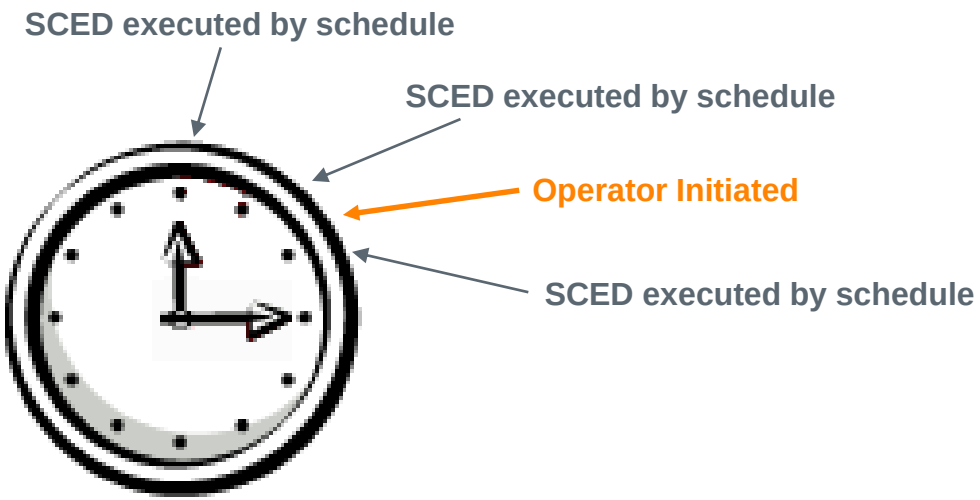
How is this possible?



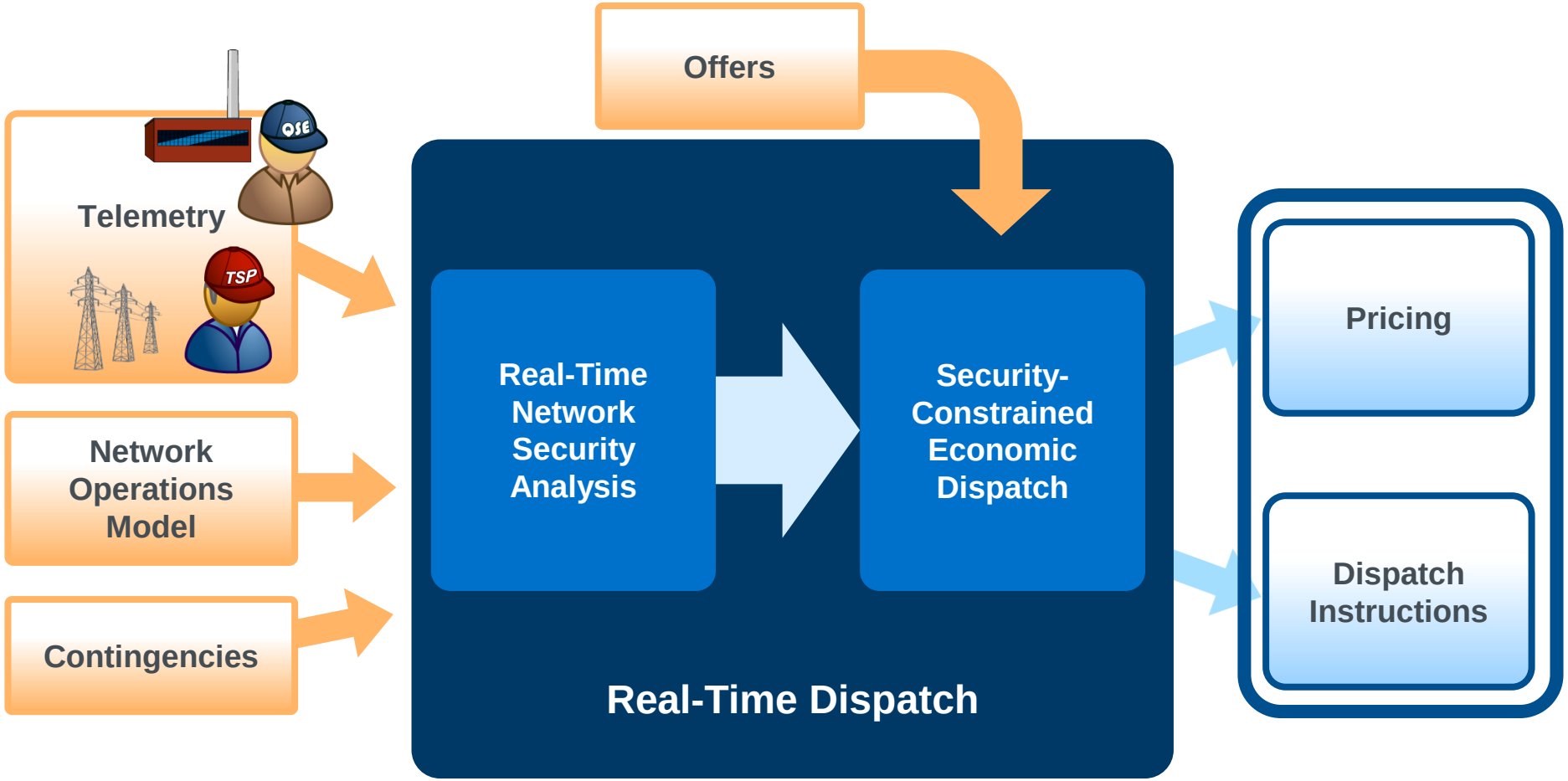
SCED Timeline

SCED is executed:

- Every five minutes (at a minimum)
- More often as needed by ERCOT operators or other ERCOT systems.

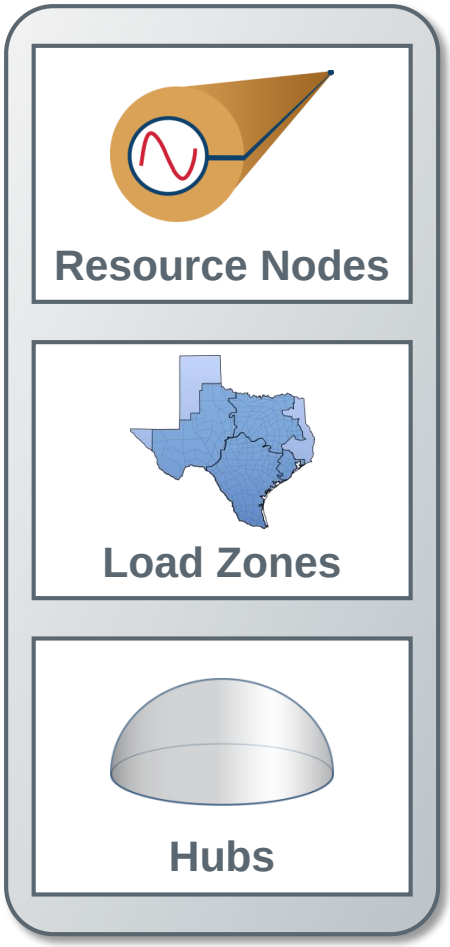


The SCED Process



Locational Marginal Prices (LMPs)

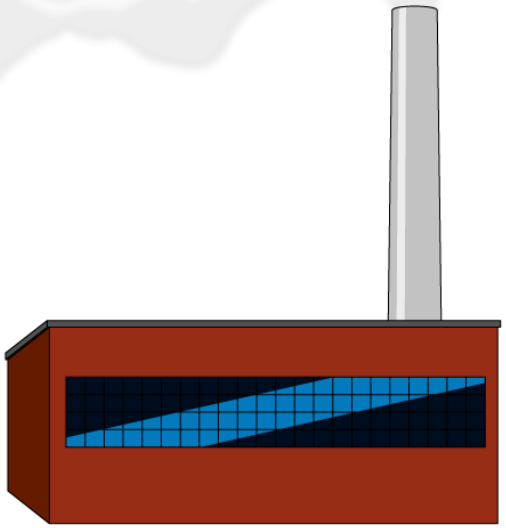
- Marginal cost of serving the next increment of Load at an Electrical Bus
- Used to calculate Settlement Point Prices
  - Resource Nodes
  - Load Zones
  - Hubs



SCED issues Resource-Specific Base Points

Base Point Dispatch instructions must include the following information:

- Resource Identifier
- Desired MW output level
- Time of the Dispatch Instruction



Communication of Dispatch Instructions

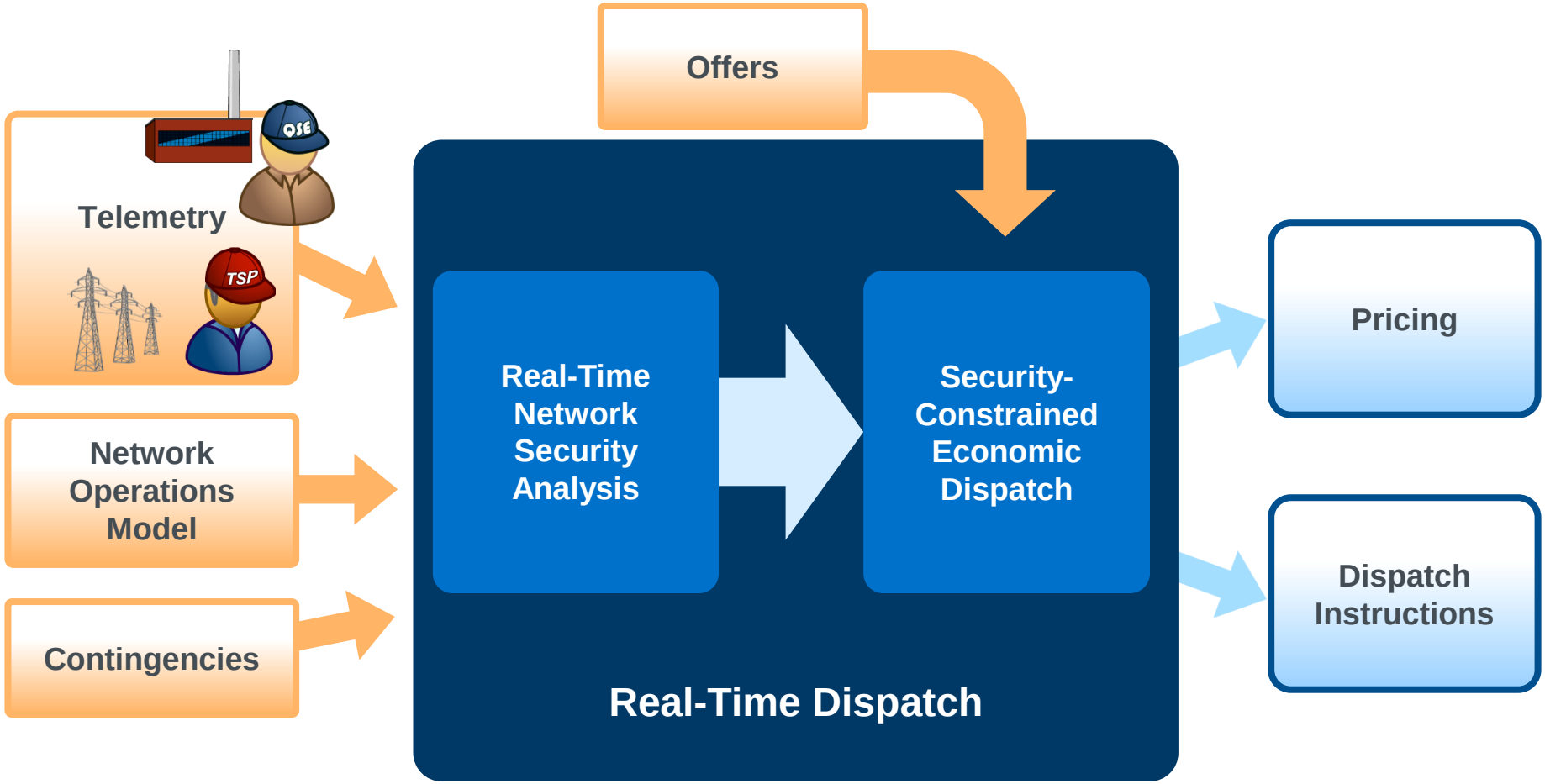
- ERCOT sends dispatch instructions to QSEs
- QSEs are responsible for communicating the instructions to the appropriate Resources

Market Information System Postings

- LMPs for each Electrical Bus
- Active and Binding Transmission Constraint and Contingency pairs
- Settlement Point Prices for each Settlement Point

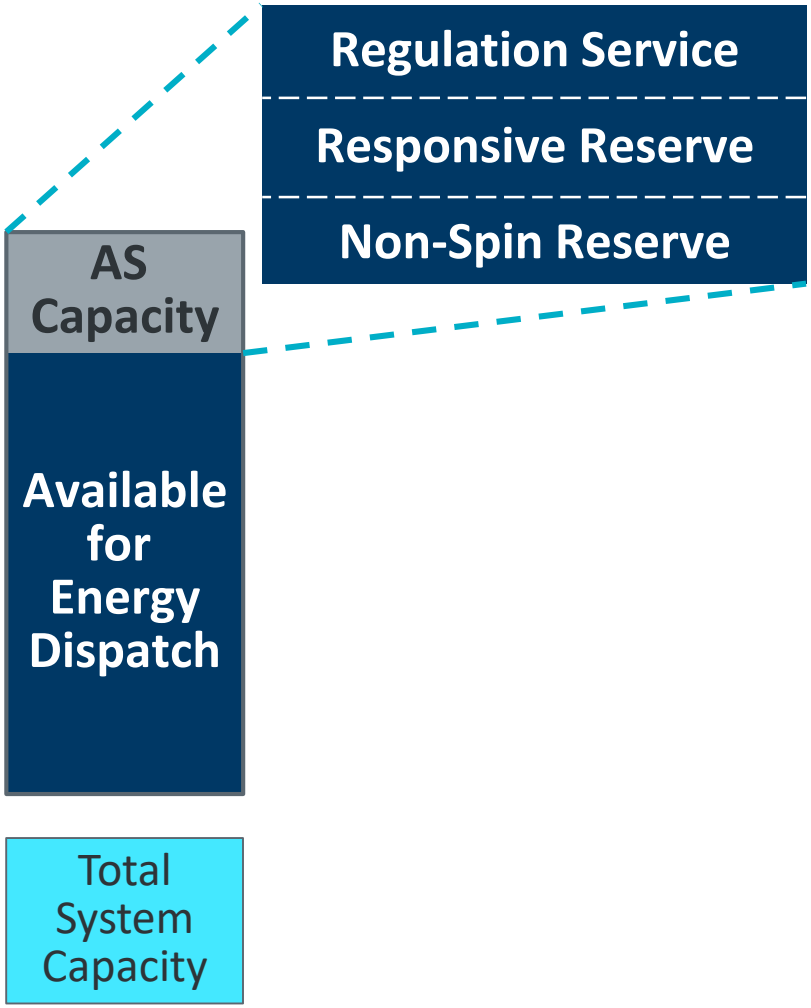
Real-Time Prices are final at 16:00 on the second Business Day after the Operating Day.

Energy Dispatch Overview



Resource Capacity in Real-Time

- Some is immediately available to SCED
  - Dispatched to achieve Power Balance
  - Dispatched to manage Congestion
- Some is reserved for Ancillary Services



Method Varies by Ancillary Service Product

Deployed by Load Frequency Control

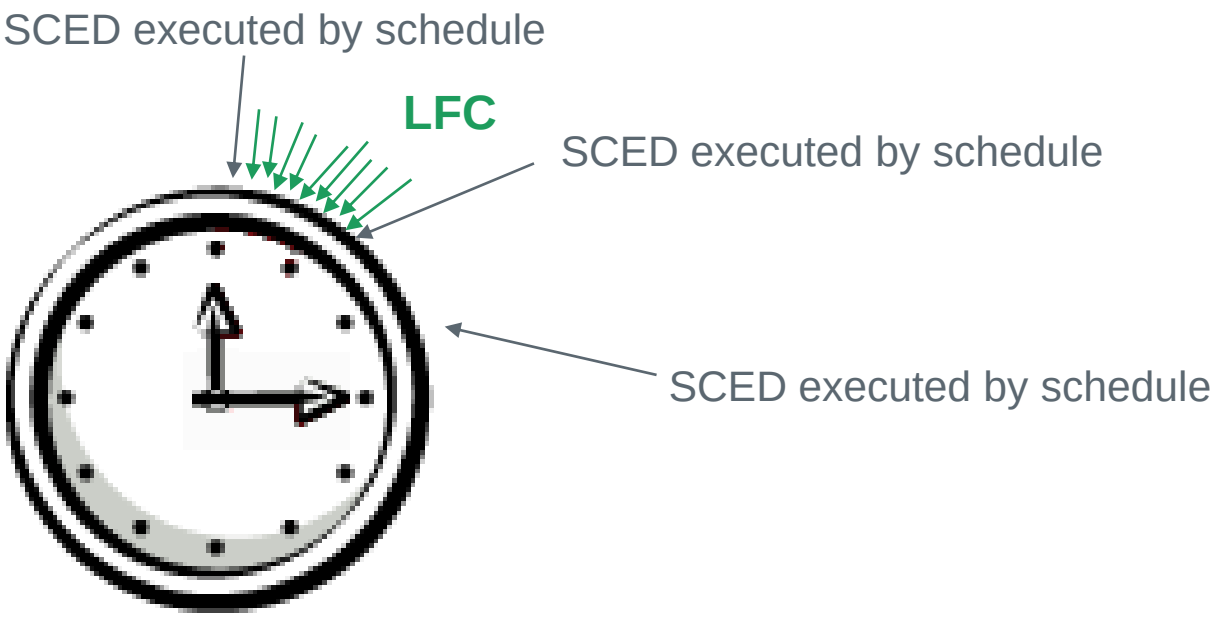
- Regulation Service
- Responsive Reserve Service

Deployed by Operator Dispatch Instruction

- Non-Spin Reserve

Why Load Frequency Control?

- SCED is scheduled to run every 5 minutes
- In that same 5-minute interval, LFC runs 75 times



Purpose of Load Frequency Control

Load Frequency Control (LFC) maintains system frequency, without cost optimization

- Responds to frequency deviations
- Automated control signals to QSEs
  - Regulation Service
  - Responsive Reserve Service

Regulation Service

Provides capacity that can respond to signals from ERCOT within seconds to maintain system frequency

Two Types of Regulation Service

- Regulation Up (Reg Up)
- Regulation Down (Reg Down)

Must be capable of ramping through reserved capacity in 5 minutes

Regulation Service

May be provided by Generation Resources and Controllable Load Resources

Not a Resource-Specific Deployment

- Deployed proportionally by QSE's share of Regulation provided
- QSE choses how to distribute across their Resources

Regulation Service Communications

QSEs to ERCOT:

- AS Resource Responsibility
- Participation Factors

ERCOT to QSEs:

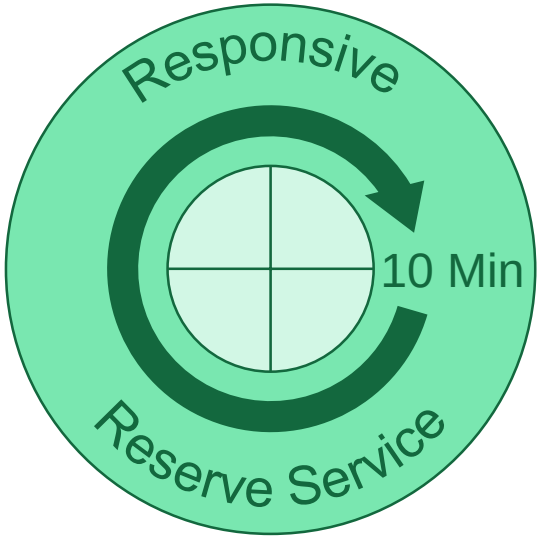
- Control Signal (4 second)
- Portfolio deployment

Responsive Reserve Service

Provides capacity reserves intended to:

- Respond to significant frequency deviations
- Serve as backup Regulation
- Provide additional capacity during an Energy Emergency Alert (EEA)

Must be capable of ramping through reserved capacity in 10 minutes



Responsive Reserve Communications

QSEs to ERCOT:

- AS Resource Responsibility
- AS Schedule

ERCOT to QSEs:

- Control Signal (4 second)
- Portfolio deployment

For Responsive Reserve:

AS Schedule = AS Resource Responsibility – AS Deployment

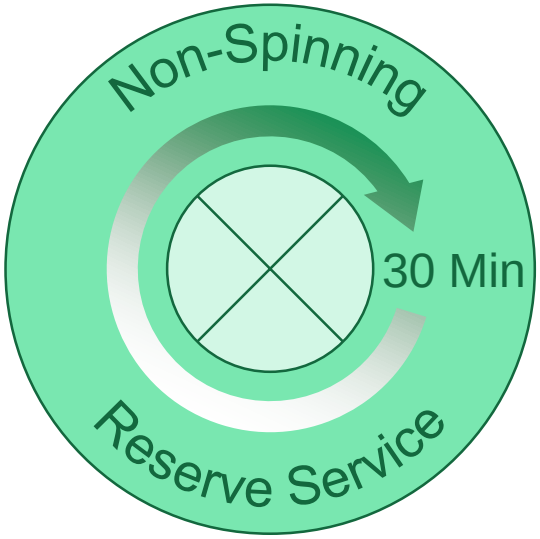
Responsive Reserve Deployment

QSE chooses Resources by reducing AS Schedules

ERCOT triggers SCED to dispatch Resources

Non-Spinning Reserve Service

Provides additional capacity reserves that can be utilized within 30 minutes



Uses

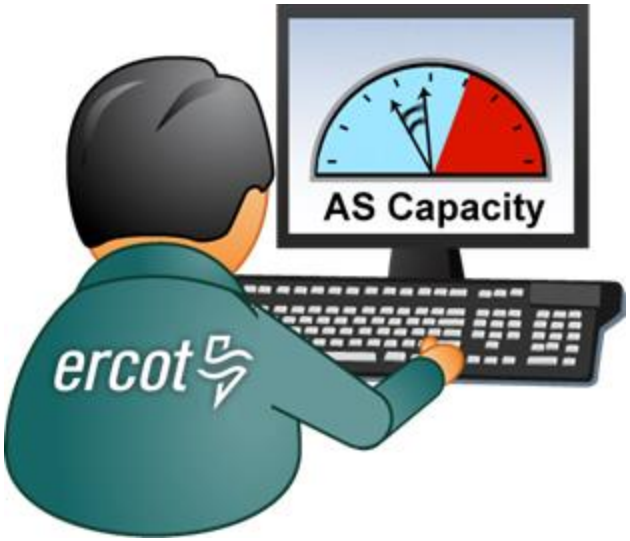
- System-Wide capacity needs
- Local capacity needs
- Recover Responsive Reserve Service in a timely manner

Non-Spinning Reserve Deployment

Resource Type	Requirements	Note
Off-Line Generation Resource	Capable of ramping through Non-Spin Resource Responsibility within 30 minutes of Dispatch Instruction.	Energy is dispatched by SCED
On-Line Generation Resource	Standing Deployment during Operating Hour with $75 floor price	Energy is dispatched by SCED
Controllable Load Resource	Capable of ramping through Non-Spin Resource Responsibility within 30 minutes of Dispatch Instruction.	Energy is dispatched by SCED

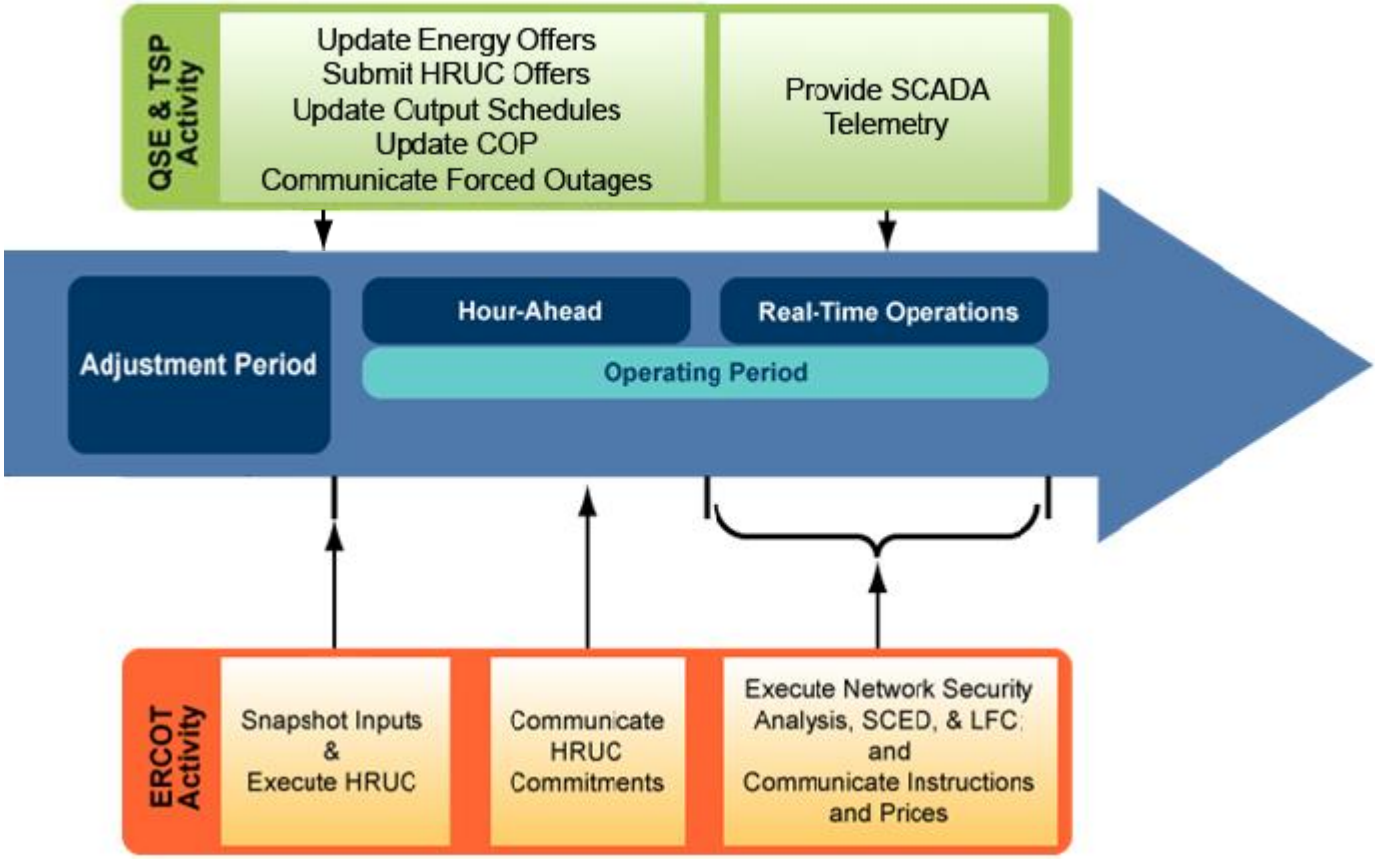
Ancillary Services Capacity Monitor

- Calculates available levels of Resource capacity as per Real-time telemetry
- Calculated every 10 seconds
- Available on MIS
- Streamed over ICCP



http://www.ercot.com/content/cdr/html/as_capacity_monitor.html

Real-Time Operations Timeline



Real-Time Financial Impacts

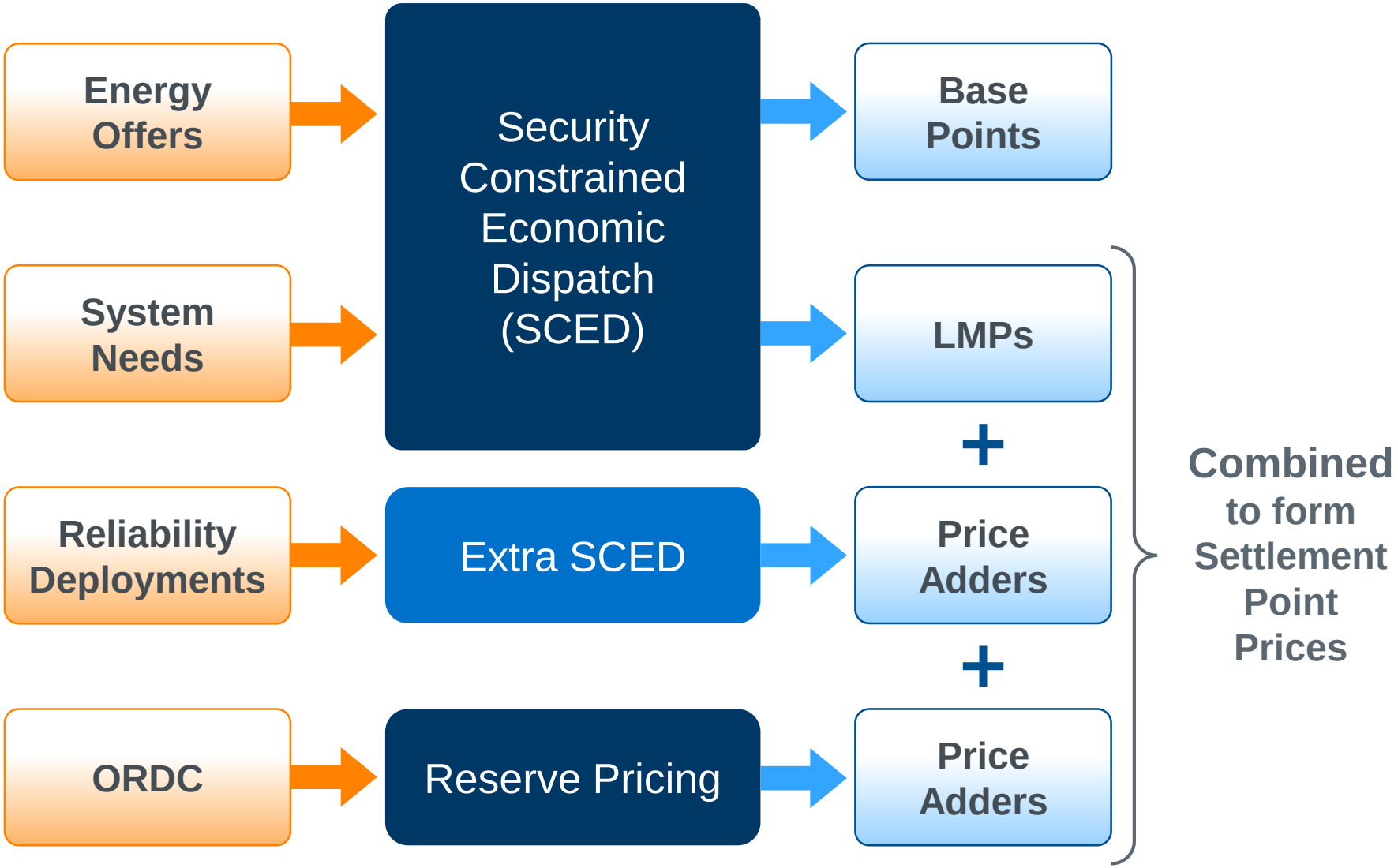
Real-Time Financial Impacts

1. Real-Time Pricing
2. Real-Time Energy Imbalance
3. Real-Time Ancillary Service Imbalance
4. Base Point Deviation

Real-Time Financial Impacts

1. Real-Time Pricing
2. Real-Time Energy Imbalance
3. Real-Time Ancillary Service Imbalance
4. Base Point Deviation

Real-Time Pricing

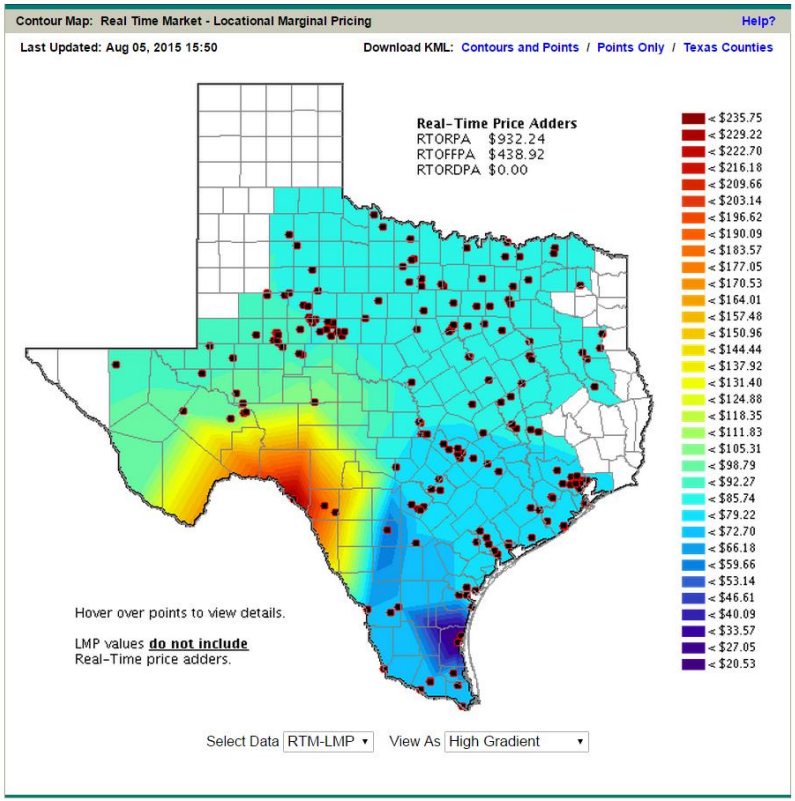


Real-Time Price Adders

RTORPA – On-Line Reserve Price Adder

RTOFFPA – Off-Line Reserve Price Adder

RTORDPA – On-Line Reliability Deployment Price Adder



… for each SCED interval

Settlement Point Prices

= Ave (LMPs) + Ave (RTORPA) + Ave (RTORDPA)

… for each 15-minute interval

Real-Time Financial Impacts

1. Real-Time Pricing
2. Real-Time Energy Imbalance
3. Real-Time Ancillary Service Imbalance
4. Base Point Deviation

The Basic Idea at any Settlement Point:

$$(-1)\left[\left(\text{SUPPLIES}\right)-\left(\text{OBLIGATIONS}\right)\right]*\text{RTSPP}$$

RTSPP = Real-Time Settlement Point Price

At a Load Zone:

$$(-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales} + \text{Adjusted Metered Load}\right)\right] * \text{RTSPP}$$

Each Settlement Point settled separately

At a Resource Node:

$$(-1)\left[\left(\text{Metered Generation} + \text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales}\right)\right] * \text{RTSPP}$$

Each Settlement Point settled separately

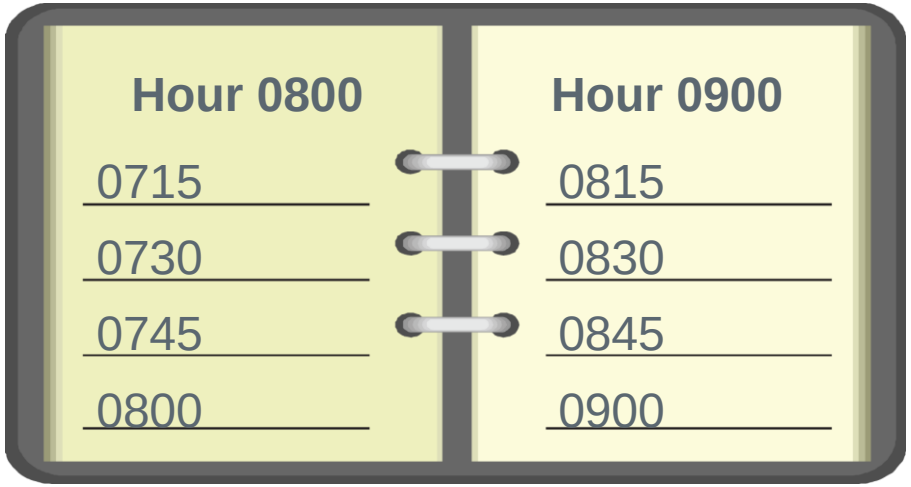
At a Hub:

$$(-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales}\right)\right] * \text{RTSPP}$$

Each Settlement Point settled separately

DAM Awards & Trades in Real-Time Energy Settlements

- DAM is awarded as *hourly MWs*
- Energy Trades are reported as *hourly MWs*
- Real-Time is settled as *15-minute MWhs*

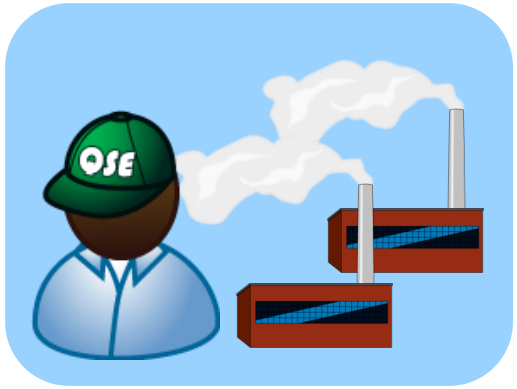


DAM awards and Trades must be multiplied by ¼ hour

Scenarios

Real Time Energy Imbalance Scenarios

- QSE with Load ***but no*** Generation
- QSE with ***only*** Generation
- QSE with ***neither*** Generation nor Load



Scenario 1

QSE with Load but no Generation

DAM Energy Purchase for Hour 0900

- 28 MW
- North Load Zone

Real-Time Load for Interval 0900

- 5 MWh
- North Load Zone
- RTSPP = $40/MWh

Real-Time Energy Imbalance at North Load Zone

$$= (-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales} + \text{Metered Load}\right)\right] * \text{RTSPP}$$

$$= (-1)\left[\left(\qquad\qquad\right) - \left(\qquad\qquad\right)\right] * \$40/\text{MWh}$$

$$=$$

Scenario 2

QSE with Load but no Generation

Trade Energy Purchase for Hour 0900

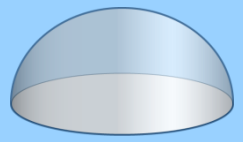
- 28 MW
- North Hub

Real-Time Load for Interval 0900

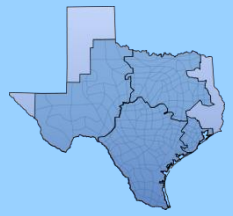
- 5 MWh
- North Load Zone

Scenario 2

Must calculate at two Settlement Points



North Hub
RTSPP = $35/MWh



North Load Zone
RTSPP = $40/MWh

Real-Time Energy Imbalance at North Hub

$$= (-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales} + \text{Metered Load}\right)\right] * \text{RTSPP}$$

$$= (-1)\left[\left(\qquad\qquad\right) - \left(\qquad\qquad\right)\right] * \$35/\text{MWh}$$

$$=$$

Real-Time Energy Imbalance at North Load Zone

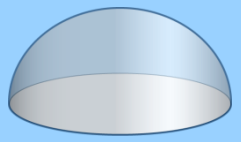
$$= (-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales} + \text{Metered Load}\right)\right] * \text{RTSPP}$$

$$= (-1)\left[\left(\qquad\qquad\right) - \left(\qquad\qquad\right)\right] * \$40/\text{MWh}$$

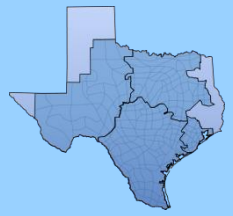
$$=$$

Scenario 2

QSE's Net Real-Time Energy Imbalance



Payment at Hub



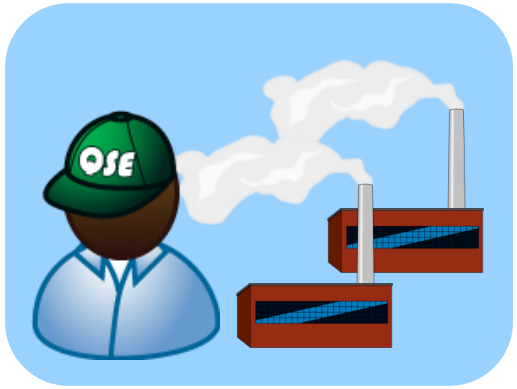
Charge at Load Zone

Net = –$245 + 200 = –$45

Scenarios

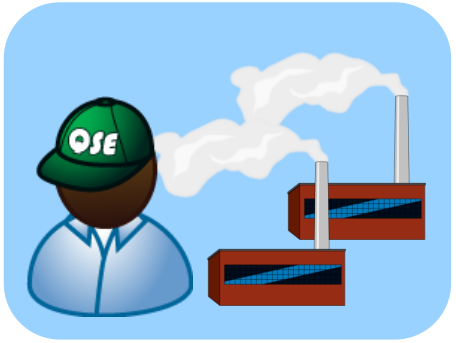
Real Time Energy Imbalance Scenarios

- QSE with Load *but no* Generation
- QSE with ***only*** Generation
- QSE with *neither* Generation nor Load



Scenario 3

QSE with only Generation



DAM Energy Sale for Hour 0900

- 120 MW
- BigGen Resource Node

Real-Time Generation for Interval 0900

- 25 MWh
- BigGen Resource Node
- RTSPP = $30/MWh

Real-Time Energy Imbalance at BigGen Resource Node

$$= (-1)\left[\left(\text{Metered Generation} + \text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales}\right)\right] * \text{RTSPP}$$

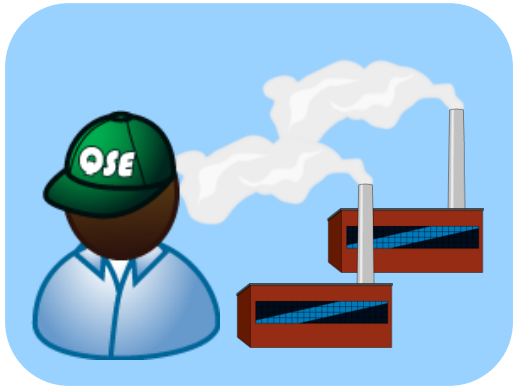
$$= (-1)\left[\left(\qquad\qquad\right) - \left(\qquad\qquad\right)\right] * \$30/\text{MWh}$$

$$=$$

Scenarios

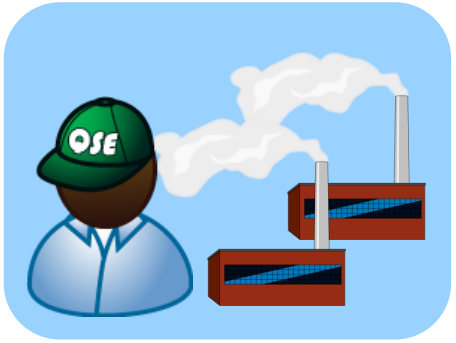
Real Time Energy Imbalance Scenarios

- QSE with Load but no Generation
- QSE with only Generation
- QSE with neither Generation nor Load



Scenario 4

QSE with neither Generation nor Load



Awarded DAM Energy-Only Offer for Hour 0900

- 32 MW
- North Load Zone
- RTSPP = $40/MW

Real-Time Energy Imbalance at North Load Zone

$$= (-1)\left[\left(\text{DAM Energy Purchases} + \text{Trade Energy Purchases}\right) - \left(\text{DAM Energy Sales} + \text{Trade Energy Sales} + \text{Metered Load}\right)\right] * \text{RTSPP}$$

$$= (-1)\left[\left(\qquad\qquad\right) - \left(\qquad\qquad\right)\right] * \$40/\text{MWh}$$

$$=$$

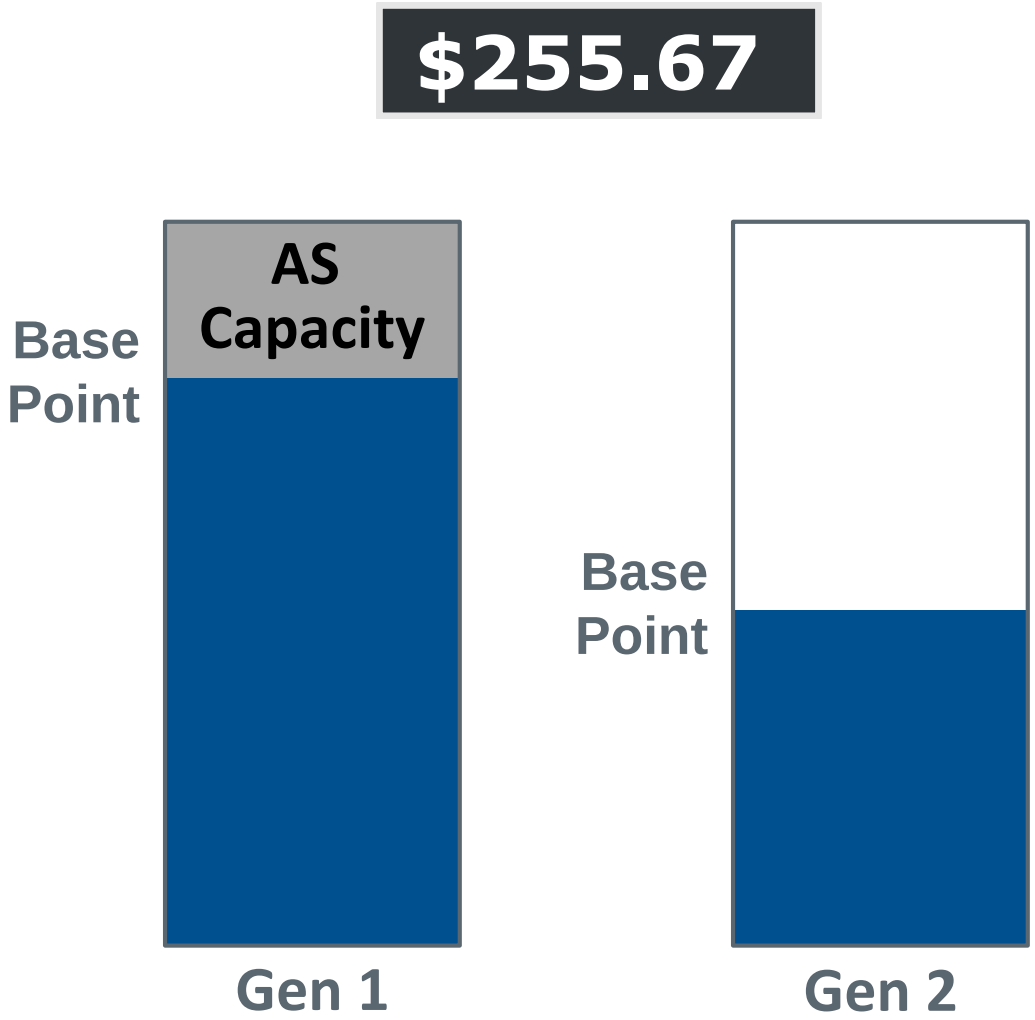
Real-Time Financial Impacts

1. Real-Time Pricing
2. Real-Time Energy Imbalance
3. Real-Time Ancillary Service Imbalance
4. Base Point Deviation

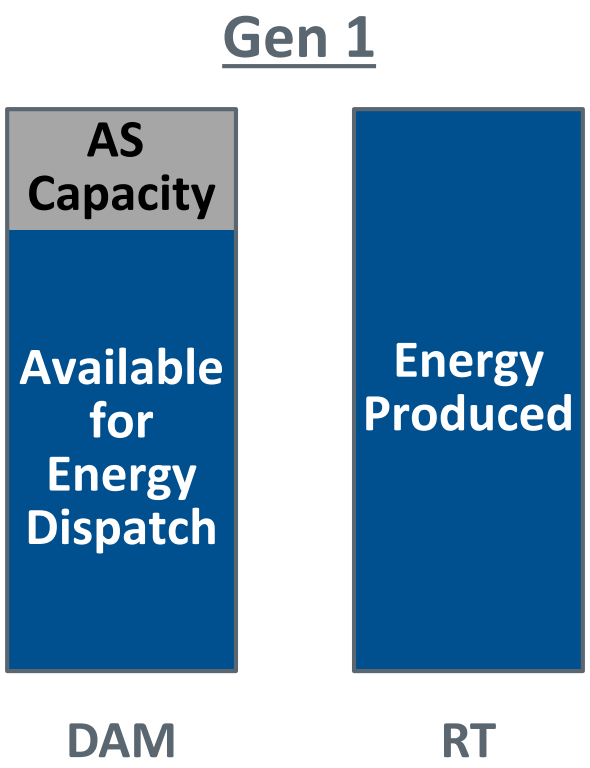
Scenario

What if . . .

- We could keep on producing Energy from Gen 1?
- We could shift the AS from Gen 1 to Gen 2?



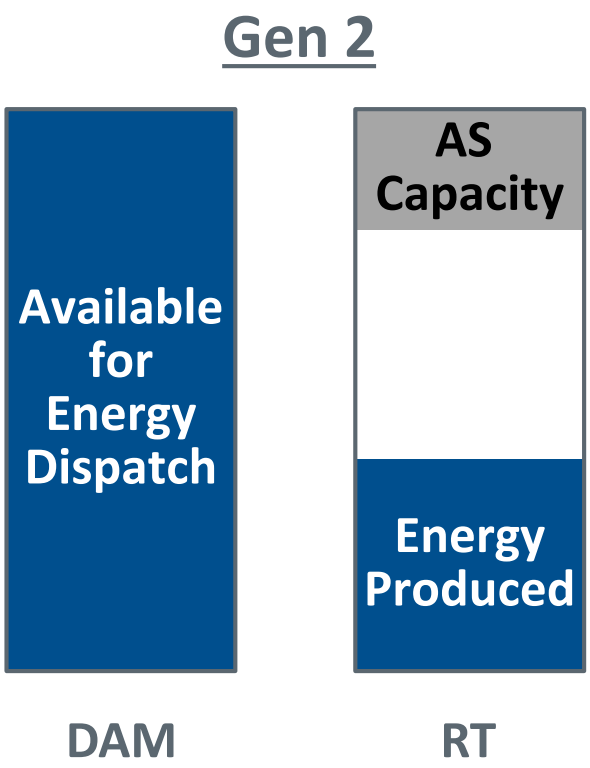
What would Real-Time Co-optimization look like?



QSE Real-Time Settlement:

- Paid RTSPP for energy produced in Real-Time
- Buy back AS Capacity at Real-Time AS Price

What would Real-Time Co-optimization look like?



QSE Real-Time Settlement:

- Paid RTSPP for energy produced in Real-Time
- Paid for AS Capacity at Real-Time AS Price

What would Real-Time Co-optimization Look Like?

Currently,

- No Real-Time Co-optimization
- No Real-Time AS Prices

But we do have Real-Time Reserve Prices

Real-Time Ancillary Service Imbalance

Real-Time capacity reserves are settled at one of the Real-Time Reserve Prices.

- Approximates settlement impacts of Real-Time Co-optimization
- Provides payment for *all* capacity reserves that may be utilized during the next hour

The Basic Idea:

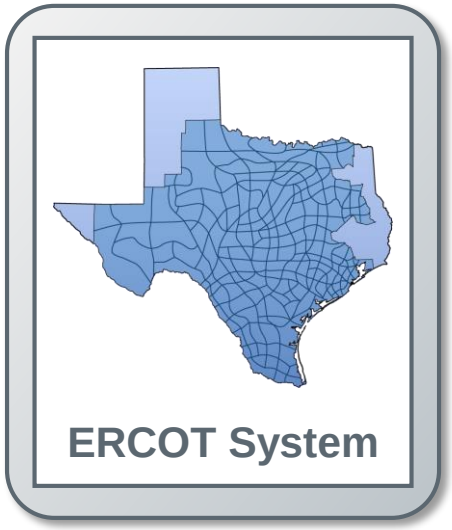
$$(-1)\left[\left(\text{On-Line Reserve SUPPLIES} - \text{On-Line Reserve OBLIGATIONS}\right) * \text{On-line Reserve Price} + \left(\text{Off-Line Reserve SUPPLIES} - \text{Off-Line Reserve OBLIGATIONS}\right) * \text{Off-line Reserve Price}\right]$$

Calculated ERCOT-wide per QSE

Real-Time Reserve Prices

On-line Reserve Price = **Time-Weighted Average** (**RTORPAs**)

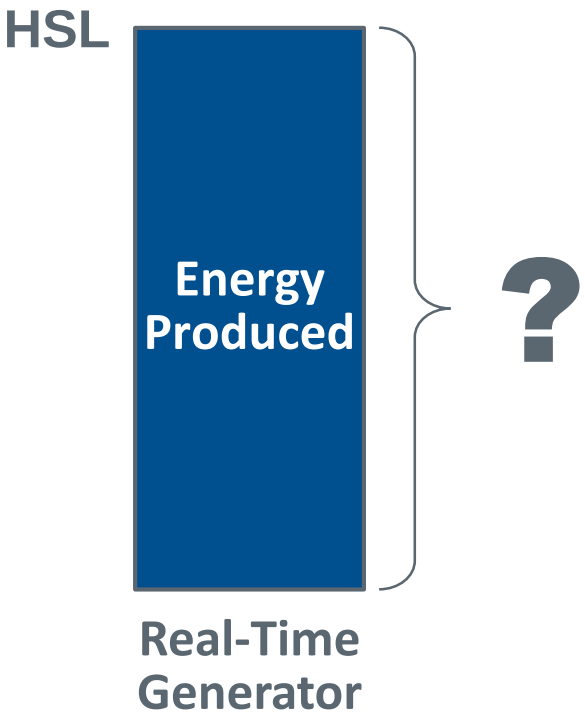
Off-line Reserve Price = **Time-Weighted Average** (**RTOFFPAs**)



… for each 15-minute interval

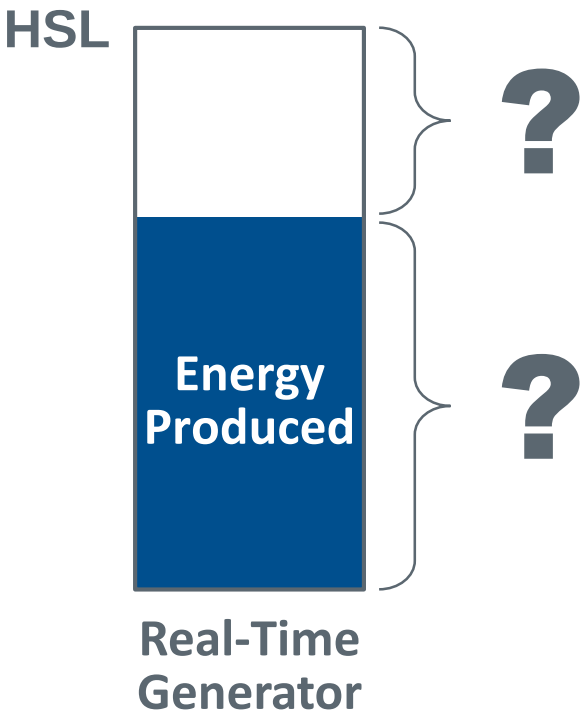
Scenario 1

How's it settled?



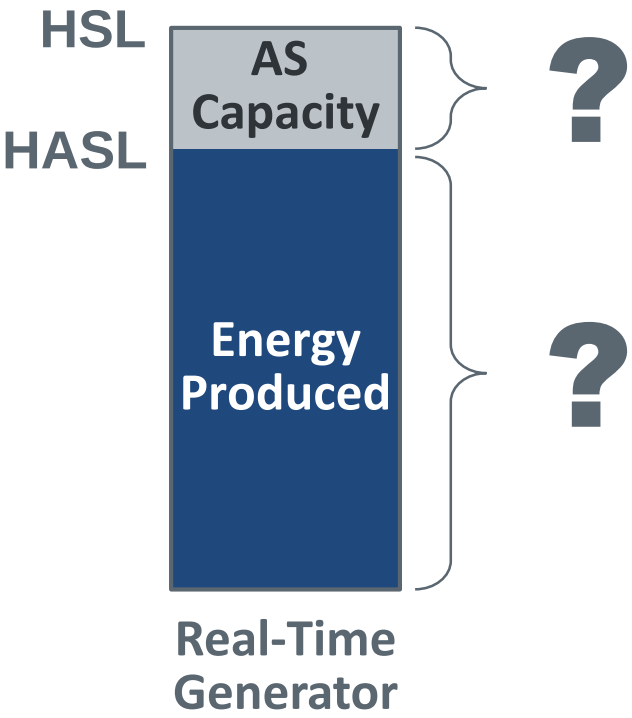
Scenario 2

How's it settled?



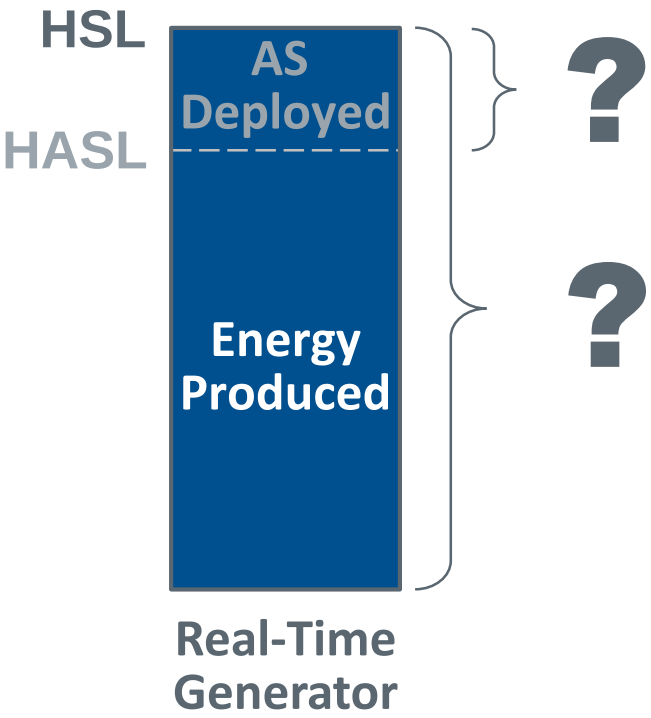
Scenario 3

How's it settled?



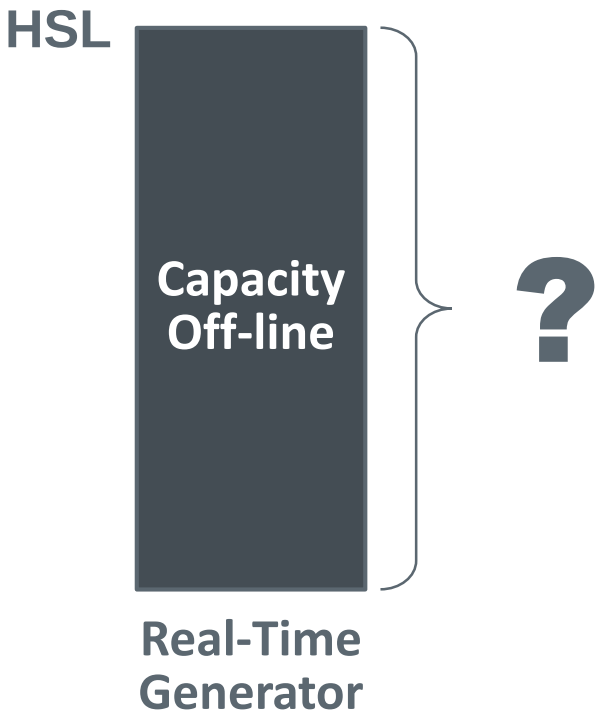
Scenario 4

How's it settled?



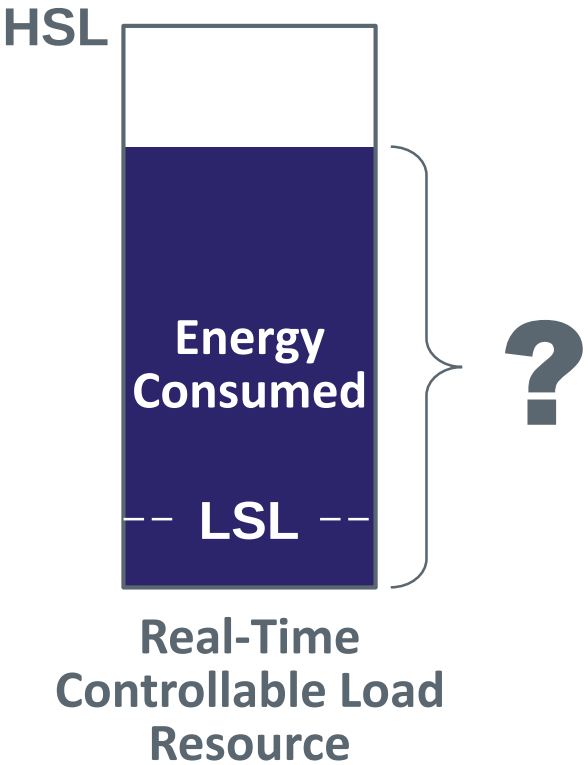
Scenario 5

How's it settled?



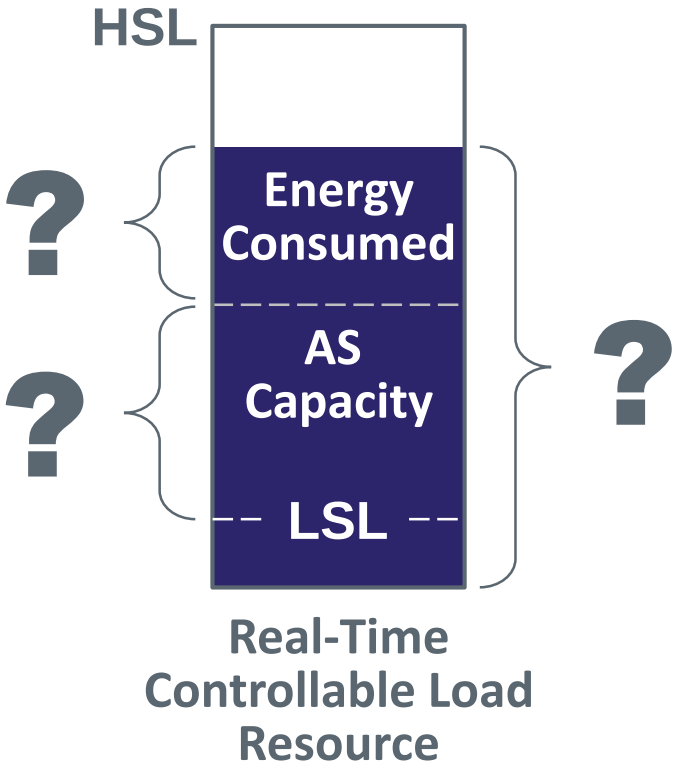
Scenario 6

How's it settled?



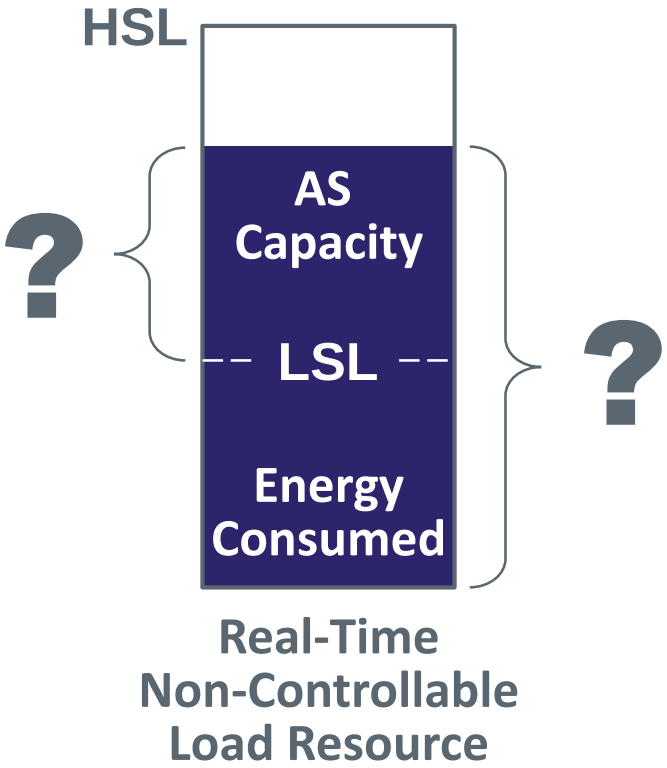
Scenario 7

How's it settled?



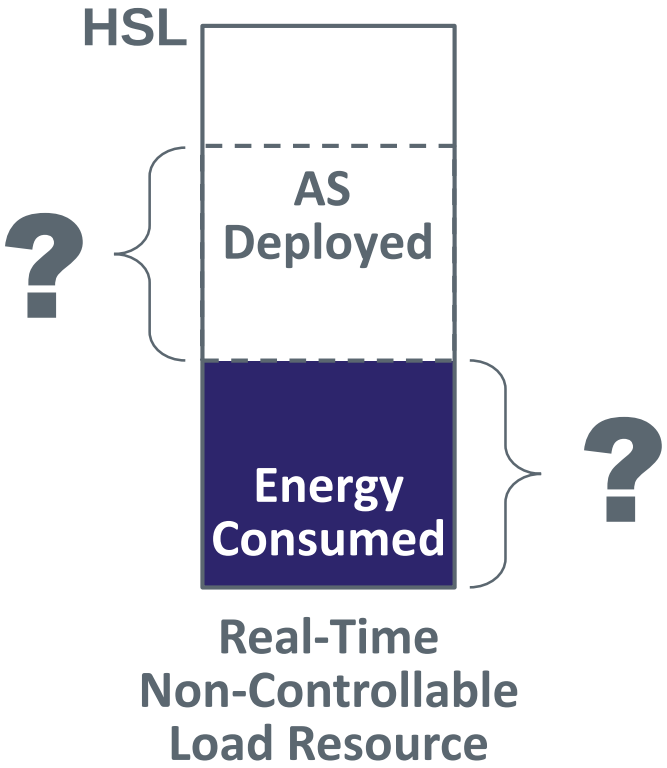
Scenario 8

How's it settled?



Scenario 9

How's it settled?



Real-Time Financial Impacts

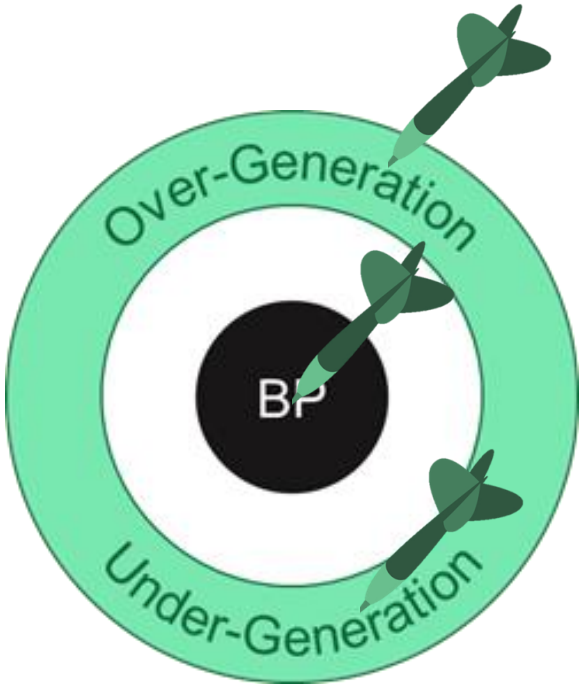
1. Real-Time Pricing
2. Real-Time Energy Imbalance
3. Real-Time Ancillary Service Imbalance
4. Base Point Deviation Charge

From Resource Dispatch to Real-Time Energy Settlement

- Resource follows ERCOT's Base Point instructions
- QSE settled through Real-Time Energy Imbalance

But what if the Resource:

- Over-generates?
- Under-generates?

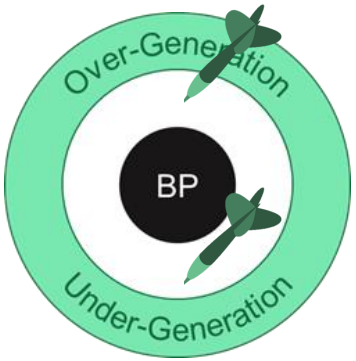


From Resource Dispatch to Real-Time Energy Settlement

A QSE for a Generation Resource shall pay a base point deviation charge if the Resource did not follow Dispatch Instructions and Ancillary Services deployments within defined tolerances.

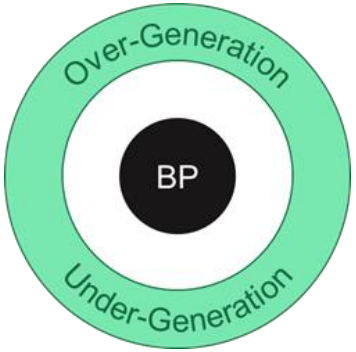
The ERCOT Protocols tolerances are:

- ± 5% or ± 5MW, whichever is greater
- + 10% for Intermittent Renewable Resources (IRR's)



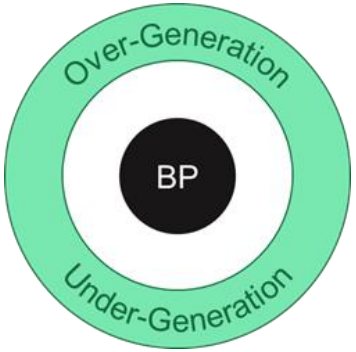
Base Point Deviation Charge Exclusions

- No charge during a frequency deviation greater than 0.05 Hz if the QSE's deviation contributes to frequency correction
- No charge during intervals in which Responsive Reserve is deployed



Some Resources are Exempt

- RMR units
- Qualifying Facilities (as defined by PURA) that do not submit energy offer curves
- Quick Start Generation Resources (QSGRs) exempt for the first Settlement Interval after they are deployed



Scenarios

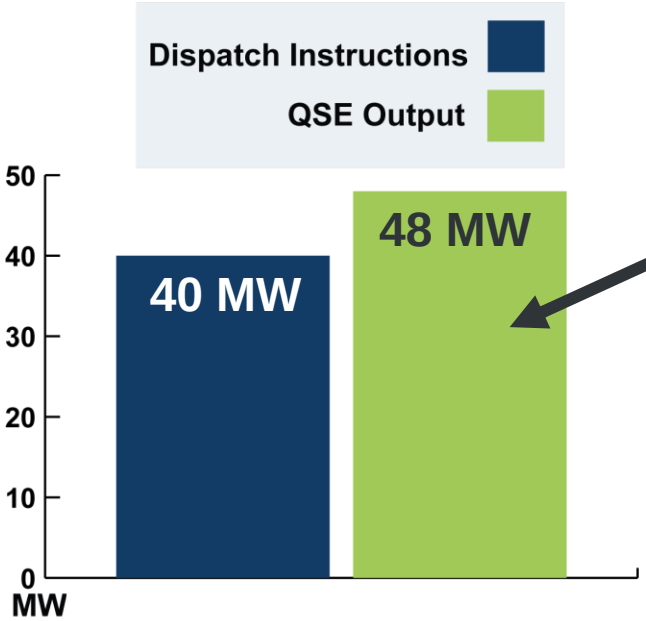
Setup for all scenarios:

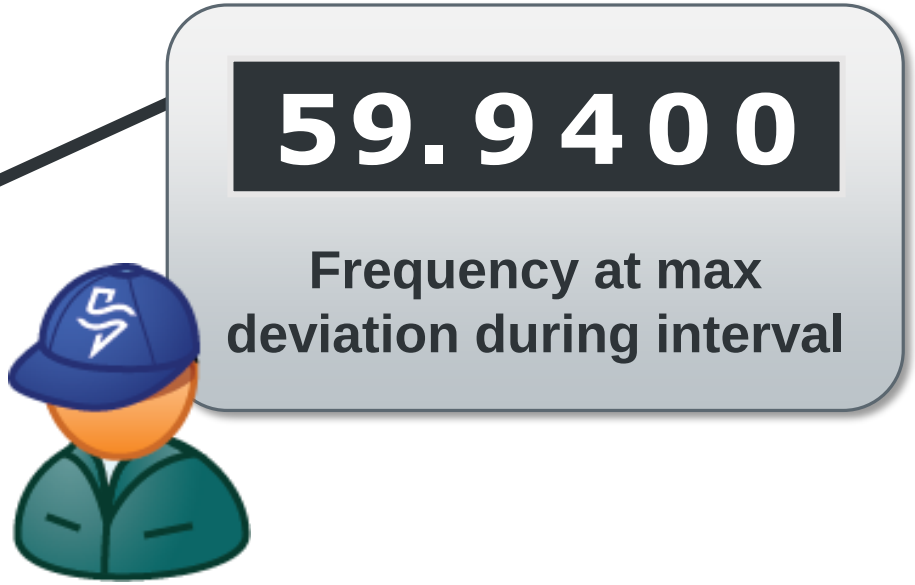
1. QSE has a single generator in ERCOT system.
2. Resource is not a QSGR
3. QSE does not provide Ancillary Services.
4. QSE receives Base Point dispatches from ERCOT to operate at 40 MW during Interval Ending 0900.

Scenario 1

Conditions:

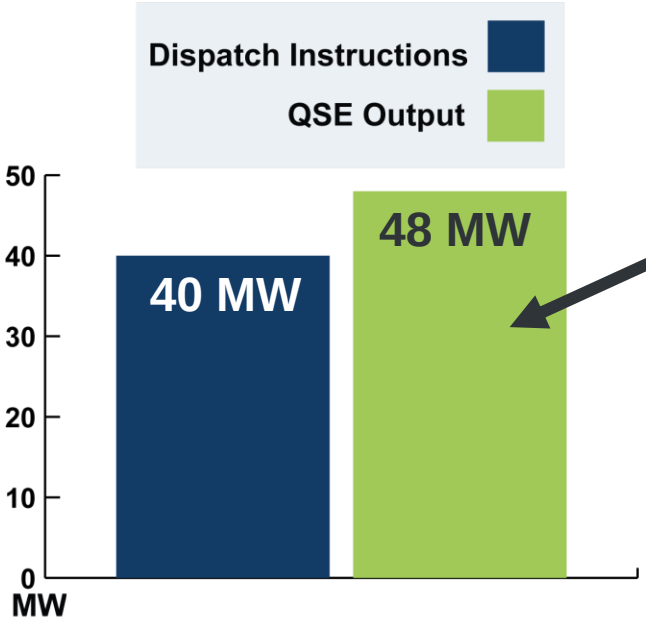
- Resource output exceeds Dispatch Instructions by 8MW
- System Frequency reaches 59.9400 Hz





Scenario 1

Does the QSE incur a Base Point Deviation Charge?



59.9400

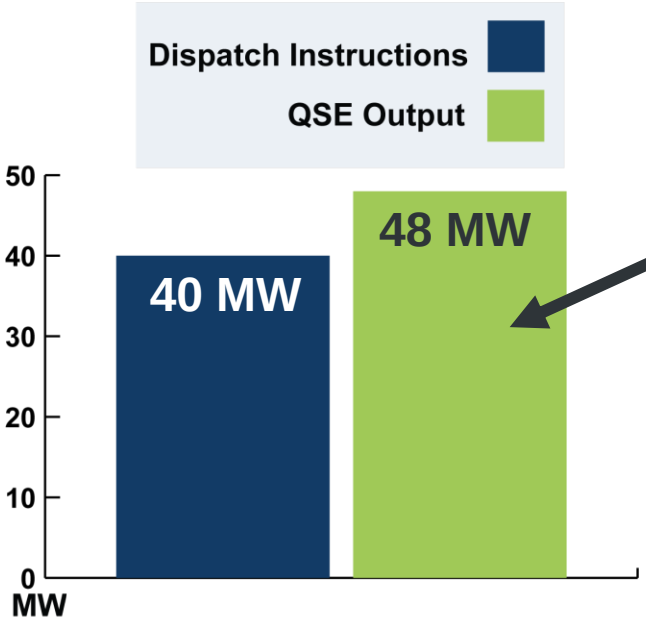
Frequency at max deviation during interval

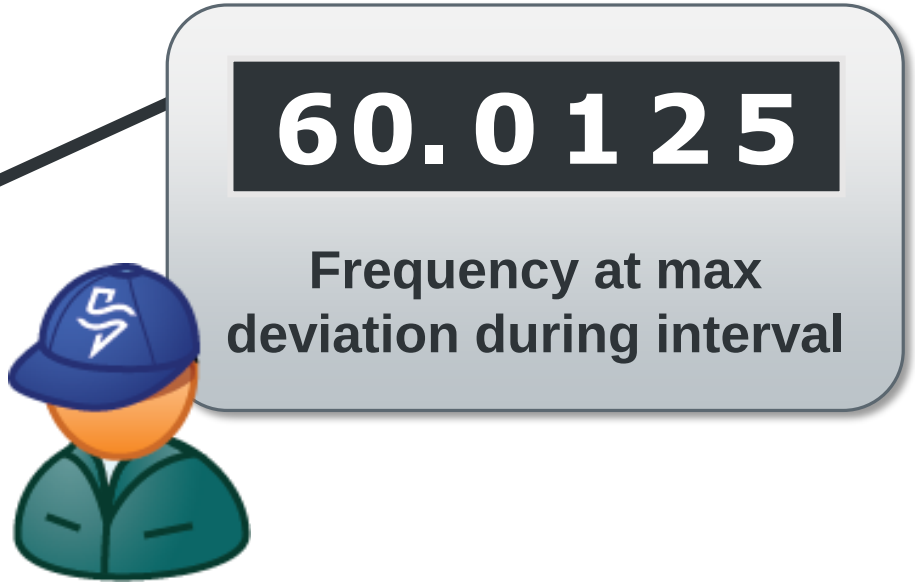
-0.06

Scenario 2

Conditions:

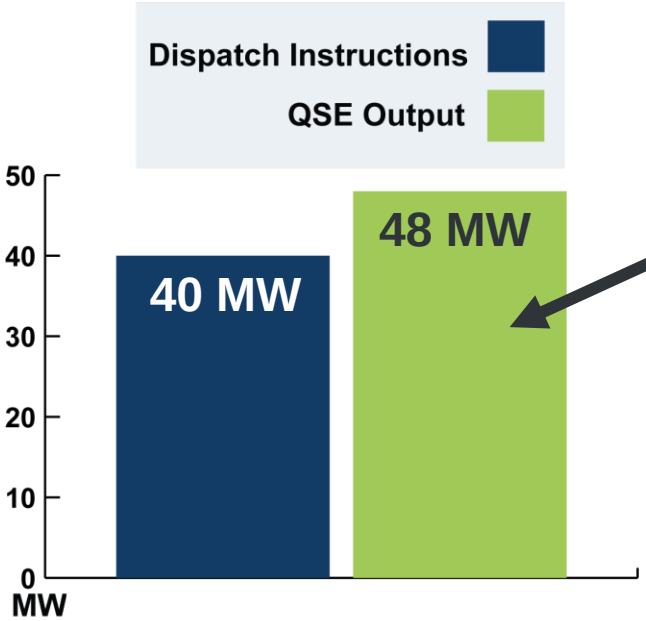
- Resource output exceeds Dispatch Instructions by 8MW
- System Frequency reaches 60.0125 Hz

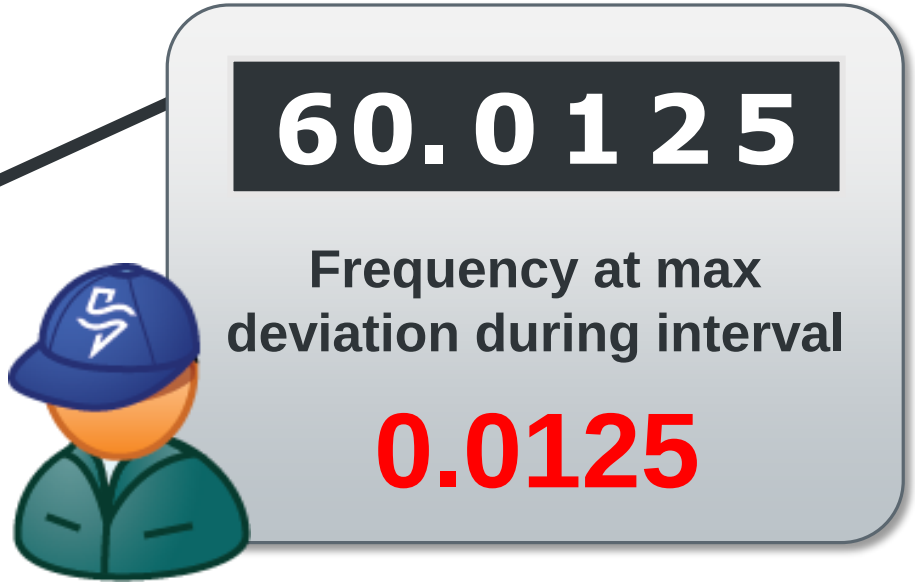




Scenario 2

Does the QSE incur a Base Point Deviation Charge?

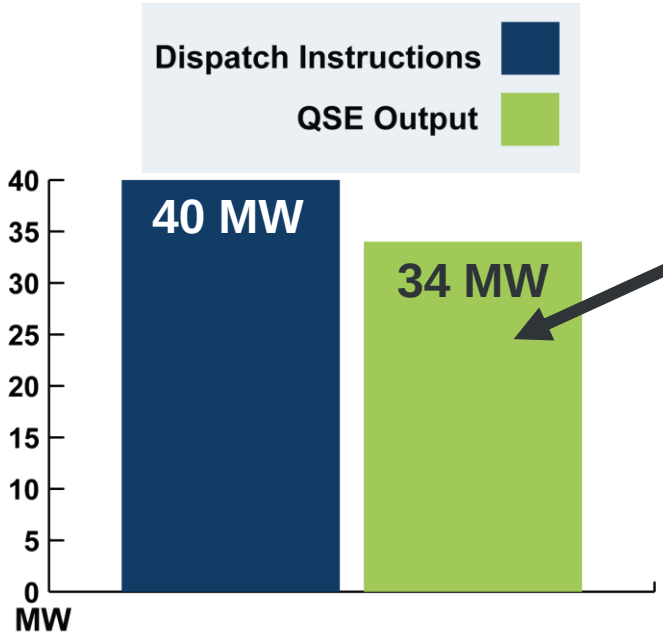


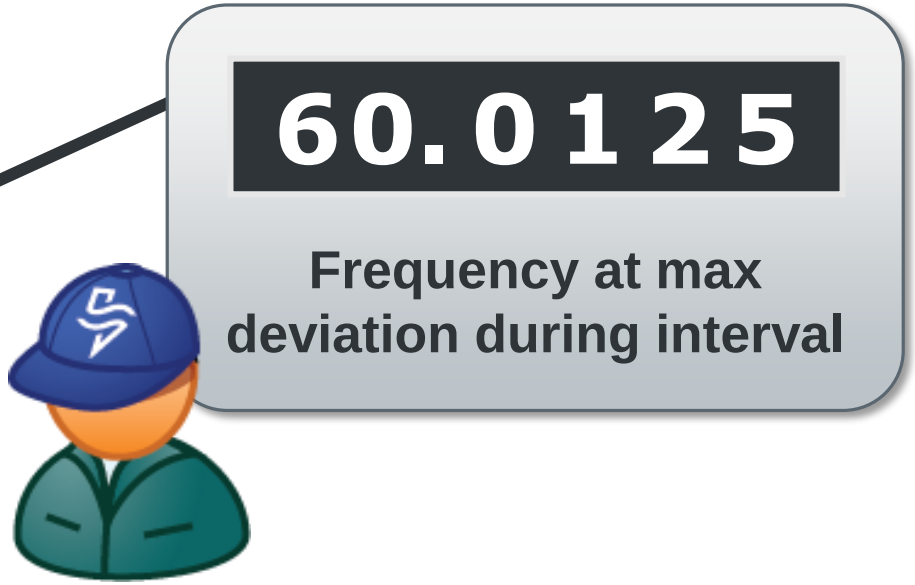


Scenario 3

Conditions:

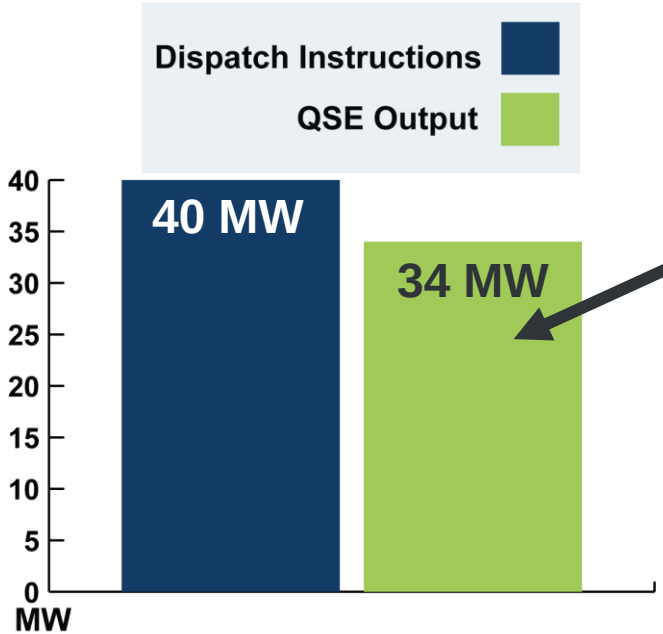
- Resource output falls short of Dispatch Instructions by 6MW
- System Frequency reaches 60.0125 Hz

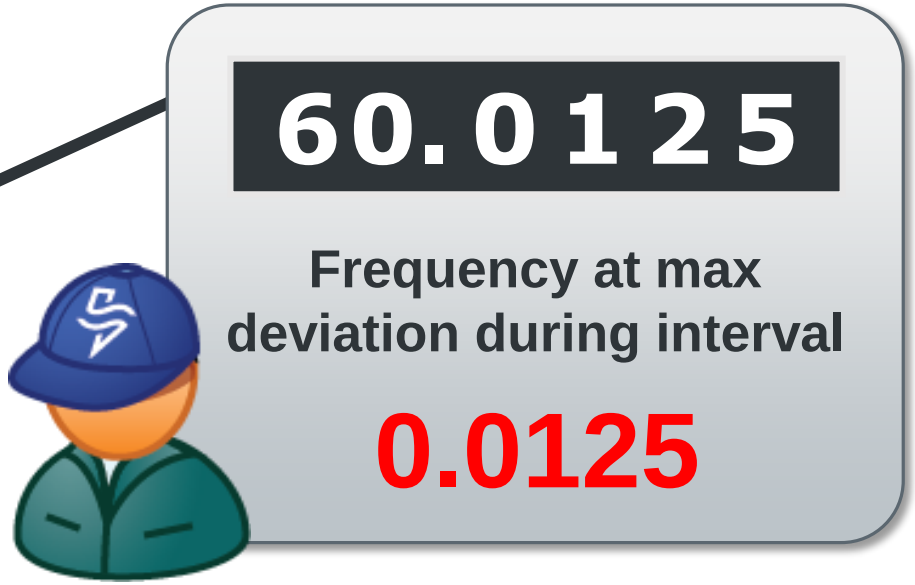




Scenario 3

Does the QSE incur a Base Point Deviation Charge?

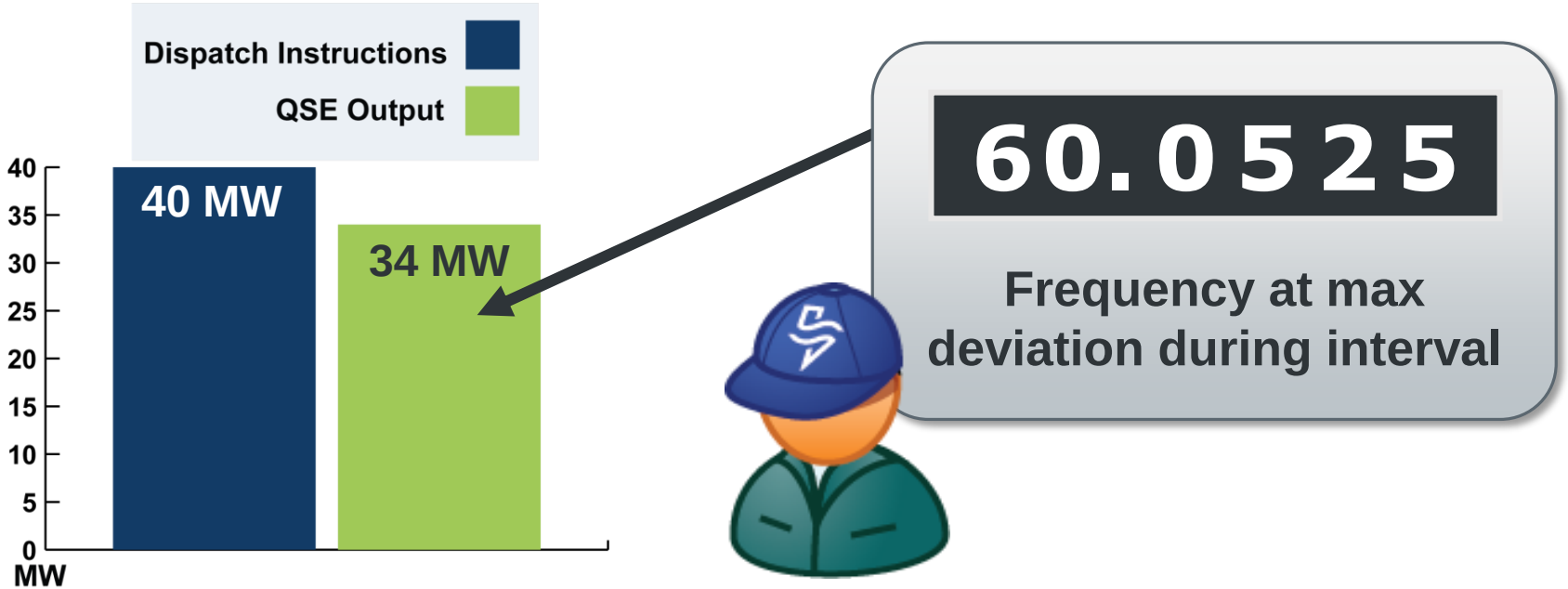




Scenario 4

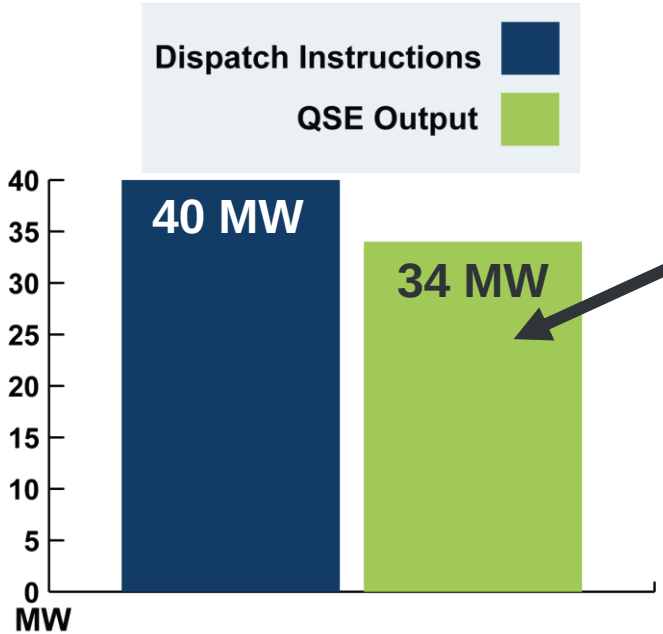
Conditions:

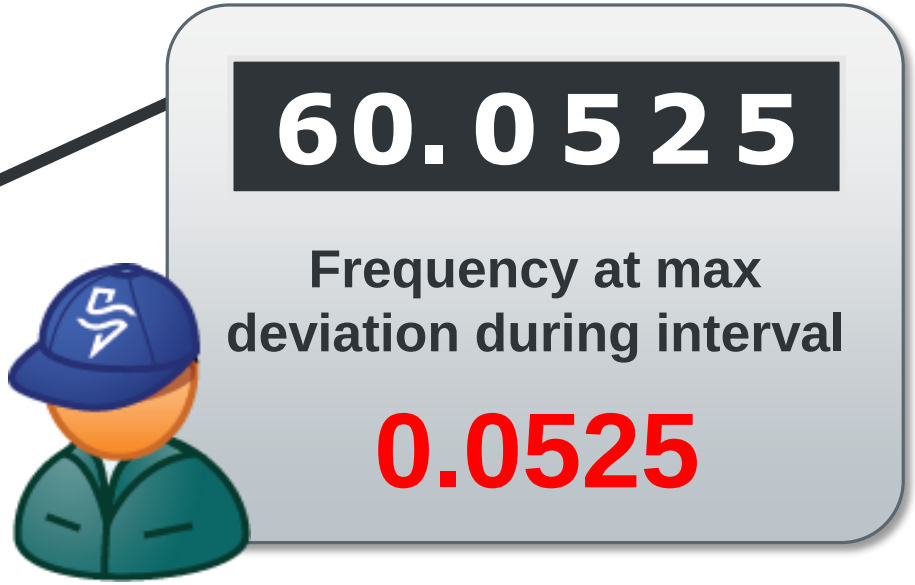
- Resource output falls short of Dispatch Instructions by 6MW
- System Frequency reaches 60.0525 Hz



Scenario 4

Does the QSE incur a Base Point Deviation Charge?





Determining Base Point Deviation

ERCOT compares Adjusted Aggregated Base Points to the Time-Weighted Telemetered Generation.

Time-Weighted Telemetered Generation

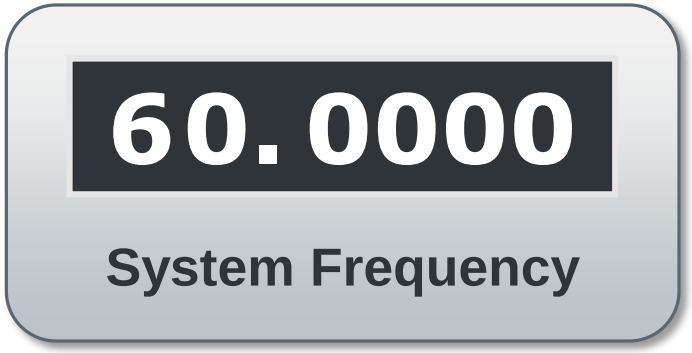
Adjusted Aggregated Base Point

Calculating Adjusted Aggregated Base Point

Adjusted Aggregated Base Point = **Average Base Point** + **Average Regulation**

15 Minute Value

Considers Ramping



Base Point Deviation for QSE with Regulation

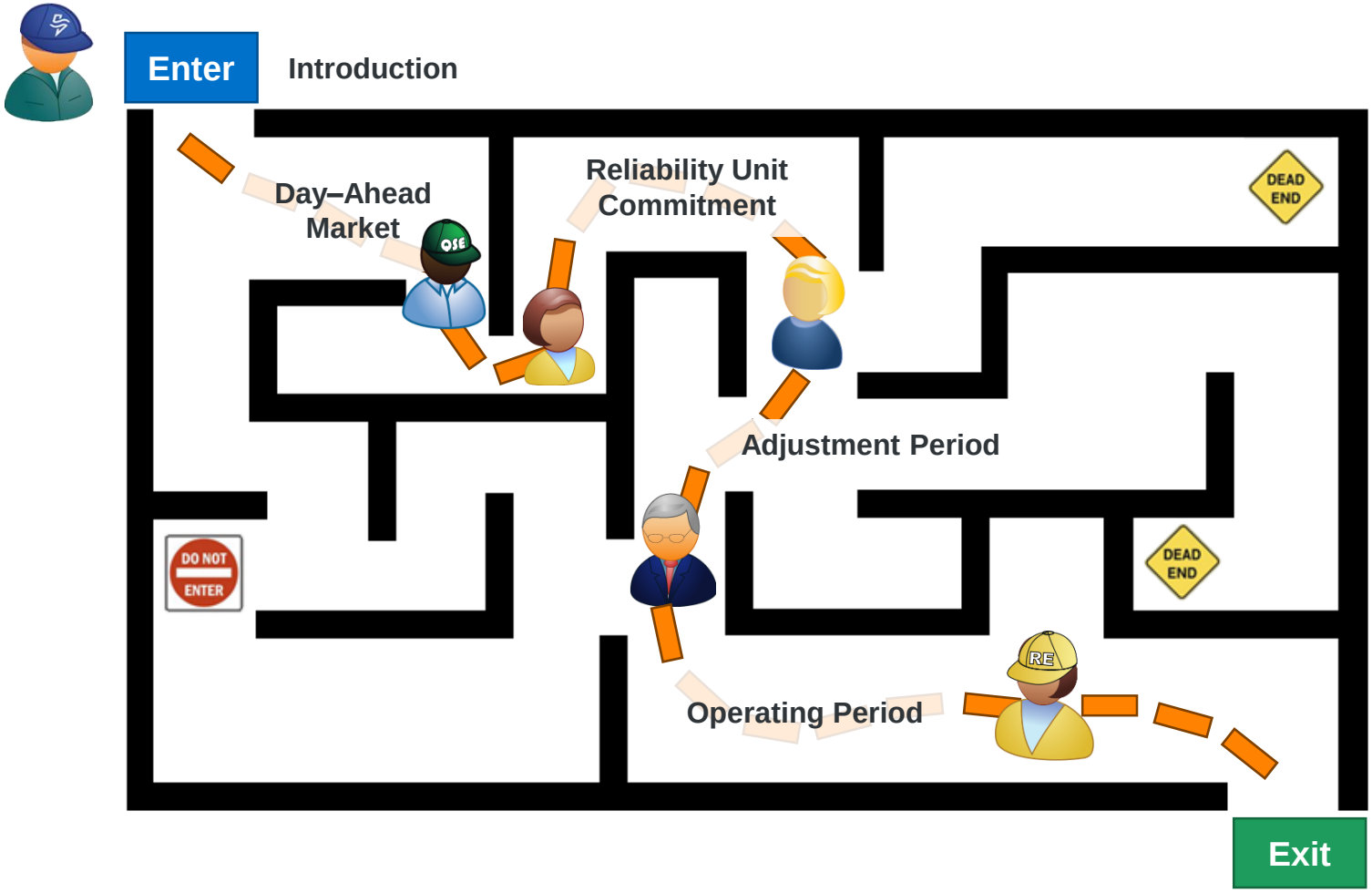
- Not following Reg-down instructions looks like *over-generating*.
- Not following Reg-up instructions looks like *under-generating*.

You have learned about:

- The timeline and processes of the Operating Period
- Inputs, processes, and outputs related to Real-Time Energy Dispatch
- The functions of Load Frequency Control
- The primary financial impacts associated with the Operating Period

Conclusion:
You may amaze yourself!

Conclusion – You may a-MAZE yourself!



Class Discussion

Day-Ahead Market

1. *What are some possible QSE outcomes in the Day-Ahead Market?*

2. *Why would a QSE want such outcomes?*

Class Discussion

Reliability Unit Commitment

1. *What are some possible <u>operational</u> outcomes from the Reliability Unit Commitment process?*

2. *What are some possible <u>financial</u> outcomes from the Reliability Unit Commitment process?*

Class Discussion

Adjustment Period

1. *What are some possible ERCOT actions during the Adjustment Period?*

2. *What are some possible QSE actions during the Adjustment Period?*

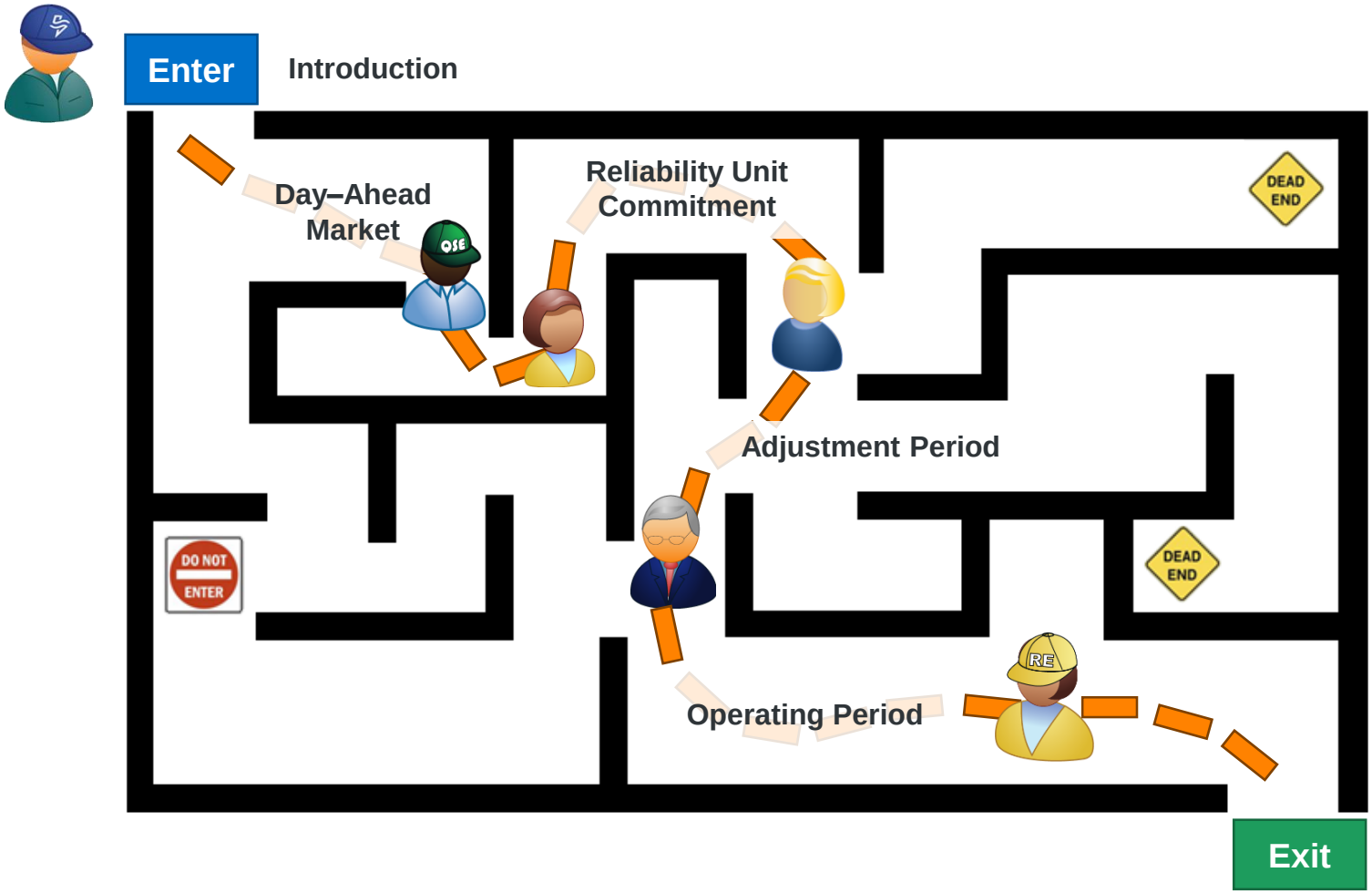
Class Discussion

Operating Period

1. *Is the Operating Period <u>operationally</u> dependent on previous market processes?*

2. *Is the Operating Period <u>financially</u> dependent on previous market processes?*

Congratulations! You've completed Wholesale Markets 201!



Accessing additional information

ERCOT Protocols
http://www.ercot.com/mktrules/nprotocols/

ERCOT Training
http://www.ercot.com/services/training/

ERCOT Account Management Services
ErcotAccountManagers@ercot.com

ERCOT Credit
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