ERCOT Market Education

Resources and Day-Ahead Operations

2024_01 Resource_DA_Ops

**Greetings
and
Introductions**

Format	Title
WBT	Resources in ERCOT
	Resource Responsibilities in ERCOT

Format	Title	Topic
ILT	Resources and Day-Ahead Operations	Resource Constraints in the Day-Ahead Market
		Resource Commitment in the Day-Ahead Market
		Resource Commitment after the Day-Ahead Market
	Resources and Real-Time Operations	Resource Dispatch in Real-Time
		Resource Reserve Deployment in Real-Time
		Resources and their Financial Impacts

WebEx Tips

- **Windows**

- **Buttons**

Attendance

Questions / Chat

PROTOCOL DISCLAIMER

This presentation provides a general overview of the Texas Nodal Market and is not intended to be a substitute for the ERCOT Protocols, as amended from time to time. If any conflict exists between this presentation and the ERCOT Protocols, the ERCOT Protocols shall control in all respects.

For more information, please visit:

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

Resource Constraints in the Day-Ahead Market

1 Resource Limits in Day-Ahead Market

2 Linked Offer Constraints

3 Temporal Constraints

Responsive Reserve Service Subtypes

Load Resource on Under-Frequency Relay

Primary Frequency Response

RRSUF

RRSPF
Min 1185 MW

Max (RRSUF + RRSFF) = 60 % Total RRS

RRSFF
Max 450 MW

Fast Frequency Response
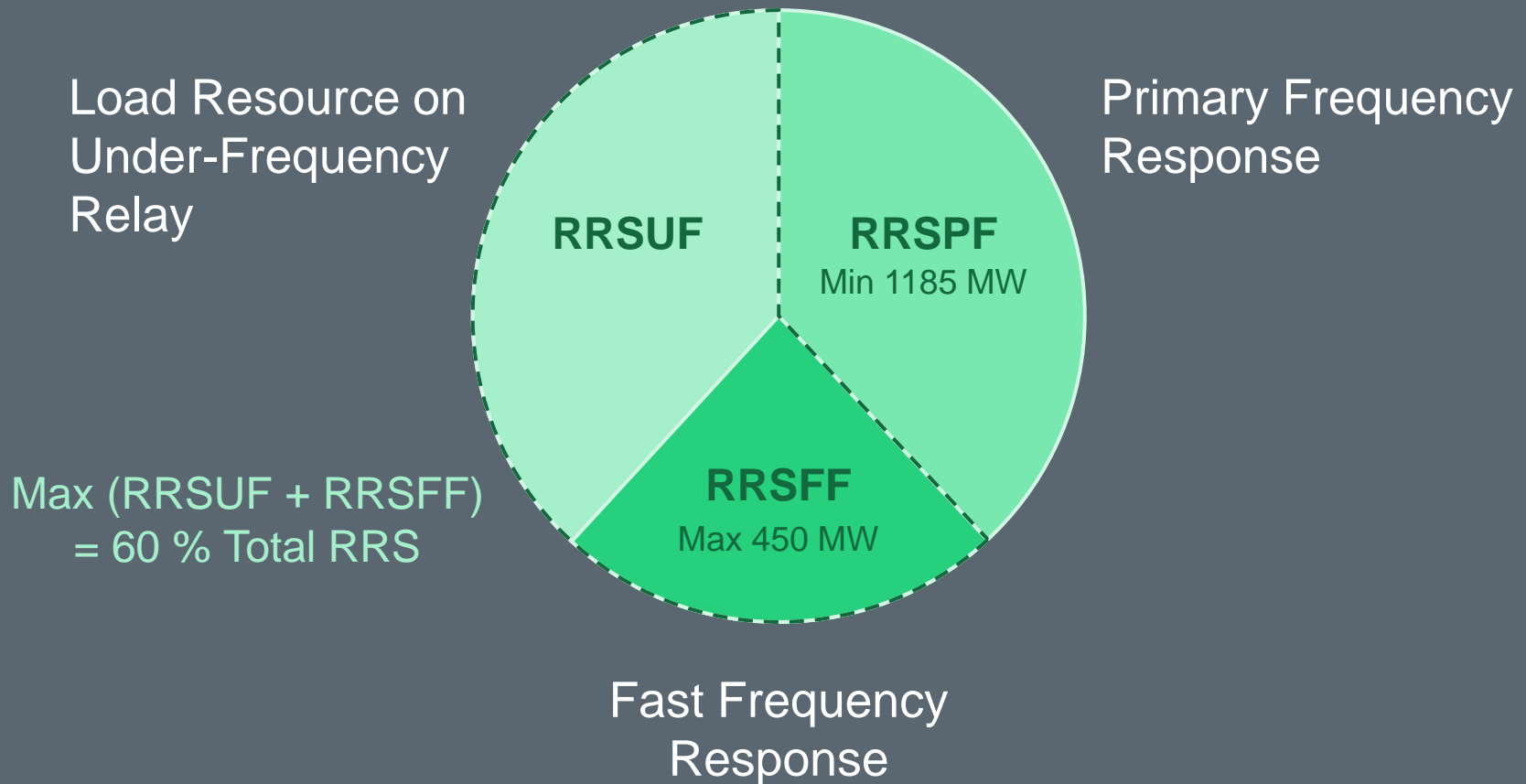
Limits enforced by Day-Ahead Market:

Generation Resources	Responsive Reserve (RRSPF subtype)	Award ≤ RRSPF% of HSL (20% or Proven)
	Responsive Reserve (RRSFF subtype)	Award ≤ 15-minute capacity (Proven)
	ERCOT Contingency Reserve Service (ECRS)	Award ≤ 10 * Emergency Ramp Rate
	Energy and AS Capacity	Total Award ≤ HSL
Load Resources	Responsive Reserve	Award ≤ HSL - LSL

A QSE offers Ancillary Services from a Generation Resource:

- **50MW Regulation-Up (Reg-Up)**
- **100MW Responsive Reserve (RRSPF)**

Can DAM award both offers?

Real-Time required capabilities?

| Resource Limits	
HSL	500 MW
LSL	100 MW
RRSPF%	20% of HSL
Normal Ramp Rate	10 MW/min
Emergency Ramp Rate	10 MW/min

A QSE offers Ancillary Services and is awarded by DAM:

- **50MW Regulation-Up (Reg-Up)**
- **50MW Responsive Reserve (RRSPF)**

In Real Time:

- Ramp Rate = 10MW/min
- RRSPF is deployed at t = 0
- Reg-up consumes Ramp Rate
- More capacity for SCED at t = 5
- Resource may ramp through Reg-up and RRSPF by t=10

HSL =500 MW

| 50 MW | Reg-Up | Reg-Up |
| 50 MW | RRSPF | 450 MW |

400 MW

SCED Dispatch Limit

t = 0   5   10

11
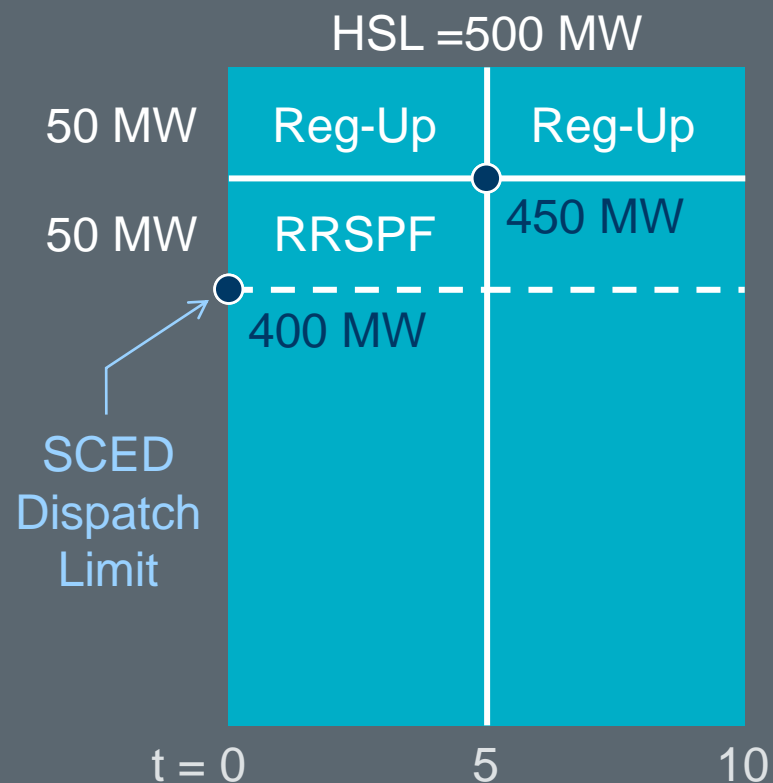
Generalizing this approach . . .

| Offer	Less than or equal to
Regulation Up	NRR * 5
Regulation Down	NRR * 5
ECRSS	ERR * 10
Responsive Reserve	Min(RRSPF% * HSL , ERR * 10 – REGUP offer – ECRSS offer)
Non-Spin Reserve	Min(NRR * 20 + ERR * 10 – REGUP – RRSPF – ECRSS , NRR * 30)

Where NRR = Normal Ramp Rate
ERR = Emergency Ramp Rate
ECRSS= ECRS SCED-dispatchable

A QSE offers a Generation Resource in DAM:

- **300MW Off-line Non-Spin**
- **300MW Energy**

DAM awards as follows:
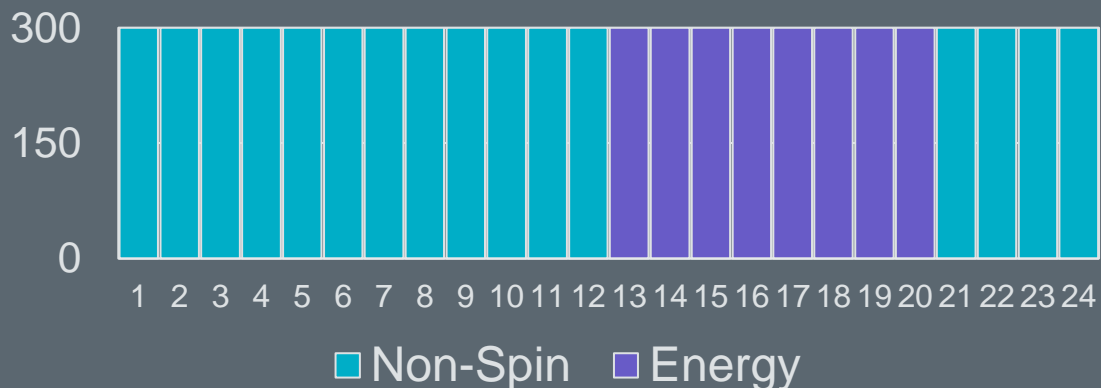
Resource Limits	
HSL	300 MW
LSL	100 MW
Ramp Rate	10 MW/min

Is it possible to produce entire Energy Award during Hour 13?

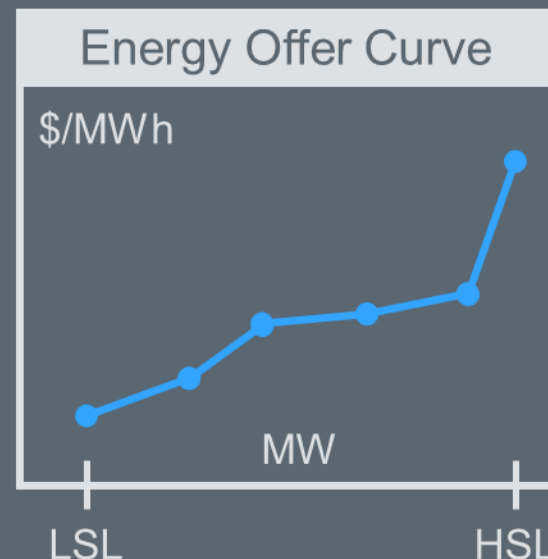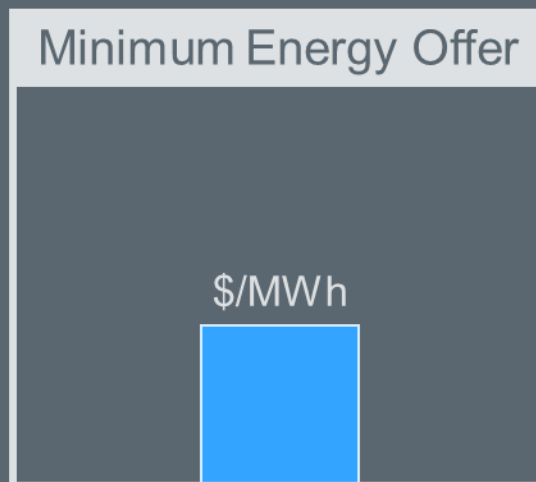**1**   Resource Limits in Day-Ahead Market

2   Linked Offer Constraints

3   Temporal Constraints

Single Resource may be offered for Energy Inclusive or Exclusive of Ancillary Service Offers

AS Type	Offer	
Reg-Up	MW	$ / MW
Reg-Down	MW	$ / MW
Responsive	MW	$ / MW
ECRS	MW	$ / MW
Non-Spin	MW	$ / MW

Startup Offer

$/Start

Minimum Energy Offer

$/MWh

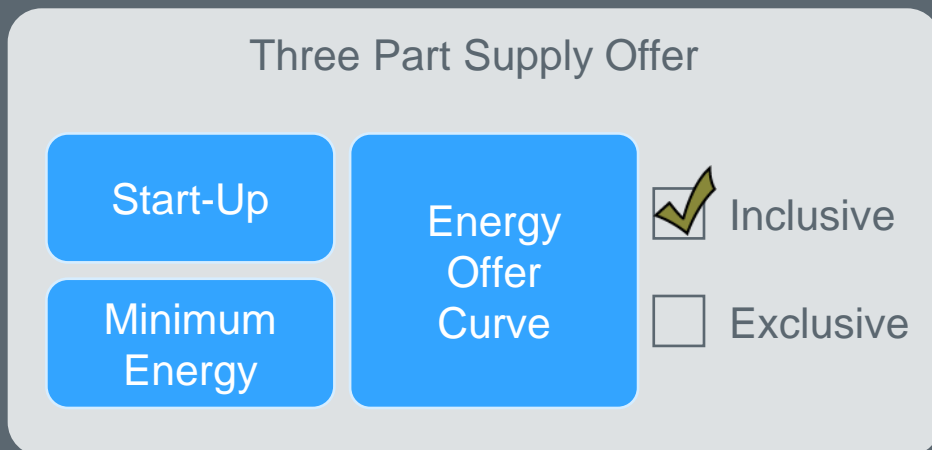### Energy Offer Curve

$/MWh

MW

LSL   HSL

1. **Break into teams**

2. **Determine possible DAM Awards**

   a. **Odd-numbered groups work on Linked Inclusive Offers**

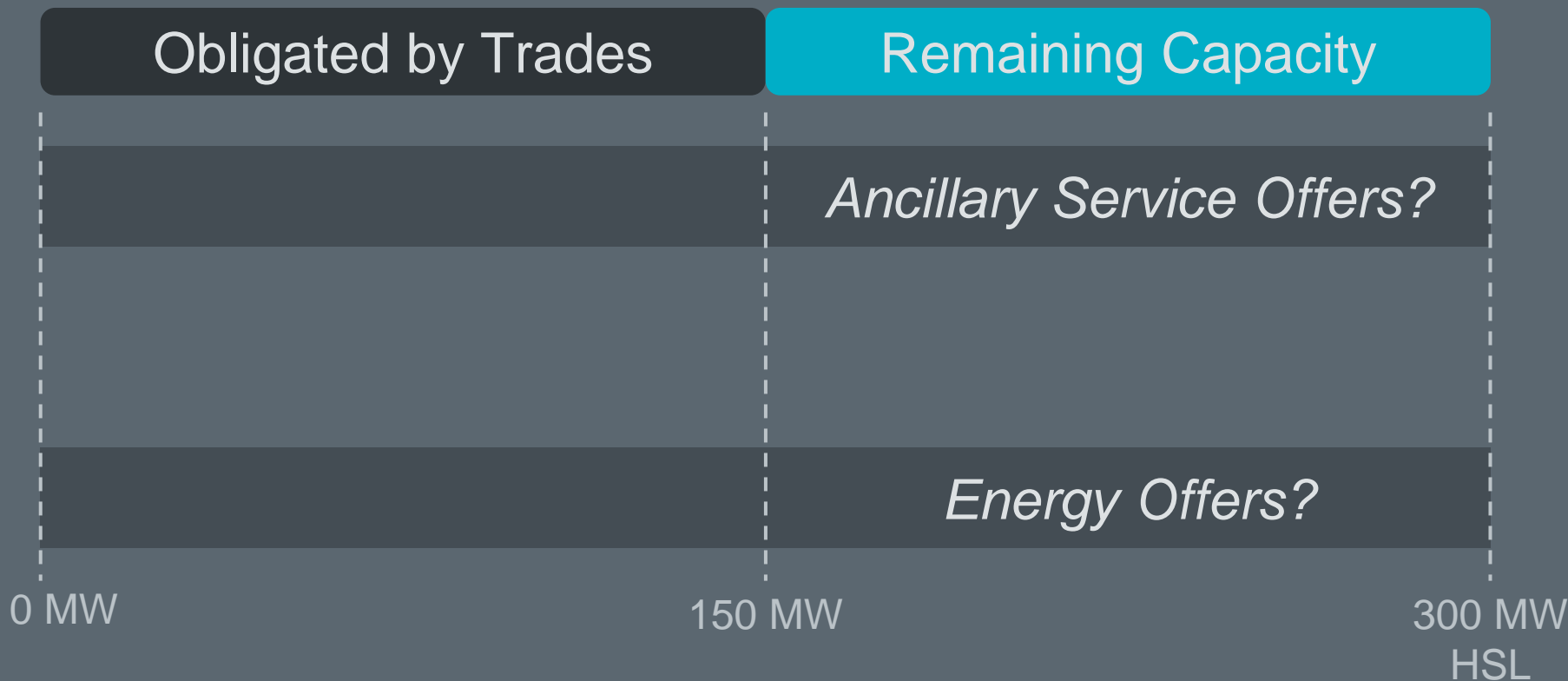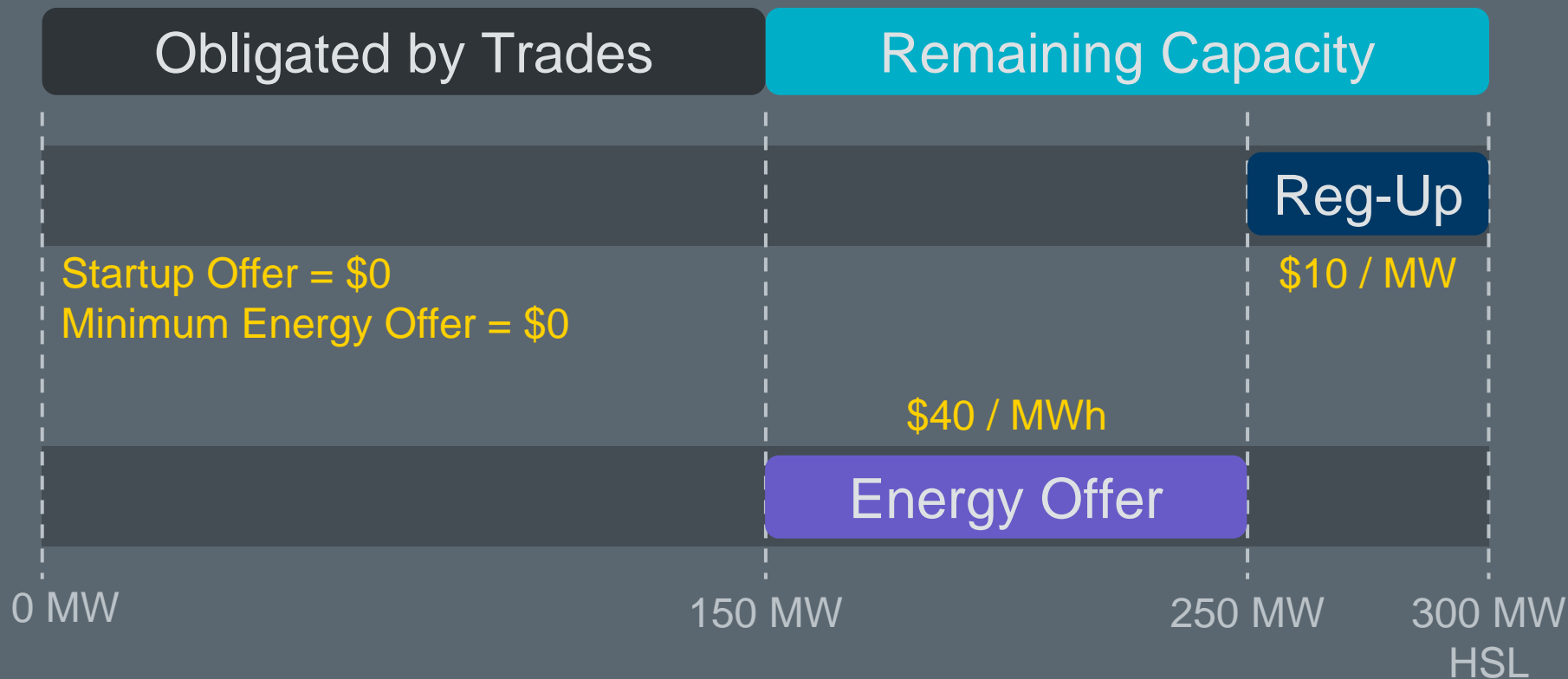   b. **Even-numbered groups work on Linked Exclusive Offers**

3. **Enforce Resource Limits from Slide 9**

Three Part Supply Offer

Start-Up

Minimum Energy

Energy Offer Curve

☑ Inclusive

☐ Exclusive

AS Type	Offer	
Reg-Up	MW	$ / MW
Reg-Down	MW	$ / MW
Responsive (RRSPF)	MW	$ / MW
ECRS	MW	$ / MW
Non-Spin	MW	$ / MW

Obligated by Trades	Remaining Capacity
	Ancillary Service Offers?
	Energy Offers?

0 MW   150 MW   300 MW HSL

Obligated by Trades	Remaining Capacity

Reg-Up

Startup Offer = $0
Minimum Energy Offer = $0

$10 / MW

$40 / MWh

Energy Offer

0 MW   150 MW   250 MW   300 MW
                                              HSL

Possible outcome:

Reg-Up

150 MW Trade Obligation

DAM Energy Award

0 MW · 150 MW · 250 MW · 300 MW HSL

Clears at $20/MWh

ercot

What DAM actually saw:

				Reg-Up	

Min Energy Offer | Energy Offer

0 MW   100 MW LSL   150 MW   250 MW   300 MW HSL

Obligated by Trades

Remaining Capacity

Reg-Up

$10 / MW

Startup Offer = $0
Minimum Energy Offer = $0

$40 / MWh

Energy Offer

0 MW   100 MW   150 MW   250 MW   300 MW
                                                                          HSL

Possible outcome:

Reg-Up

150 MW Trade Obligation

DAM Energy Award

0 MW   100 MW   250 MW   300 MW HSL

Clears at $20/MWh

What DAM actually saw:

What DAM actually sees:

Reg-Up

Energy Offer

0 MW   100 MW   250 MW   300 MW
HSL
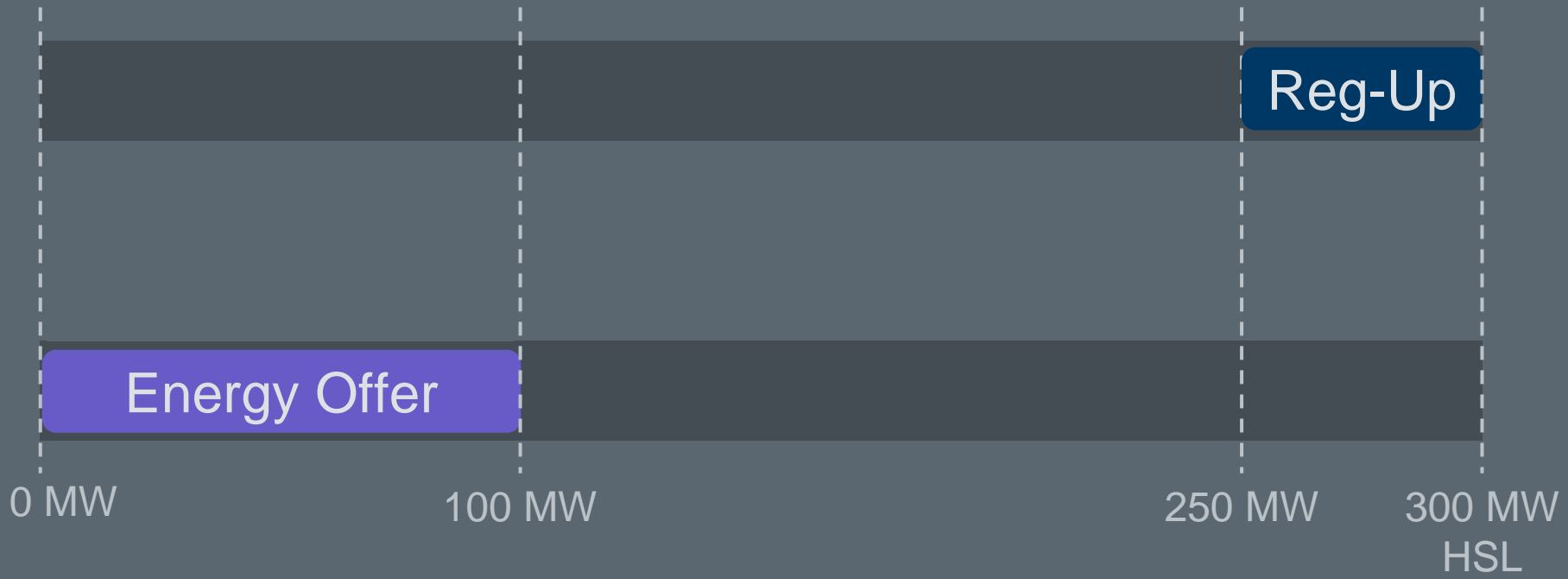
LSL constraint ignored

Possible outcome:

Reg-Up

150 MW Trade Obligation

DAM Energy Award

0 MW | 100 MW | 250 MW | 300 MW HSL

Clears at or above $40/MWh
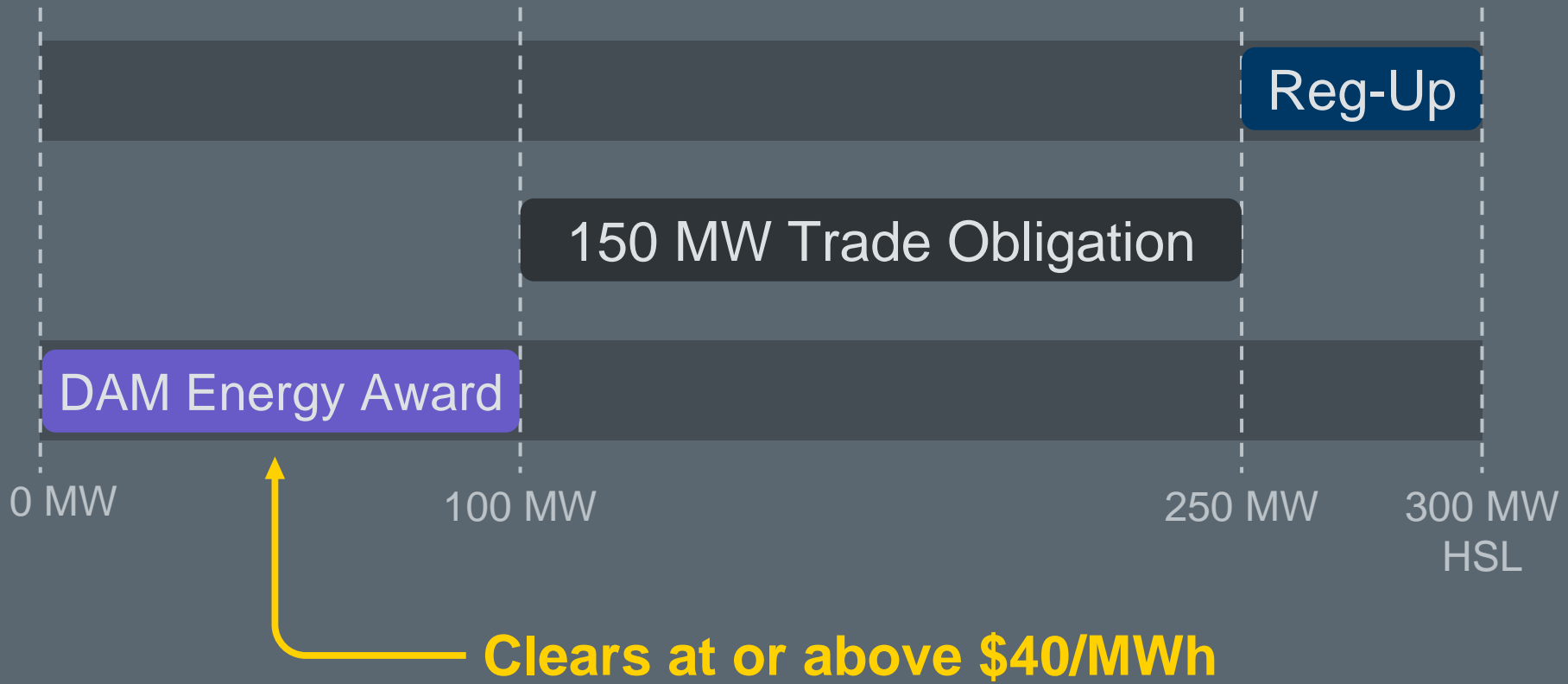
Energy Storage Resources (ESR-Gen, ESR-CLR)	REGUP RRSPF RRSFF ECRS ONNS REGDN	Can offer simultaneously
		Can be awarded concurrently
Non-Controllable Load Resources	RRSFF RRSUF ECRS ONNS	Can offer simultaneously
		Cannot carry concurrently

1   Resource Limits in Day-Ahead Market

2   Linked Offer Constraints

3   Temporal Constraints
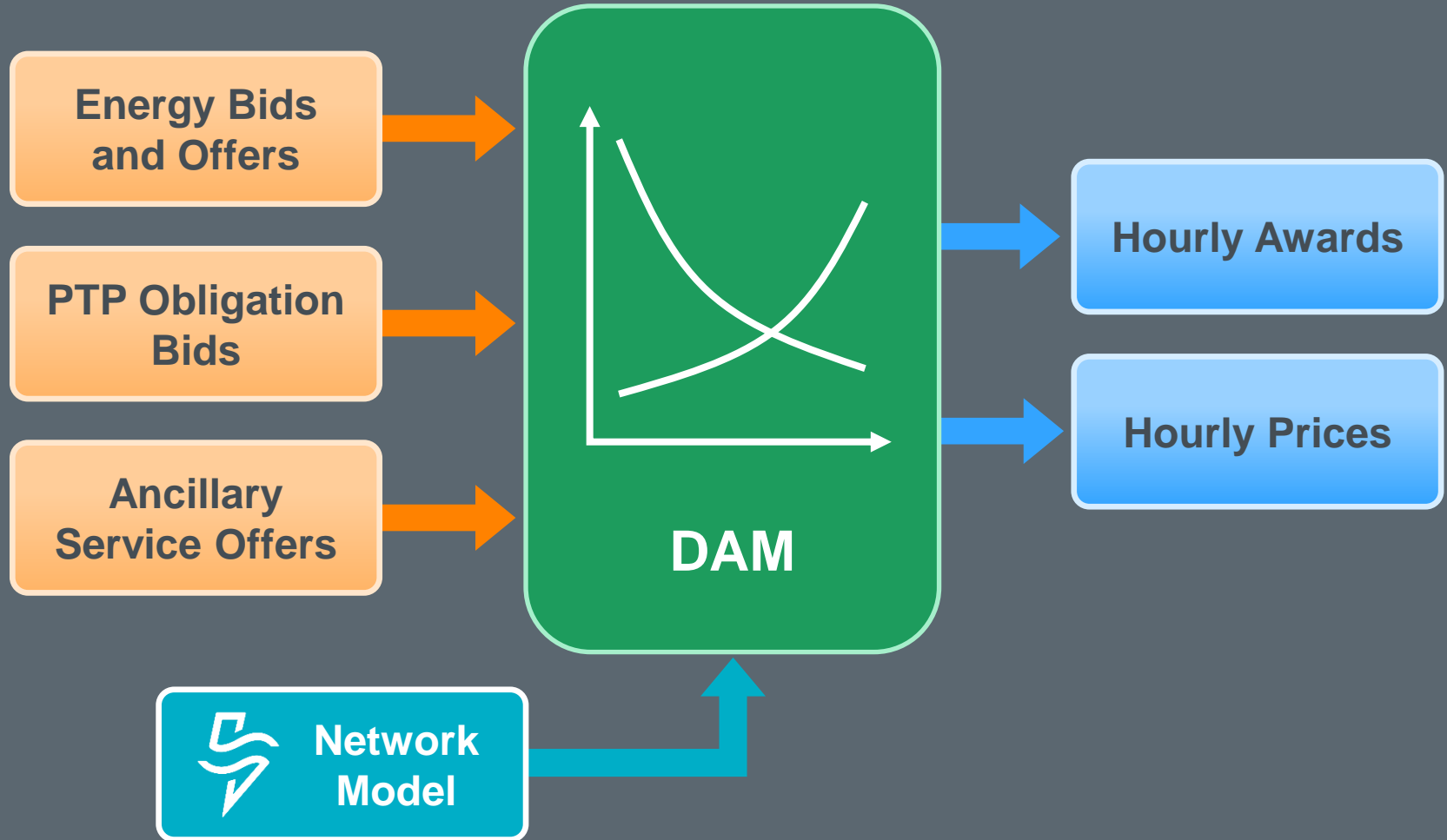
DAM Enforces certain Temporal Constraints

Start Time
Min On-Line Time
Min Off-Line Time
Maximum Daily Starts

X RARF

Resource Commitment
in the Day-Ahead Market

# Economically optimized subject to constraints

Energy Bids and Offers → DAM

PTP Obligation Bids → DAM

Ancillary Service Offers → DAM

Network Model → DAM

DAM → Hourly Awards

DAM → Hourly Prices

Constraints Enforced by DAM

Type	Constraints
Network Security	Power Balance Constraint
	Transmission Constraints
Resource	Resource Limits
	Linked Offers
	Temporal
Ancillary Service	Requirements for each Type

Maximize Bid-Based Revenues minus Offer-Based Costs
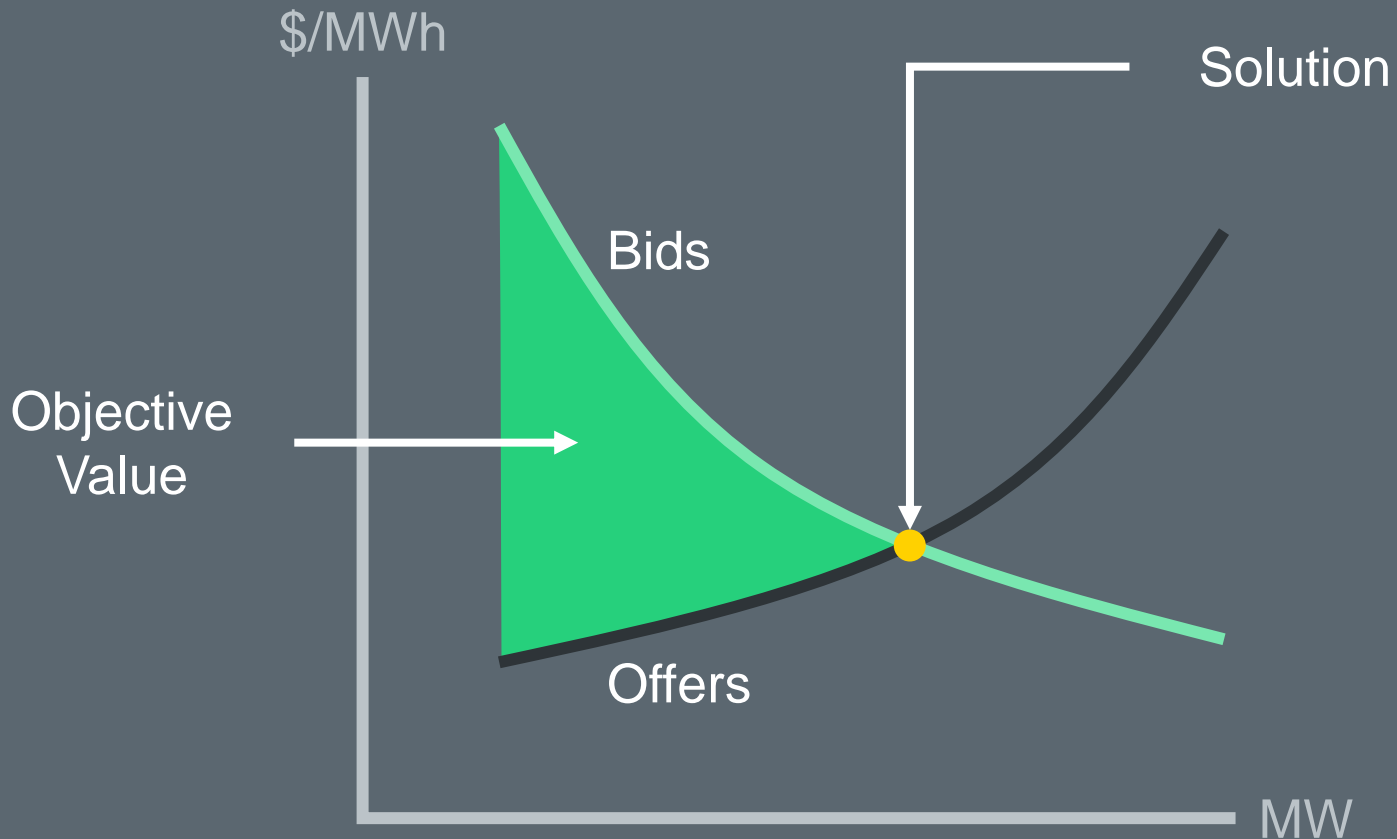
But Resource Offers are lumpy!

$/MWh

Bids

Cumulative offer curve depends on how DAM commits Resources

Offers

MW
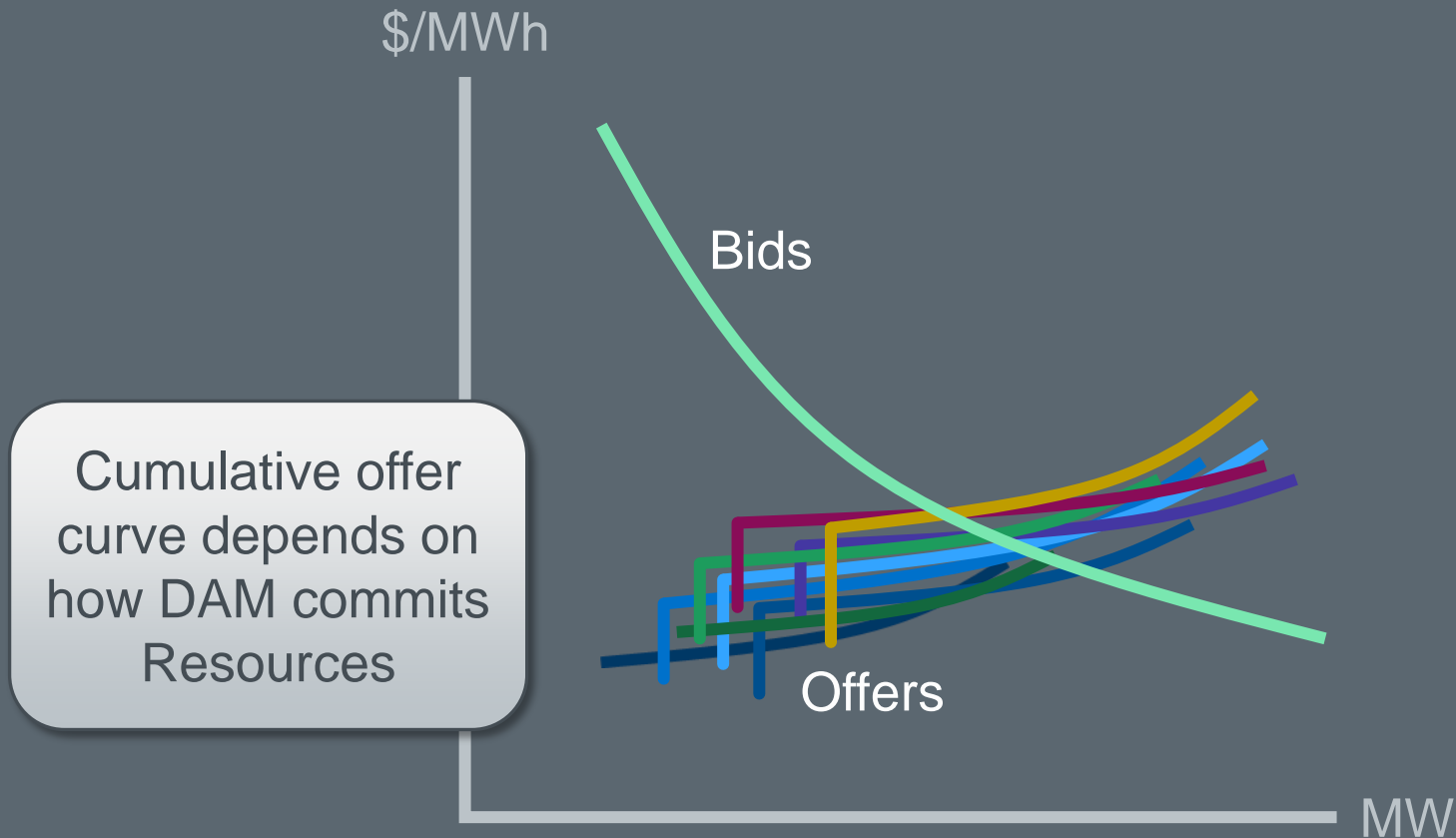
DAM Commitment of Resources
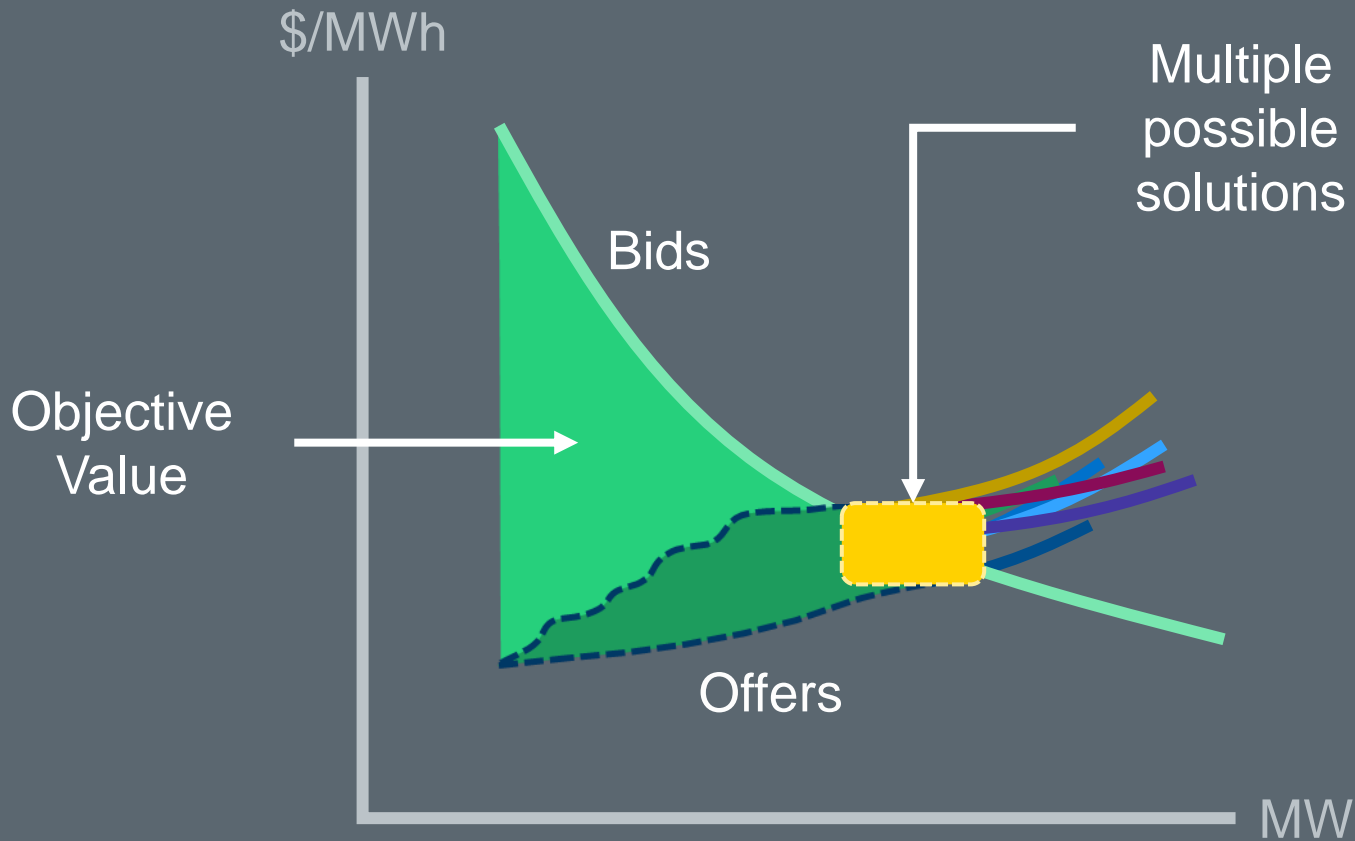
DAM Optimization calculates Shadow Prices

- SP_{demand} for the Power Balance Constraint

- SP_c for each Transmission Constraint

- $SP_{(AS)}$ for each Ancillary Service Requirement

  - Regulation Up

  - Regulation Down

  - Responsive Reserve

  - Contingency Reserve (ECRS)

  - Non-Spin Reserve

Shadow Price is the improvement in Objective Value as a constraint is relaxed

Locational Marginal Prices for Energy

$$LMP_{bus} = SP_{demand} - \sum_{c} SF_{bus,c} * SP_c$$

Shift Factor of the bus on
Transmission Constraint "c"

Also known as
System Lambda (λ)

Market Clearing Prices for Ancillary Service Capacities

- $MCPC_{(Reg\text{-}Up)} = SP_{(Reg\text{-}Up)}$

- $MCPC_{(Reg\text{-}Down)} = SP_{(Reg\text{-}Down)}$

- $MCPC_{(Responsive)} = SP_{(Responsive)}$

- $MCPC_{(ECRS)} = SP_{(ECRS)}$

- $MCPC_{(Non\text{-}Spin)} = SP_{(Non\text{-}Spin)}$

Regulation Up

Regulation Down

Responsive Reserve

Contingency Reserve

Non-Spin Reserve

AS Capacity

Sold as Energy

DAM Awards
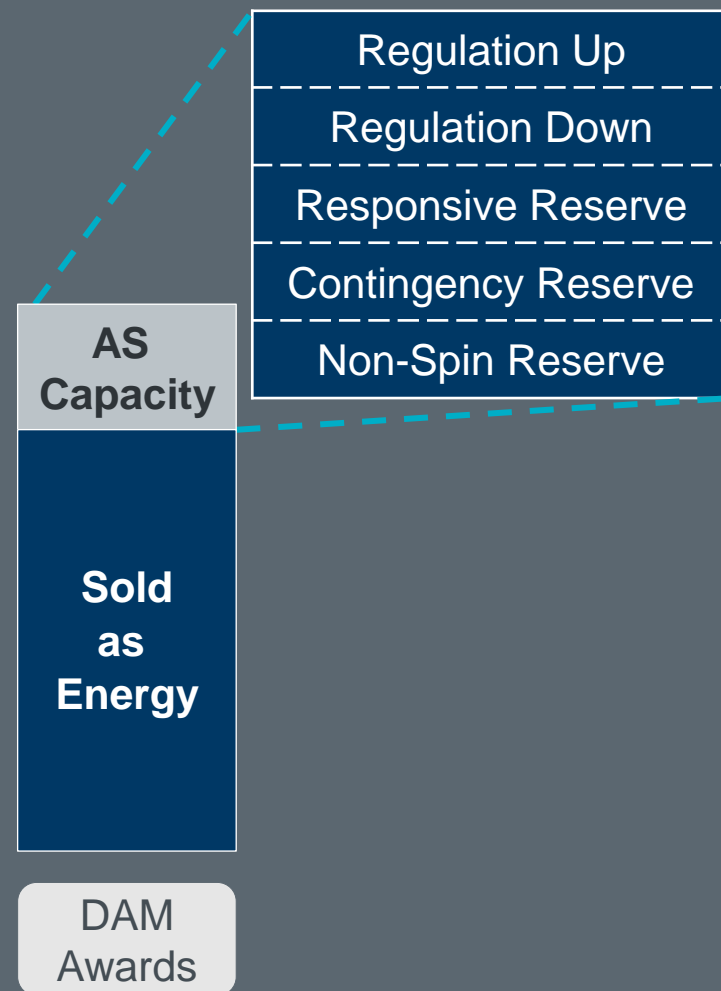
Introducing a simple Network Model …

Shadow Price for Power Balance (λ) is determined at reference bus

C

100 MW

A — 100 MW — B

100 MW

Reference Bus → D
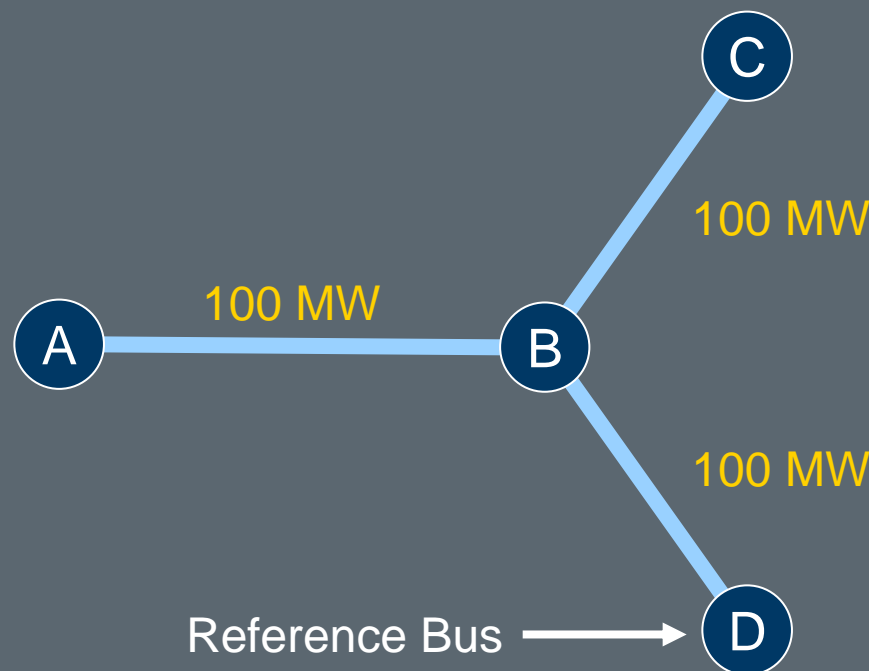
● = Settlement Point

MW = Transmission Capacity

Determine Awards and Prices

QSE	Product	Bid or Offer	Location	MW	Price	Award
QSE 1	Energy	Offer	A	100	$20	
QSE 2	Energy	Offer	C	60	$30	
QSE 3	Energy	Bid	D	90	$40	
QSE 4	PTP Obl	Bid	A to B	30	$20	

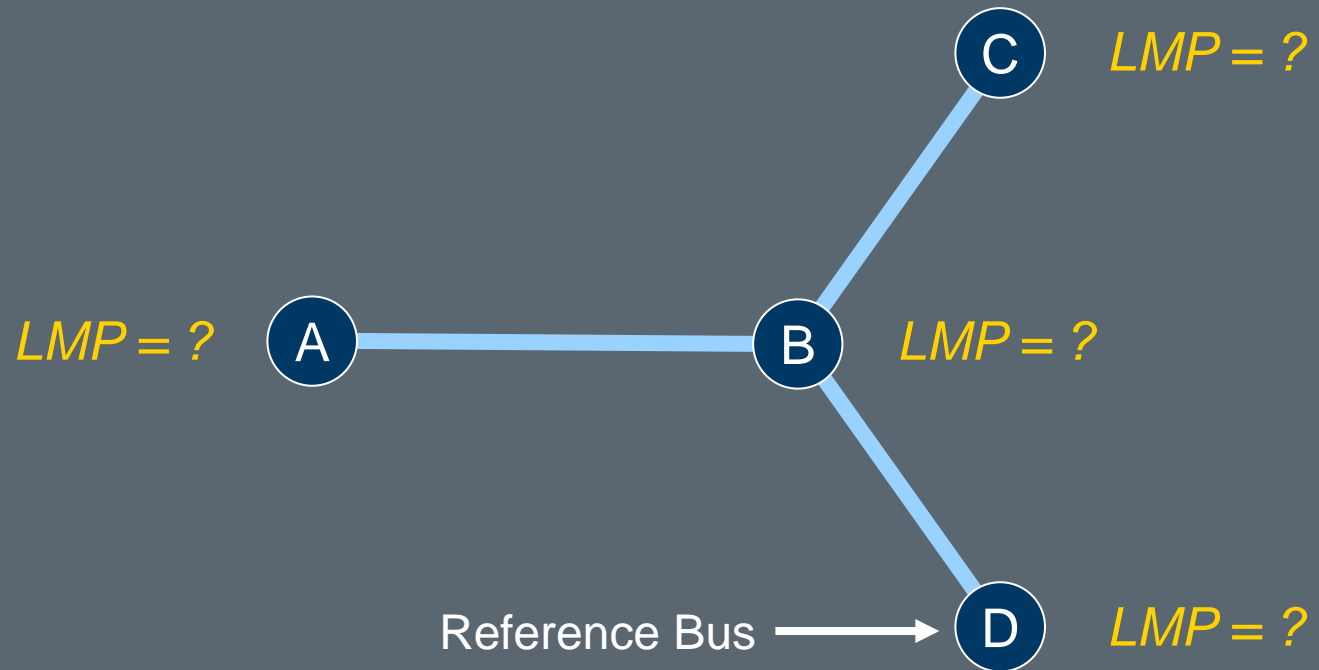| Bid-based Revenues − Offer-based Costs	(Objective Value)

Shadow Prices	
SP_{demand}	$SP_{constraint\ AB}$

Determining Locational Marginal Prices

$$LMP_{bus} = SP_{demand} - \sum_c SF_{bus,c} * SP_c$$

C *LMP = ?*

LMP = ? A ——— B *LMP = ?*

Reference Bus ⟶ D *LMP = ?*

Does solution make sense?

Result	MW	Price

A —100 MW— B
B —100 MW— C
B —100 MW— D
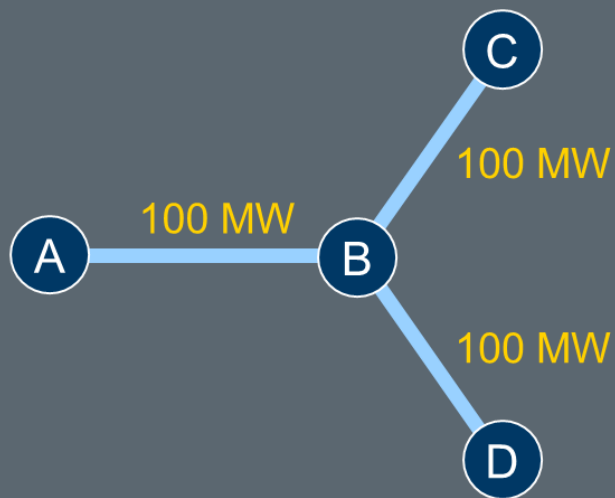
Determine Awards and Prices

QSE	Product	Bid or Offer	Location	MW	Price	Award
QSE 1	Energy	Offer	A	100	$20	
QSE 2	Energy	Offer	C	60	$30	
QSE 3	Energy	Bid	D	90	$40	
QSE 4	PTP Obl	Bid	A to B	30	$5	

Bid-based Revenues — Offer-based Costs	(Objective Value)

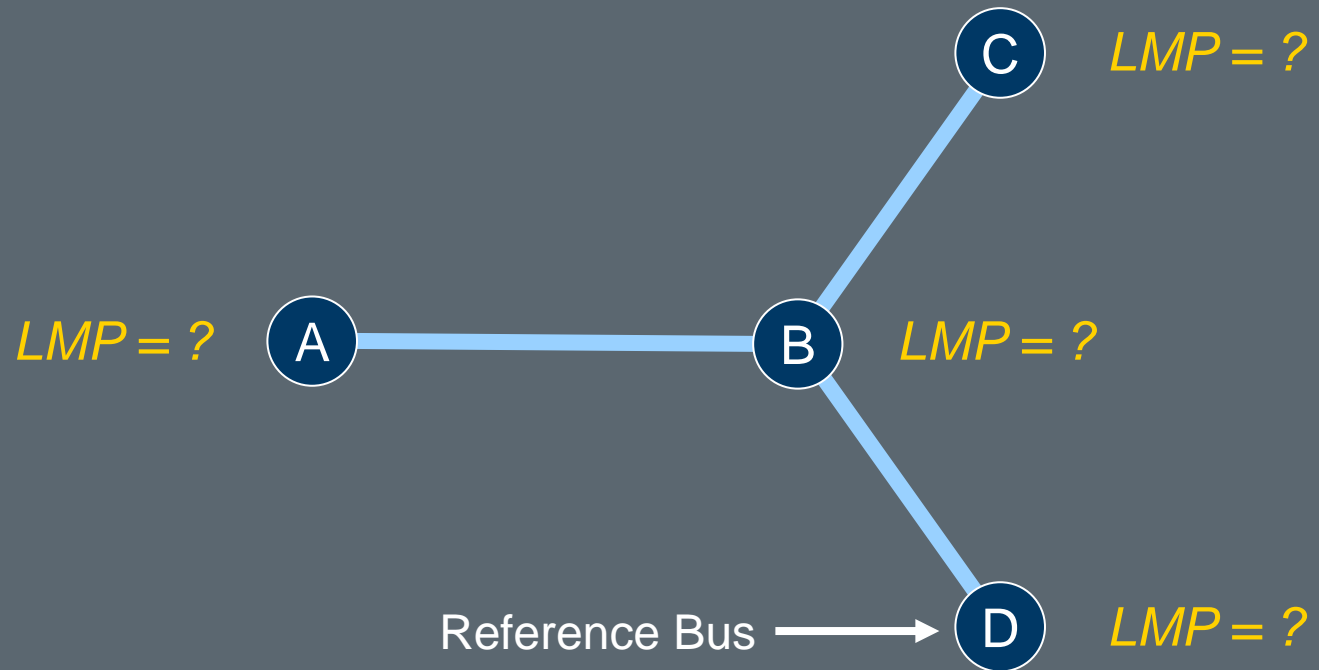| Shadow Prices	
SP_{demand}	$SP_{constraint\ AB}$

Determining Locational Marginal Prices

$$LMP_{bus} = SP_{demand} - \sum_{c} SF_{bus,c} * SP_c$$

C   *LMP = ?*

LMP = ?   A ——— B   *LMP = ?*

Reference Bus ⟶ D   *LMP = ?*

Does solution make sense?
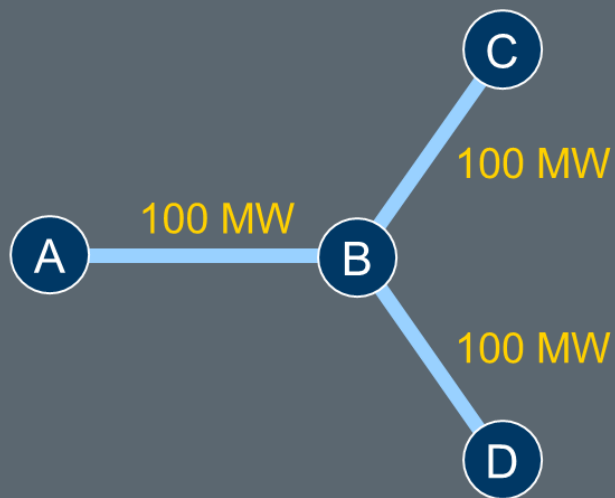
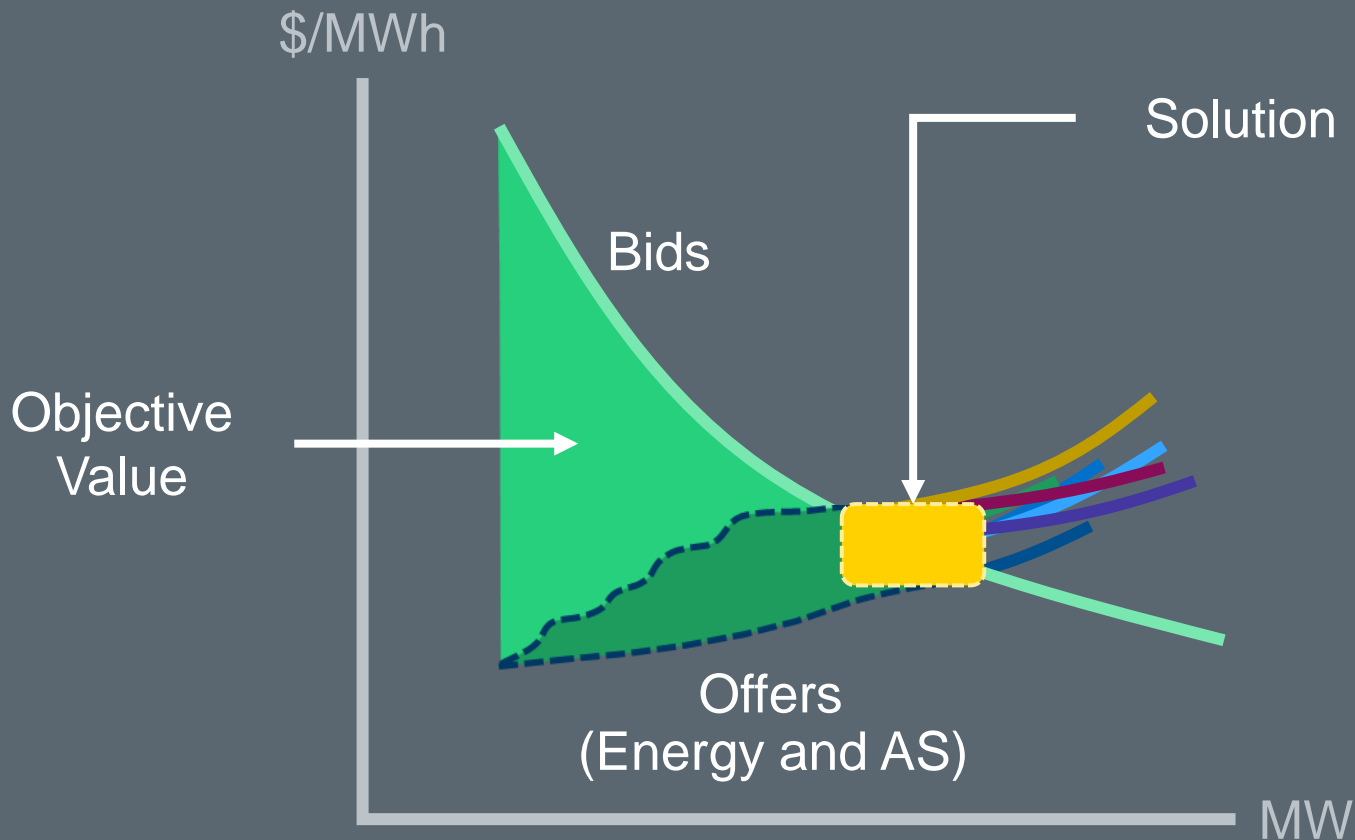| Result	MW	Price

ERCOT must also clear Ancillary Service Requirememts
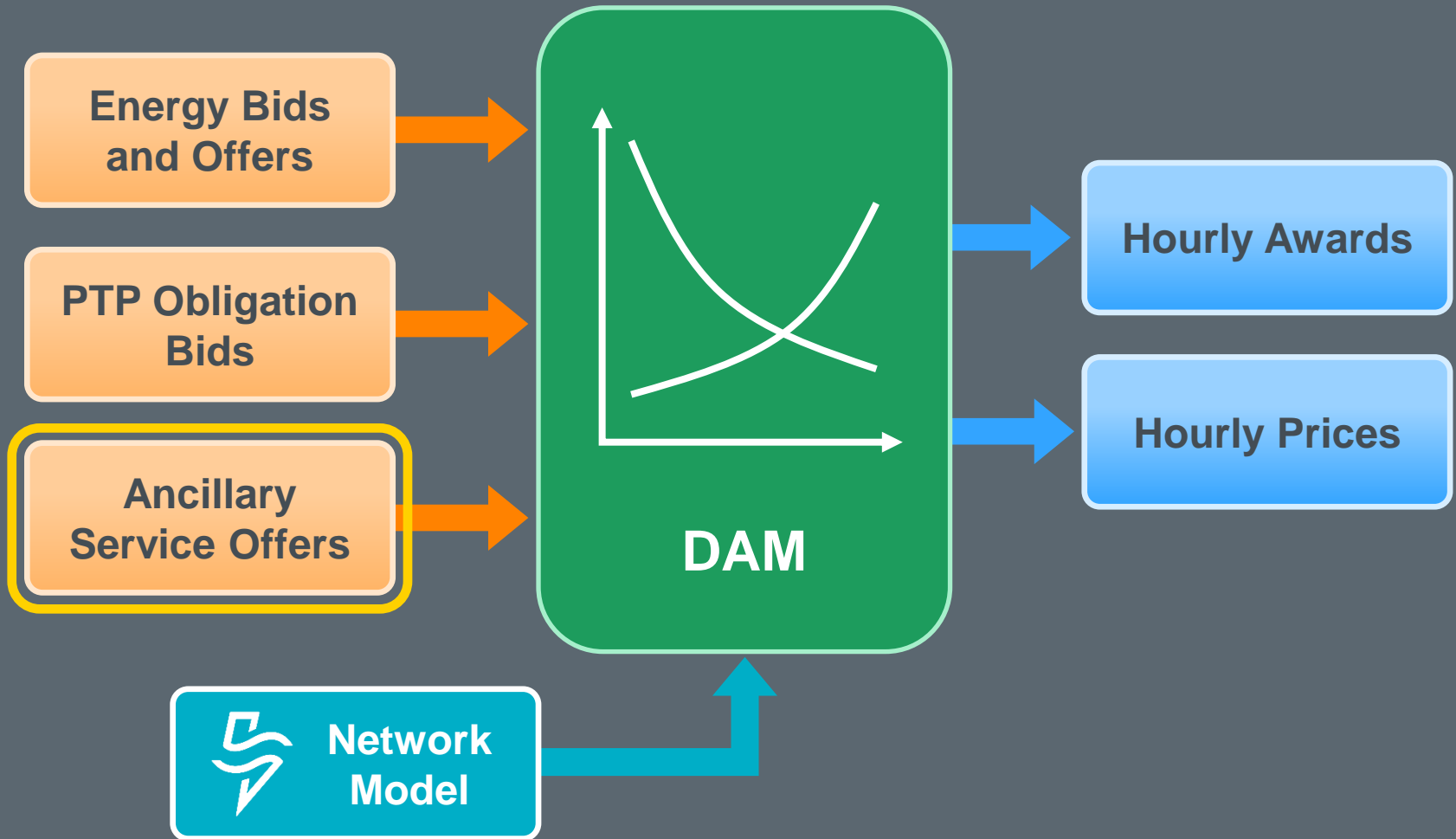
Energy and Ancillary Services are co-optimized

For HE 1300 ERCOT needs to procure:

- 1 MW of Regulation Up (RegUp)
- 1 MW of Responsive Reserve (RRSPF)

QSE Bids and Offers:

QSE	Bids		Offers			
	MW	**Energy**	**MW**	**Energy**	**RegUp**	**RRSPF**
QSE A			2	$25	$10	$5
QSE B			2	$30	$11	$9
QSE C	1	$50				

Scenario: Day-Ahead Market Co-Optimization

A Few Potential Solutions

Case 1

QSE	Energy	RegUp	RRSPF
QSE A	$25	$10	
QSE B			$9

Bid-based Revenues	−	Offer-based Costs
$50 − $25 − $10 − $9 = $6		

Case 2

QSE	Energy	RegUp	RRSPF
QSE A	$25		$5
QSE B		$11	

Bid-based Revenues	−	Offer-based Costs
$50 − $25 − $11 − $5 = $9		

Case 3

QSE	Energy	RegUp	RRSPF
QSE A		$10	$5
QSE B	$30		

Bid-based Revenues	−	Offer-based Costs
$50 − $30 − $10 − $5 = $5		

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Determining Prices

- Cost of additional increment of demand

- How would Day-Ahead Market clear additional MW?

Offers Provided

QSE	MW	Energy	RegUp	RRSPF
QSE A	2	$25	$10	$5
QSE B	2	$30	$11	$9

Offers Awarded

QSE	Energy	RegUp	RRSPF
QSE A	$25		$5
QSE B		$11	

Offers Provided

QSE	MW	Energy	RegUp	RRSPF
QSE A	2	$25	$10	$5
QSE B	2	$30	$11	$9

Clearing Additional MW of Energy

QSE	Energy	RegUp	RRSPF
QSE A	1MW @ $25		$5
QSE B	1MW @ $30	$11	

→ Increases cost by $30

QSE	Energy	RegUp	RRSPF
QSE A	2MW @ $25		
QSE B		$11	$9

→ Increases cost by $29

Offers Provided

QSE	MW	Energy	RegUp	RRSPF
QSE A	2	$25	$10	$5
QSE B	2	$30	$11	$9

Clearing Additional MWs of AS

QSE	Energy	RegUp	RRSPF
QSE A	$25		1MW @ $5
QSE B		$11	1MW @ $9

QSE	Energy	RegUp	RRSPF
QSE A	$25		$5
QSE B		2MW @ $11	

QSE Bids and Offers:

QSE	Bids		Offers			
	MW	Energy	MW	Energy	RegUp	RRSPF
QSE A			2	$25	$10	$5
QSE B			2	$30	$11	$9
QSE C	1	$50				

Does solution make sense?

Result	MW	Price

Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	0	0	0	0	0
ThatOne	ONL	30	0	0	0	0	0	0	0	0
OtherOne	OFF	100	25	0	0	0	0	0	0	0

Resource QSEs must maintain a
COP for each hour of the next 7 days

QSE must update COP by 14:30

Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF	100	25	0	0	0	0	0	0	0

QSE may also cover obligation
with AS Trade by 14:30

QSE may update COP at a suitable time

Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		Current Operating Plan								
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF ▼	100	25	0	0	0	0	0	0	0
	ON									

Resource Commitment after the Day-Ahead Market

It's 11:00. For hours ending 14:00-18:00, the Load Forecast exceeds the committed Resource Capacity by 400 MW.

1. **What options does ERCOT have?**

2. **How do the ERCOT operators choose?**
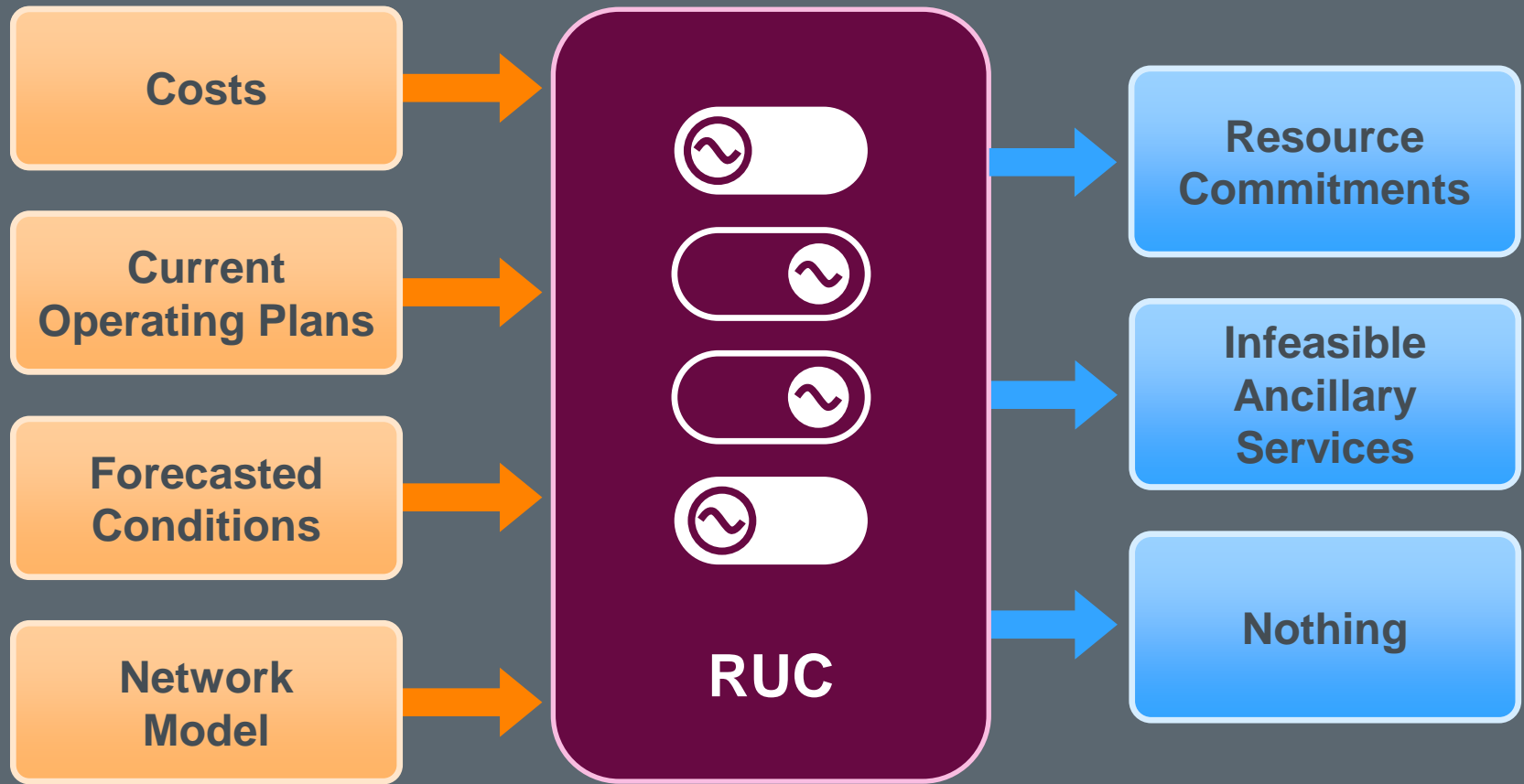
Provides a critical input to RUC

Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF	100	25	0	0	0	0	0	0	0
NotToday	OUT	250	50	0	0	0	0	0	0	0

What else is required?

Initial Unit Commitment

Solution Secure?

Security Violations

Transmission Security Analysis

Security Constrained Unit Commitment
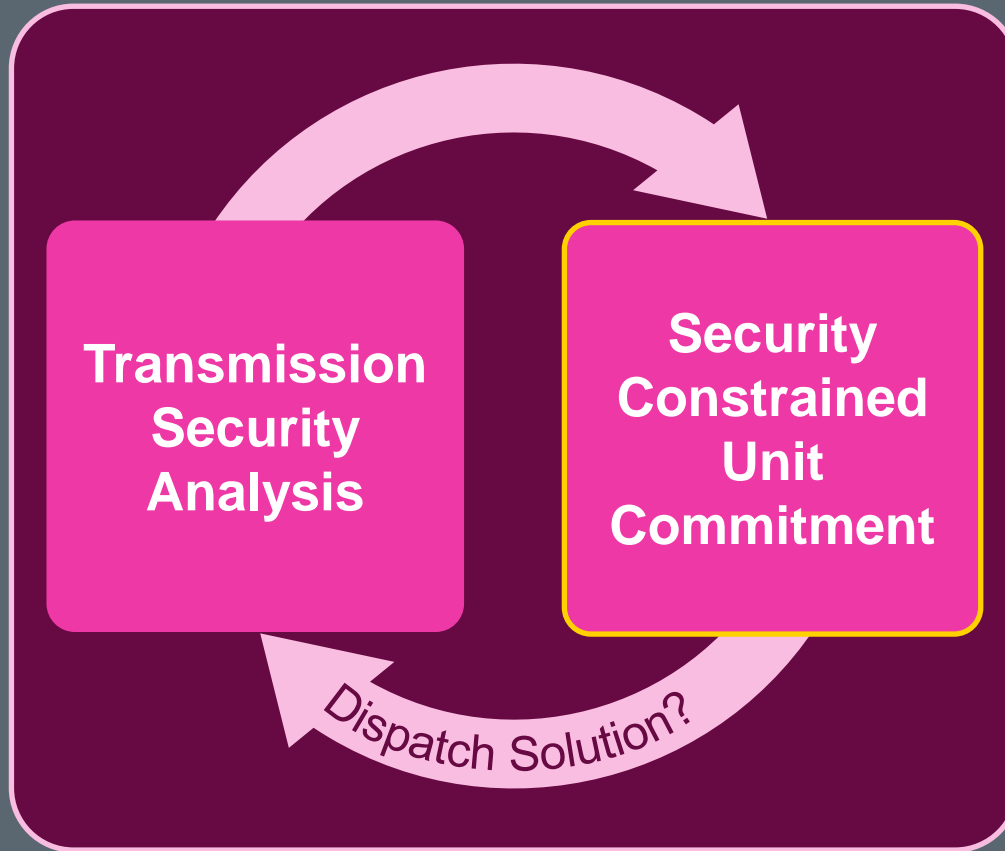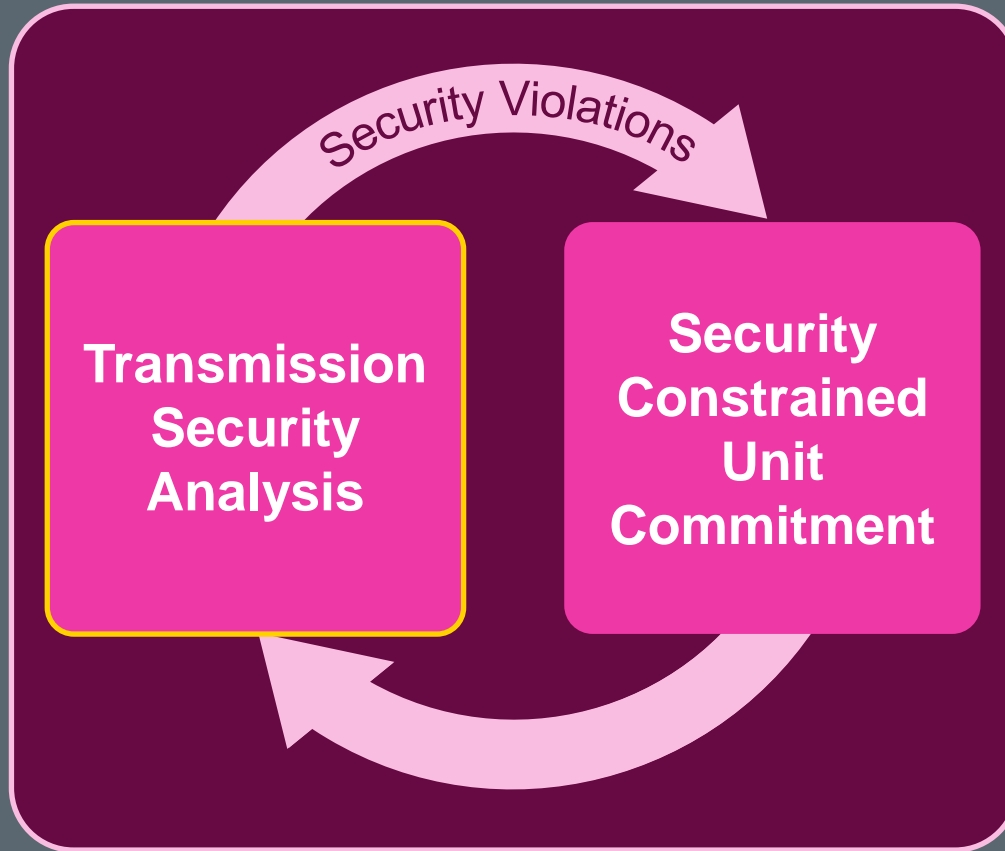
Revise Unit Commitment if needed
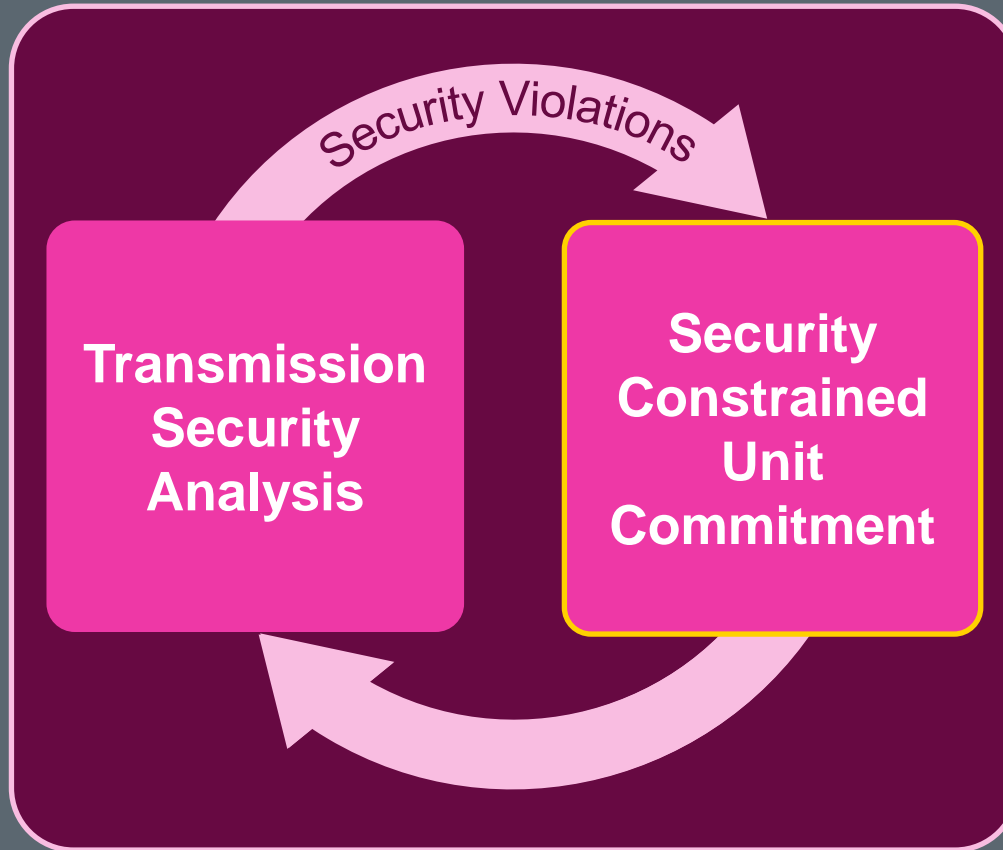
RUC Observes certain Temporal Constraints

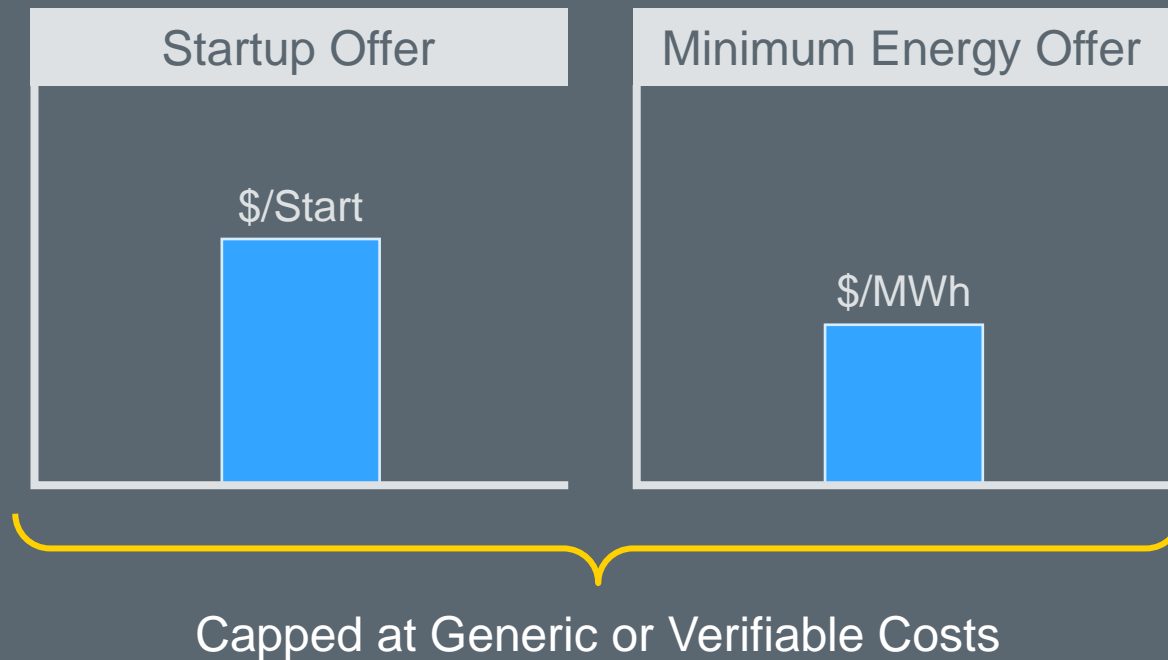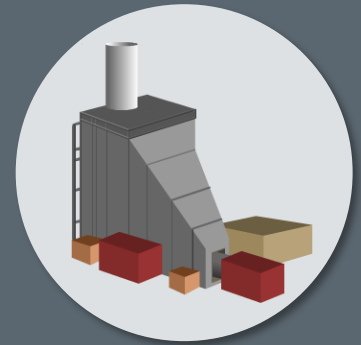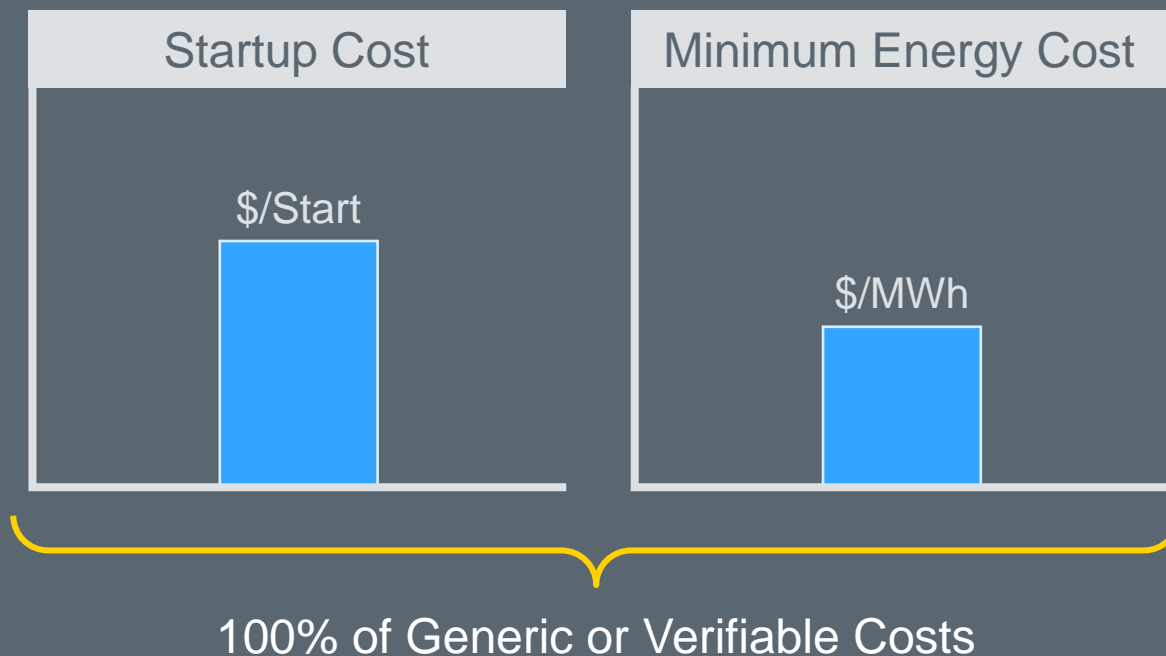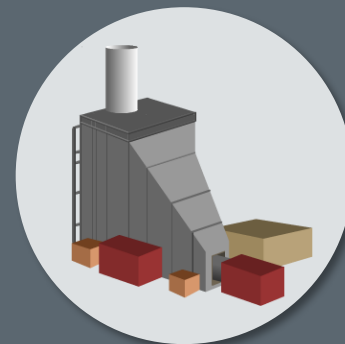| |
|---|
| Start Times (Hot, Intermediate, Cold) |
| Min On-Line Time |
| Max On-Line Time |
| Min Off-Line Time |
| Maximum Daily Starts |

X RARF

64
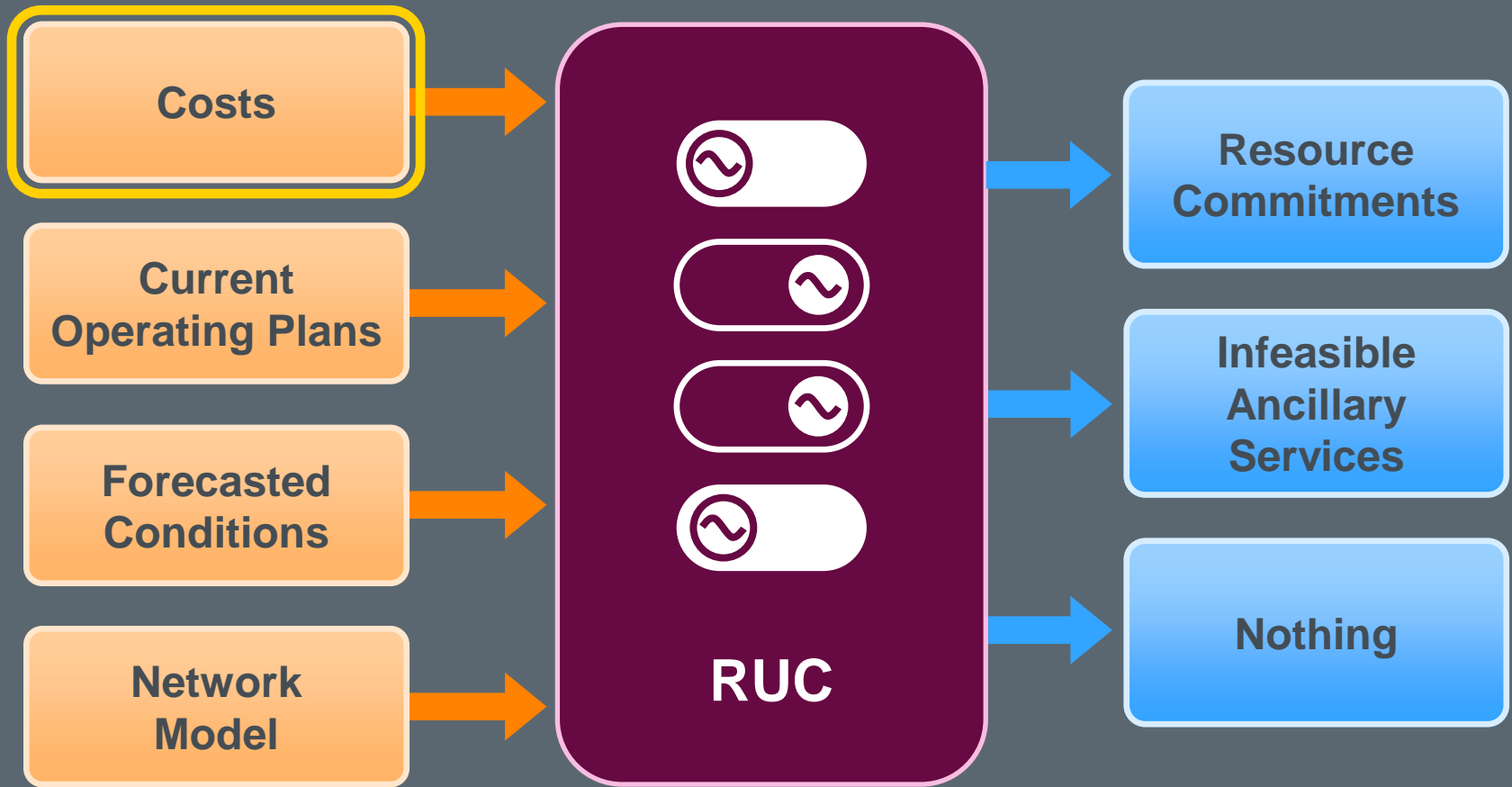
Costs from Three Part Supply Offer

Startup Offer	Minimum Energy Offer
$/Start	$/MWh

Capped at Generic or Verifiable Costs

Costs from Generic or Verifiable

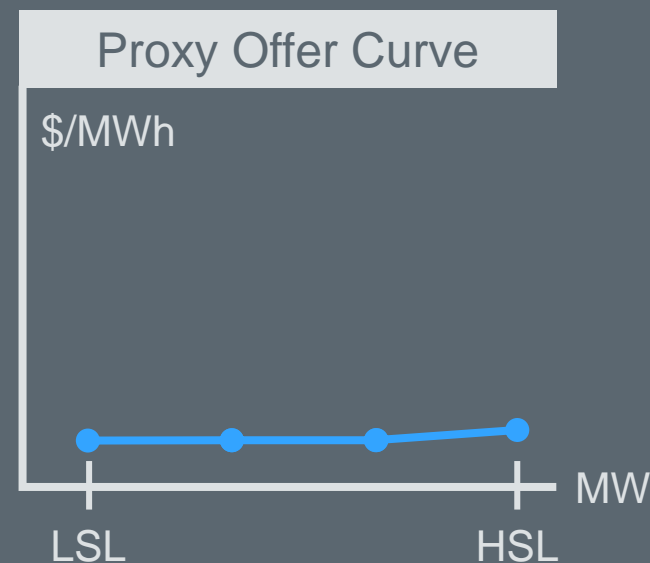| Startup Cost	Minimum Energy Cost
$/Start	$/MWh

100% of Generic or Verifiable Costs

To see if a dispatch solution even possible

Mitigated Offer Cap

$/MWh

MW

LSL   HSL   MW

0.10%

Proxy Offer Curve

$/MWh

LSL   HSL   MW

Must approve

Costs

Current Operating Plans

Forecasted Conditions

Network Model

RUC

Resource Commitments

Infeasible Ancillary Services

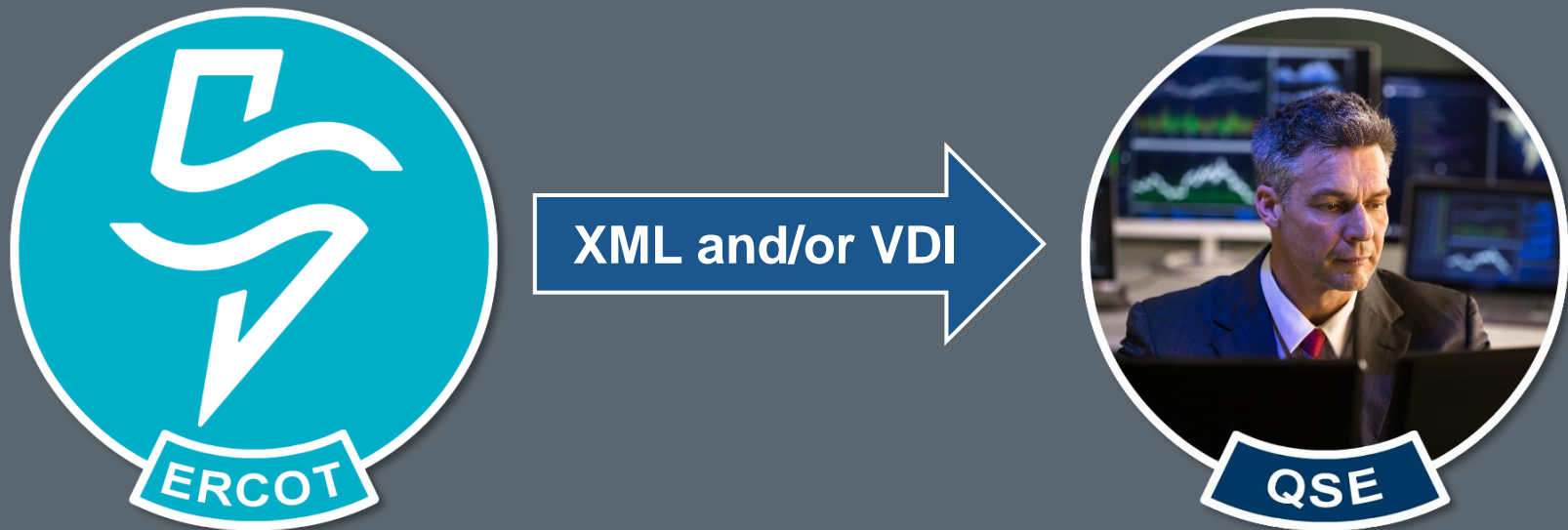**Nothing**
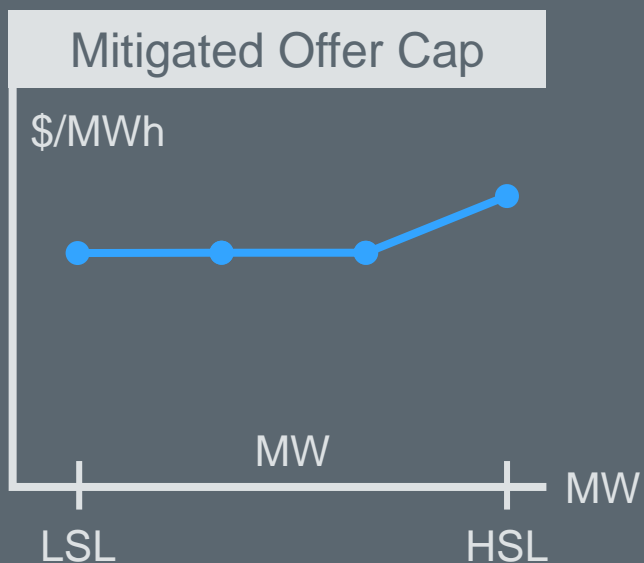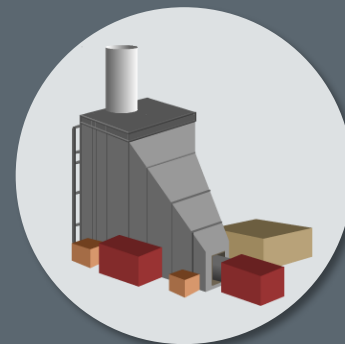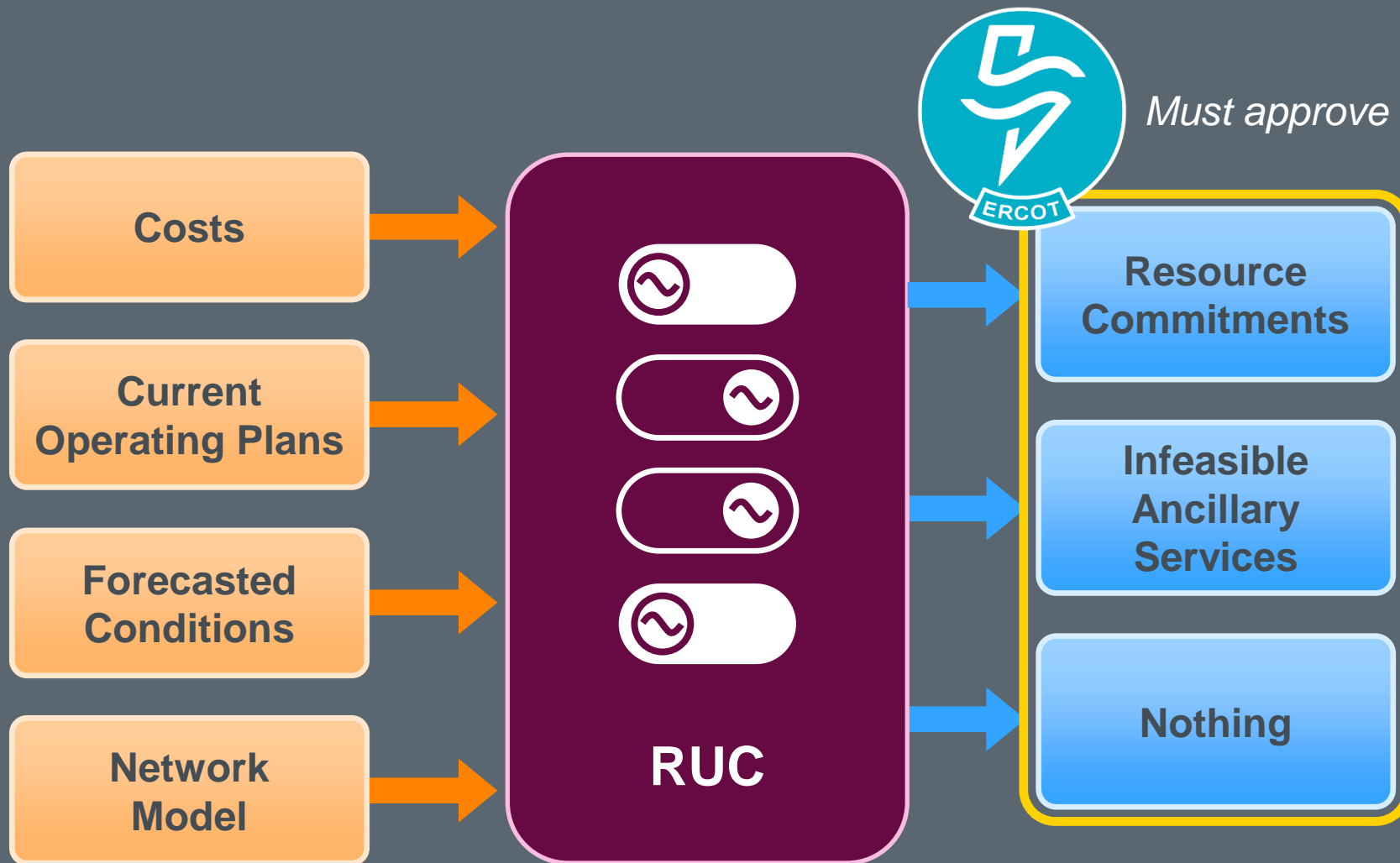
Start hour and duration sent to QSEs

XML and/or VDI

XML = Extensible Mark-Up Language
VDI = Verbal Dispatch Instruction

QSE must update COP within 60 minutes

Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF ▼	100	25	0	0	0	0	0	0	0

ONRUC
ONOPTOUT

Resource Financial Impacts

- **Floor price**

- **RUC Settlement**

  - Make-Whole
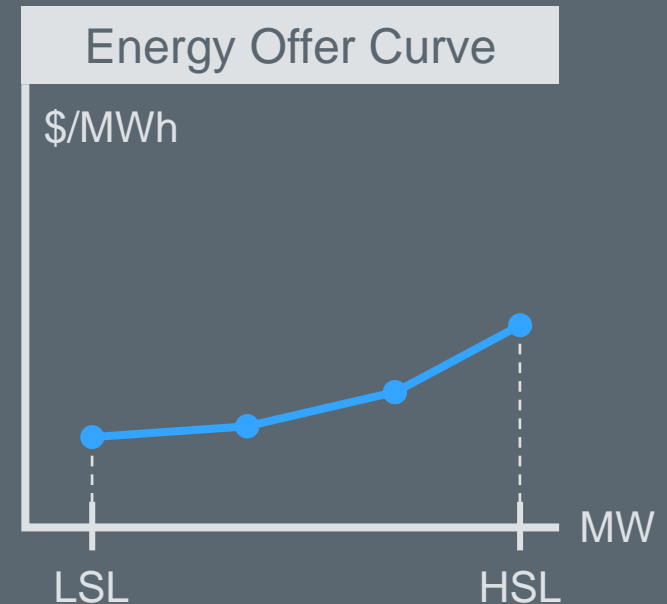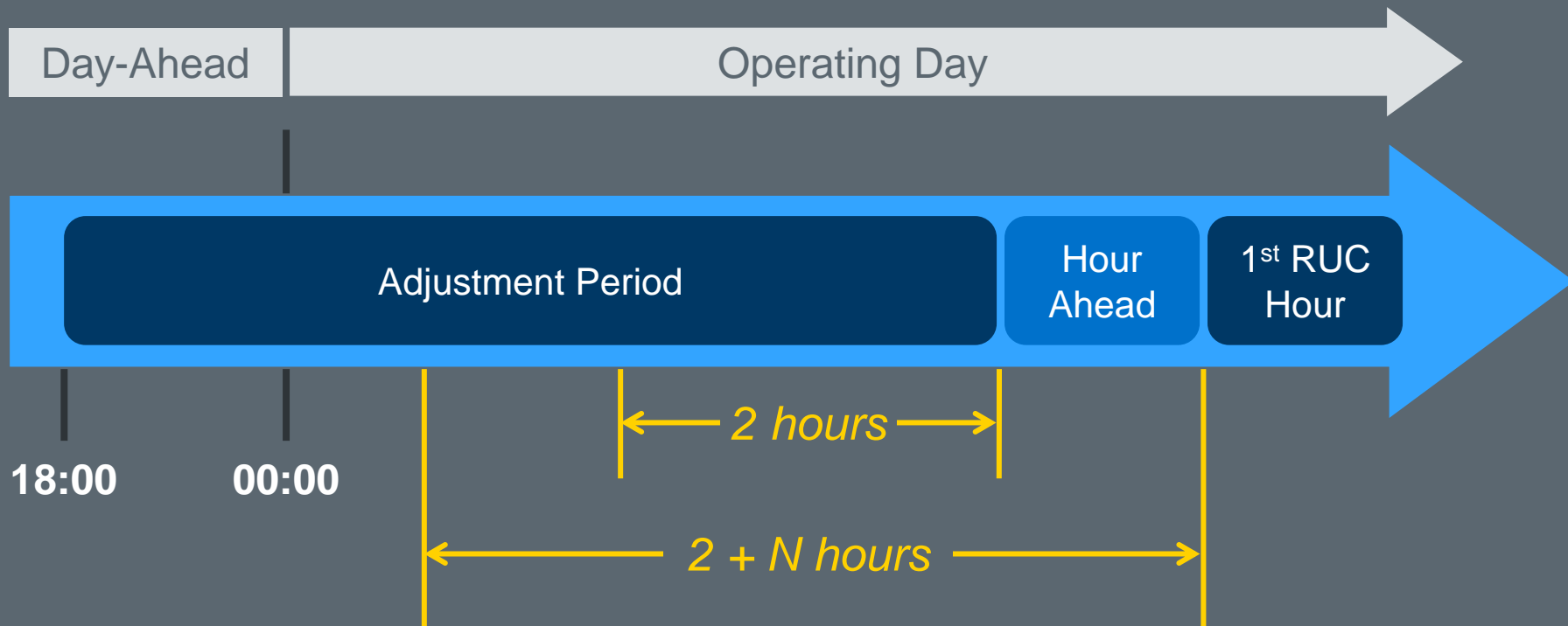
  - Clawback

**ERCOT adjusts
if QSE does not**

Energy Offer Curve

$/MWh

$250/MWh

LSL   HSL

MW
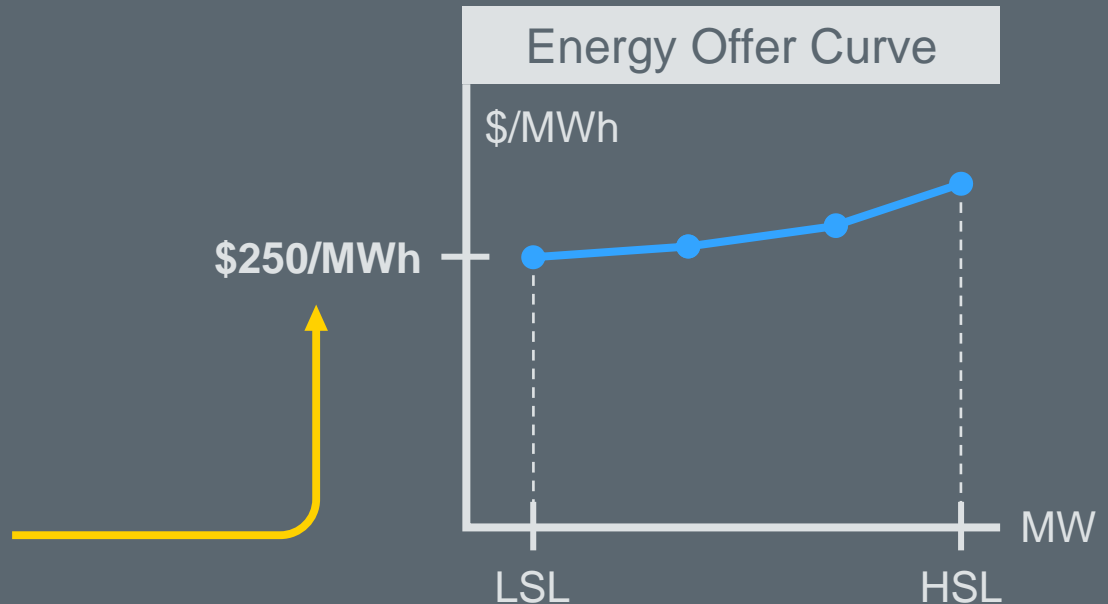
Resource Financial Impacts

- **No floor price**

- **No RUC Settlement**

QSE must update COP prior to Opt Out Snapshot

Energy Offer Curve

$/MWh

MW

LSL   HSL

Taken at the earlier of:

Day-Ahead	Operating Day

Adjustment Period | Hour Ahead | 1st RUC Hour

2 hours

18:00   **00:00**

2 + N hours

Where N is Start Time

QSE notified of Resource, Service and impacted hours

Notification

OPTIONS:

    1.

    2.

    3.

QSE

OPTIONS:

    1.

    2.
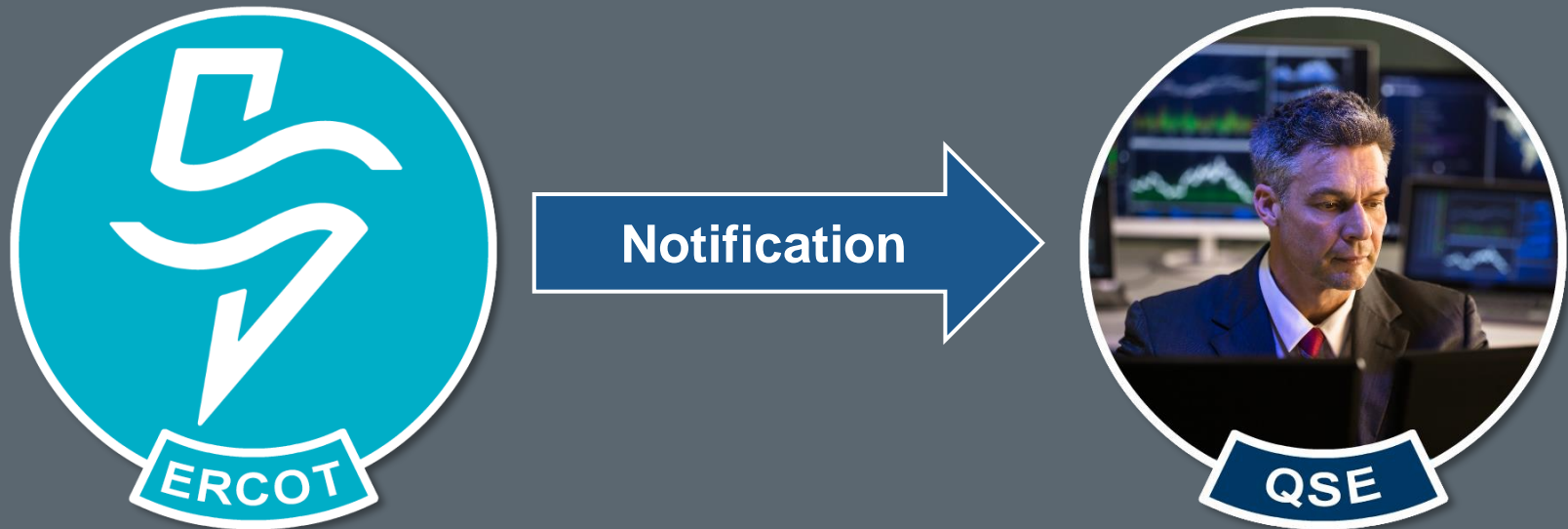
ERCOT

Financial Impacts

Return payment for cleared AS Offer

DAM

Still responsible for AS Obligations

ERCOT

Bilateral Trade

Course Wrap-Up

Format	Title
WBT	Resources in ERCOT
	Resource Responsibilities in ERCOT

Format	Title	Topic
ILT	Resources and Day-Ahead Operations	Resource Constraints in the Day-Ahead Market
		Resource Commitment in the Day-Ahead Market
		Resource Commitment after the Day-Ahead Market
	Resources and Real-Time Operations	Resource Dispatch in Real-Time
		Resource Reserve Deployment in Real-Time
		Resources and their Financial Impacts

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