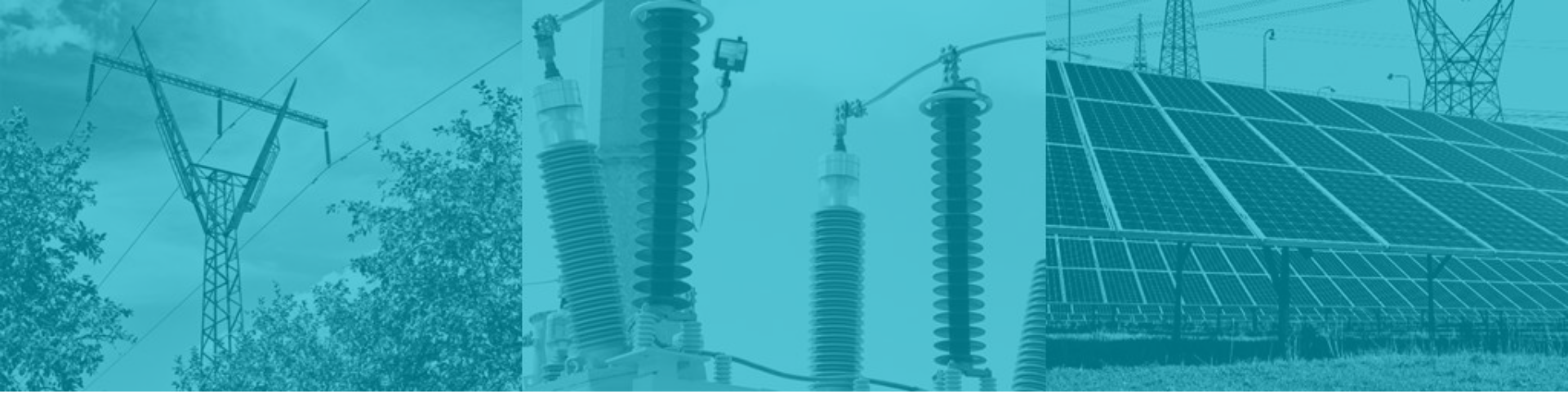


ERCOT Market Education

Resources and Day-Ahead Operations

Class begins at 8:30

Greetings and Introductions

Suite of Resource Courses

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/

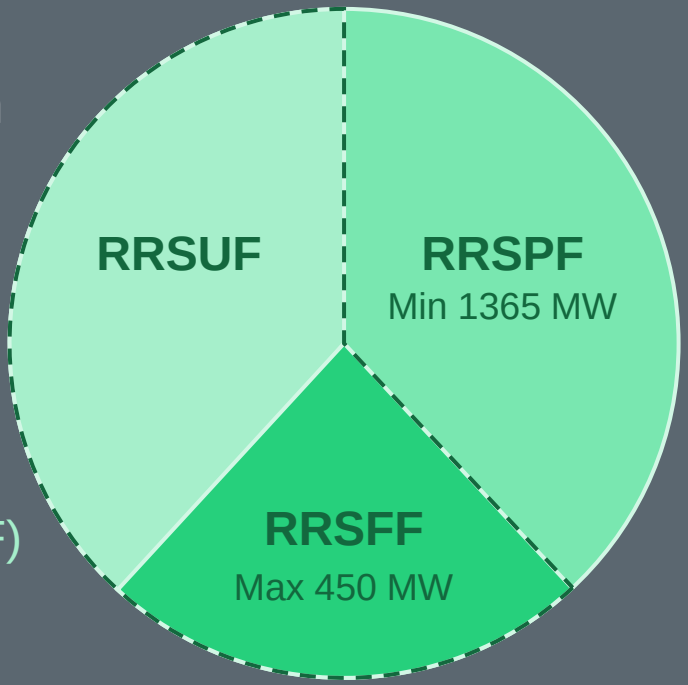
Resource Constraints in the Day-Ahead Market

1. Resource Limits in Day-Ahead Market
2. Linked Offer Constraints
3. Temporal Constraints

Responsive Reserve Service Subtypes

Load Resource on Under-Frequency Relay

Max (RRSUF + RRSFF) = 60 % Total RRS



Primary Frequency Response

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

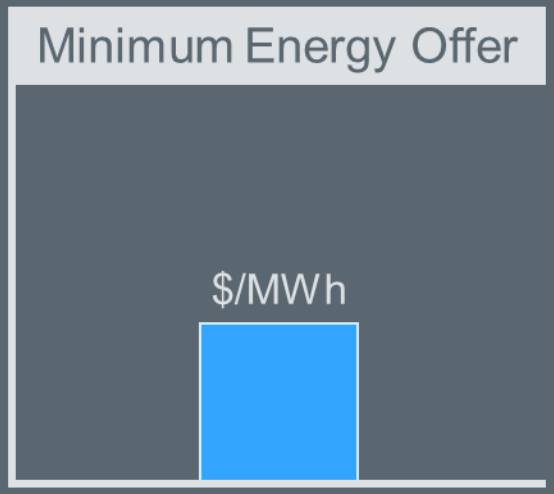
1 Resource Limits in Day-Ahead Market

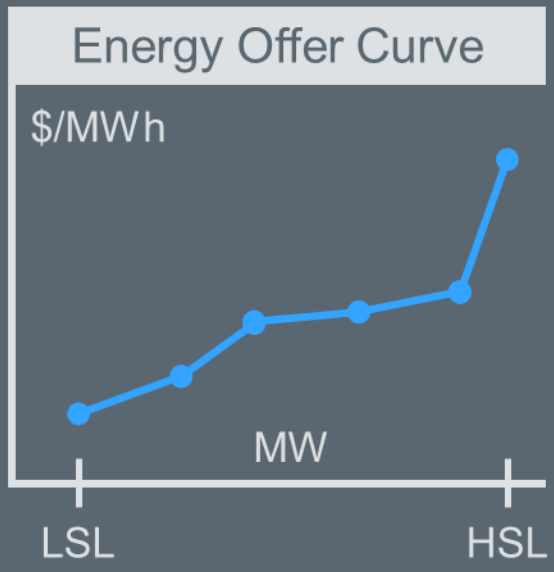
2 Linked Offer Constraints

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





Scenarios: Linked AS and Three Part Supply Offers

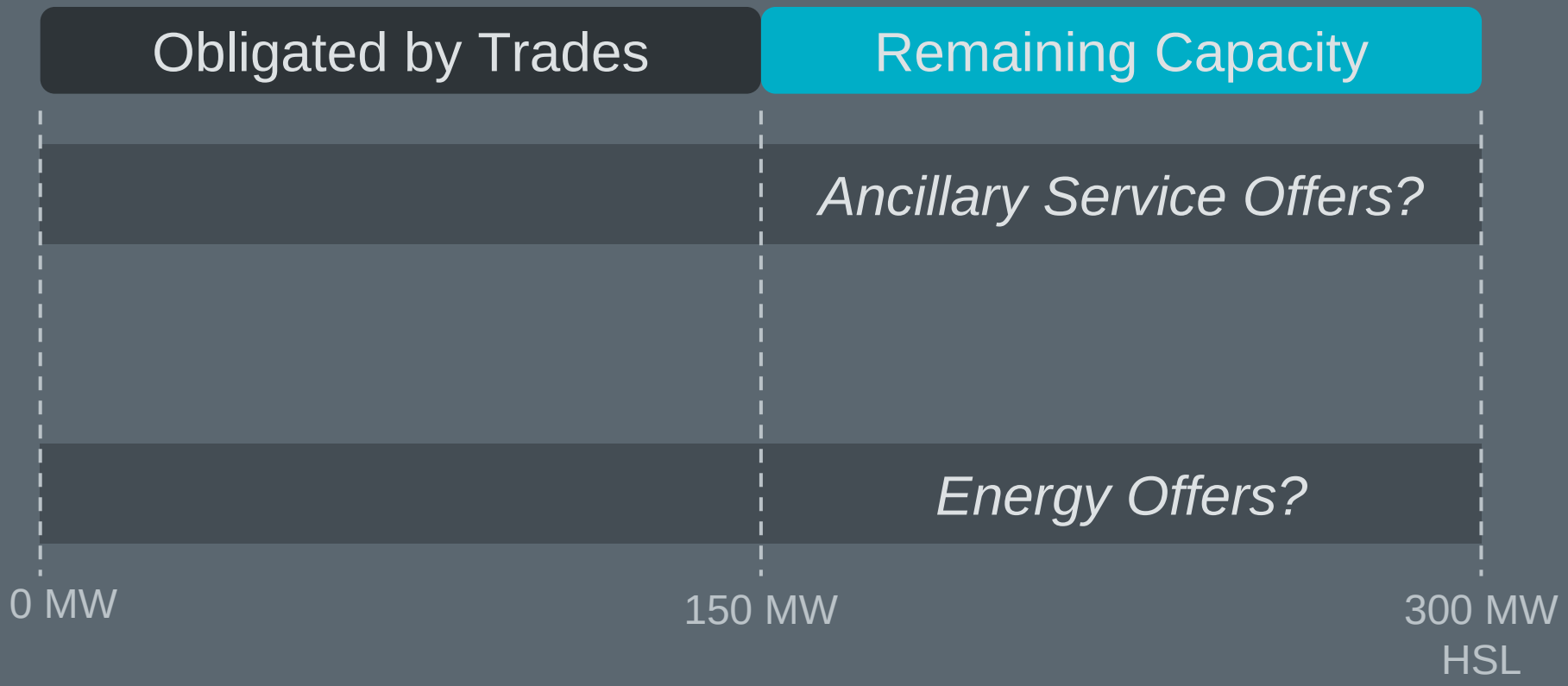
1. **Break into teams**
2. **Determine possible DAM Awards**
   a. Odd-numbered groups work on Linked Inclusive Offers
   b. Even-numbered groups work on Linked Exclusive Offers
3. **Enforce Resource Limits from Slide 9**

Three Part Supply Offer

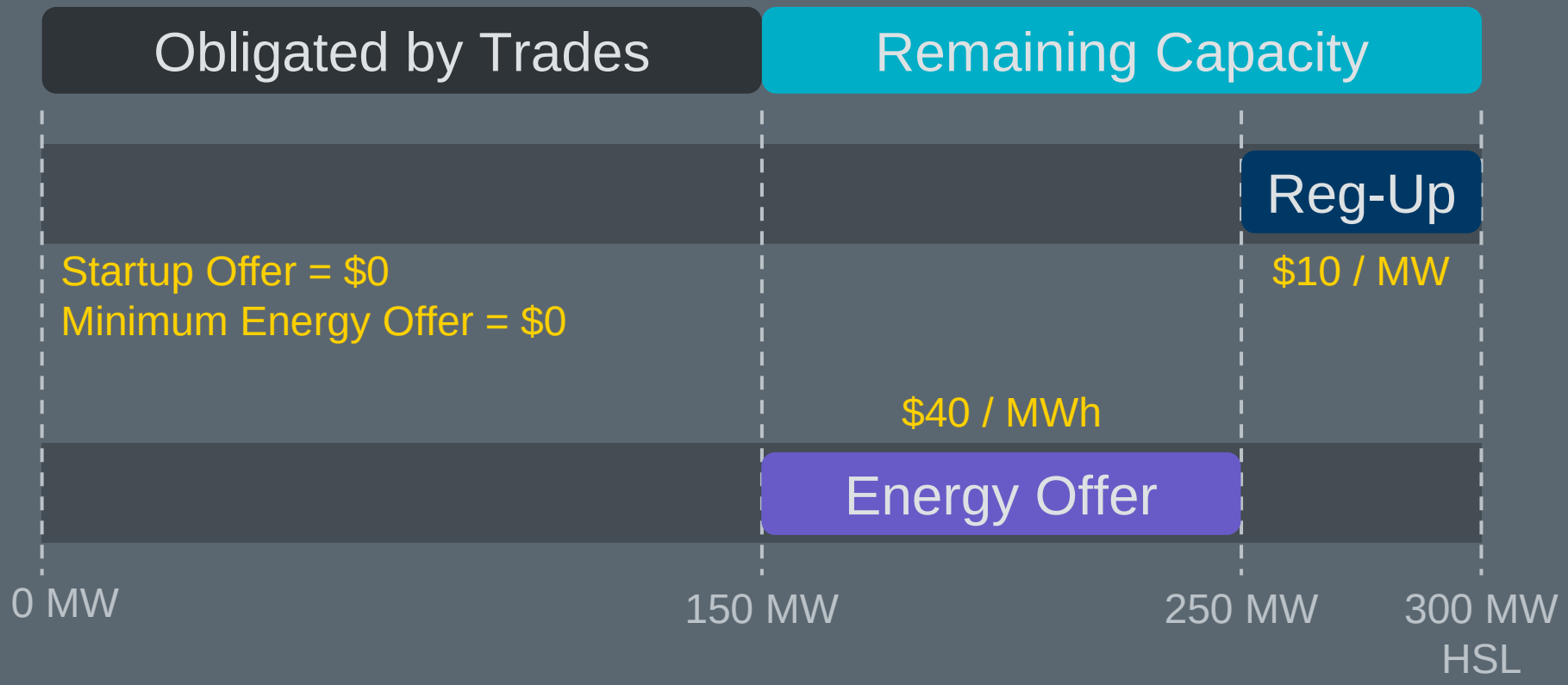
- Start-Up
- Minimum Energy
- Energy Offer Curve
  - ☑ Inclusive
  - ☐ Exclusive

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

Examples: Linked Offers when QSE already plans to run

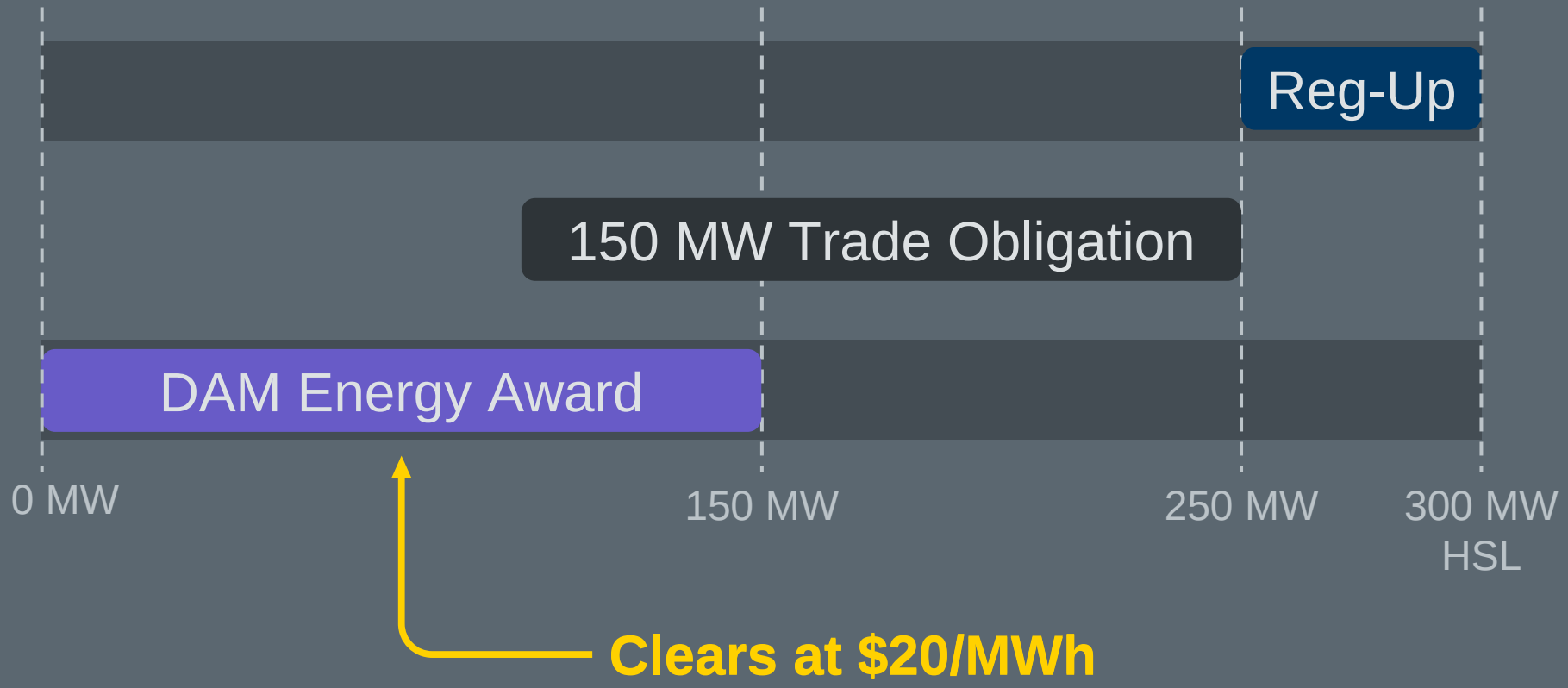


Example 1: Inclusive Three-Part Offer with Reg-Up



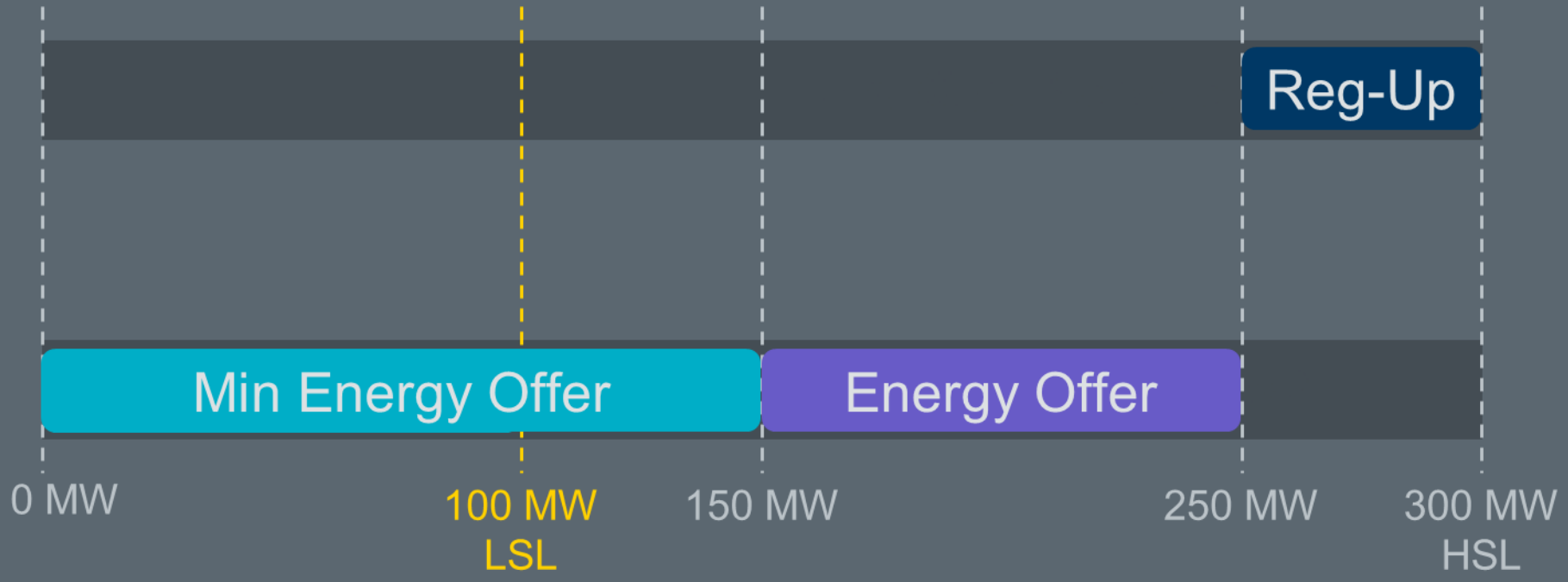
Example 1: Inclusive Three-Part Offer with Reg-Up

Possible outcome:

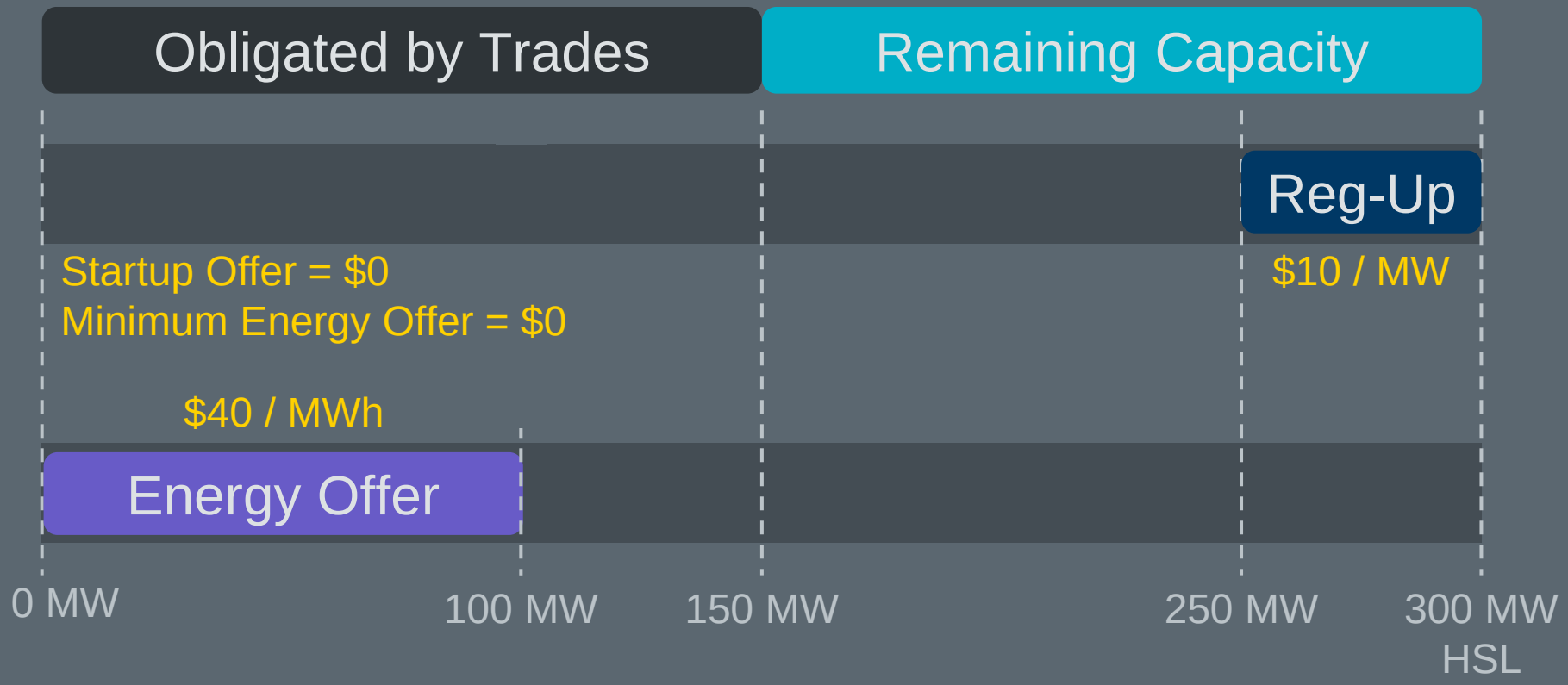


Example 1: Inclusive Three-Part Offer with Reg-Up

What DAM actually saw:

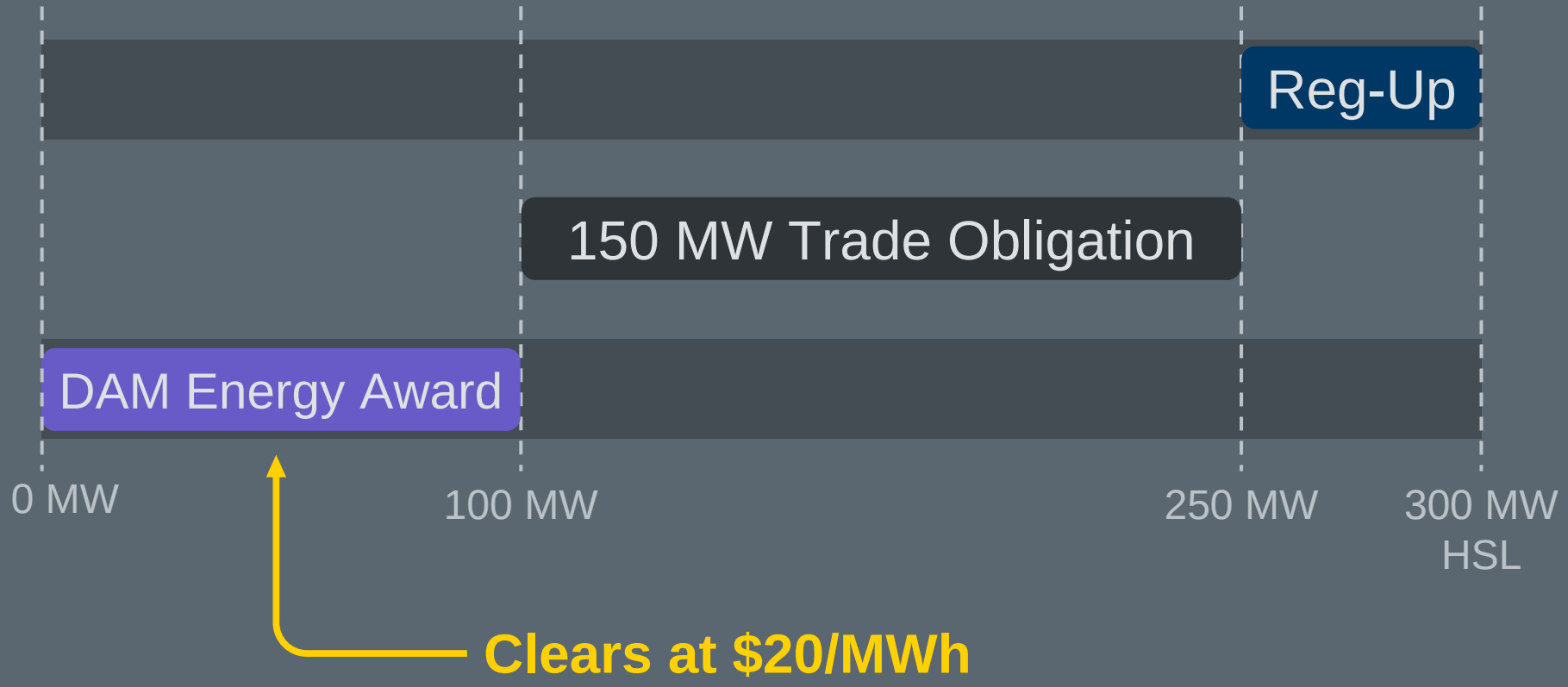


Example 2: Inclusive Three-Part Offer with Reg-Up



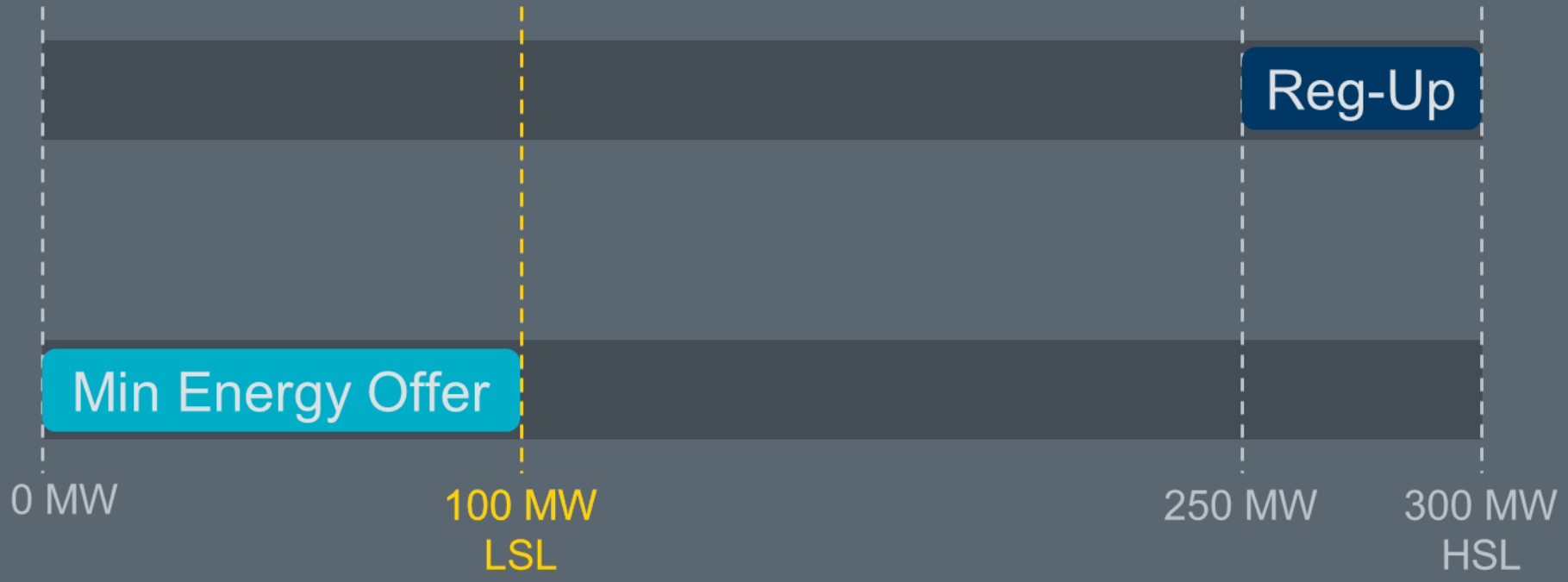
Example 2: Inclusive Three-Part Offer with Reg-Up

Possible outcome:

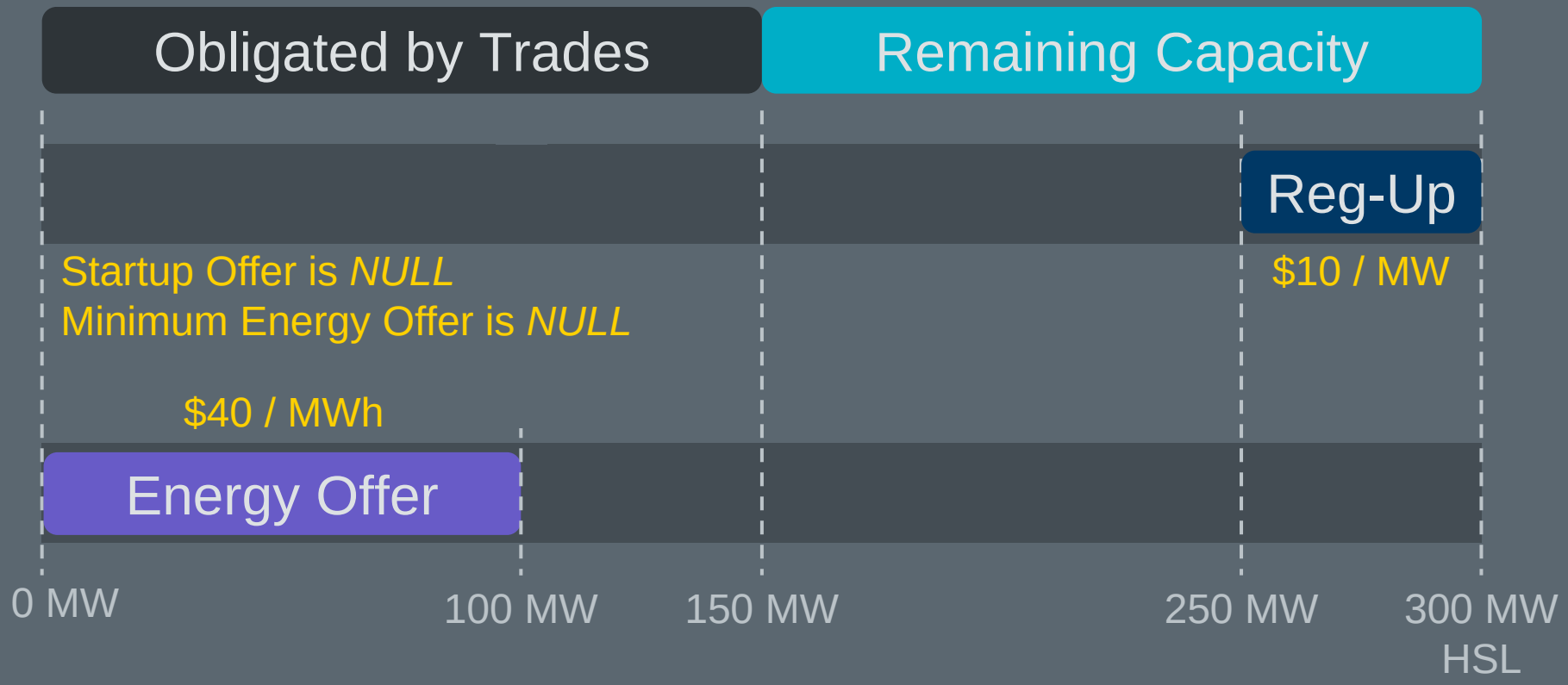


Example 2: Inclusive Three-Part Offer with Reg-Up

What DAM actually saw:

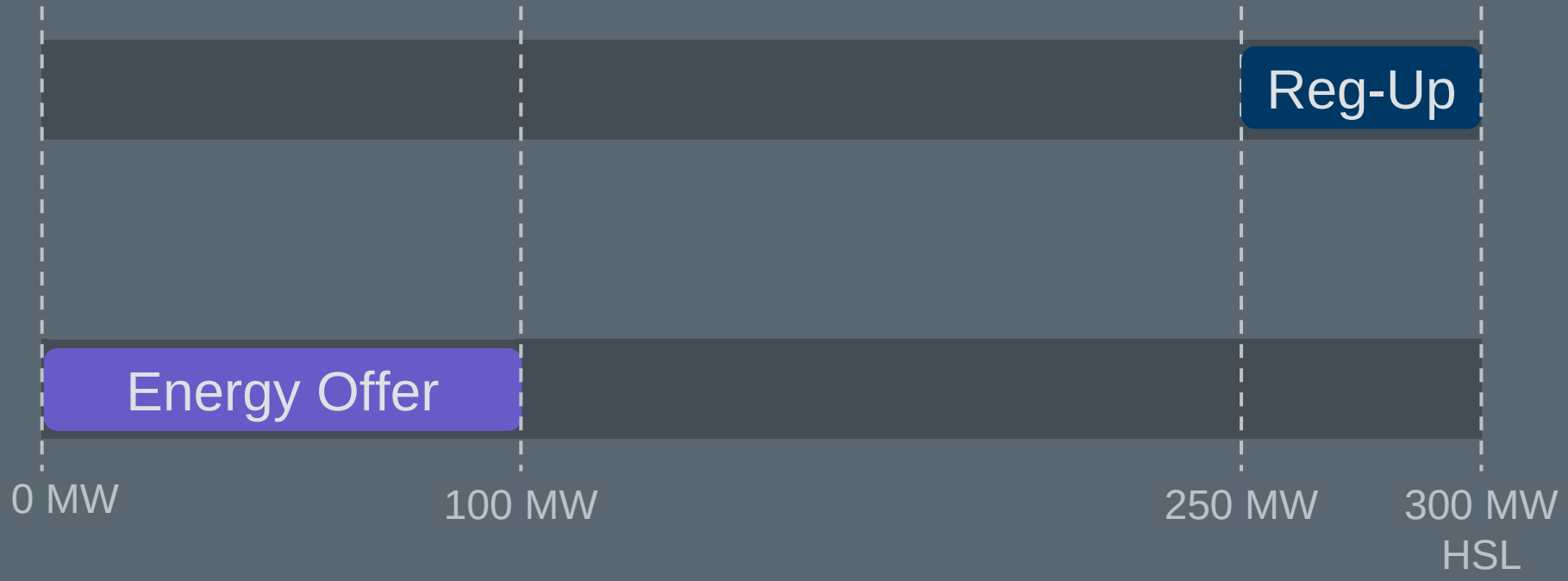


Example 3: Inclusive Three-Part Offer with Reg-Up



Example 3: Inclusive Energy Offer with Reg-Up

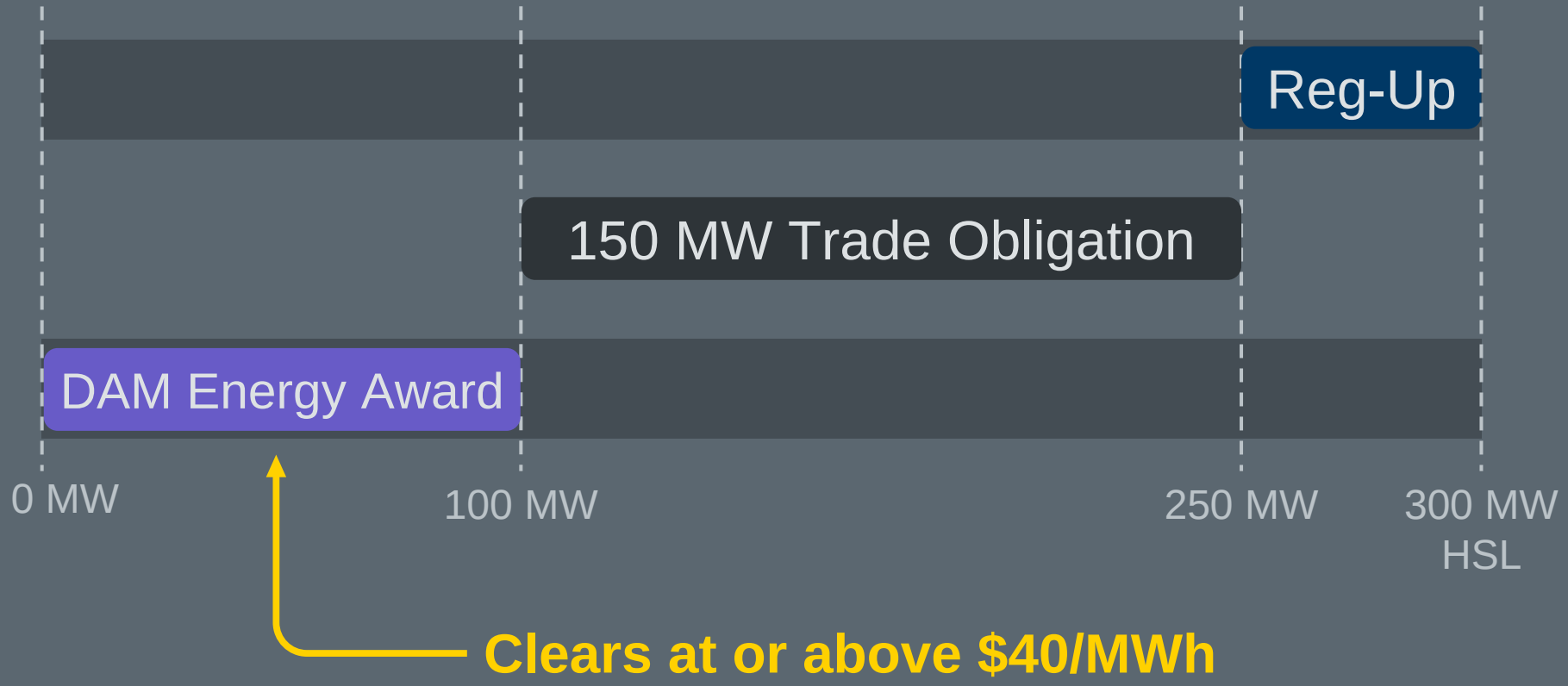
What DAM actually sees:



LSL constraint ignored

Example 3: Inclusive Energy Offer with Reg-Up

Possible outcome:



Other Linked Offer Constraints

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

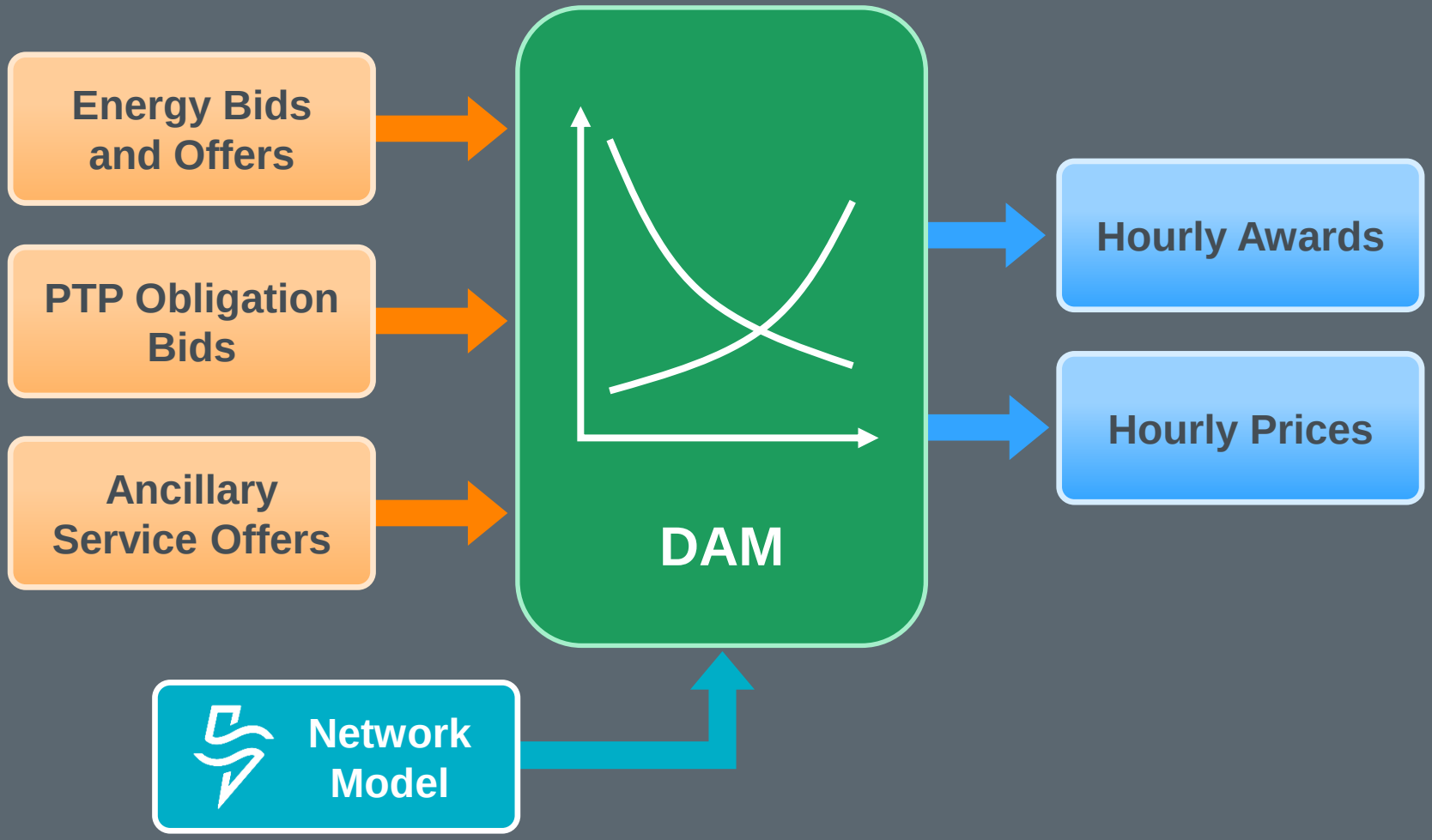
DAM Enforces certain Temporal Constraints

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

RARF

Resource Commitment in the Day-Ahead Market

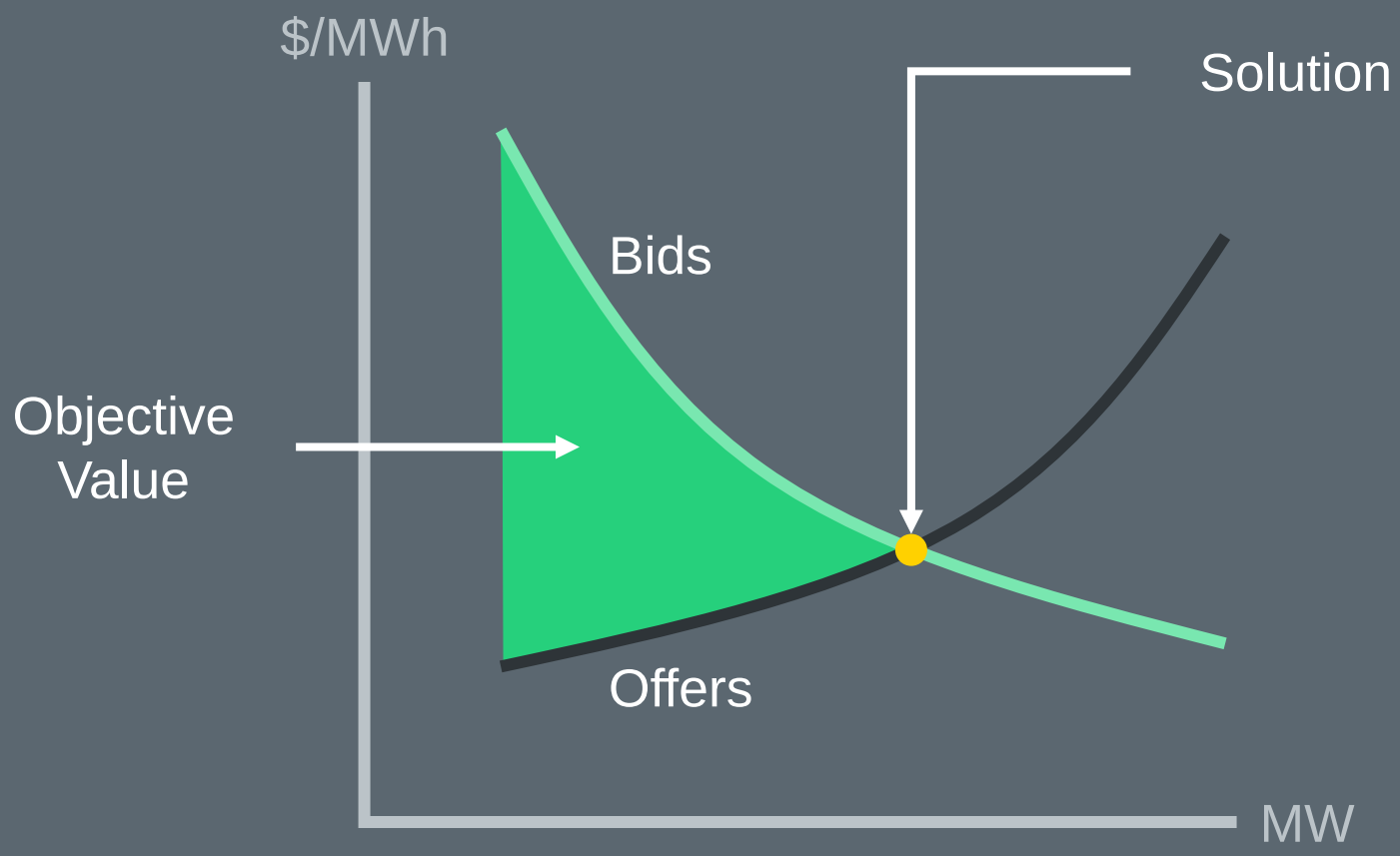
Economically optimized subject to constraints



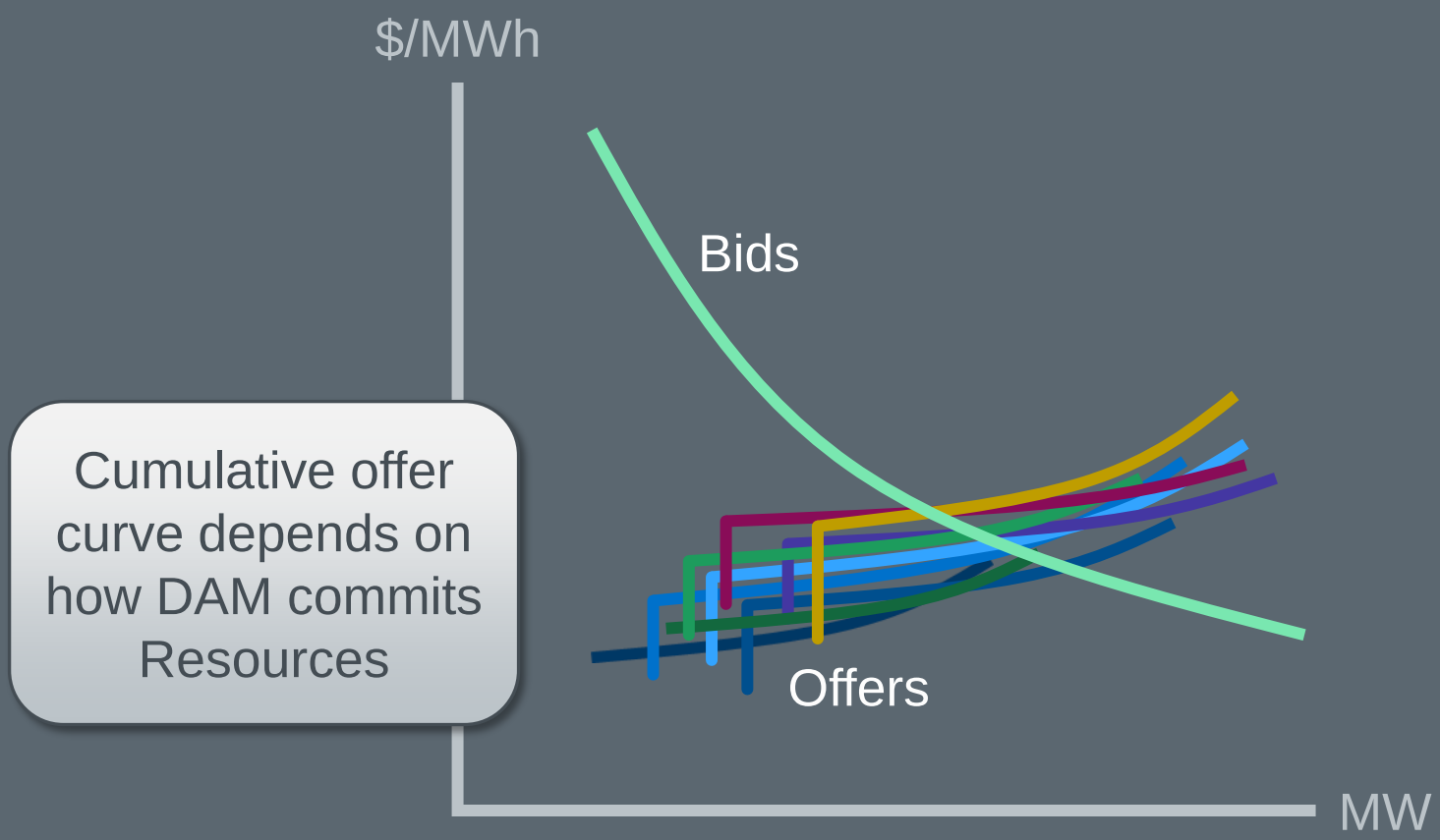
Constraints Enforced by DAM

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

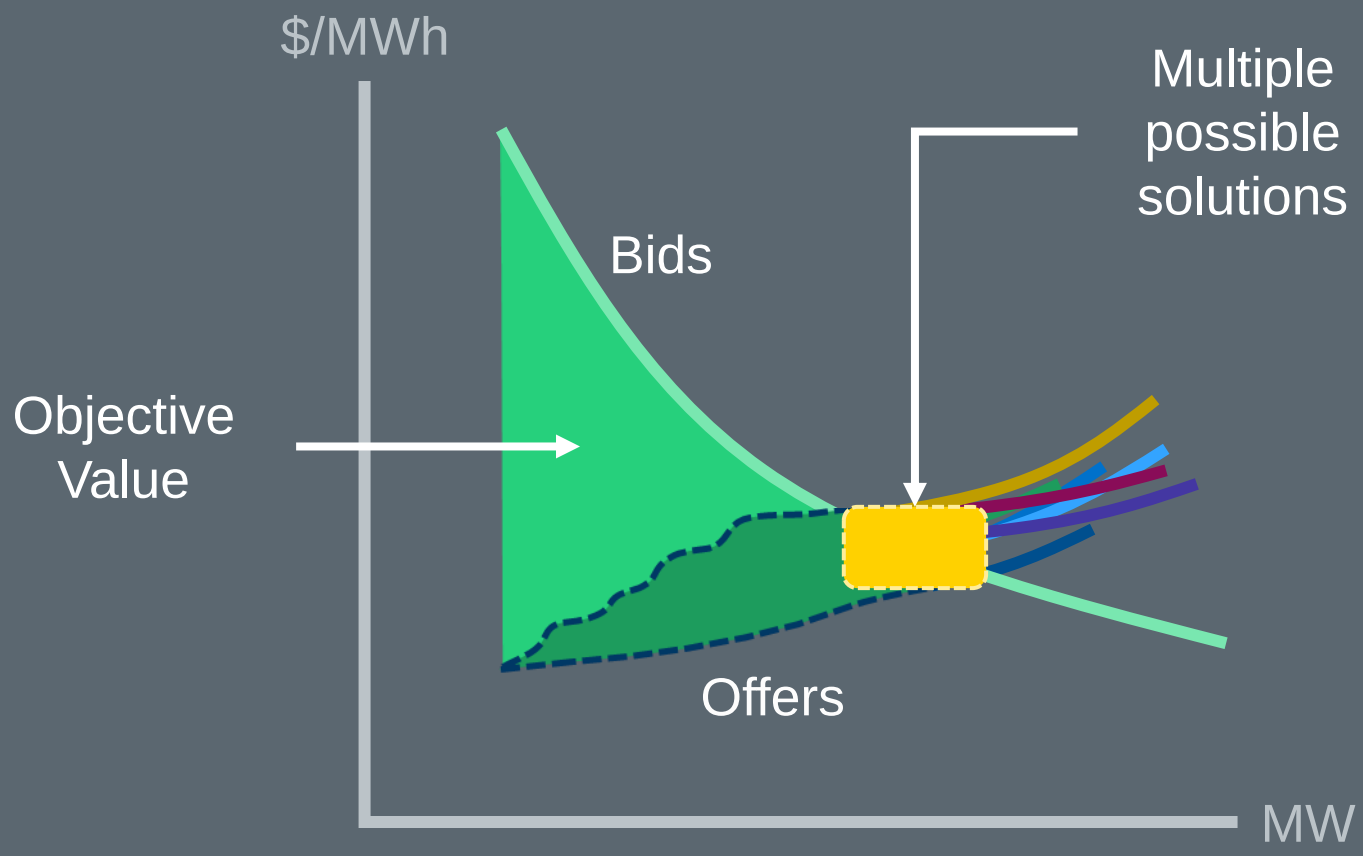
Maximize Bid-Based Revenues minus Offer-Based Costs



But Resource Offers are lumpy!



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

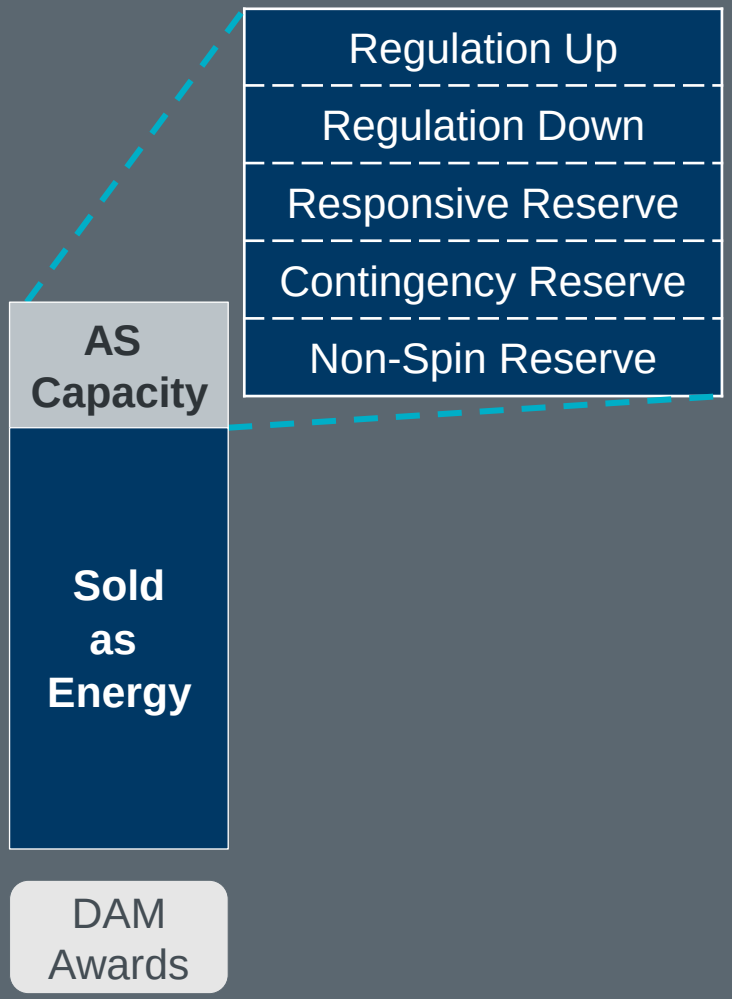
$$LMP_{bus} = SP_{demand} - \sum_{c} SF_{bus,c} * SP_c$$

Shift Factor of the bus on Transmission Constraint “c”

Also known as System Lambda (λ)

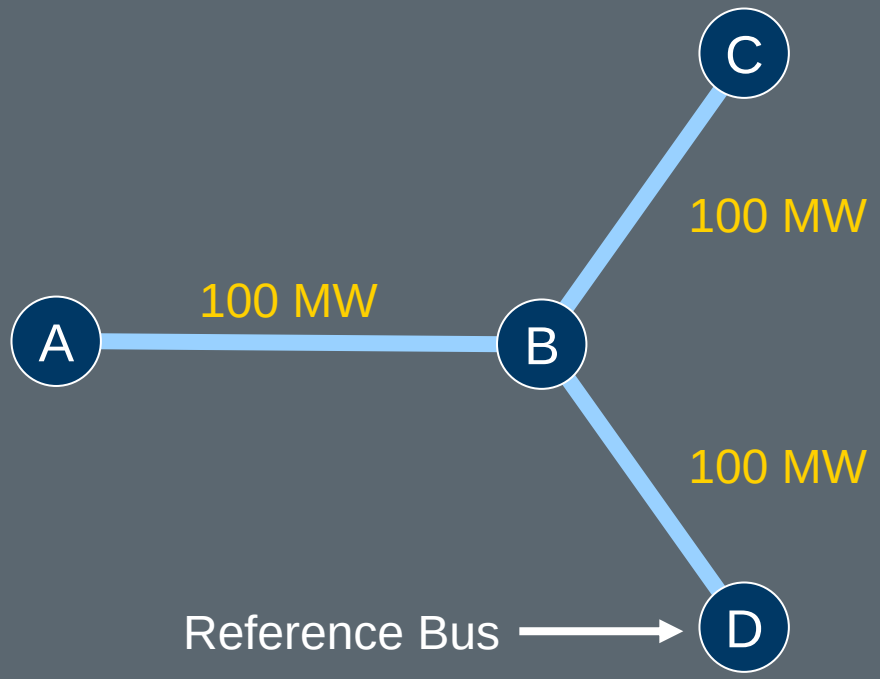
Market Clearing Prices for Ancillary Service Capacities

- $MCPC_{(Reg\text{-}Up)} = SP_{(Reg\text{-}Up)}$
- $MCPC_{(Reg\text{-}Down)} = SP_{(Reg\text{-}Down)}$
- $MCPC_{(Responsive)} = SP_{(Responsive)}$
- $MCPC_{(ECRS)} = SP_{(ECRS)}$
- $MCPC_{(Non\text{-}Spin)} = SP_{(Non\text{-}Spin)}$



Introducing a simple Network Model …

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



= Settlement Point

MW = Transmission Capacity

Determine Awards and Prices

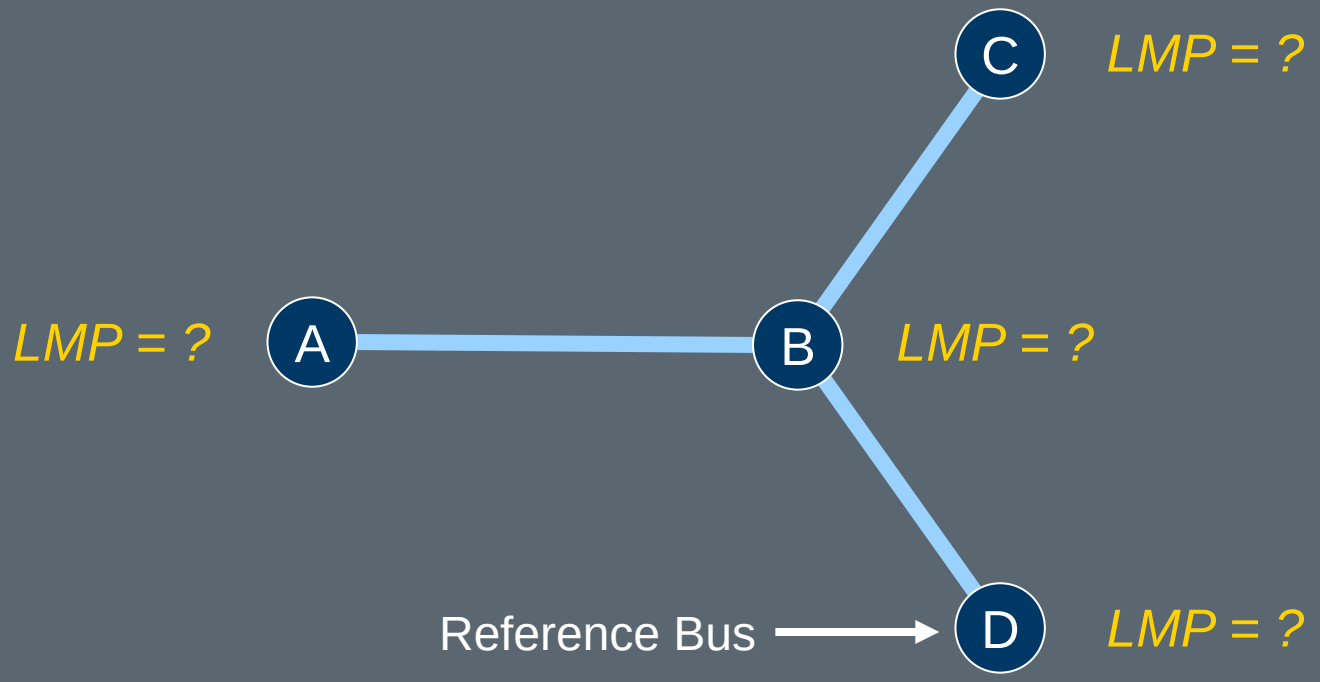
QSE	Product	Bid or Offer	Location	MW	Price	Award
QSE 1	Energy	Offer	A	100	$20	
QSE 2	Energy	Offer	C	60	$30	
QSE 3	Energy	Bid	D	90	$40	
QSE 4	PTP Obl	Bid	A to B	30	$20	

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

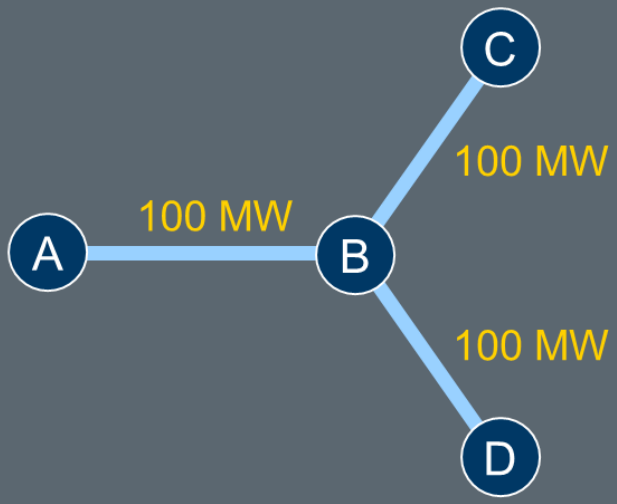
Shadow Prices	
SP_{demand}	$SP_{constraint\ AB}$

Determining Locational Marginal Prices

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



Does solution make sense?



Result	MW	Price

Determine Awards and Prices

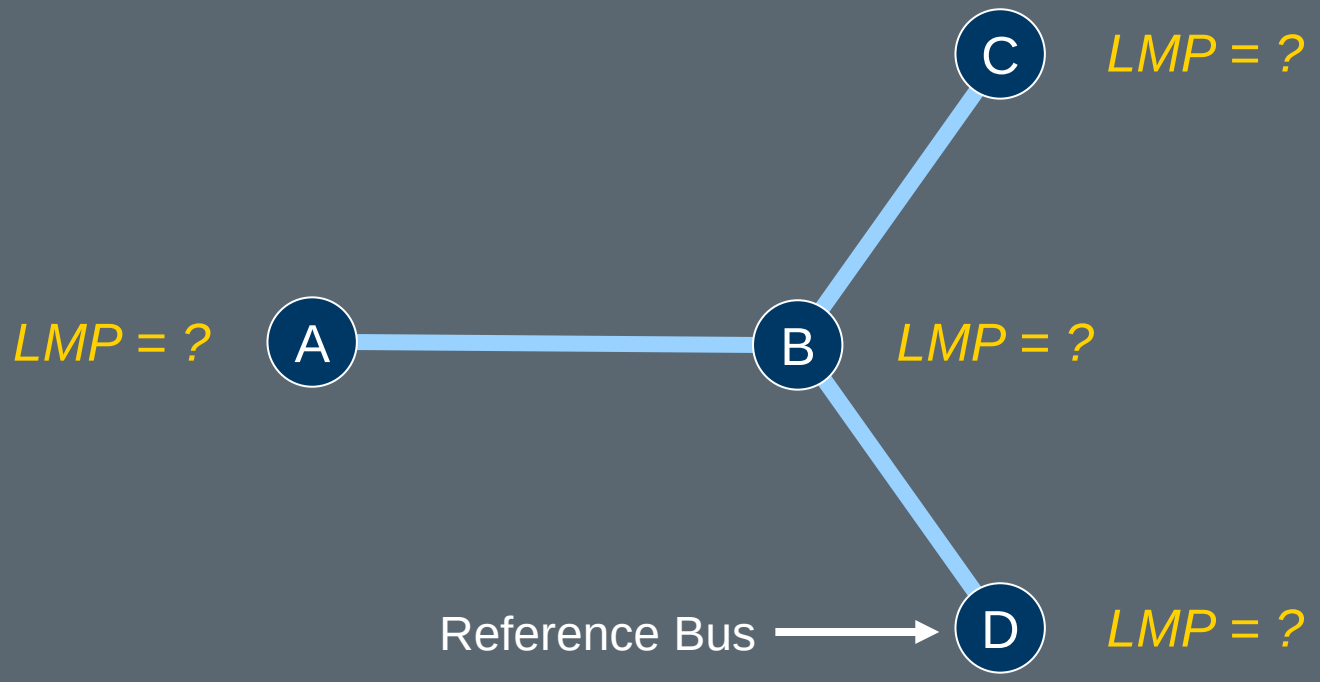
QSE	Product	Bid or Offer	Location	MW	Price	Award
QSE 1	Energy	Offer	A	100	$20	
QSE 2	Energy	Offer	C	60	$30	
QSE 3	Energy	Bid	D	90	$40	
QSE 4	PTP Obl	Bid	A to B	30	$5	

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

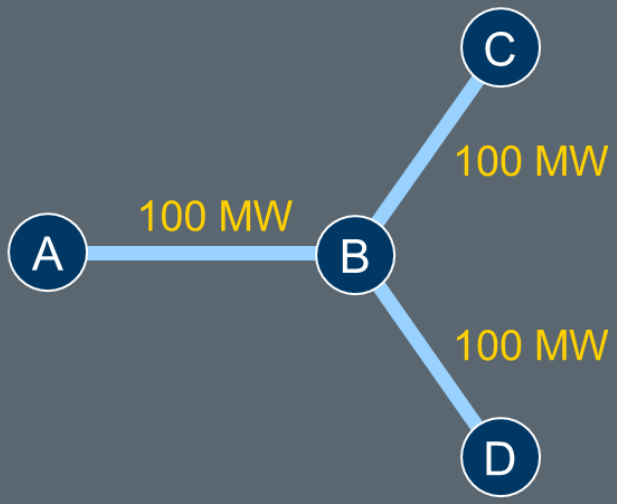
Shadow Prices	
SP_{demand}	$SP_{constraint\ AB}$

Determining Locational Marginal Prices

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

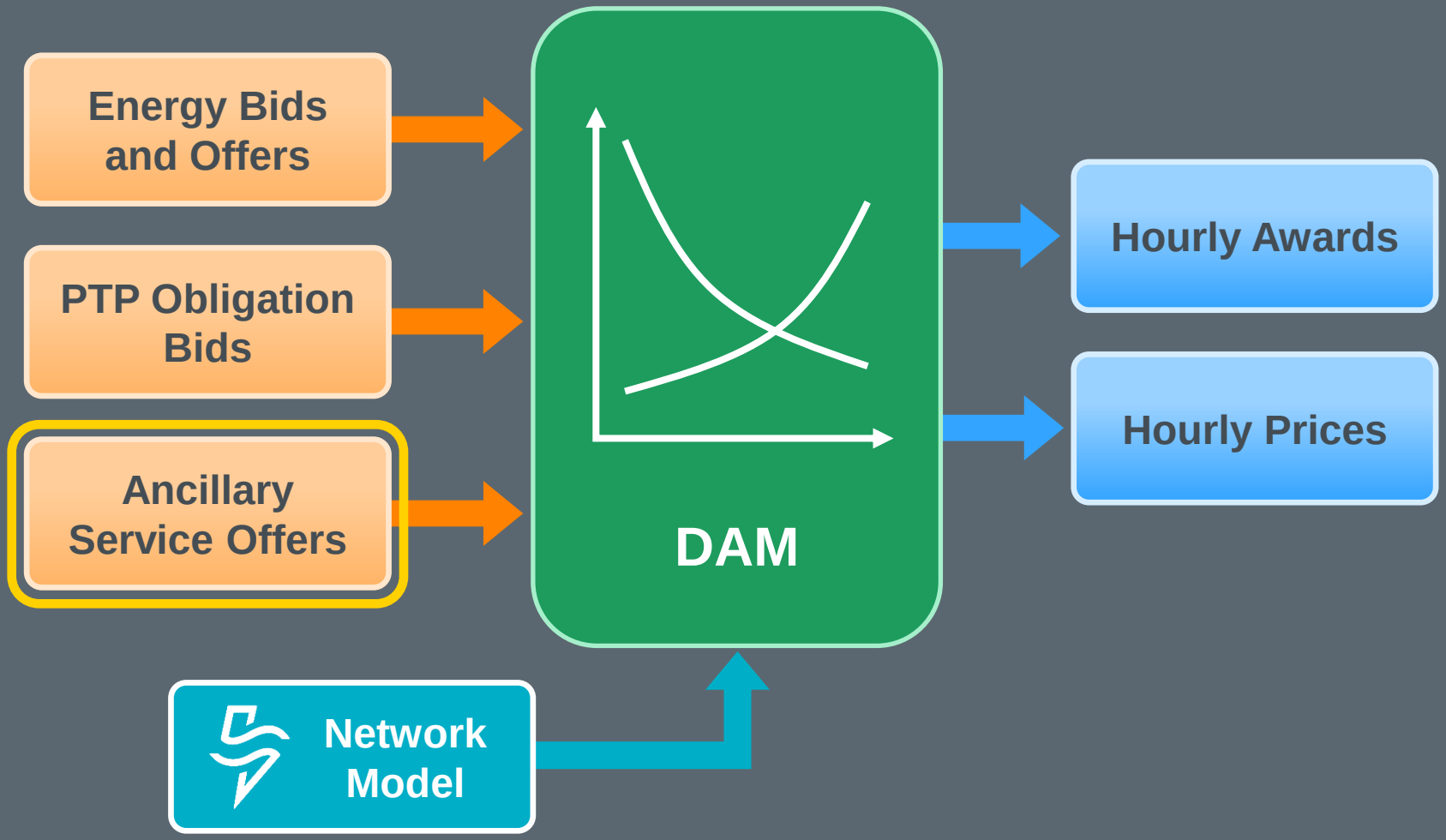


Does solution make sense?

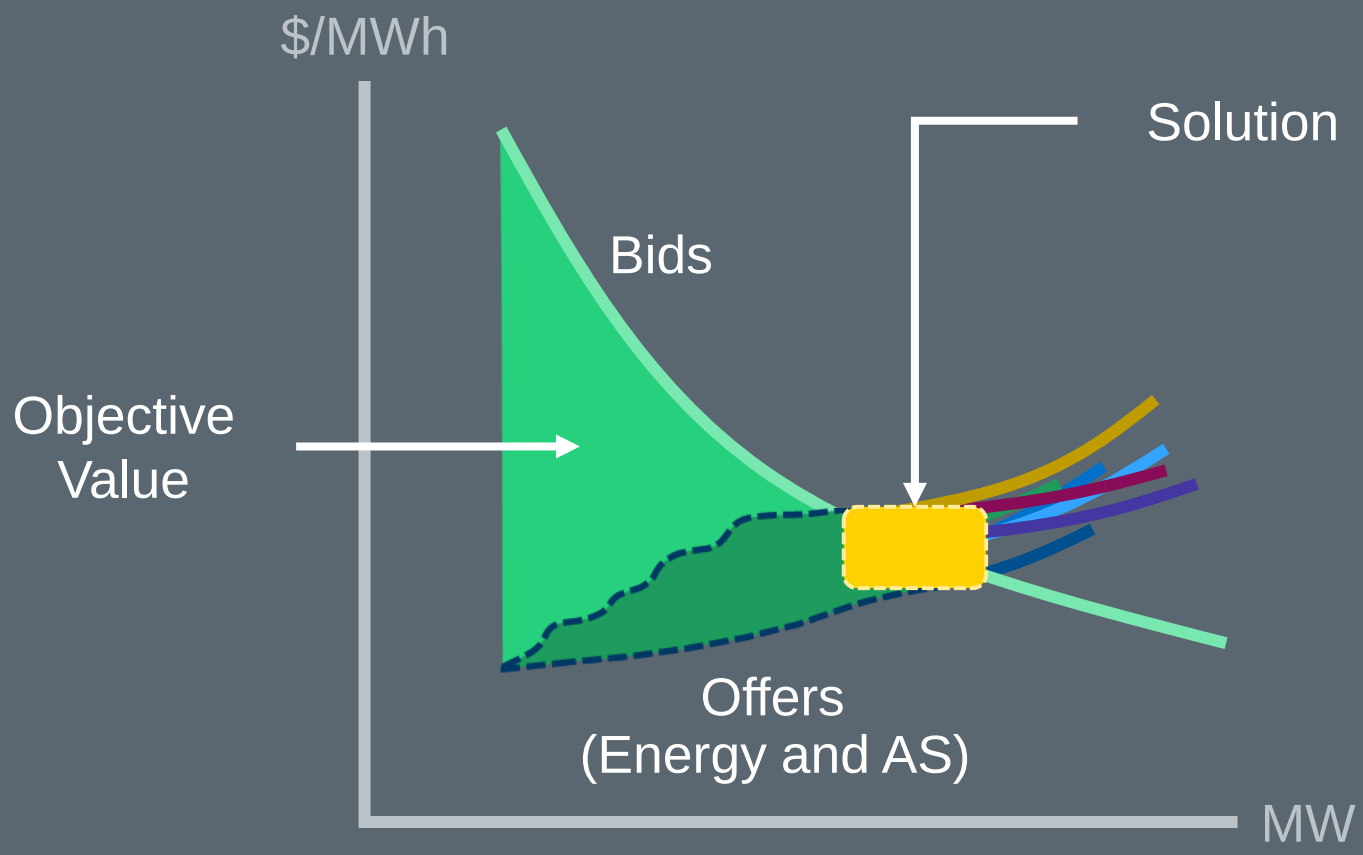


Result	MW	Price

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				

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		

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	

Scenario: Day-Ahead Market Co-Optimization

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

Scenario: Day-Ahead Market Co-Optimization

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

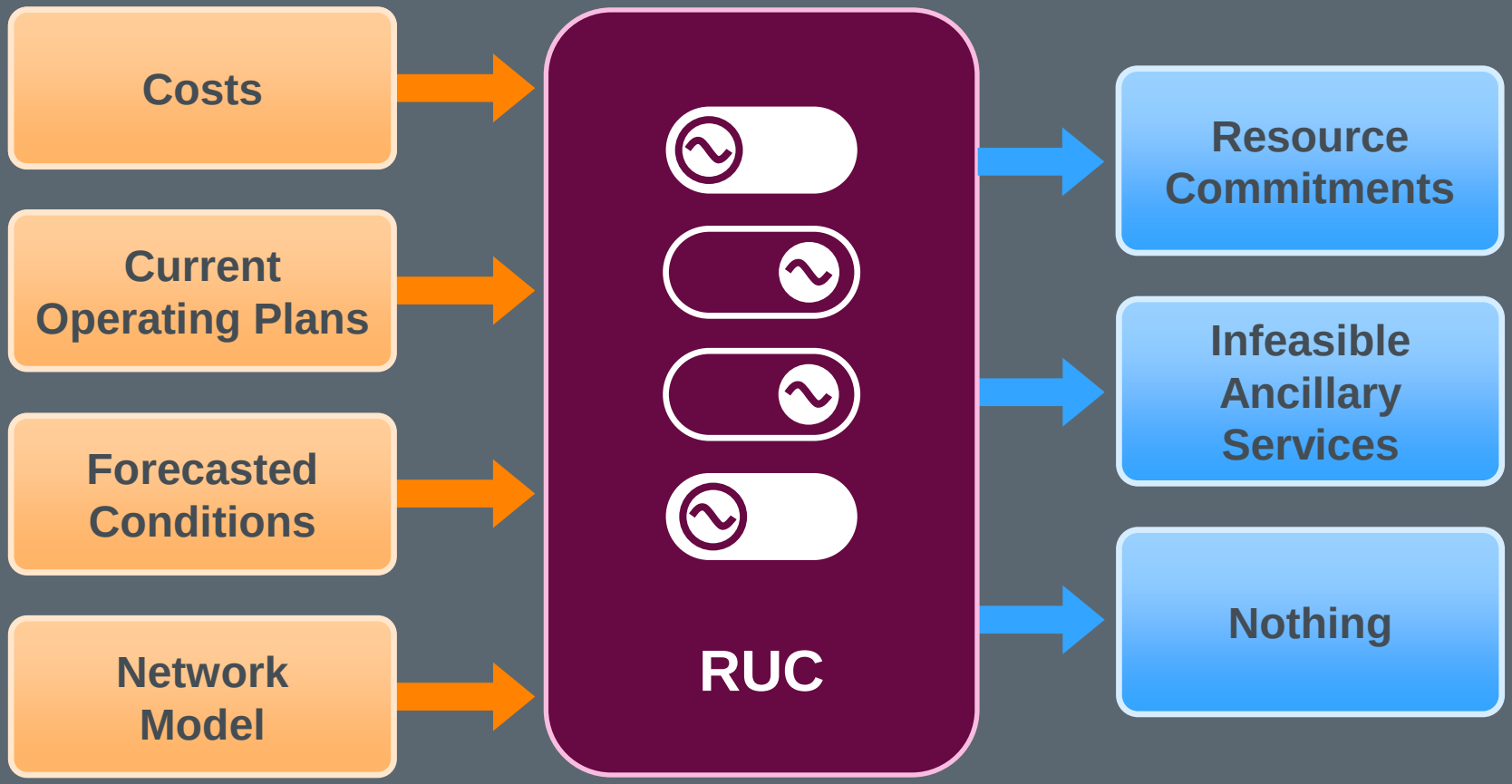
QSE may update COP at a suitable time

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
	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?

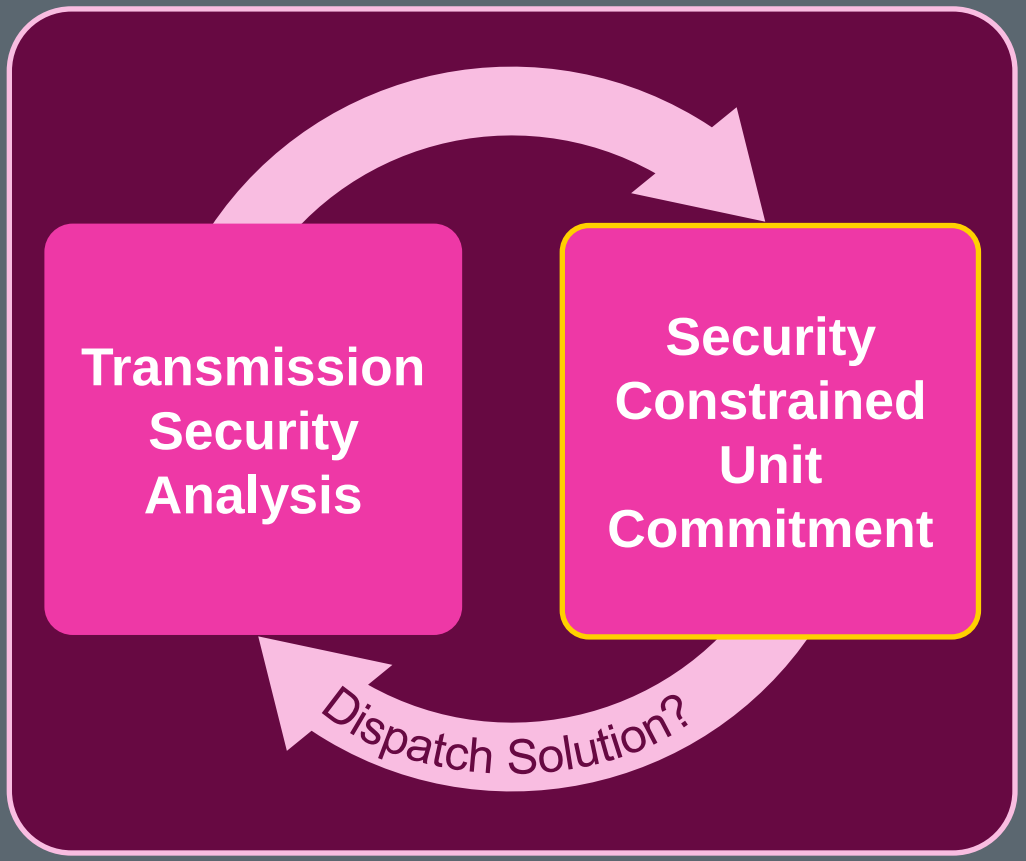

Costs
Current Operating Plans
Forecasted Conditions
Network Model
RUC
Resource Commitments
Infeasible Ancillary Services
Nothing

Provides a critical input to RUC

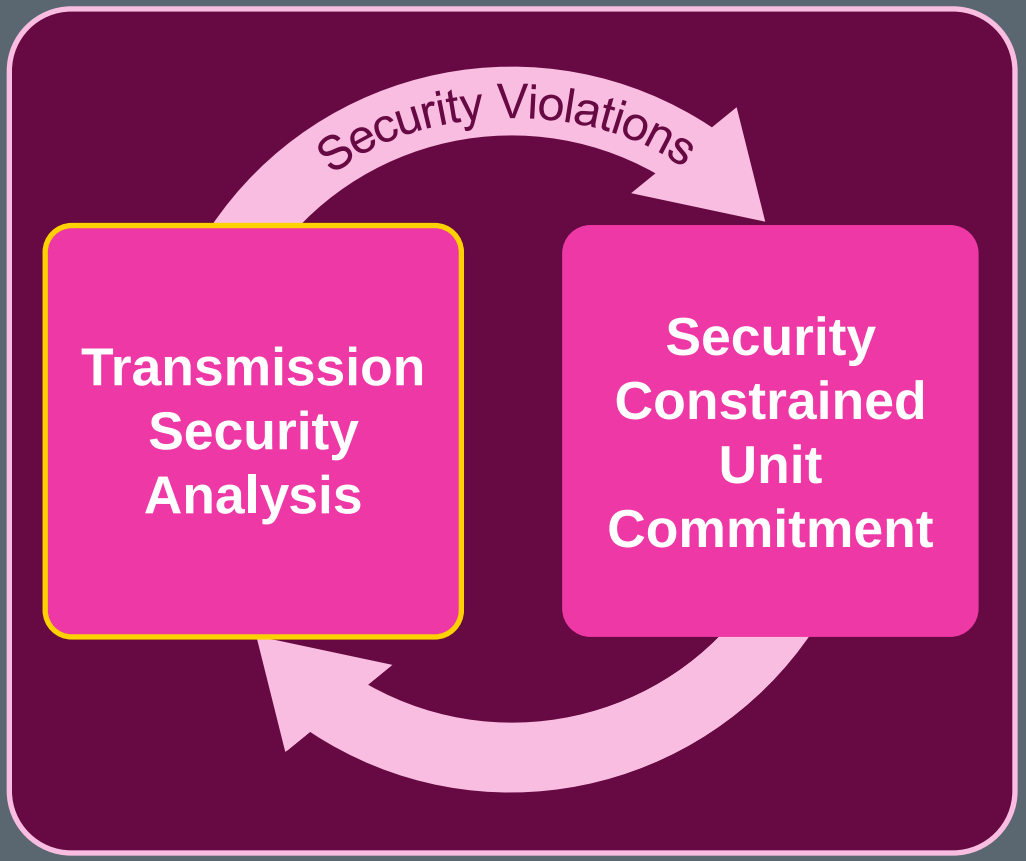
Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF	100	25	0	0	0	0	0	0	0
NotToday	OUT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

What else is required?

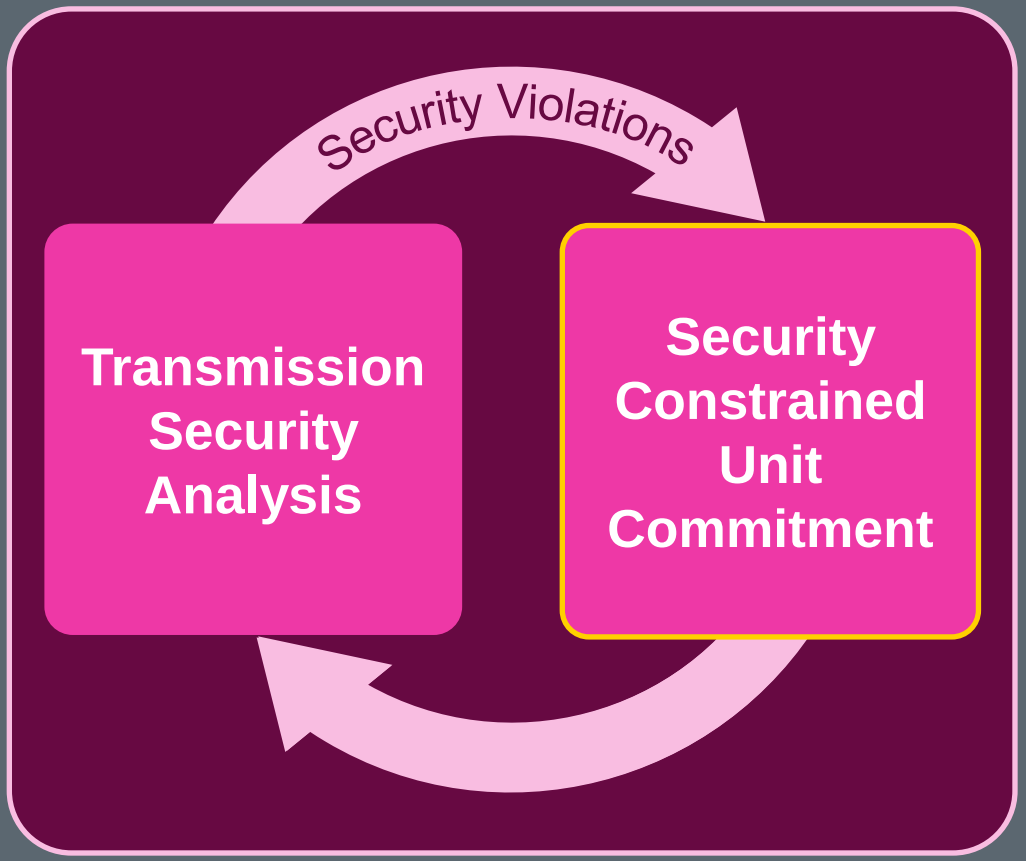
Initial Unit Commitment



Solution Secure?



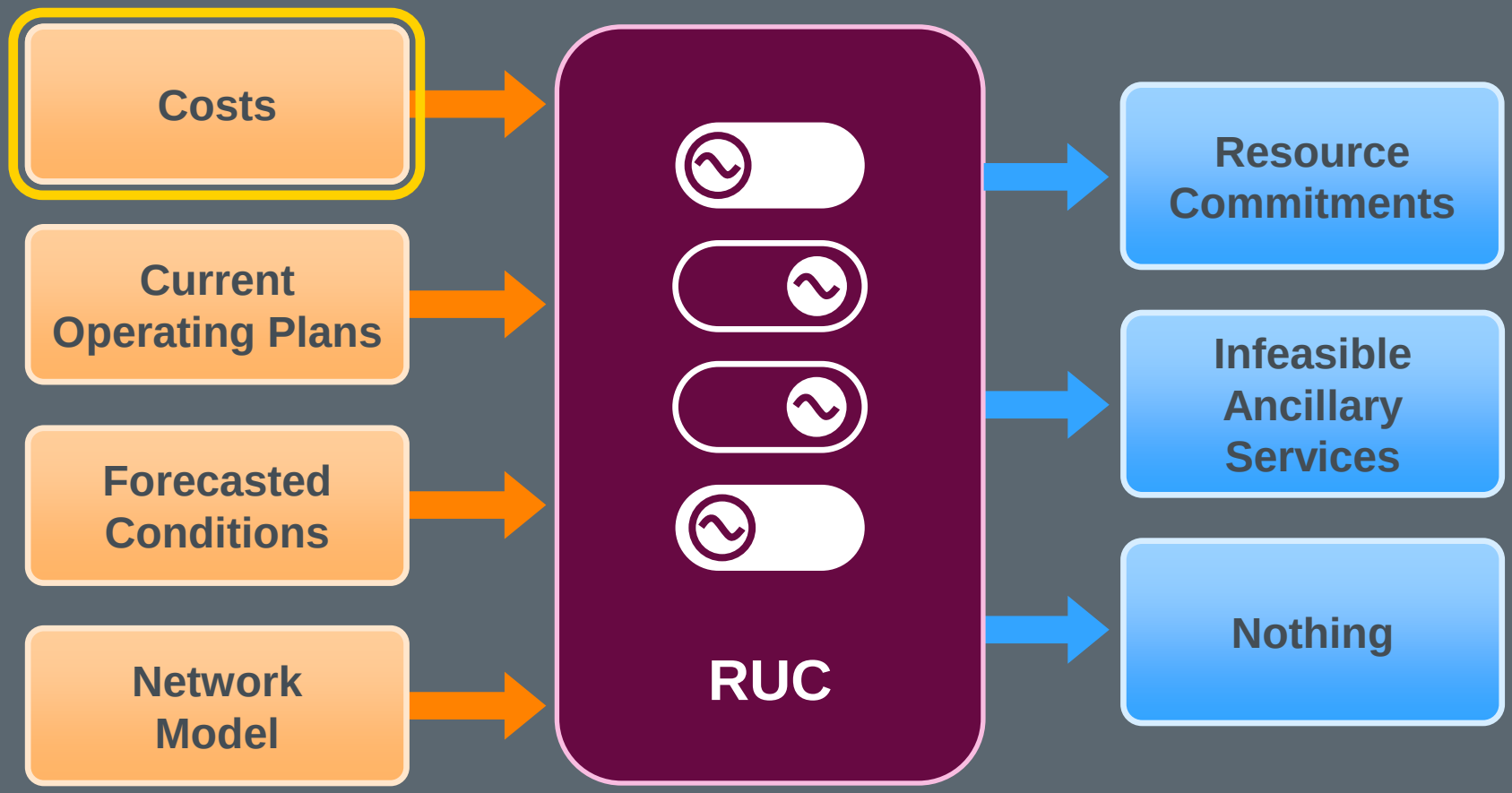
Revise Unit Commitment if needed



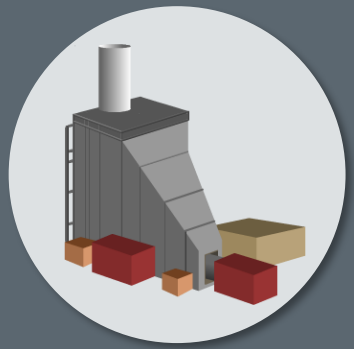
RUC Observes certain Temporal Constraints

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

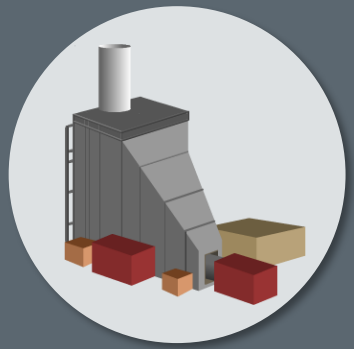
RARF

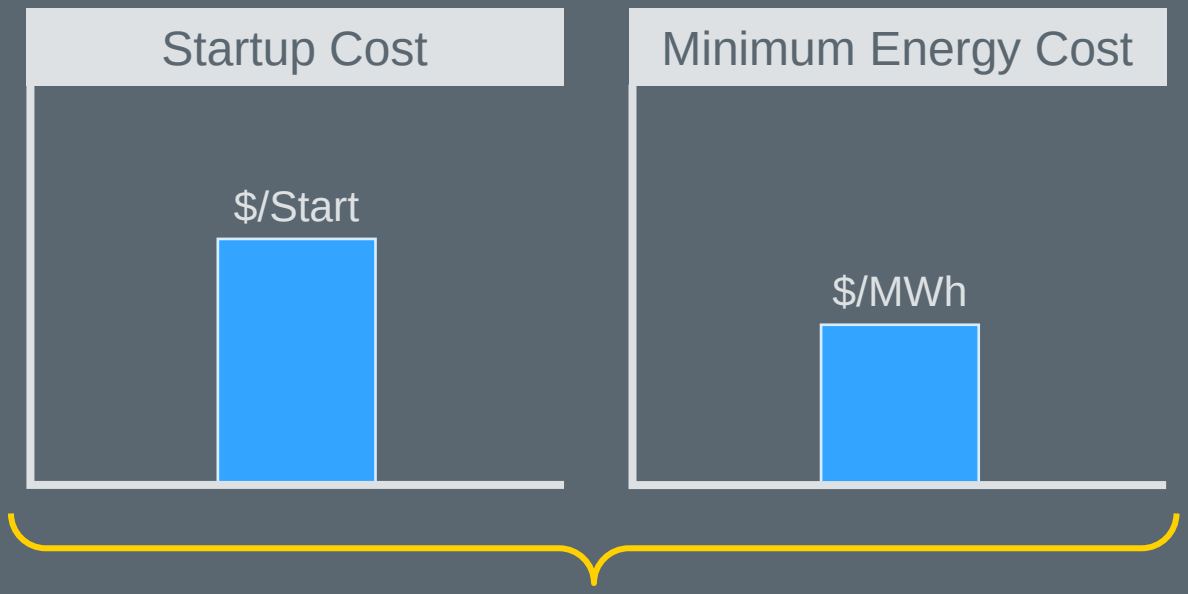

Costs
Current Operating Plans
Forecasted Conditions
Network Model
RUC
Resource Commitments
Infeasible Ancillary Services
Nothing

Costs from Three Part Supply Offer

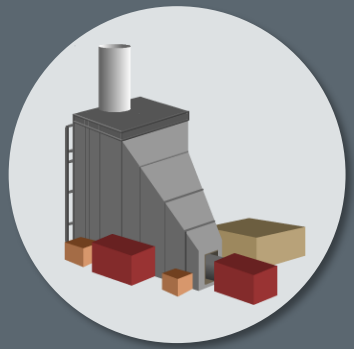


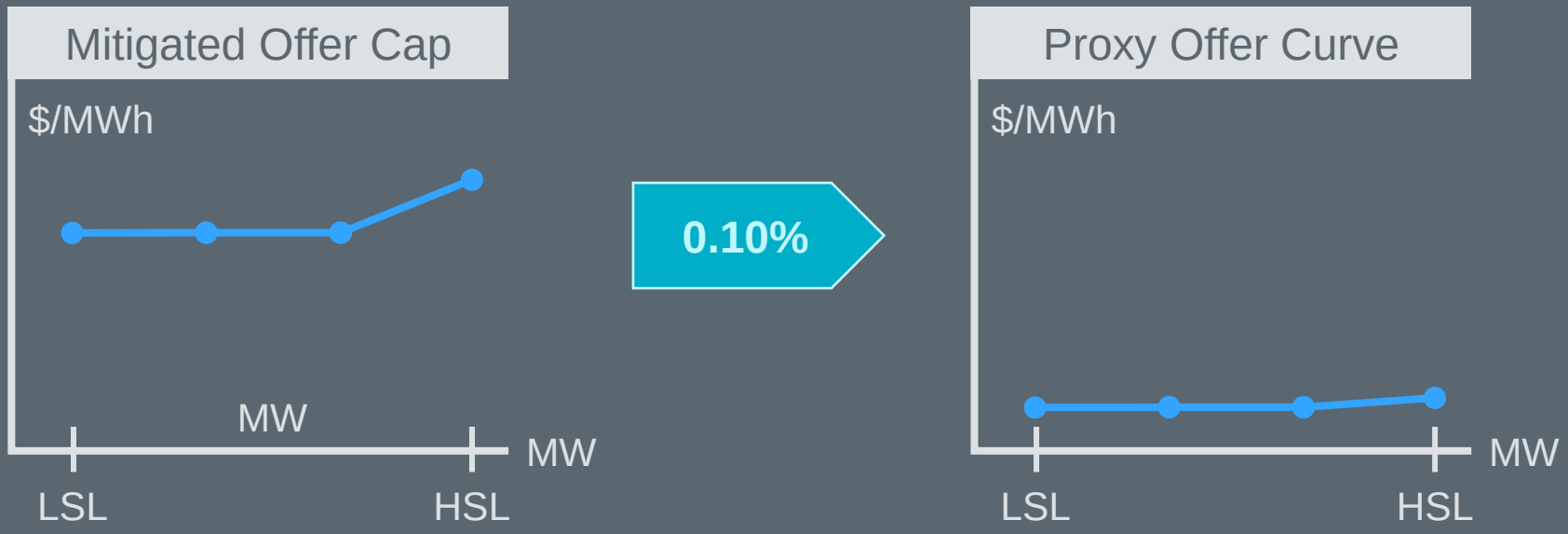
Costs from Generic or Verifiable

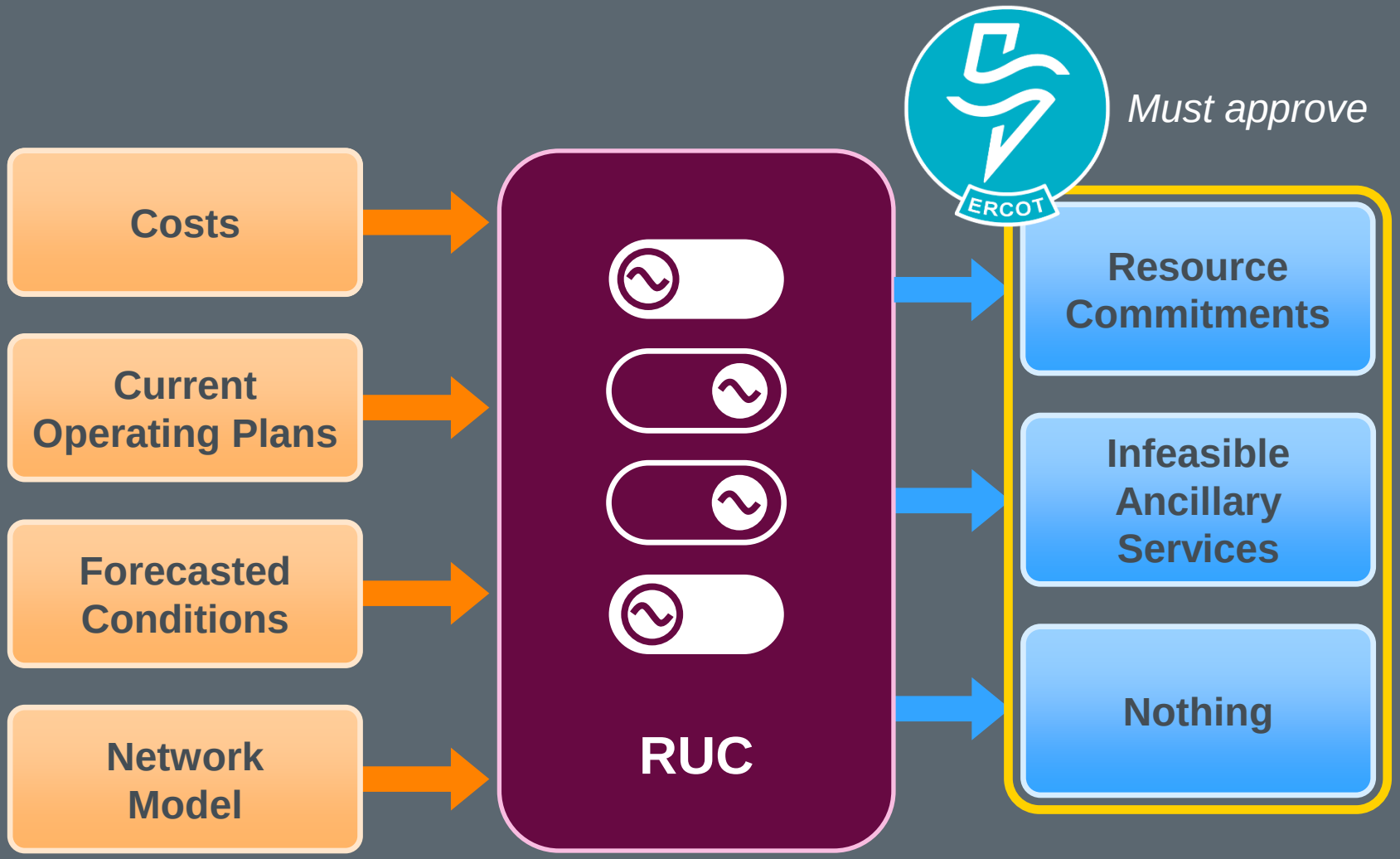




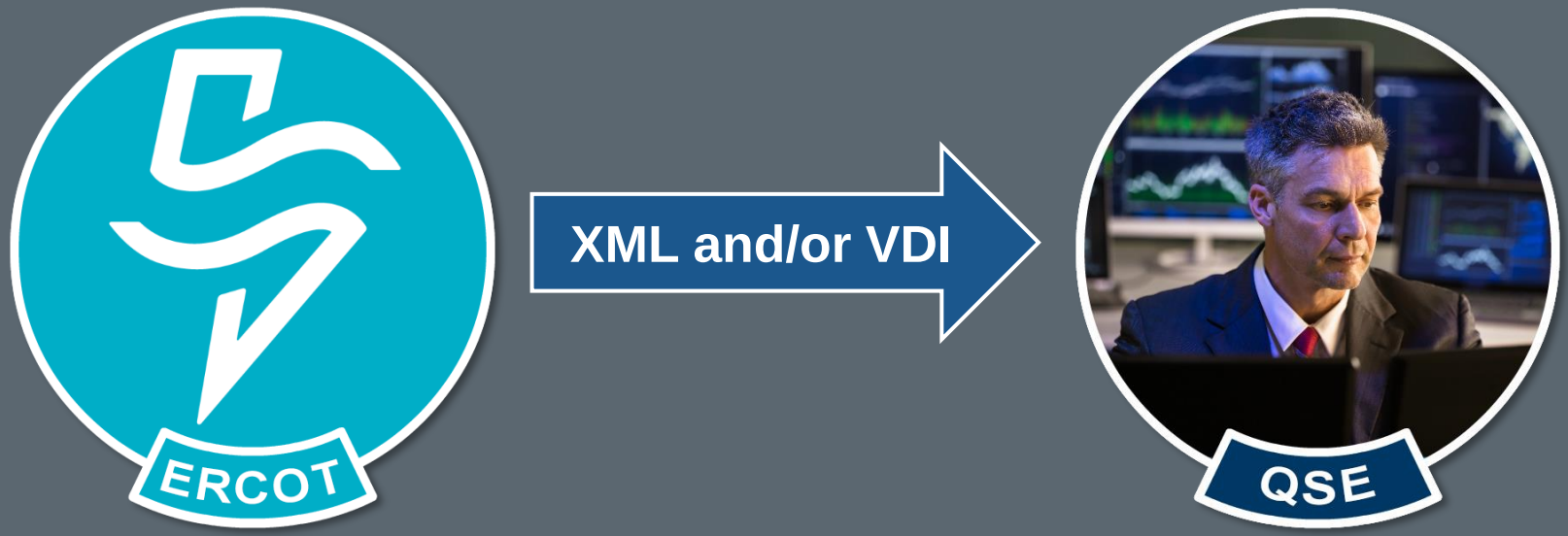
To see if a dispatch solution even possible






Costs
Current Operating Plans
Forecasted Conditions
Network Model
RUC
ERCOT
Must approve
Resource Commitments
Infeasible Ancillary Services
Nothing

Start hour and duration sent to QSEs



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

QSE must update COP within 60 minutes

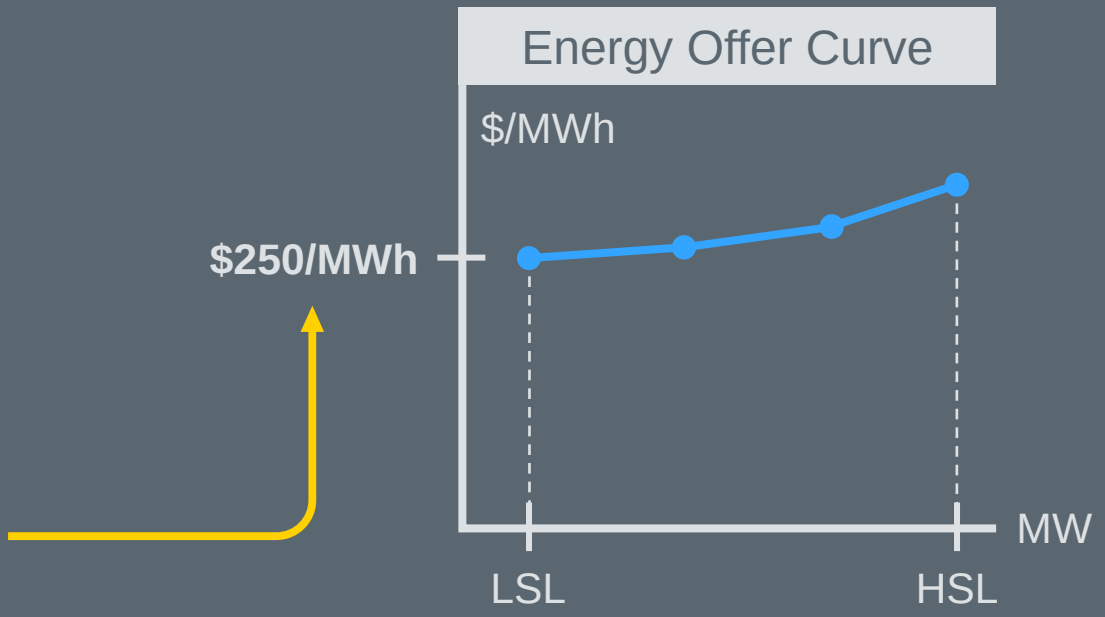
Current Operating Plan										
Resource Name	Resource Status	Resource Limits		Ancillary Service Resource Responsibility						
		HSL	LSL	Reg-Up	Reg-Dn	RRSPF	RRSUF	RRSFF	ECRS	Non-Spin
ThisOne	ONREG	400	75	20	0	40	0	0	30	0
ThatOne	ONL	30	0	0	0	0	30	0	0	0
OtherOne	OFF ▼	100	25	0	0	0	0	0	0	0

ONRUC
ONOPTOUT

Resource Financial Impacts

- **Floor price**
- **RUC Settlement**
  - Make-Whole
  - Clawback

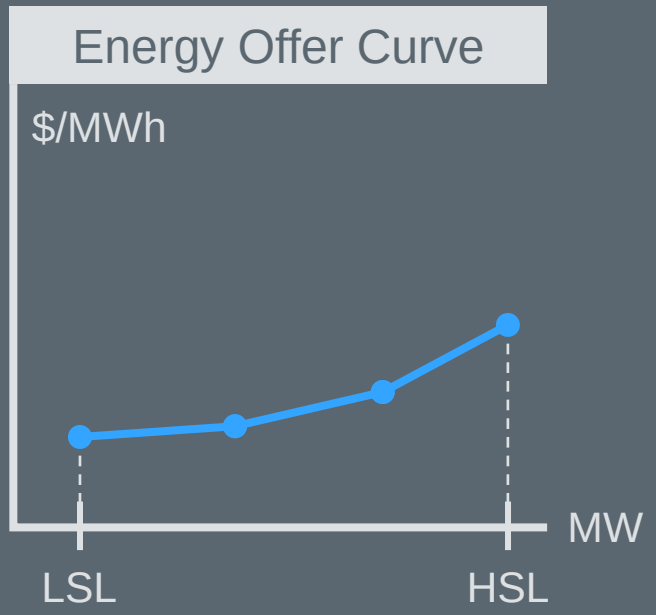
ERCOT adjusts if QSE does not



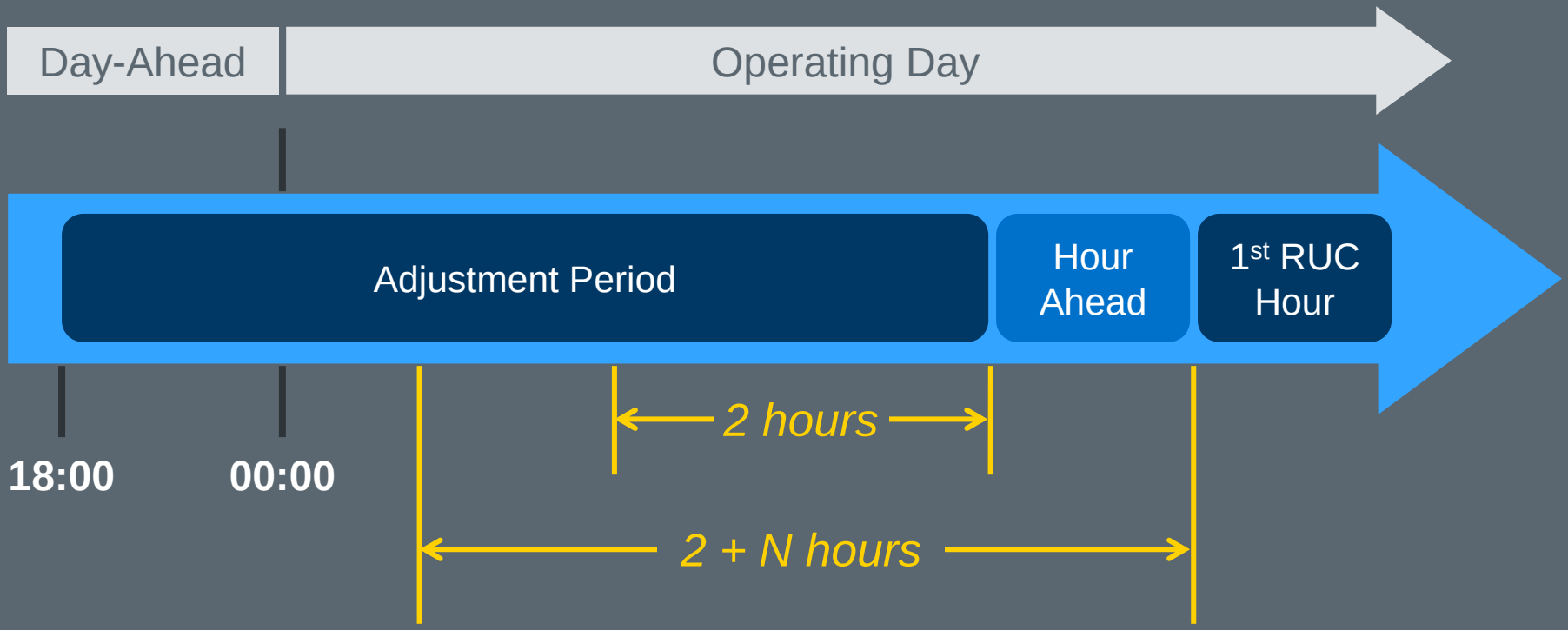
Resource Financial Impacts

- **No floor price**
- **No RUC Settlement**

QSE must update COP prior to Opt Out Snapshot



Taken at the earlier of:



Where N is Start Time

QSE notified of Resource, Service and impacted hours

ERCOT

Notification

Discussion: Infeasible Ancillary Service – What now?

OPTIONS:

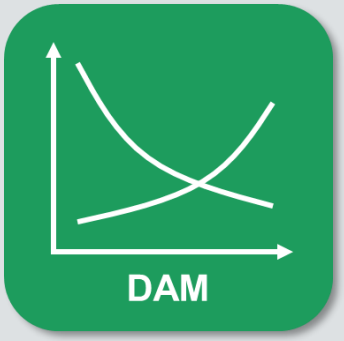
1.
2.
3.

OPTIONS:

1.
2.

Financial Impacts

Return payment for cleared AS Offer



Still responsible for AS Obligations

Course Wrap-Up

Suite of Resource Courses

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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