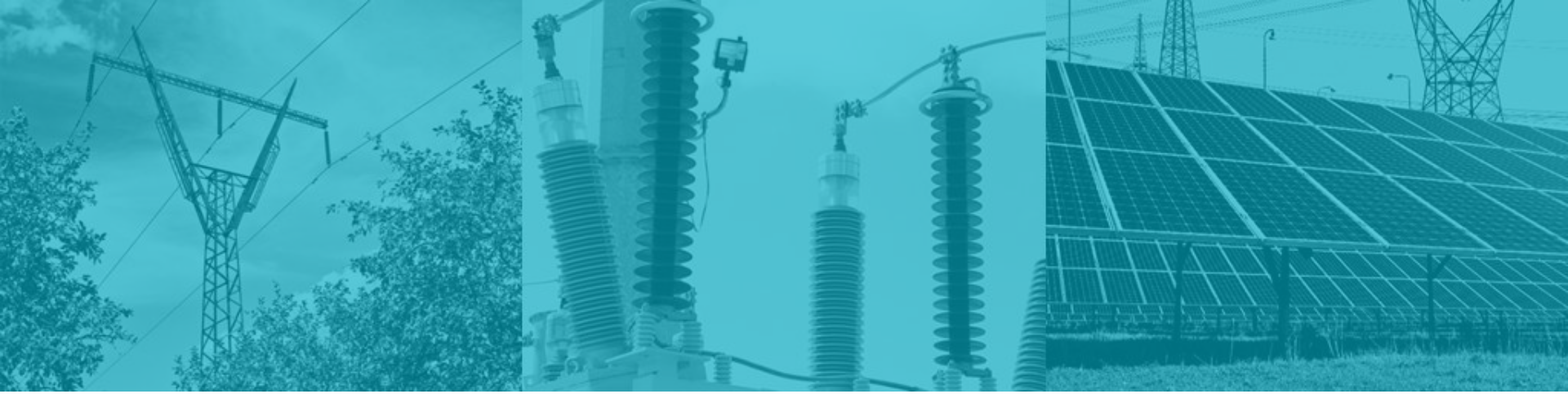


ERCOT Market Education

Intermittent Renewable Resources

2023_12 IRR

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:

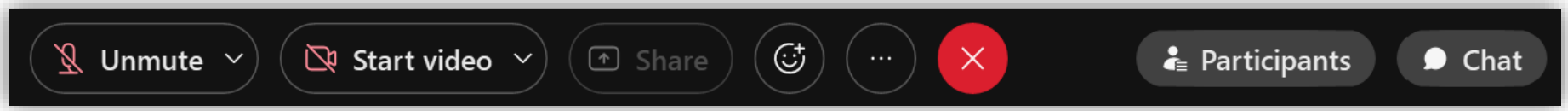
http://www.ercot.com/mktrules/nprotocols/

WebEx Training Tips

- Windows
- Buttons

Attendance

Questions / Chat



Modules in this course include:

1. IRR Definitions
2. Market Provisions and Requirements for IRRs
3. IRR Forecasting
4. IRRs in Market and System Operations
5. Financial Settlements of IRRs

Module 1

IRR Definitions

Intermittent Renewable Resource (IRR) – A Generation Resource that can only produce energy from variable, uncontrollable Resources, such as wind, solar, or run-of-the-river hydroelectricity.

Currently, two types:

- Wind-Powered Generation Resource (WGR)
- PhotoVoltaic Generation Resource (PVGR)

Typically, WGRs and PVGRs are aggregations of Wind Turbines or Photovoltaic equipment

Aggregation to form IRRs

A Resource Entity may aggregate Intermittent Renewable Resource generation equipment together to form a single IRR.

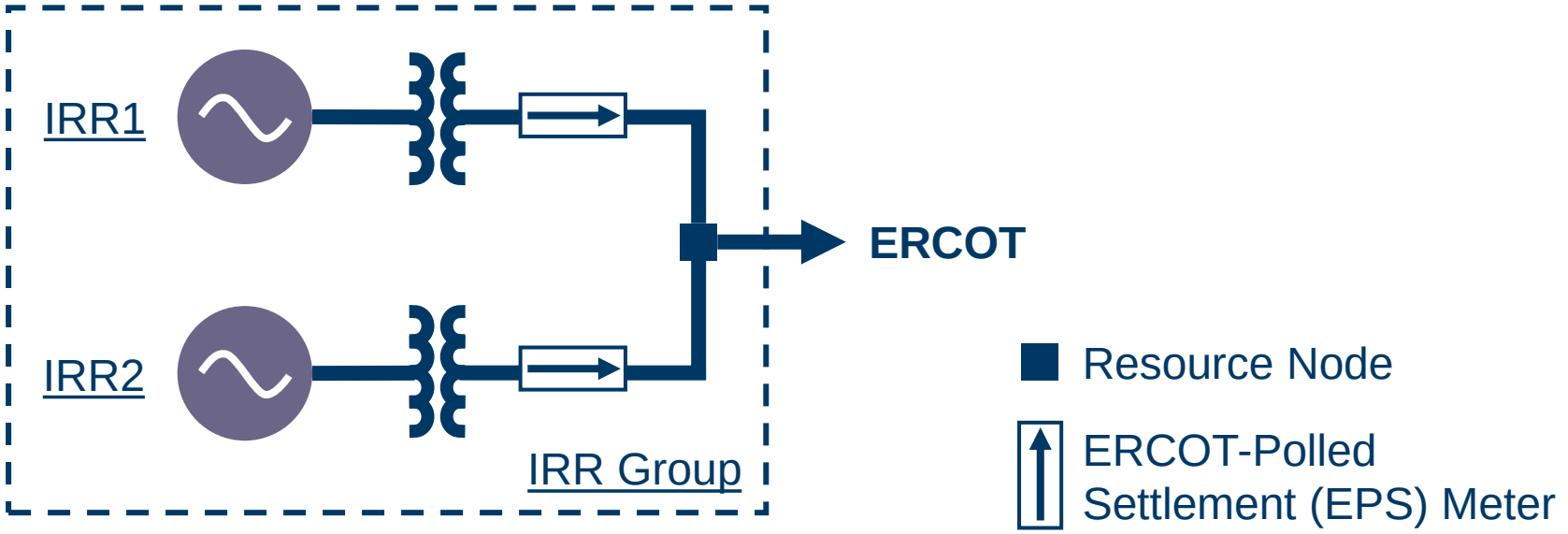
General Rules:

- Same Electrical Bus
- Generally, same model and size[1]
- Does not reduce ERCOT's ability to model

[1] See Protocol 3.10.7.2 (11) for exceptions

IRR Group – A group of two or more IRRs whose performance in responding to Security-Constrained Economic Dispatch (SCED) Dispatch Instructions will be assessed as an aggregate

- All IRRs must have the same Resource Node
- No Split Generation Resources



Discussion

A Resource Entity wants to build a single generation site with both wind generation and photovoltaic systems

1. *Can they create a single IRR?*

2. *Can they create an IRR Group?*

Module 2

Market Provisions and Requirements for IRRs

Topics in this module ...

- What makes IRRs unique?
- Impacts to ERCOT
- General IRR operating requirements

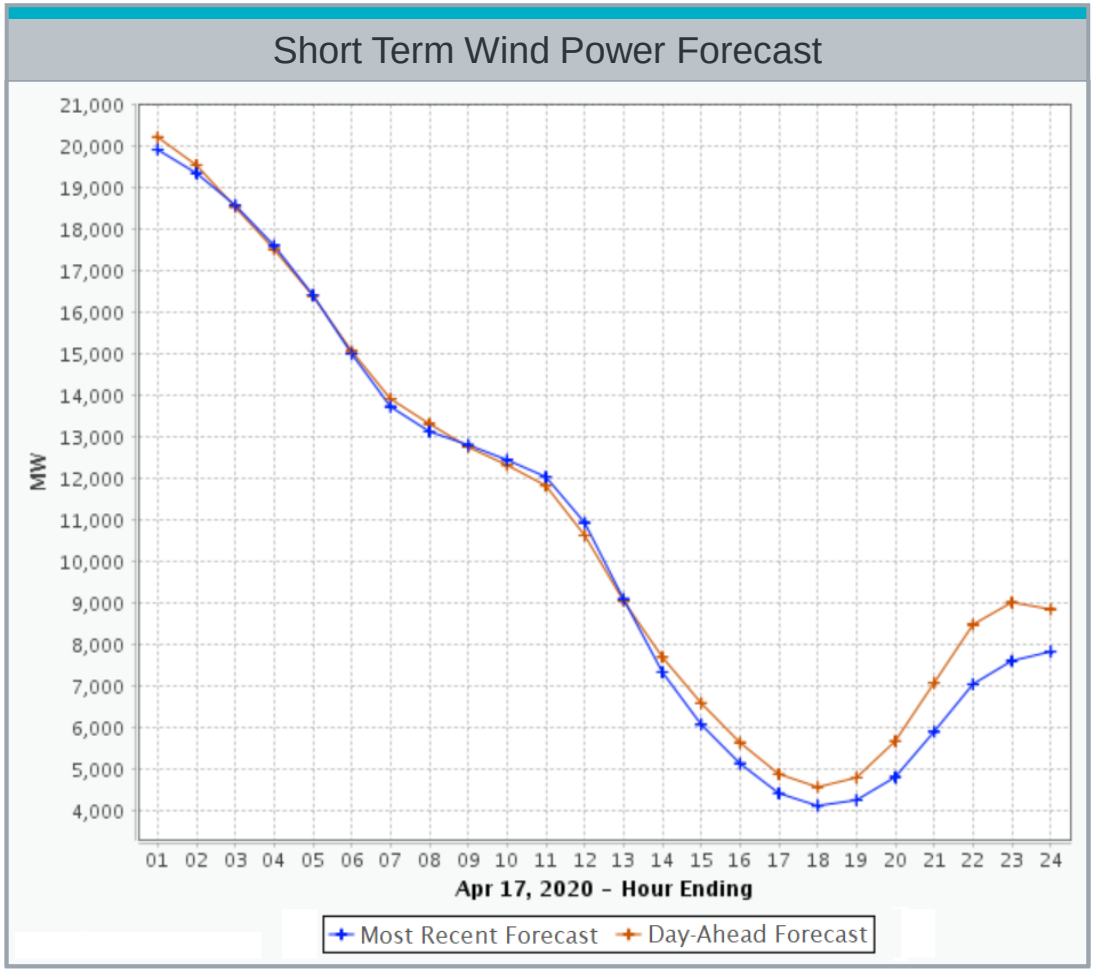
What Makes IRRs Unique?

Variability | **Technology** | **Location**

What Makes IRRs Unique?

Variability

- Intermittent Energy Supply
- Capacity Uncertainty



Variability

- Intermittent Energy Supply
- Capacity Uncertainty

Challenges

- Dispatching to a Base Point
- Managing Variances

Intermittent Energy Supply

Wind and Solar Energy – Use it or Lose it

- Non-IRRs chase their Base Points
- IRRs chase their energy supply
  - Run at max capability (unless curtailed)
  - Base Point is permissive

Intermittent Energy Supply

ERCOT responds to variability with Regulation Service

Regulation matches generation with demand by responding to changes in system frequency

Variability

Intermittent Energy Supply

Capacity Uncertainty

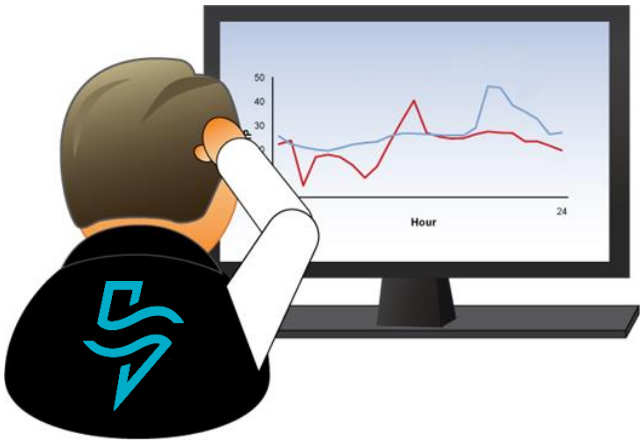
Challenges

- Difficult to predict available capacity for future hours
- Difficult to predict variability within each hour

Capacity Uncertainty

Centralized IRR Forecasting

- ERCOT responsible for IRR forecasting
- Consistent methodology for all IRRs



More details on forecasting later in the course

Capacity Uncertainty

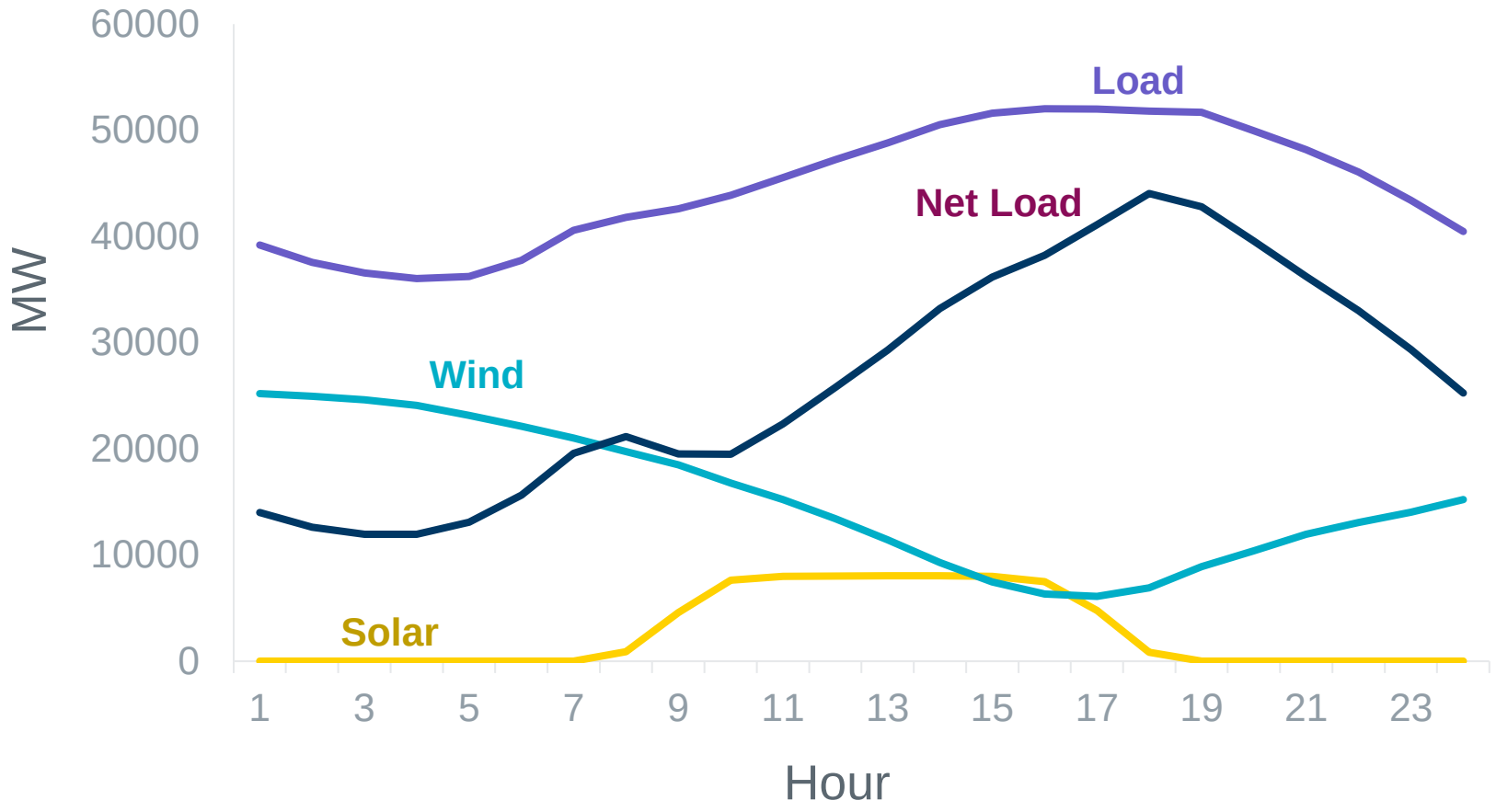
More telemetry data for IRRs means better forecasting

- Meteorological Tower Data from each site
- Detailed equipment status
  - Wind turbines in service
  - Inverters in service

	In-Service	Out	Unknown
Turbines	42	2	1
Inverters	28	1	1

Capacity Uncertainty

Net Load = System Load – IRR Output

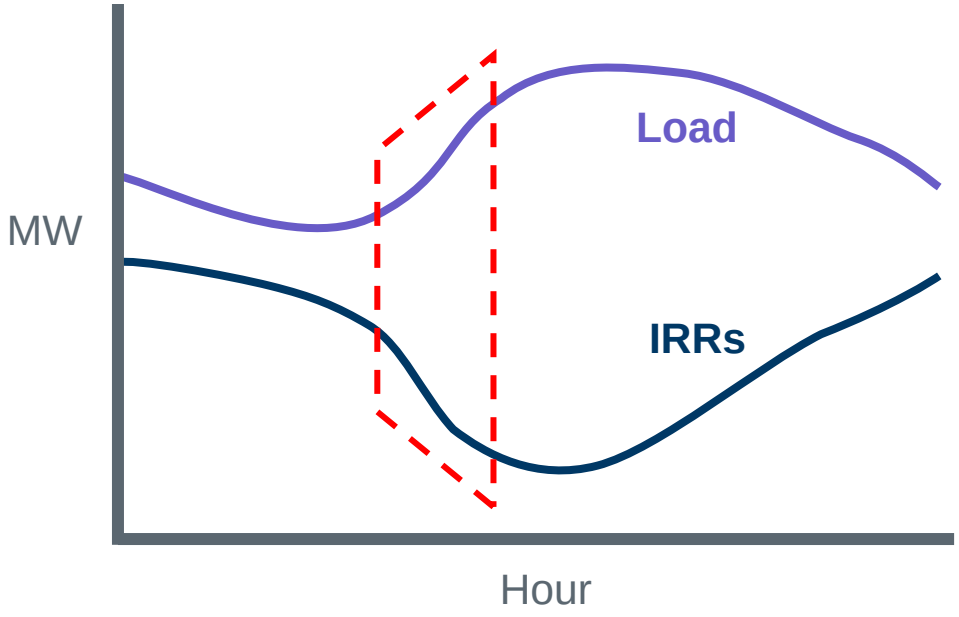


Capacity Uncertainty

Ancillary Services help us prepare for larger-than-expected Net Load ramps

- Non-Spin manages hourly Net Load uncertainty
- ECRS manages intra-hour Net Load uncertainty

Periods of increasing load with decreasing IRR output may put system at ramping risk



What Makes IRRs Unique?

Technology

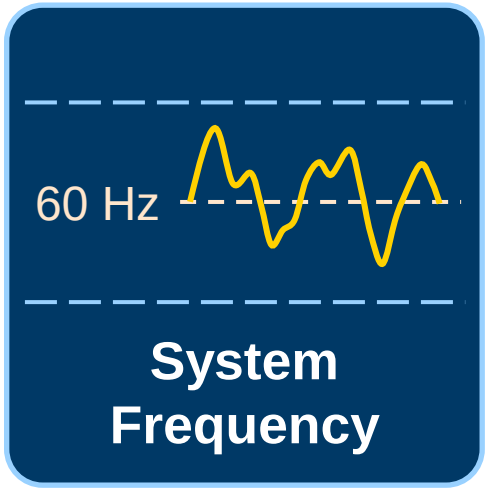
- Large Ramp Rates
- Not Synchronous Generators
- Limited Governor Control

Technology

- Large Ramp Rates
- Not Synchronous Generators
- Limited Governor Control

Challenges

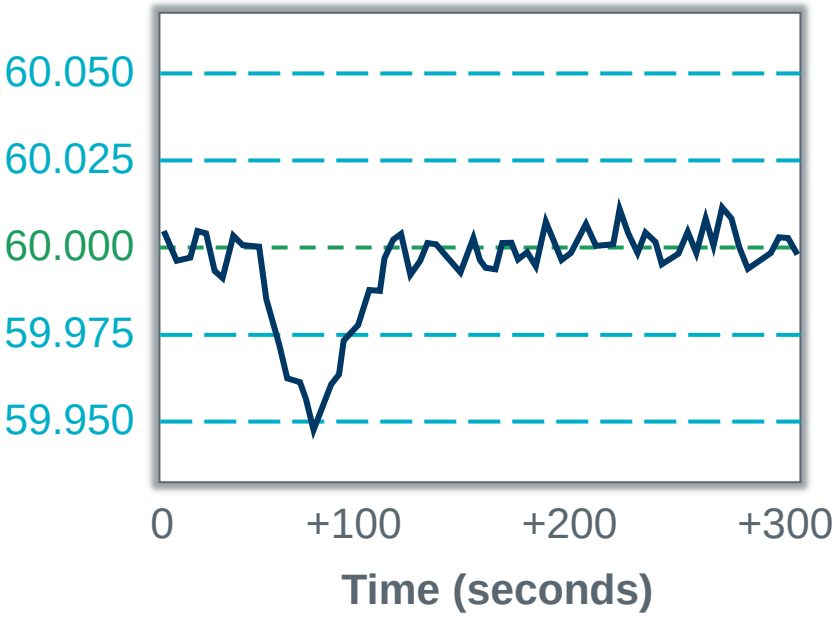
- IRRs have nearly instantaneous ramp rates
- May cause frequency issues



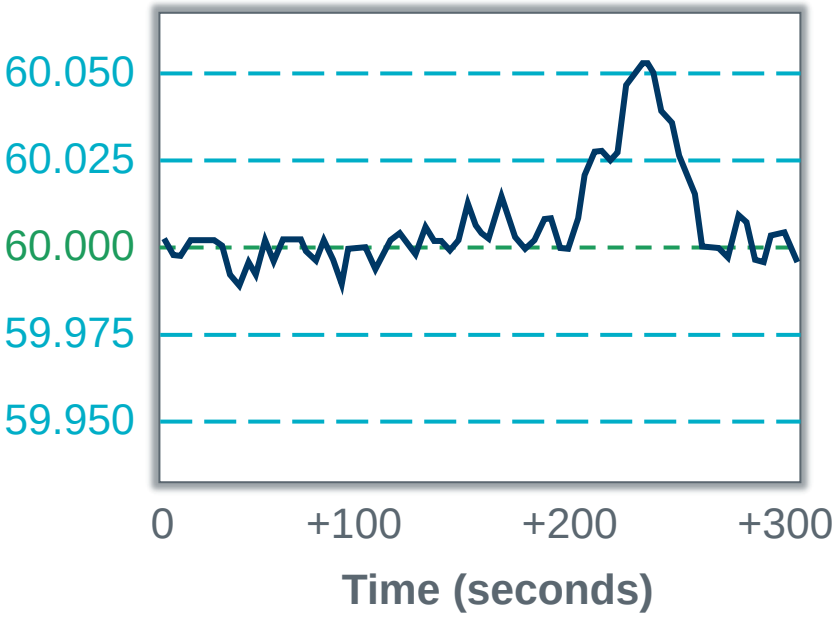
Large Ramp Rates

With nearly instantaneous ramp rates …

Frequency could dip when IRRs curtailed



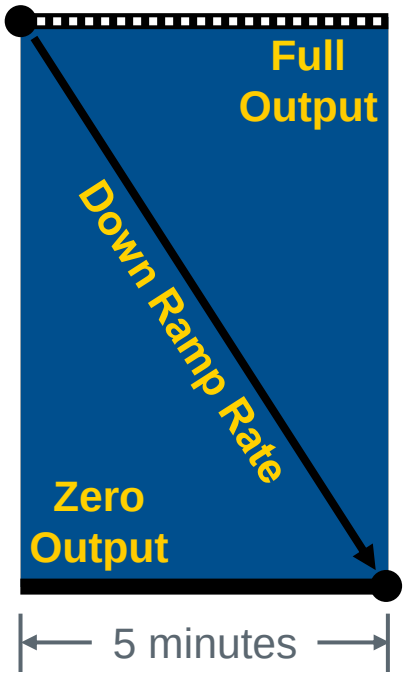
Frequency could spike when curtailment released



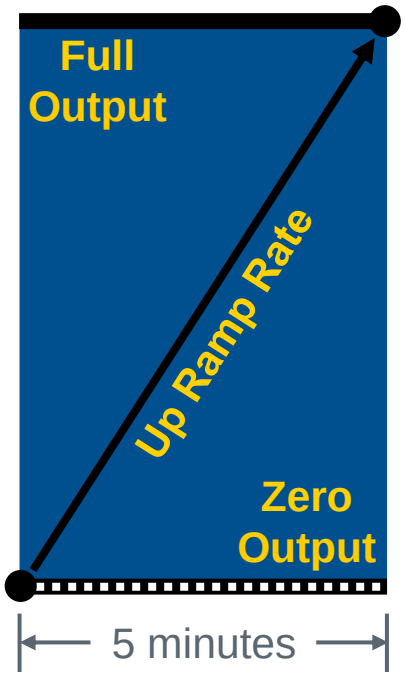
Large Ramp Rates

IRRs ramp rates limited to 20% of Nameplate Rating per minute

When curtailed by ERCOT



When released from curtailment by ERCOT

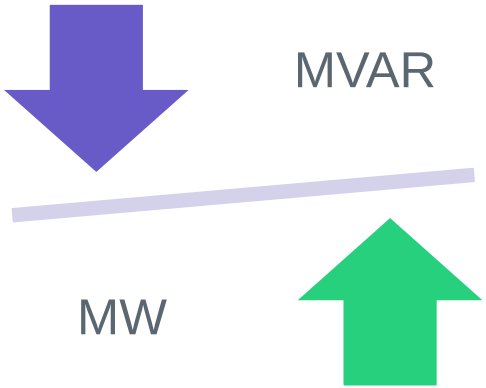


Technology

- Large Ramp Rates
- Not Synchronous Generators
- Limited Governor Control

Challenges

- All Generation Resources must provide Reactive Power
- Wind turbines and photovoltaic panels don’t produce reactive power



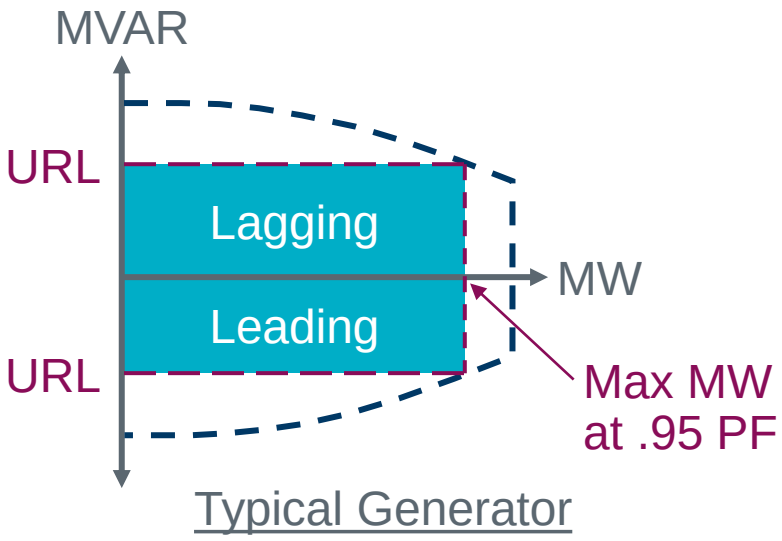
Not Synchronous Generators

IRRs must provide Reactive Power

Operating at or above 10% Nameplate Rating

- Support voltage set point at POI[1]
- Up to Unit Reactive Limit (URL)

If output is below 10% of Nameplate, ERCOT may request shutdown



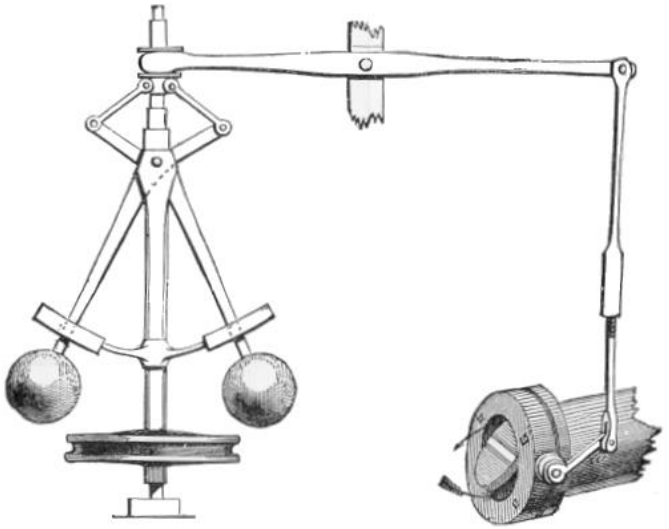
[1] Point of Interconnect

Technology

- Not Synchronous Generators
- Limited Governor Control
- Limited Governor Control

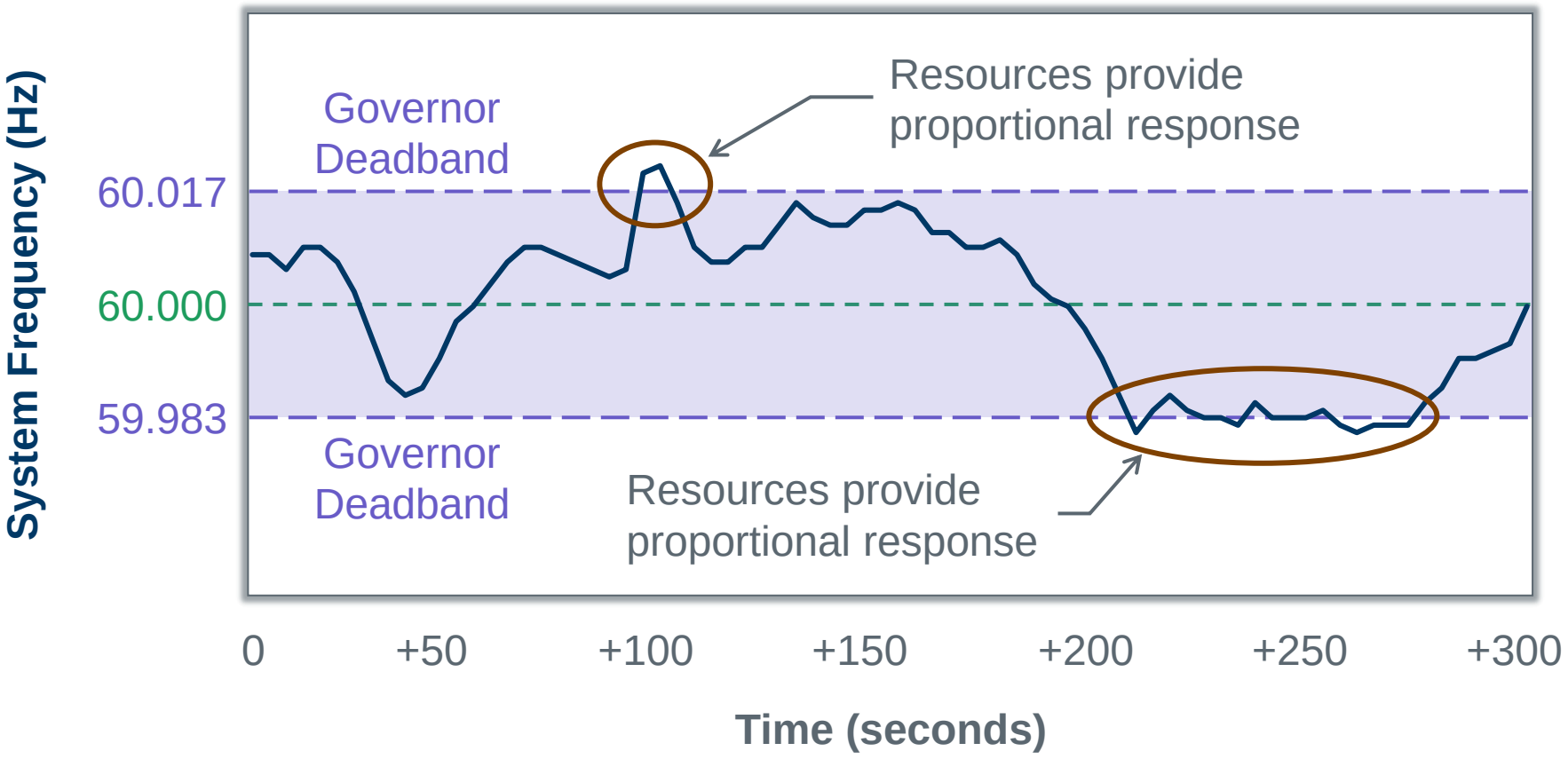
Challenges

- All Resources must provide Primary Frequency Response
- IRRs don't have traditional governors (if any)



Limited Governor Control

IRRs must provide equivalent governor response to stabilize frequency

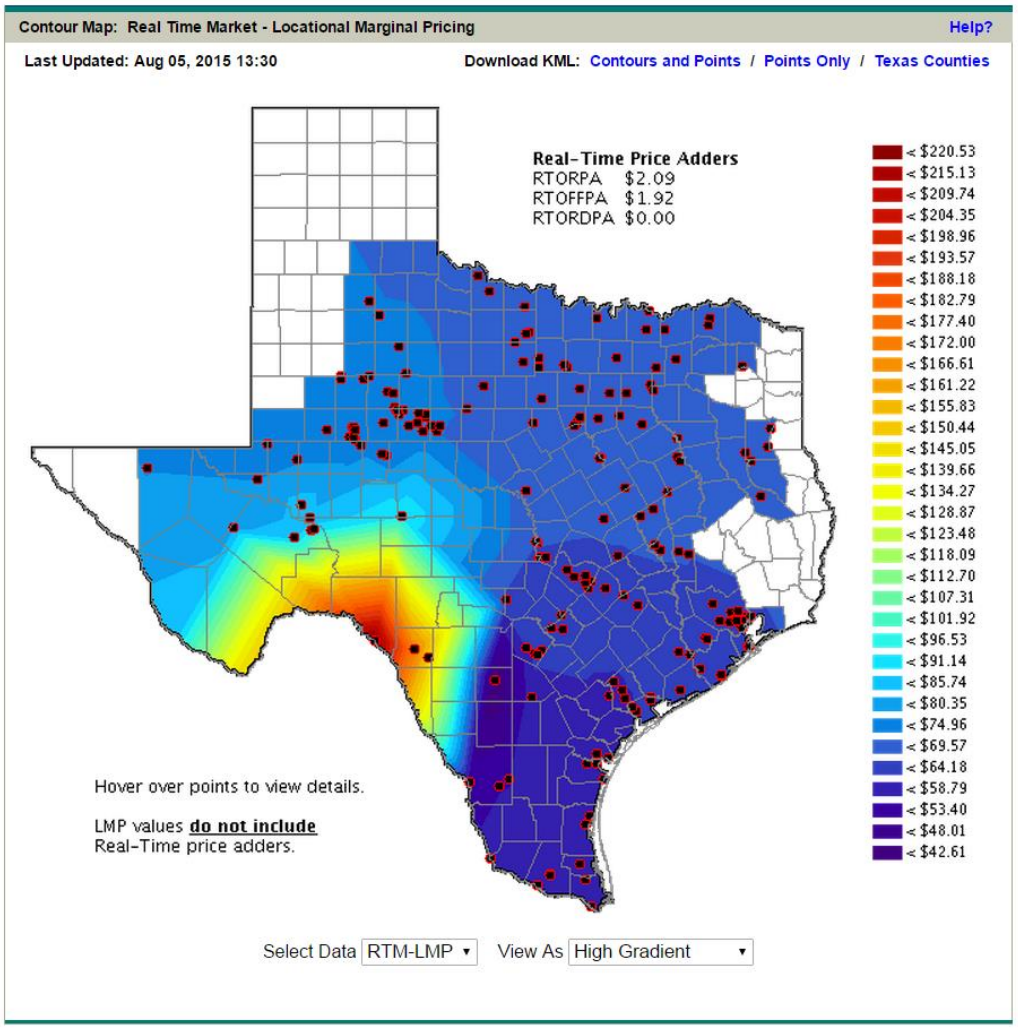


What Makes IRRs Unique?

Location

Transmission Constraints

Subsynchronous Resonance



Location

- Transmission Constraints
- Subsynchronous Resonance

Challenges

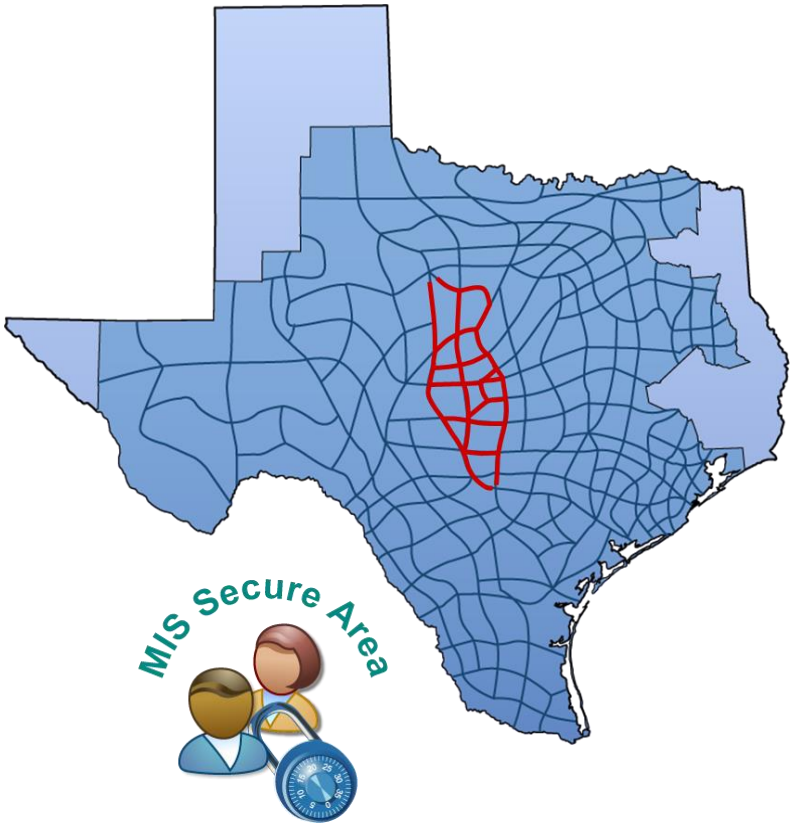
- Interconnection in remote areas
- Interconnection in weak areas

Transmission Constraints

Potential constraints highlighted in Full Interconnection Study (FIS)

FIS Study Report includes:

- Nature of constraints
  - Stability
  - Overload
    - Base Case
    - Contingency Case
- Severity of constraints

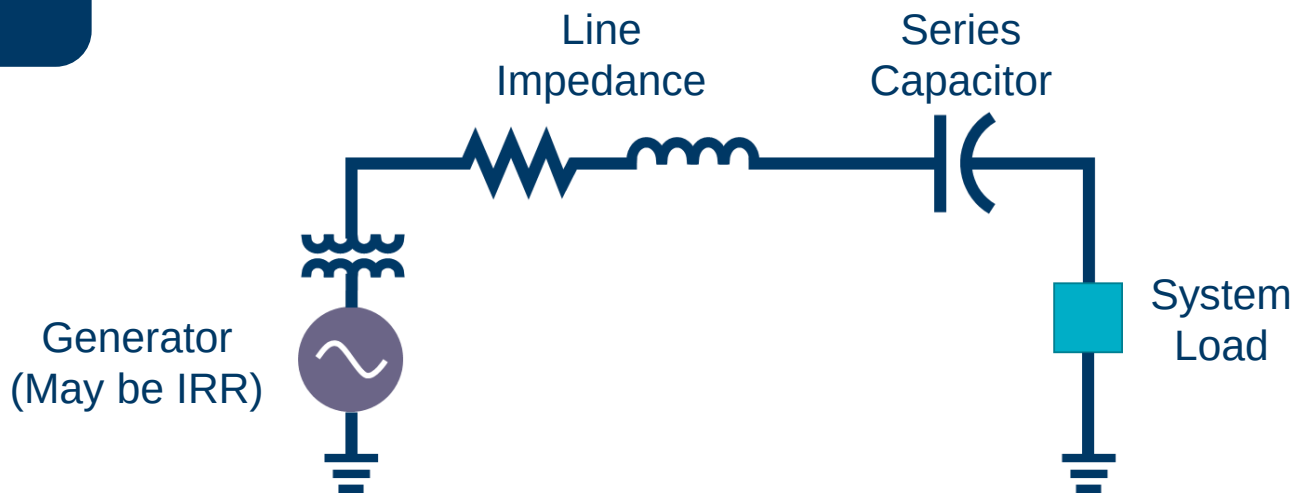


Location

- Transmission Constraints
- Subsynchronous Resonance

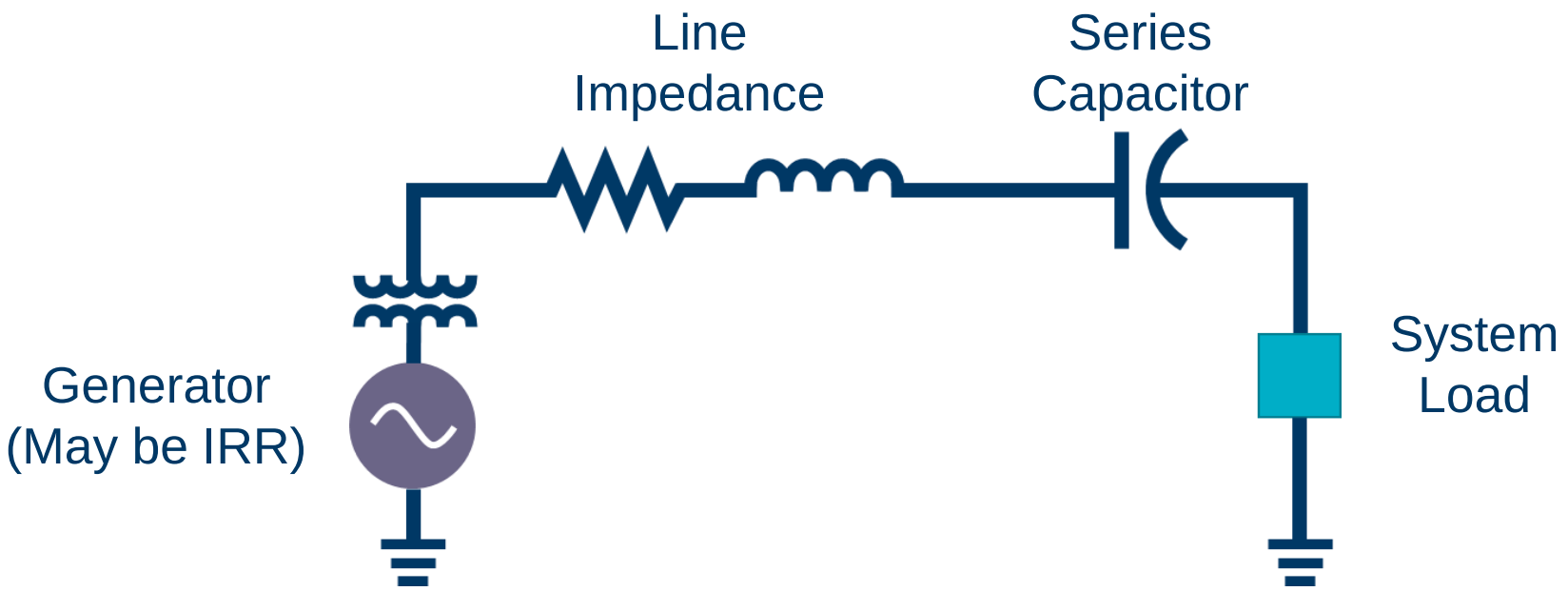
Challenges

- Series compensated lines increase likelihood of resonance at frequencies below 60Hz
- Resonance may damage generators



Video

A Bad Case of Resonance



https://youtu.be/FfNBIRdreHg

Subsynchronous Resonance

New Interconnecting Generation Resources

- Initial SSR[1] screening by ERCOT
- Vulnerability Assessment by TSP if needed

If countermeasures are required,

- Interconnecting Entity responsible
- Must be implemented prior to Initial Synchronization

[1]Subsynchronous Resonance

Subsynchronous Resonance

Resources in the Planning Model

- Annual SSR[1] Review by ERCOT
- Vulnerability Assessment by TSP if needed

If countermeasures are required,

- TSP responsible
- Must be implemented by latter of
  1. Completion of transmission project
  2. Initial Synchronization

[1]Subsynchronous Resonance

Module 3

IRR Forecasting

Topics in this module ...

- IRR Hourly Forecasting
  - Wind Generation
  - Photovoltaic Generation
- IRR Ramp Forecasting

IRR Hourly Forecasting

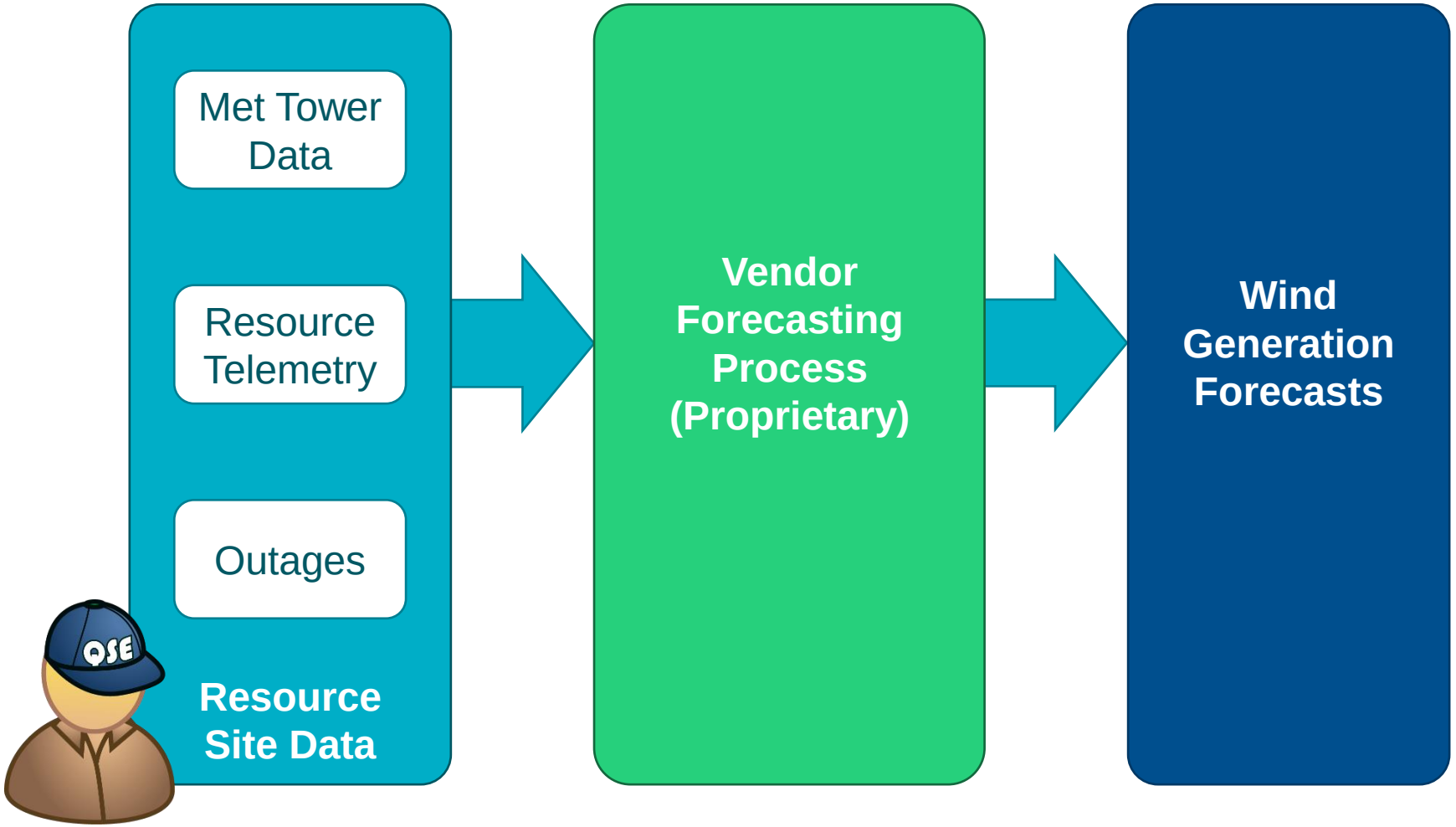
Wind Generation Forecasting

Resource Site Data

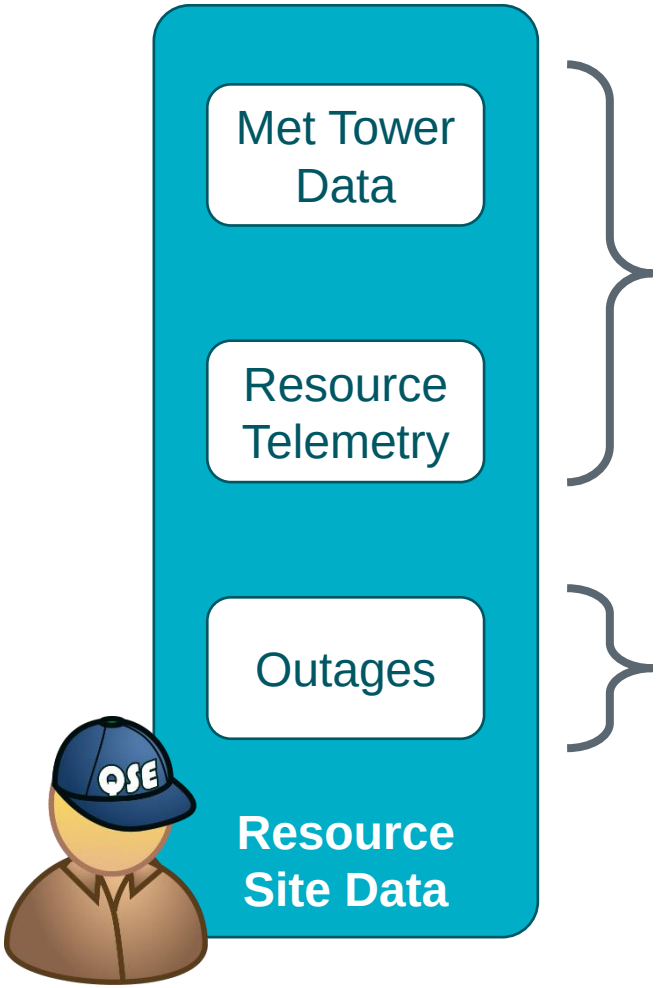
Vendor Forecasting Process (Proprietary)

Wind Generation Forecasts

Resource Site Data



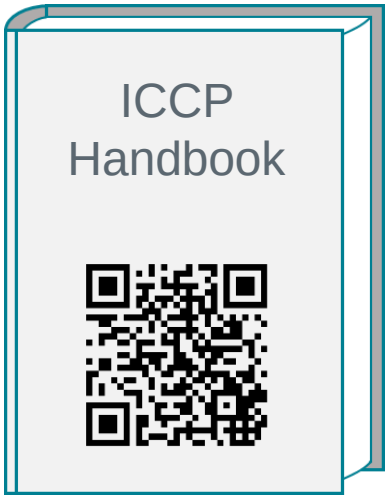
Resource Site Data



Reported through ICCP Telemetry

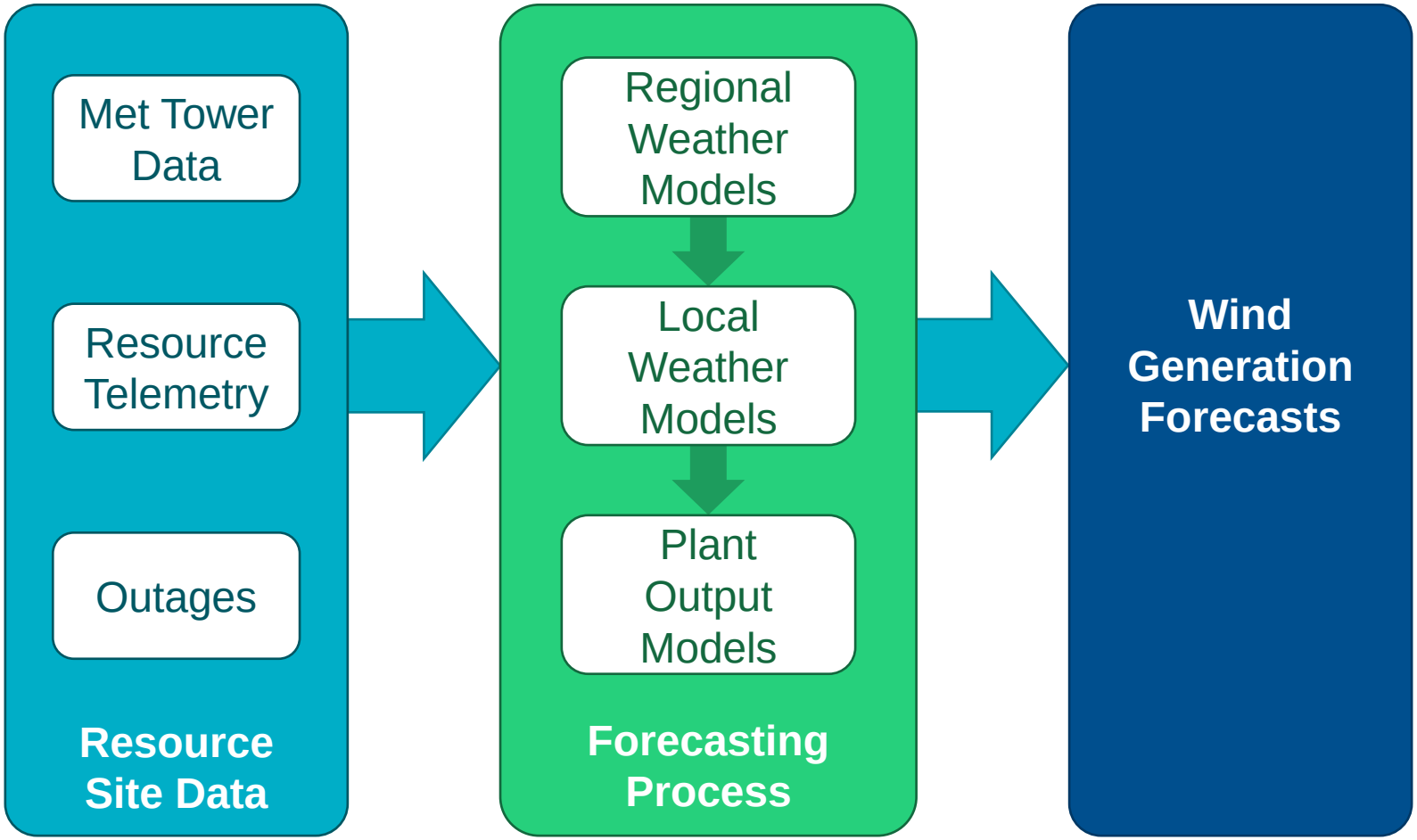
Details in ERCOT ICCP Handbook

Reported through Outage Scheduler

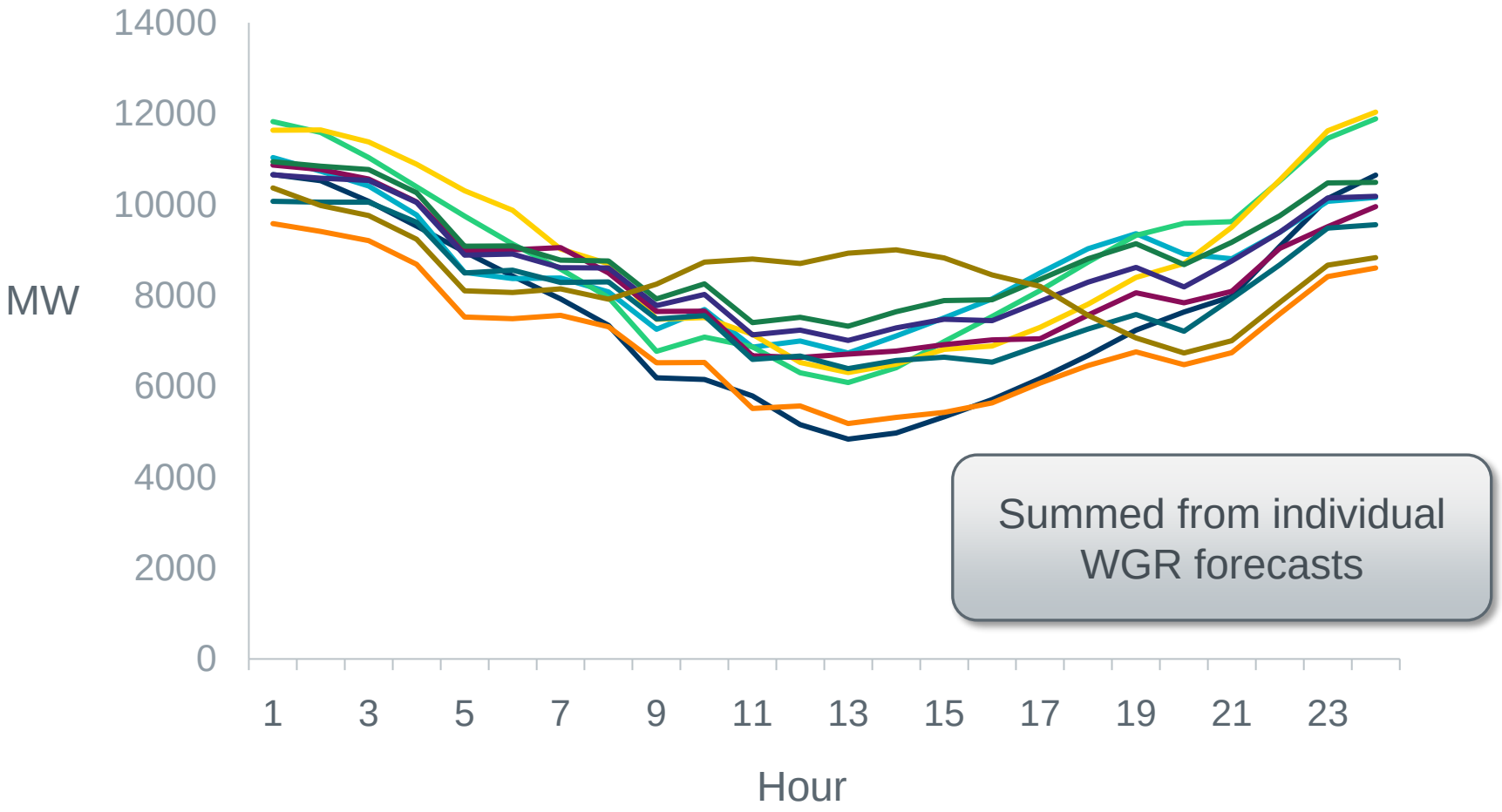


http://www.ercot.com/services/mdt/userguides

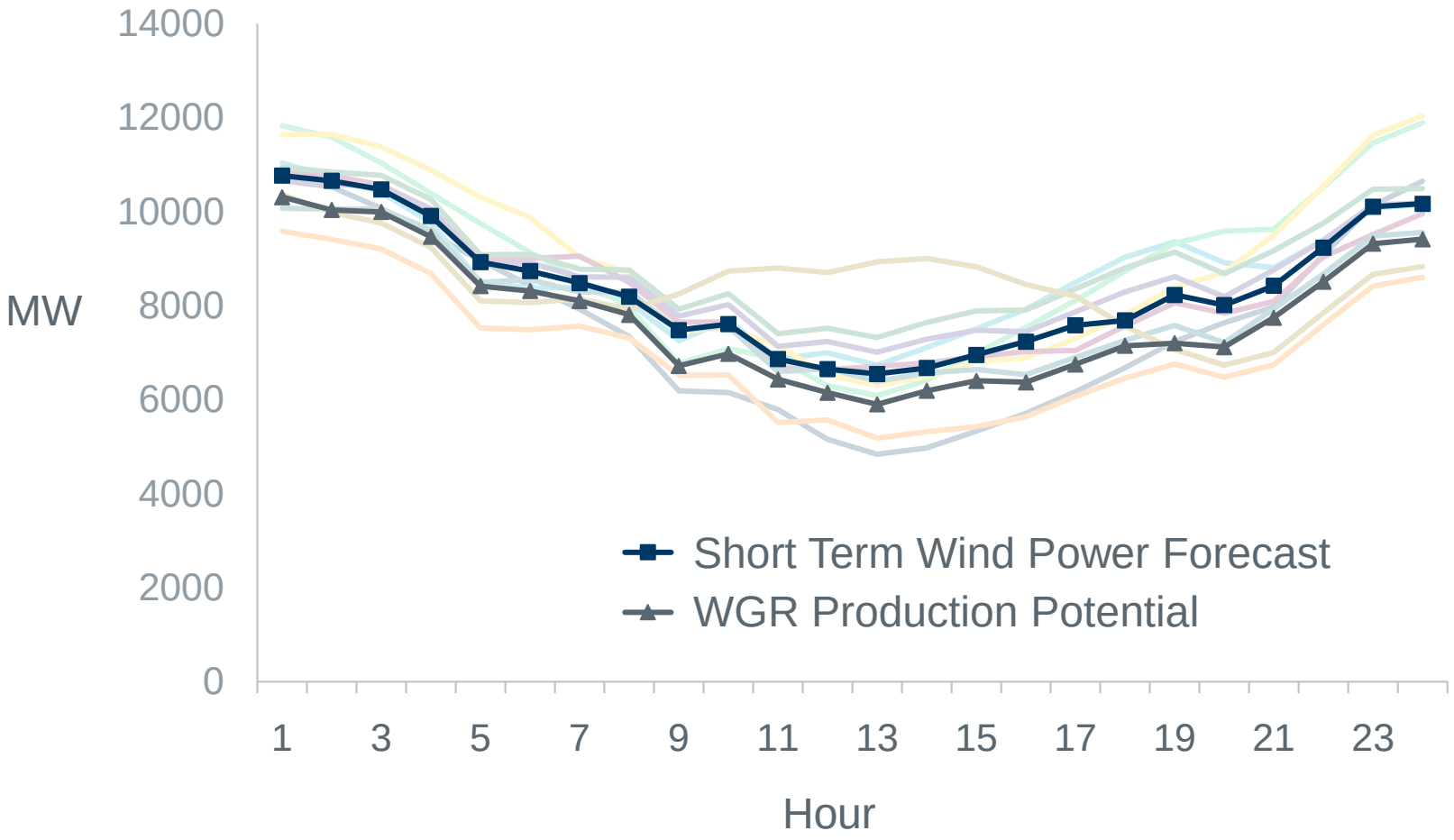
Vendor Forecasting Process



Ensemble of hourly forecasts



A Tale of Two Forecasts



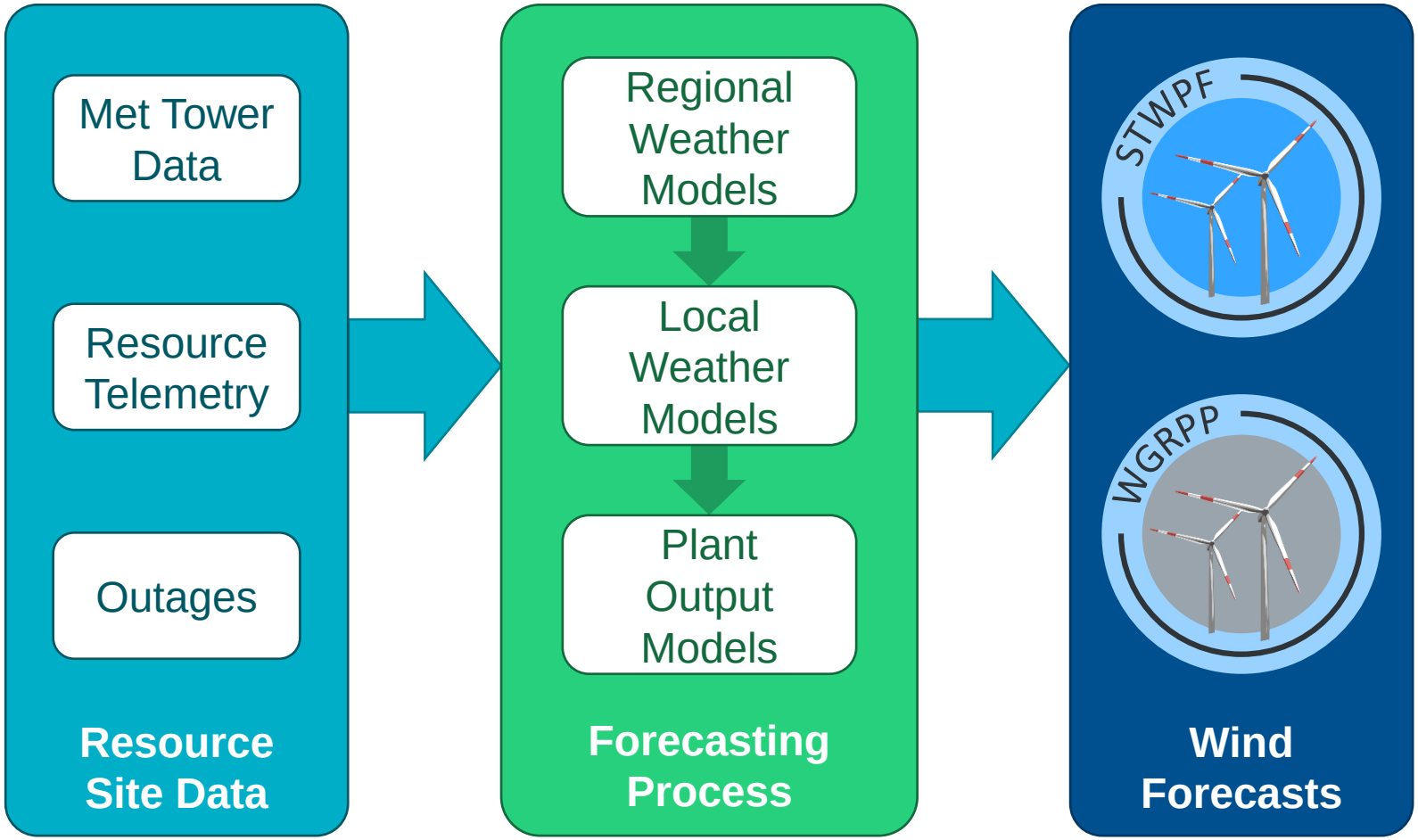
Short-Term Wind Power Forecast

- Rolling 168 hour forecast for each WGR
- Used in reliability studies

WGR Production Potential

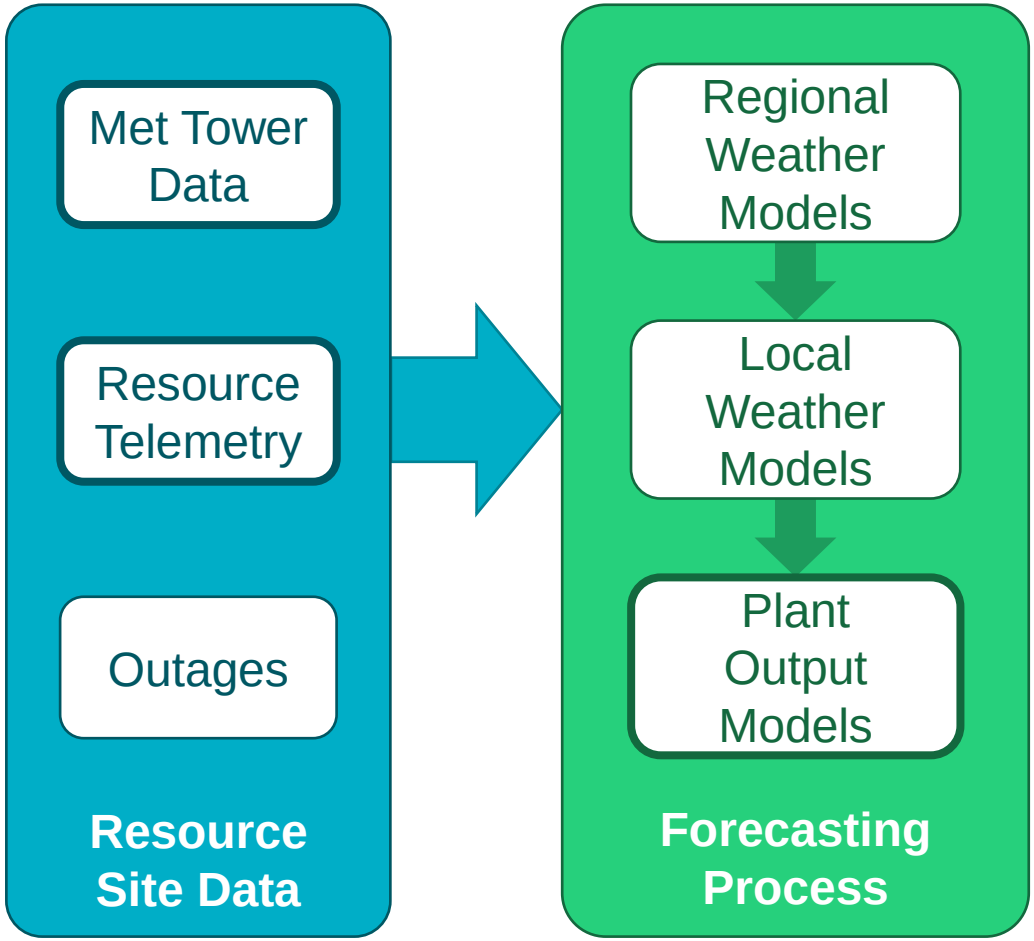
- Rolling 168 hour forecast for each WGR
- Used in financial settlements

WGR Forecasting Summary



Discussion

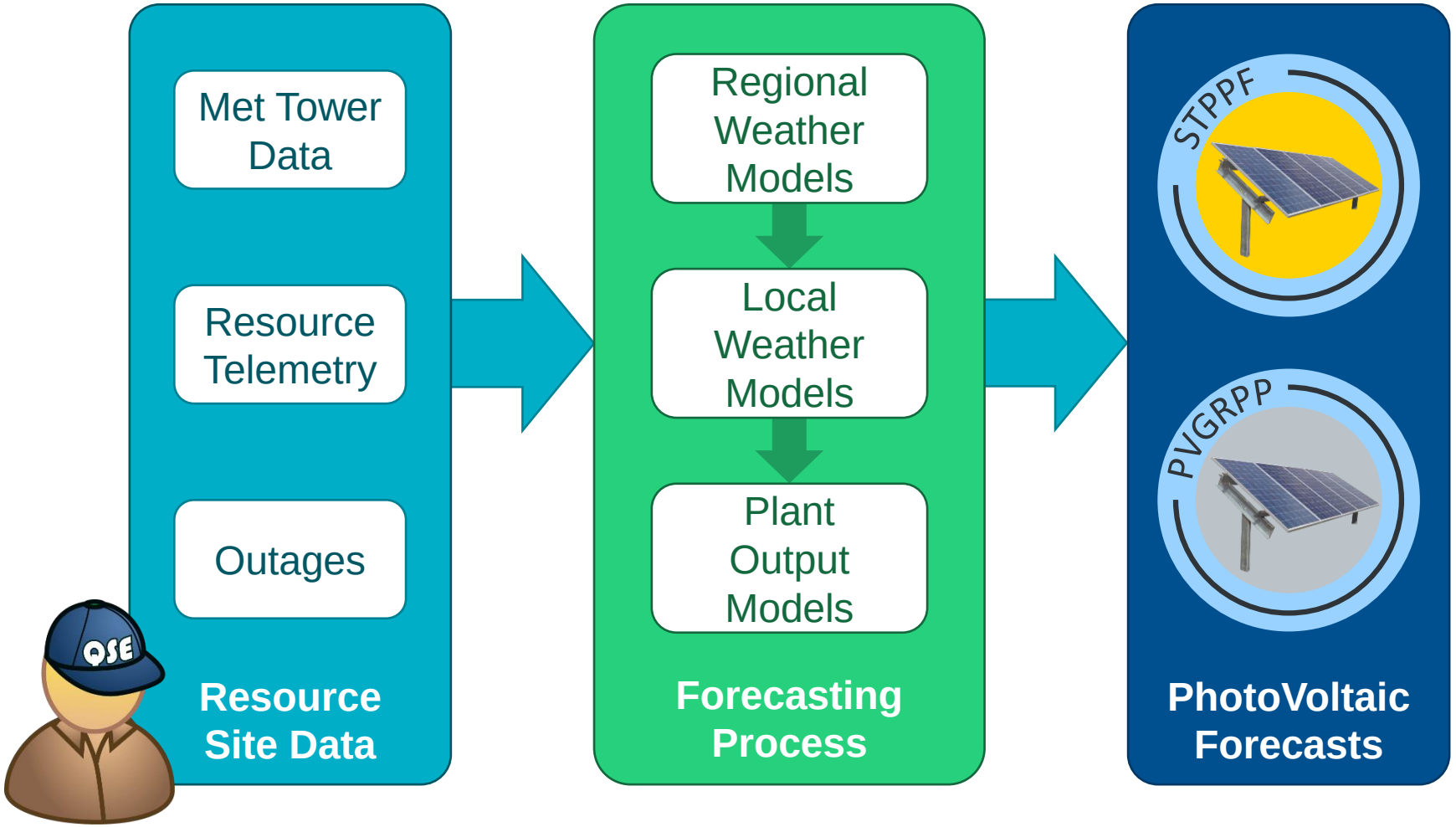
WGR Dusty Mesa has just entered commercial operation



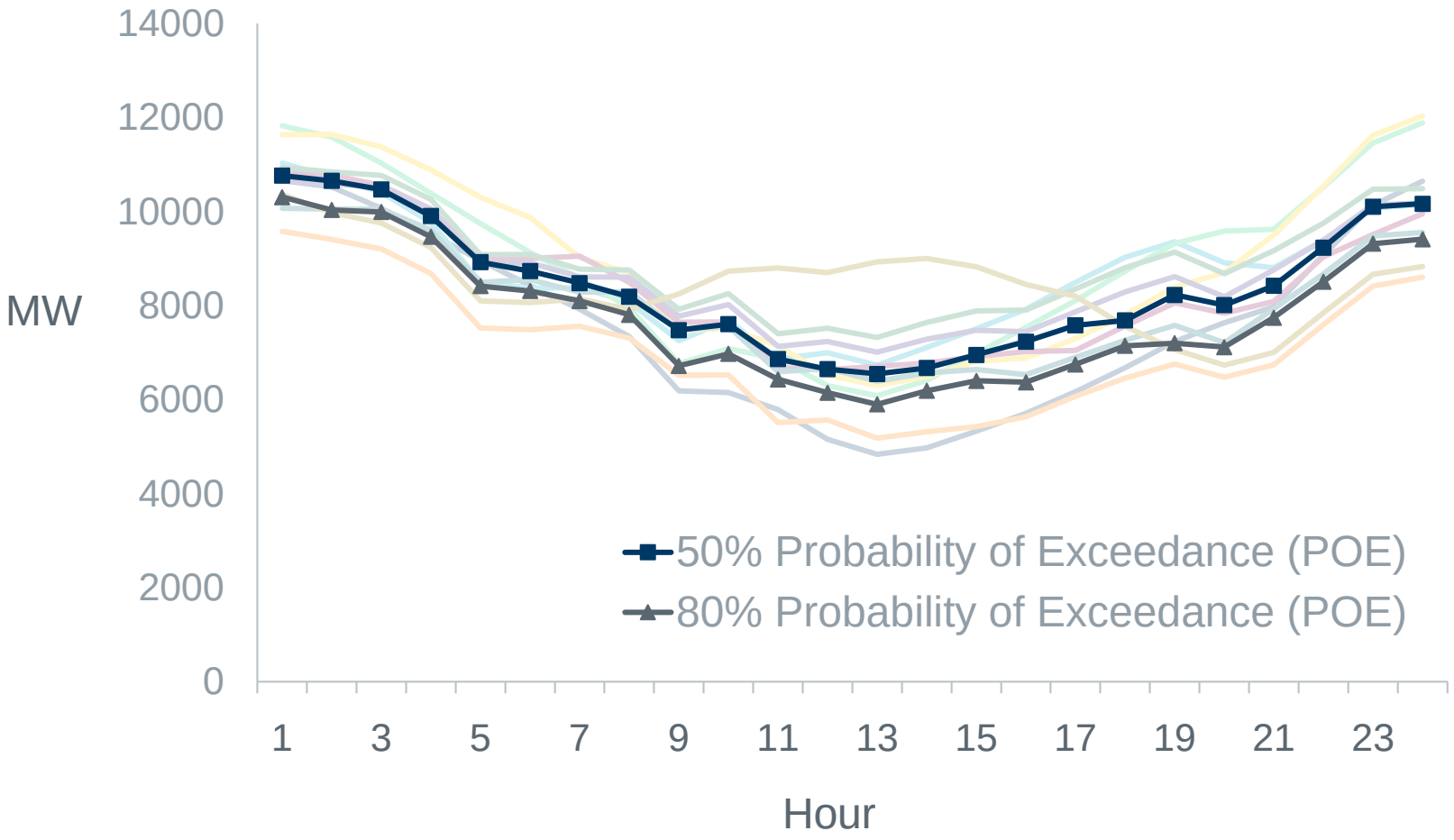
1. *What if telemetered power output is consistently low?*

2. *What if wind speed data is consistently low?*

PVGR Forecasting Summary



Ensemble of hourly forecasts



Short-Term Photovoltaic Power Forecast

- Rolling 168 hour forecast for each PVGR
- Used in reliability studies

PVGR Production Potential

- Rolling 168 hour forecast for each PVGR
- Used in financial settlements

Posted on MIS Hourly

- Individual WGR Forecasts
- Individual PVGR Forecasts

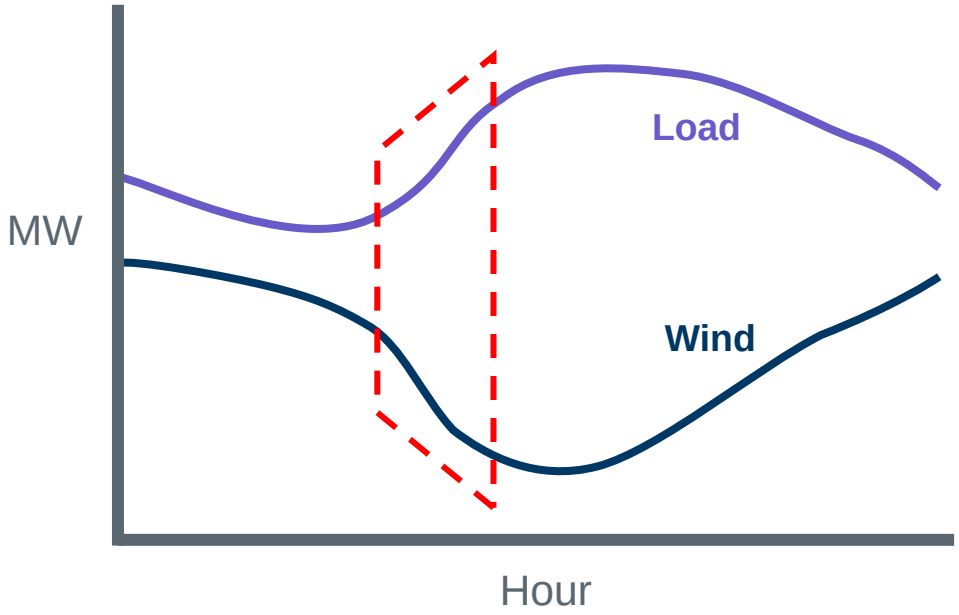
- Total WGR Forecasts
- Regional WGR Forecasts
- Total PVGR Forecasts
- Regional PVGR Forecasts

IRR Ramp Forecasting

Capacity Available Tool (CAT)

- Assesses risk of large increase in Net Load
- Estimates adequacy of scheduled Generation and Reserves to manage risk

CAT study window is six hours

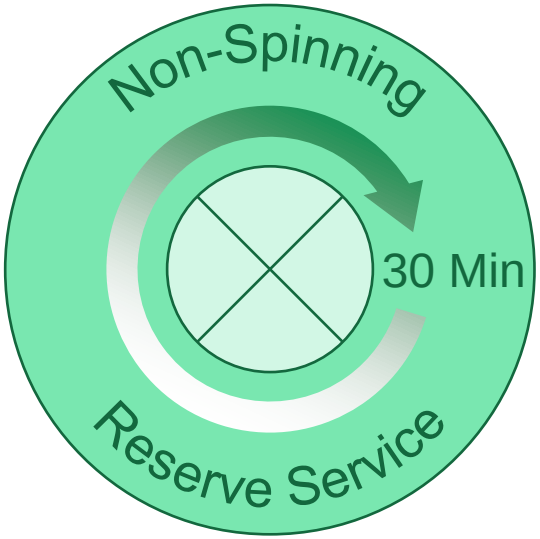


ERCOT Operators run CAT on demand

- Retrieves expected Generation schedules from COPs
- Considers historical forecast uncertainties
  - Wind
  - Solar
  - Load

ERCOT may take action to mitigate ramping risk

- Deploying Non-Spin Reserve
- Procuring additional Non-Spin Reserve
- Committing additional Resources through RUC



Module 4

IRRs in Market and System Operations

Topics in this module ...

- Preparing for Real-Time Operations
- IRRs during Real-Time Operations
- Dispatch Scenarios

Preparing for Real-Time Operations

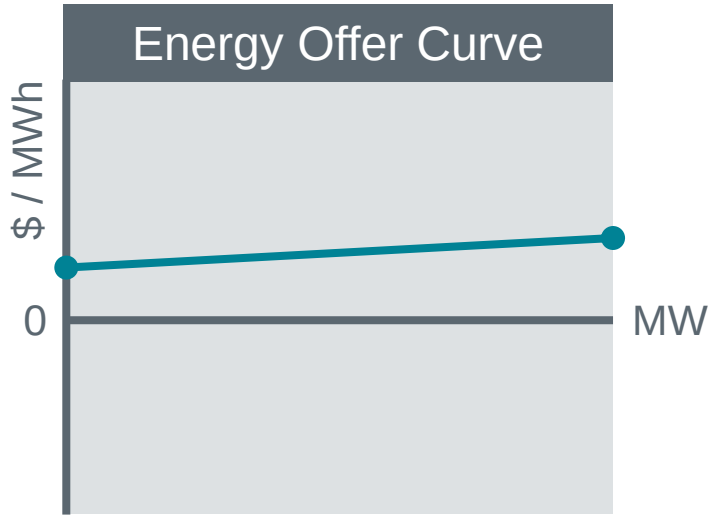
Preparing for Real-Time Operations

Submit Energy Offer Curves

Update Current Operating Plan

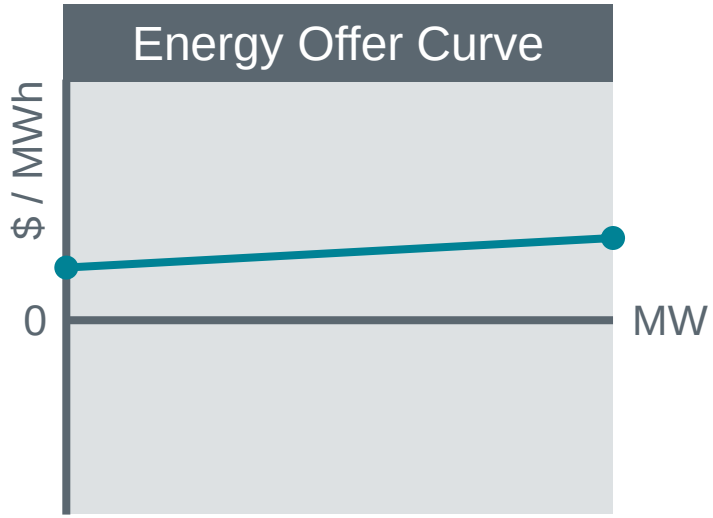
Energy Offer Curves for IRRs

- Priced between -$250/MWh and SWCAP
- May be submitted or updated until the end of the Adjustment Period



Discussion

What MW range should an IRR offer?



Preparing for Real-Time Operations

Submit Energy Offer Curves

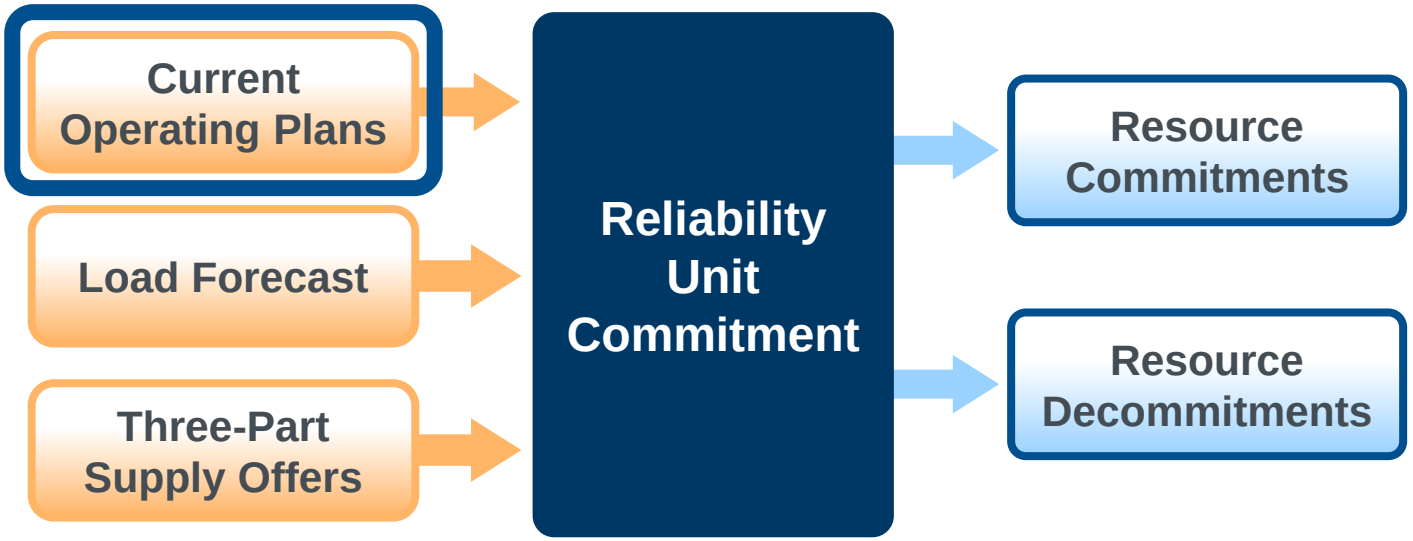
Update Current Operating Plan

QSE must maintain a Current Operating Plan (COP) for each Resource

- Reflects expected status and capabilities for each hour
- May be updated until the end of the Adjustment Period
- Must be updated within 60 minutes of any event that impacts status or capabilities

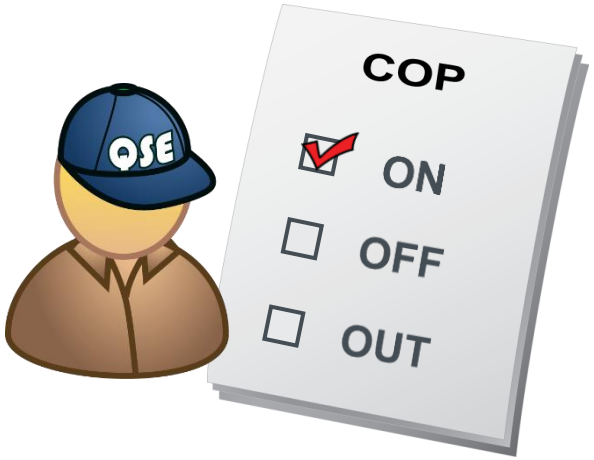
Reliability Unit Commitment (RUC) Process

- Which Resources are planned to run
- How much capacity each Resource contributes



Typical COP Statuses for IRRs

- **ON**: QSE has committed to run the Resource
- **OFF**: Resource is offline but available for commitment
- **OUT**: Resource is not available



Discussion

What is the expected HSL for an IRR?

Wind-Powered Generation Resource (WGR):

Photovoltaic Generation Resource (PVGR):

IRRs During Real-Time Operations

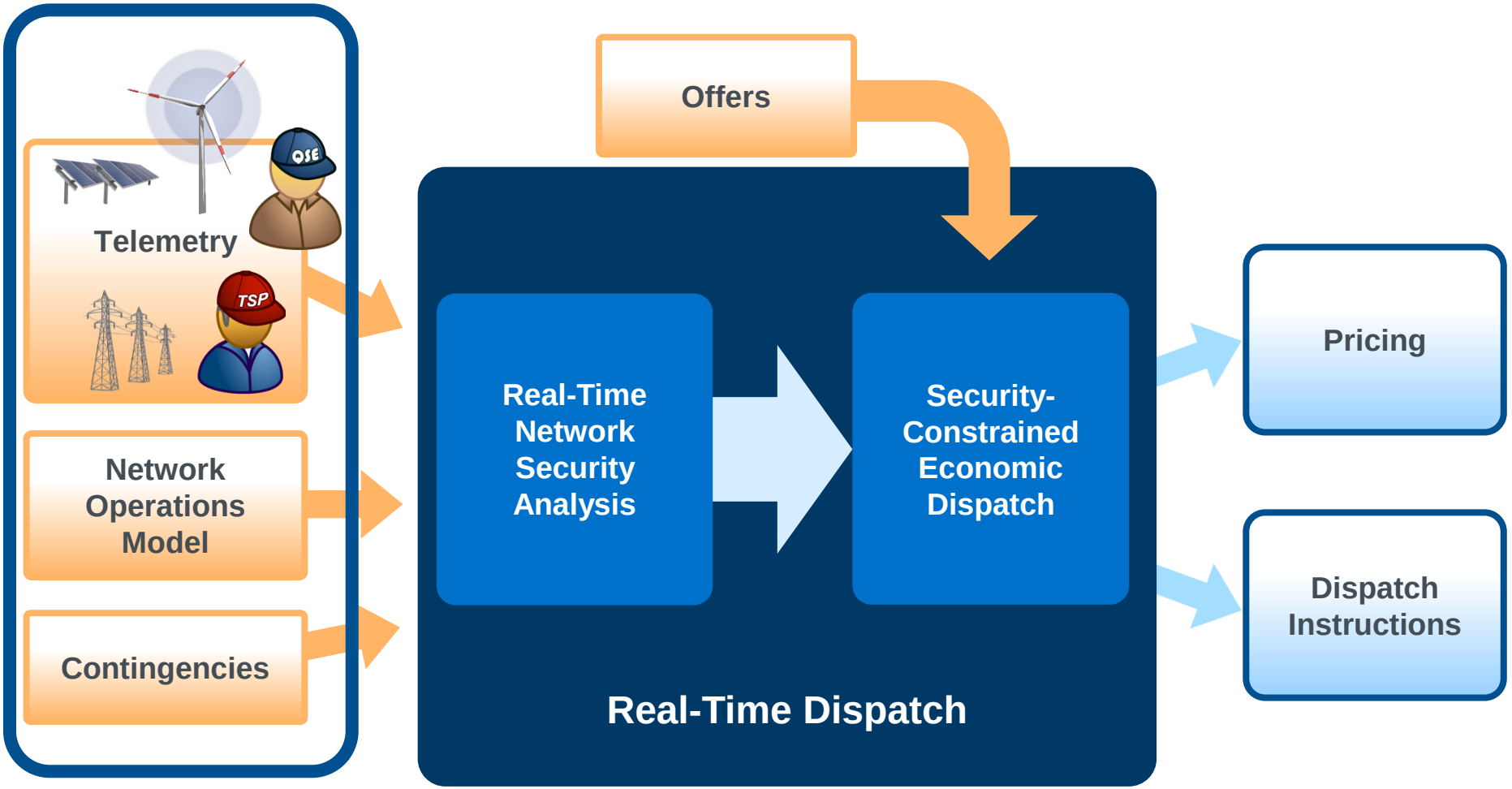
Goals of SCED

- Manage reliability
  - Resolve Transmission Constraints
  - Match generation with demand
- Operate the system at least cost

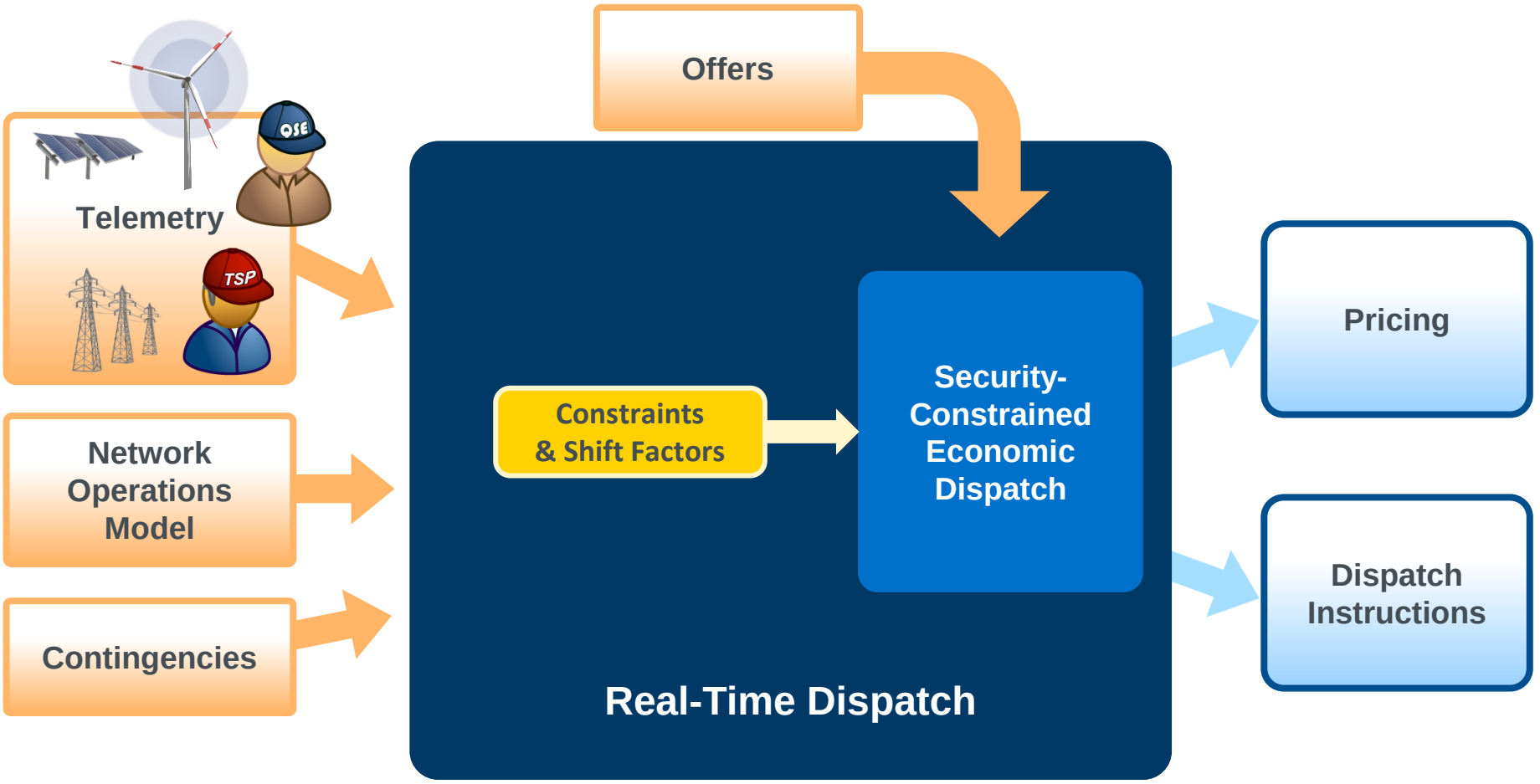
SCED dispatches all available Resources in a way that achieves these goals

SCED

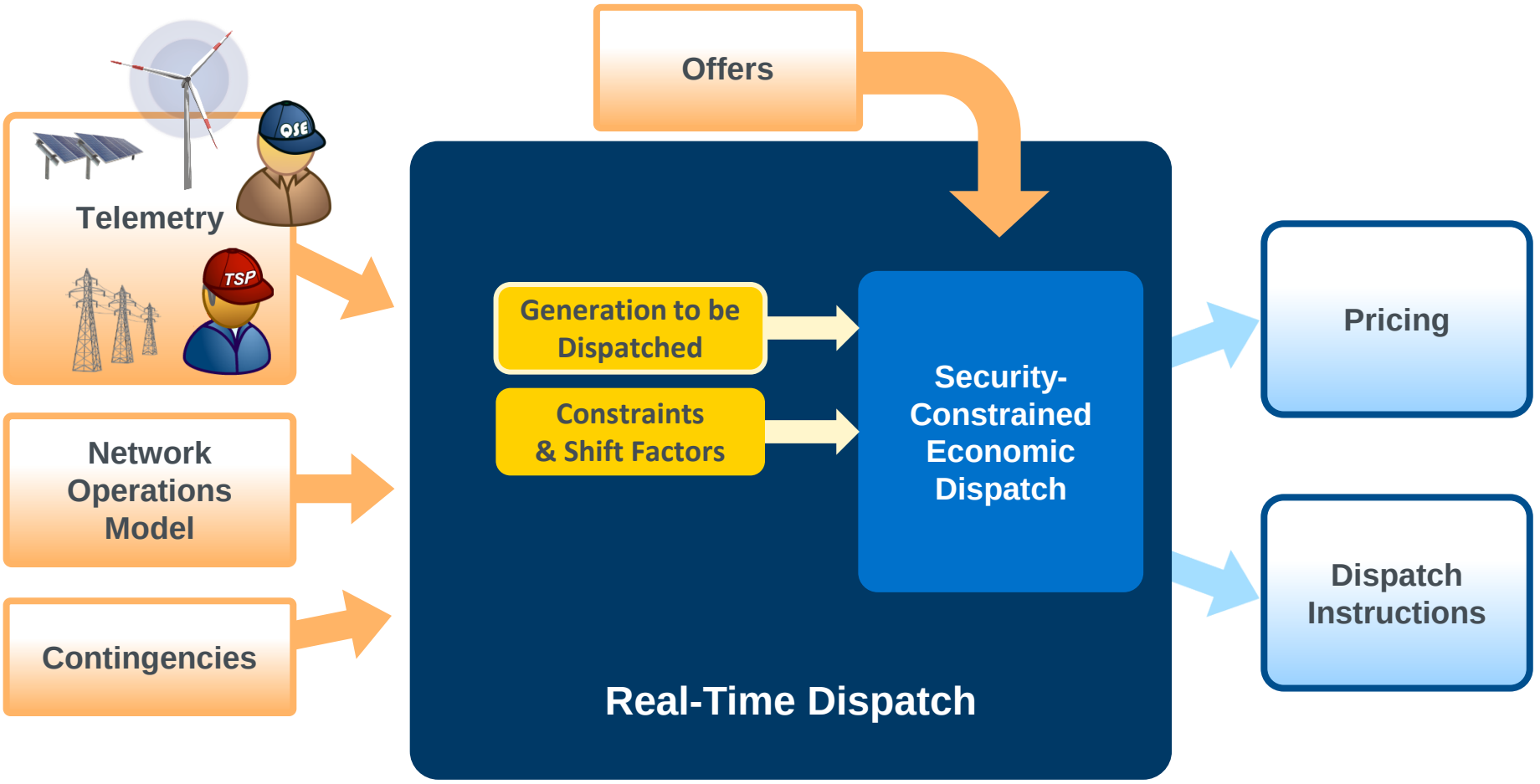
SCED requires multiple inputs



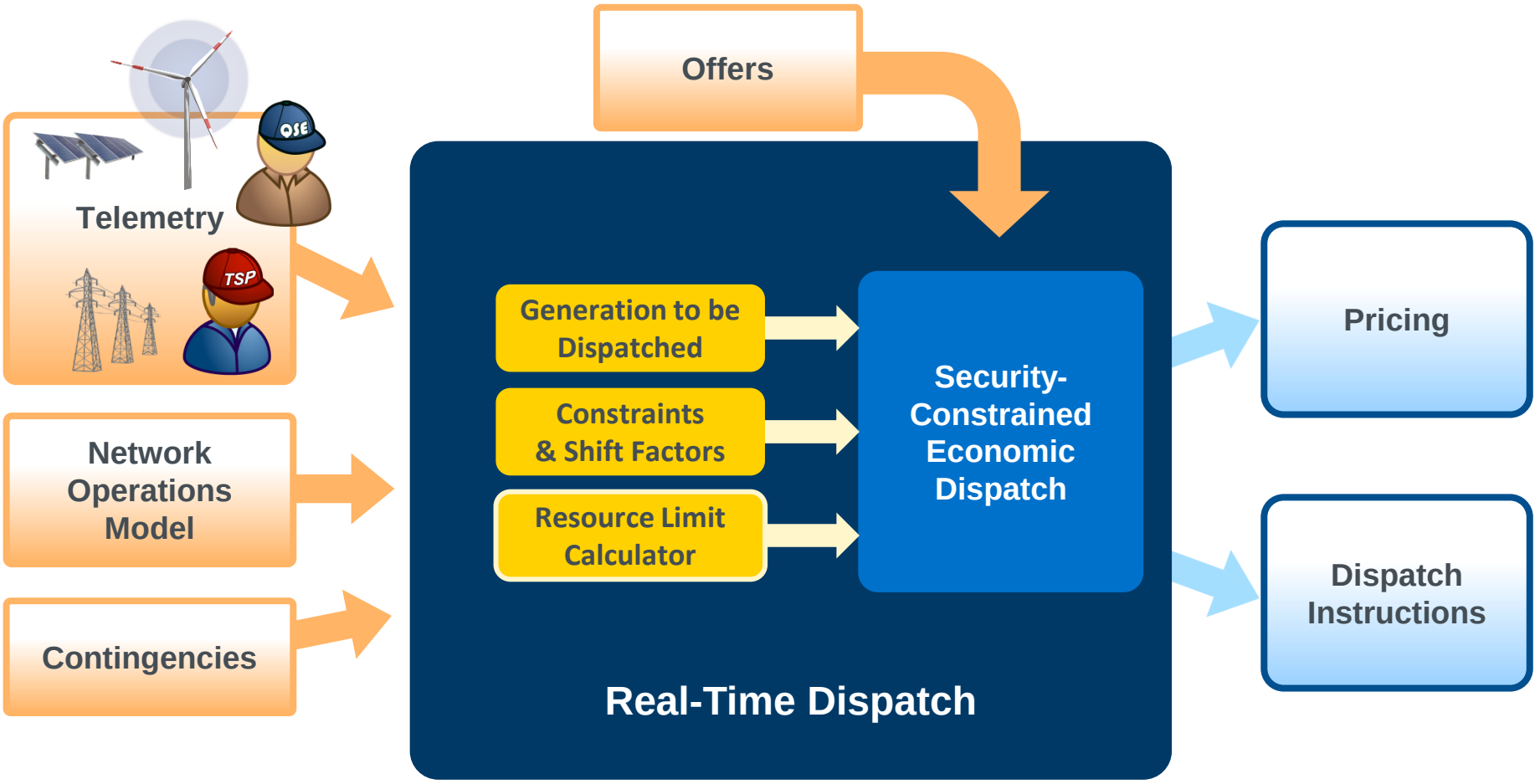
Security Analysis provides Transmission Constraints



Generation-to-be-Dispatched is the projected demand



Resource Limit Calculator determines Dispatch Limits

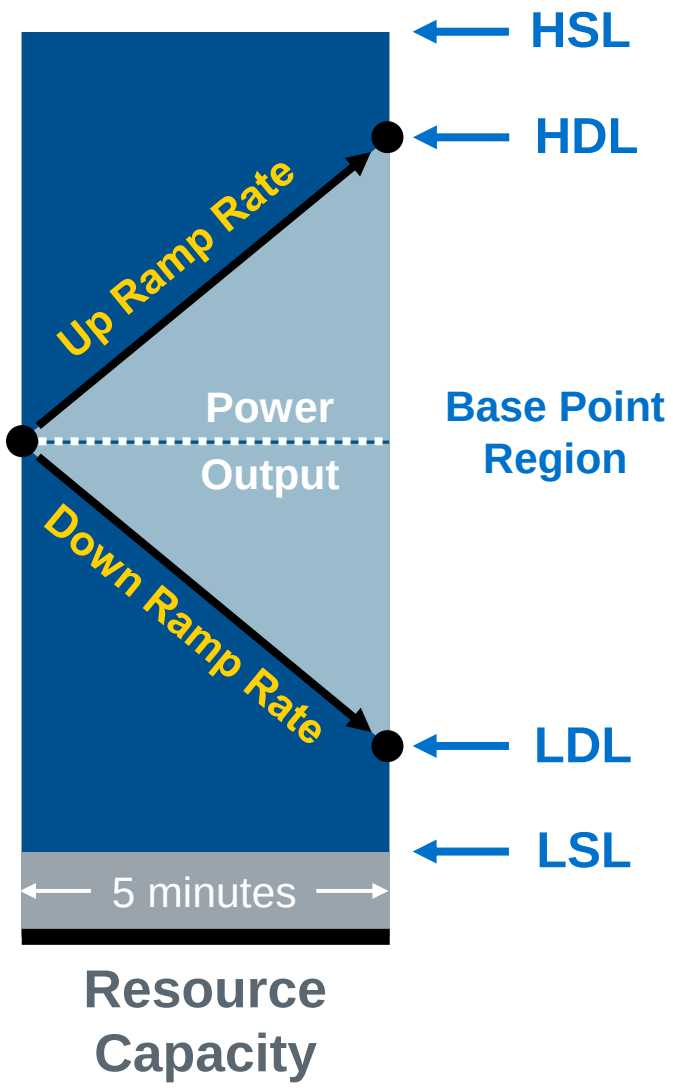


QSE Telemetry

- High Sustained Limit (HSL)
- Low Sustained Limit (LSL)
- Power Output
- Ramp Rates

Resource Limit Calculator

- High Dispatch Limit (HDL)
- Low Dispatch Limit (LDL)



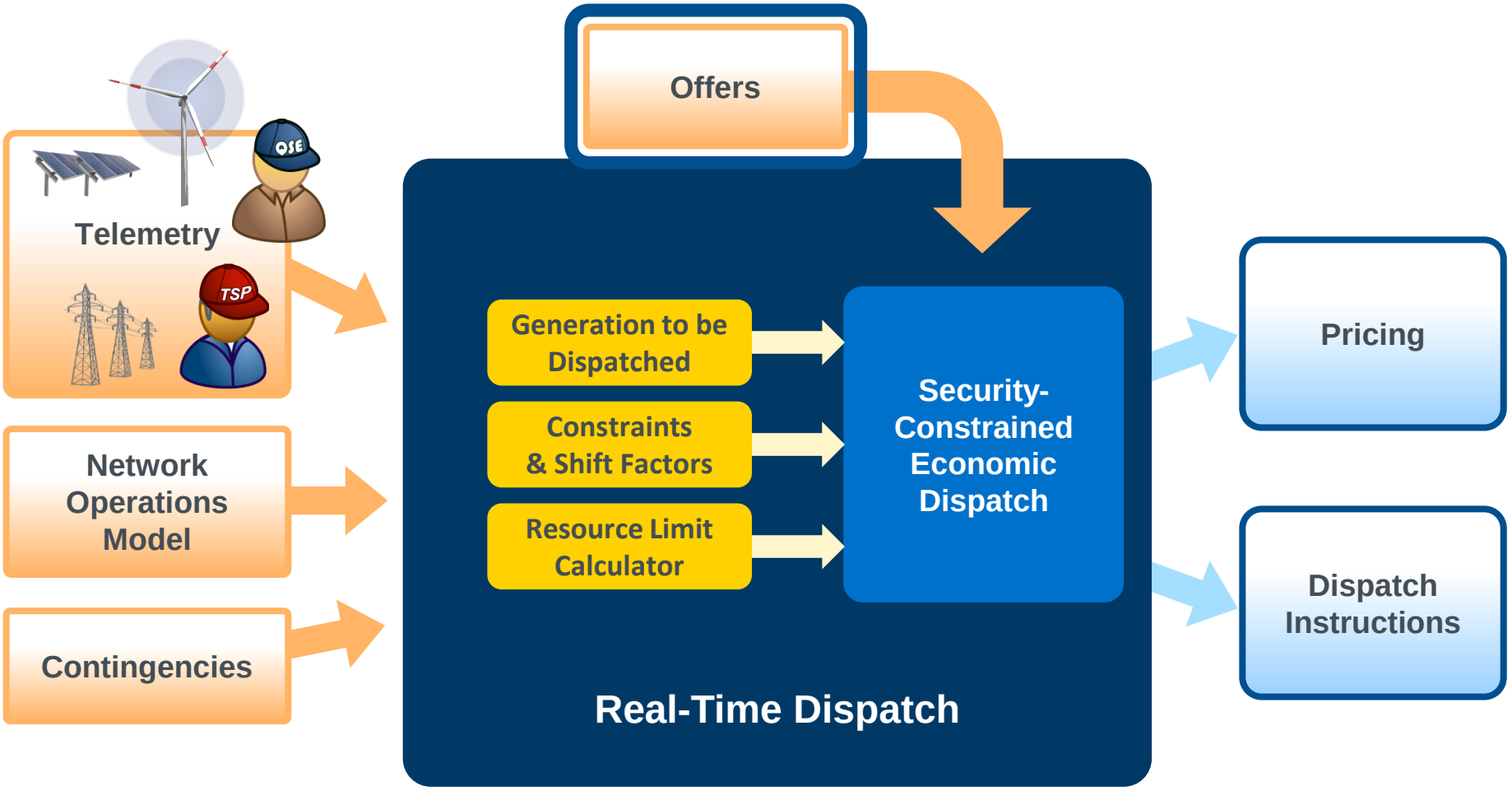
High Sustained Limit is not …

- Nameplate rating
- Max output under ideal conditions

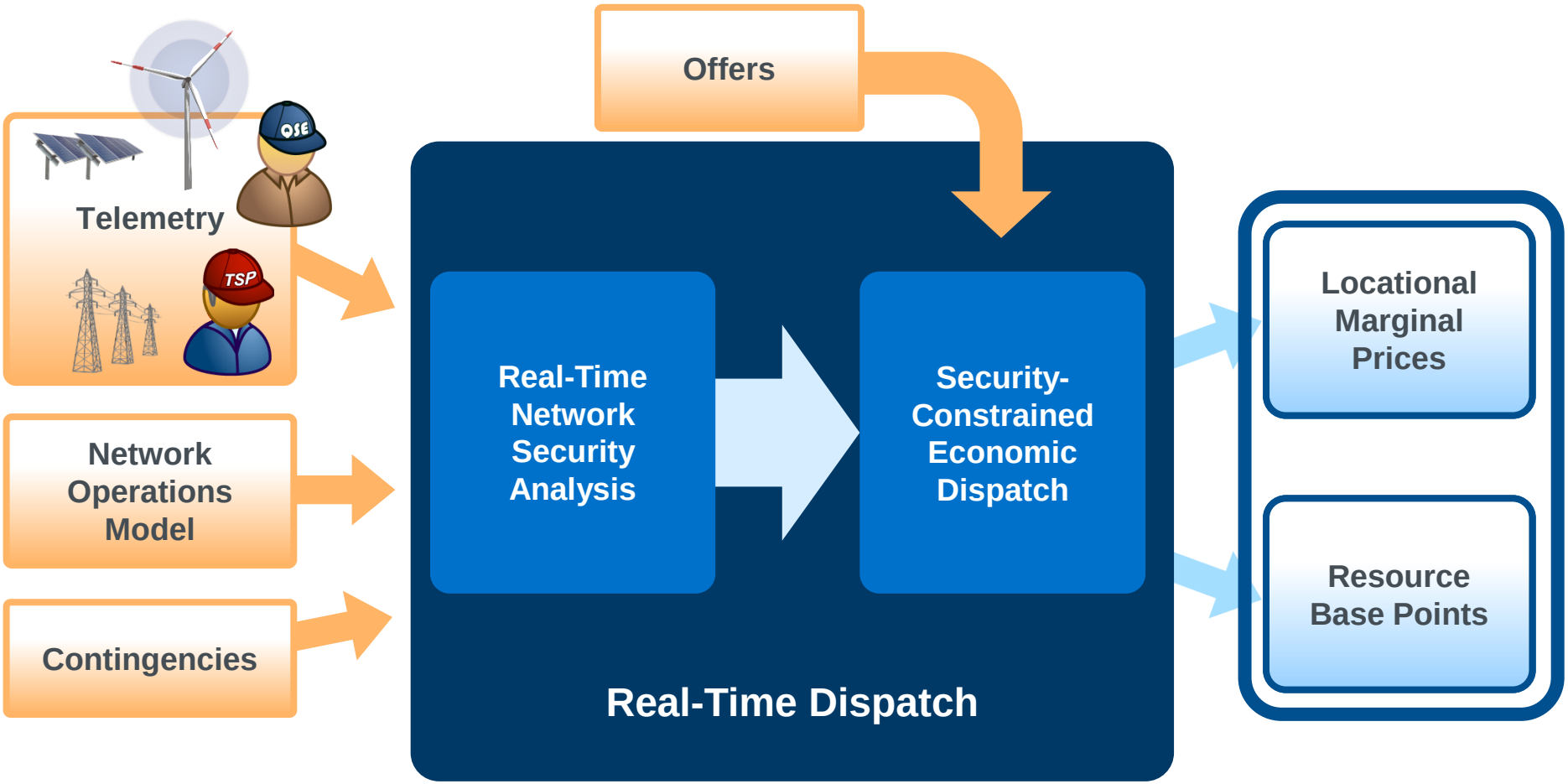
High Sustained Limit is …

- Current net output capability
- Based on current conditions
  - Wind / Irradiance
  - Turbines / Inverters online

Resource Offers provide cost information to SCED



Pricing and Dispatch Instructions



Goals of SCED

1. Dispatch to manage reliability
2. Operate the system at the least cost

Goals of IRRs

1. Dispatch to follow energy supply
2. Operate at max capability

Are IRR's goals competing with SCED's goals?

Discussion

Fitting a square peg into a round hole?

1. *How does a QSE tell SCED how much the IRR has to offer?*

2. *How can a QSE make SCED take everything the IRR has to offer?*

Dispatch Scenarios

Scenarios

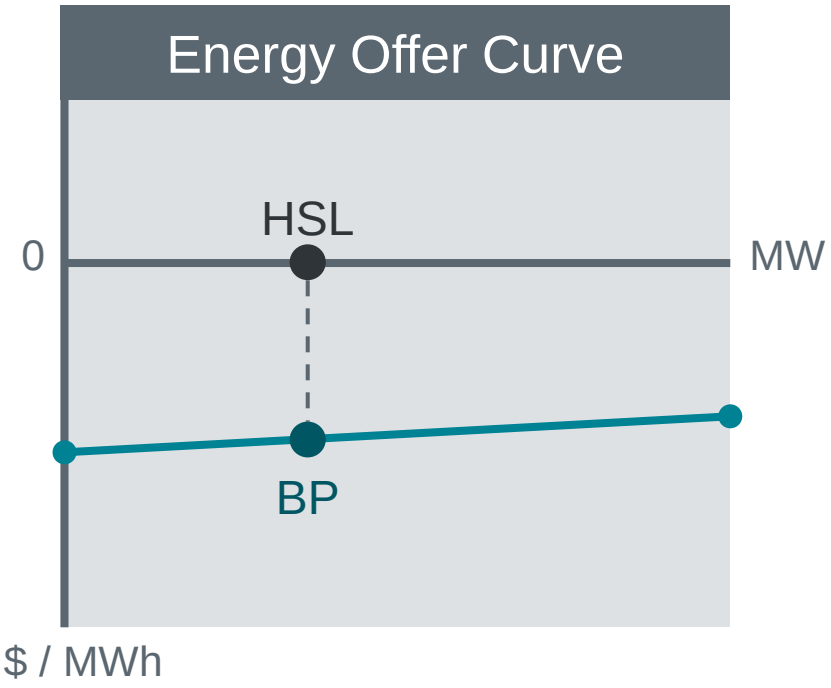
Real Time Dispatch of IRRs

1. IRR with Energy Offer Curve
2. Curtailed IRR with Energy Offer Curve
3. IRR is released from curtailment

Scenario 1

IRR is available for dispatch and not impacted by any binding constraints

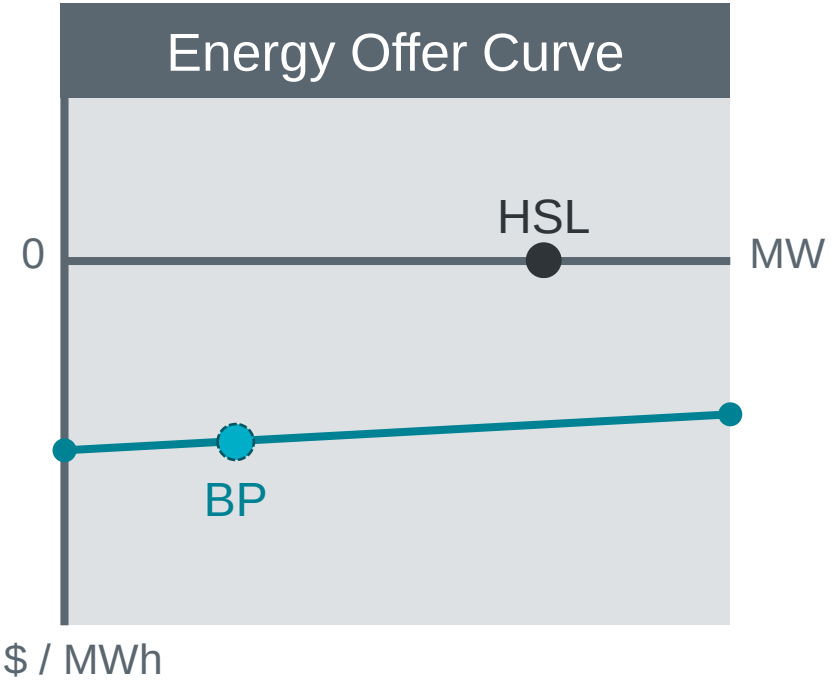
- IRR runs at HSL
- IRR is a “Price-Taker”
- Base Point follows HSL



Scenario 2

IRR has positive shift factor on a binding constraint and must be curtailed

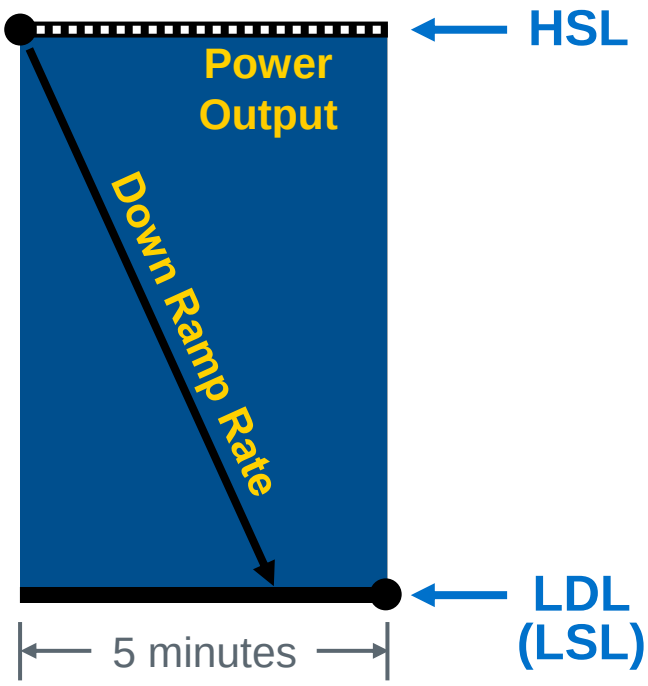
- Base Point is less than HSL
- IRR Energy Offer Curve sets LMP
- IRR must comply with Base Point



Scenario 2

IRR has positive shift factor on a binding constraint and must be curtailed

- SCED can move IRR from full output to any lower output in five minutes
- IRR must limit ramping to 20% of nameplate per minute

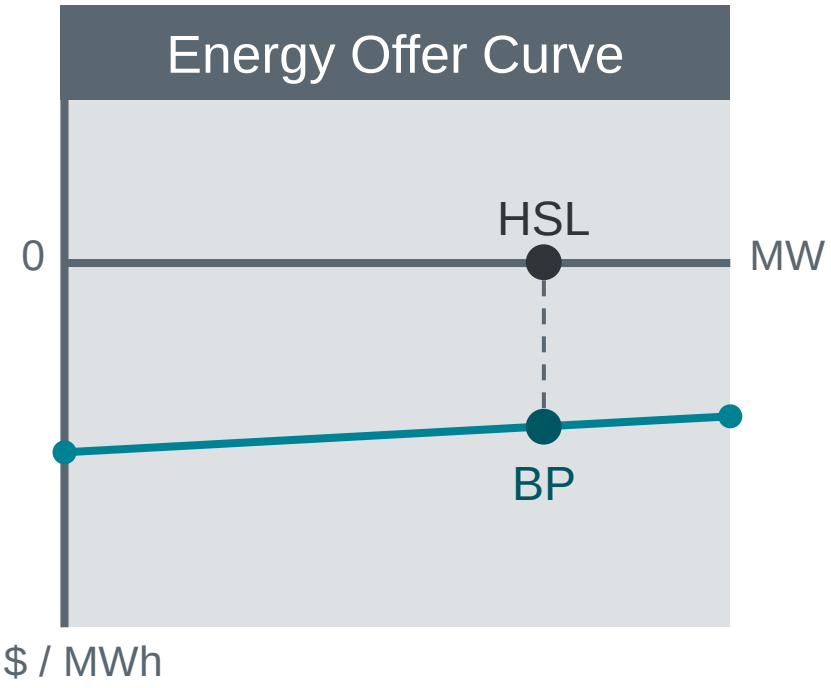


While curtailed, HSL should still represent current net output capability

Scenario 3

IRR has been curtailed because of a constraint. Curtailment is now lifted.

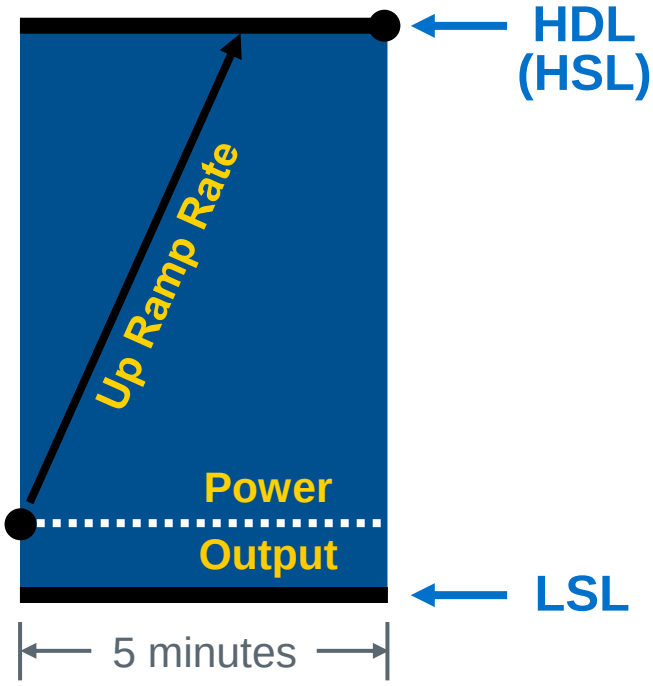
- IRR becomes a “Price Taker” once again
- SCED will set Base Point to HSL again



Scenario 3

IRR has been curtailed because of a constraint. Curtailment is now lifted.

- SCED can move IRR from curtailed output to full output in five minutes
- IRR must limit ramping to 20% of nameplate per minute



Module 5

Financial Settlements of IRRs

Topics in this module ...

- Real-Time Energy Imbalance
- Base Point Deviation Charge

Real-Time Energy Imbalance

Real-Time Energy Imbalance at a Resource Node:

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

$$+\ (-1)\left(\text{Metered Generation}\right)*\text{RTRMPR}$$

At a Resource Node,

RTSPP is used to settle financial transactions

$$\text{RTSPP} = \text{RTRSVPOR} + \text{RTRDP} + \text{Time-Weighted Average}\left[\text{LMPs}\right]$$

RTSPP	**R**eal-**T**ime **S**ettlement **P**oint **P**rice
RTRSVPOR	**R**eal-**T**ime **R**es**e**r**v**e **P**rice for **O**n-Line **R**eserves
RTRDP	**R**eal-**T**ime On-Line **R**eliability **D**eployment **P**rice

At a Resource Node,

RTRMPR is used to settle physical energy production

$$\text{RTRMPR} = \text{RTRSVPOR} + \text{RTRDP} + \left[\begin{array}{c}\text{(Base-Point * Time)}\\ \text{Weighted Average}\end{array}\ \text{LMPs}\right]$$

RTRMPR	Real-Time Resource Meter Price
RTRSVPOR	Real-Time Reserve Price for On-Line Reserves
RTRDP	Real-Time On-Line Reliability Deployment Price

Scenario 4

QSE Schedules Energy Trades on their IRR, Solaris Ventum

- 100 MW nameplate rating
- On-line continuously in Real-Time
- Trade Energy Sale of 40MW during Hour 1600
- During Interval 1515
  - Produces 10 MWh
  - RTSPP = $30.00
  - RTRMPR = $30.02

Scenario 4

Real-Time Energy Imbalance for Interval 1515:

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

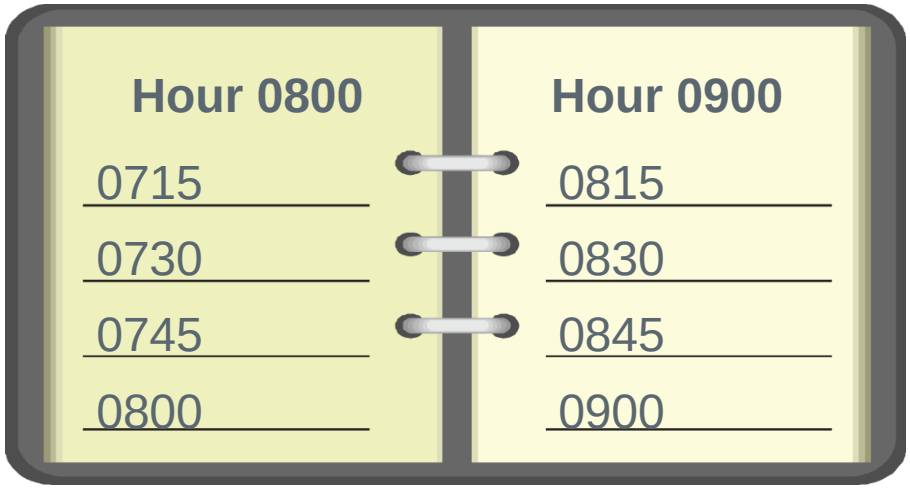
$$+\ (-1)\left[\text{Metered Generation}\right]*\text{RTRMPR}$$

Which simplifies and re-arranges to . . .

$$(-1)*\left[\text{Metered Generation}*\text{RTRMPR}-\left(\begin{array}{c}\text{DAM Energy Sales}\\+\\\text{Trade Energy Sales}\end{array}\right)*\text{RTSPP}\right]$$

Trades in Real-Time Energy Settlements

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



Trades must be multiplied by ¼ hour

Scenario 4

Real-Time Energy Imbalance for Interval 1515:

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

$$(-1) * \left[\quad ? \quad \right] = \quad ?$$

Base Point Deviation Charge

Key Differences between Intermittent Renewable Resources (IRRs) & other Resources

IRR must be Curtailed

- Curtailment Flag

IRR must be Over-Generating

- Telemetered generation
- Instructed Base Point

Wider tolerances for deviation from Base Point

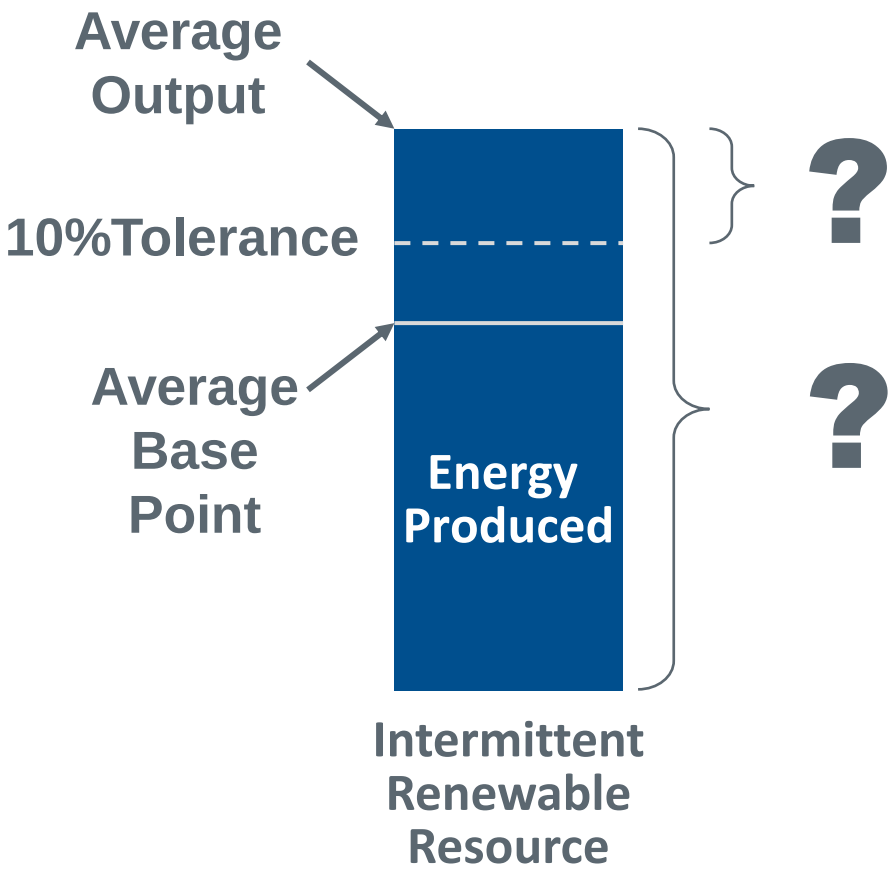
When are IRRs exposed to deviation charges?

	IRR output *within* 10% acceptable range	IRR output *exceeds* 10% acceptable range
Curtailment Flag is not set	No Charge	No Charge
Curtailment Flag *is* set	No Charge	***Charge***

IRR Groups are assessed as an aggregate

Scenario 5

IRR Solaris Ventum is curtailed. How is the QSE settled?



Course Wrap-Up

IRR Forecast and Actual Reports on ercot.com

Generation

This page provides current information on Generation Resources, including forecast and actual generation for Wind and PhotoVoltaic (Solar) Generation Resources; Resource Outages; Reliability Unit Commitment (RUC) constraints; Reliability Must Run (RMR) Resource deployments; Fuel Type; and aggregate High and Low Dispatch Limits (HDL, LDL) in the ERCOT region. The Key Documents section provides links to supporting documents related to resource asset registration, Outage scheduling, and monthly ERCOT Wind Integration Reports.

Intermittent Renewable Resources

Aggregated Solar Resource Power Potential Forecast
This report is posted every hour and includes System-wide STPPF and PVGRPP for On-Line PVGRs for the rolling future 168-hour period.

Hourly System-wide and Regional STWPF and WGRPP by Forecast Model
This report is posted every hour and includes system-wide and regional STWPF and WGRPP values produced by each forecast model for On-Line WGRs for the rolling future 168-hour period and also indicates which forecast model is used for each region to populate COPs.

Intra-Hour Wind Power Forecast By Geographical Region
Intra-Hour Wind Power Forecast (IHWPF) by wind region that provides a rolling two hour, five minute forecast of ERCOT-wide wind production potential.

Solar Power Production - Actual 5-Minute Averaged Values
This report is posted every 5 minutes and includes System-wide actual 5-minute averaged solar power production for On-Line PVGRs for a rolling historical 60-minute period.

Solar Power Production - Hourly Averaged Actual and Forecasted Values
This report is posted every hour and includes System-wide actual hourly averaged solar power production, STPPF, PVGRPP, and COP HSLs for On-Line PVGRs for a rolling historical 48-hour period as well as the System-wide STPPF, PVGRPP and COP HSLs for On-Line PVGRs for the rolling future 168-hour period.

Wind Power Production - Actual 5-Minute Averaged Values
This report is posted every 5 minutes and includes System-wide and Regional actual 5-minute averaged wind power production for a rolling historical 60-minute period.

Wind Power Production - Hourly Averaged Actual and Forecasted Values
This report is posted every hour and includes System-wide and Regional actual hourly averaged wind power production, STWPF, WGRPP and COP HSLs for On-Line WGRs for a rolling historical 48-hour period as well as the System-wide and Regional STWPF, WGRPP and COP HSLs for On-Line WGRs for the rolling future 168-hour period.

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IRR Integration Reports on ercot.com

ercot

About ERCOT | Services | Committees and Groups | Market Rules | Market Information | Grid Information | Market Participants

Home > Grid Information > Generation > Wind and Solar Integration Reports

Wind and Solar Integration Reports

These reports provide a system-wide overview of wind and solar generation at ERCOT. The reports and their contents are listed below.

Dashboards

Combined Wind and Solar
Combined Wind and Solar is a graphical representation of the most recent estimated wind and solar power production amounts for the Current Operating Day (COP).

Reports

IRR Forecasting Process
Describes the process used to forecast IRR capacity on a rolling 168 hour basis.

PVGR Integration Report
Contains high-level statistical highlights of solar generation and penetration, including daily peak load and solar penetration during that hour, as well as daily and all-time peak solar generation and penetration. Also provides graphs displaying: actual solar output vs. actual load, over a day; actual solar output as a percentage of the total installed solar capacity; actual solar output as a percentage of the ERCOT load; and actual solar output vs. ERCOT load, for the week prior to the report's creation.

Wind Integration Report
Contains high-level statistical highlights of wind generation and penetration, including daily peak load and wind penetration during that hour, as well as daily and all-time peak wind generation and penetration. Also provides graphs displaying: actual wind output vs. actual load, over a day; actual wind output as a percentage of the total installed wind capacity; actual wind output as a percentage of the ERCOT load; and actual wind output vs. ERCOT load, for the week prior to the report's creation.

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 Market Education Contact
Training@ercot.com

Scan this QR code to take the course survey!

https://www.surveymonkey.com/r/ERCOTILT