

# **Beyond Real Time: the Computational Challenges of Forecasting Dynamic Line Ratings**

Highly Accurate Predictions of  
Tomorrow's Transmission Capacity,  
Integrated with Economic Dispatch

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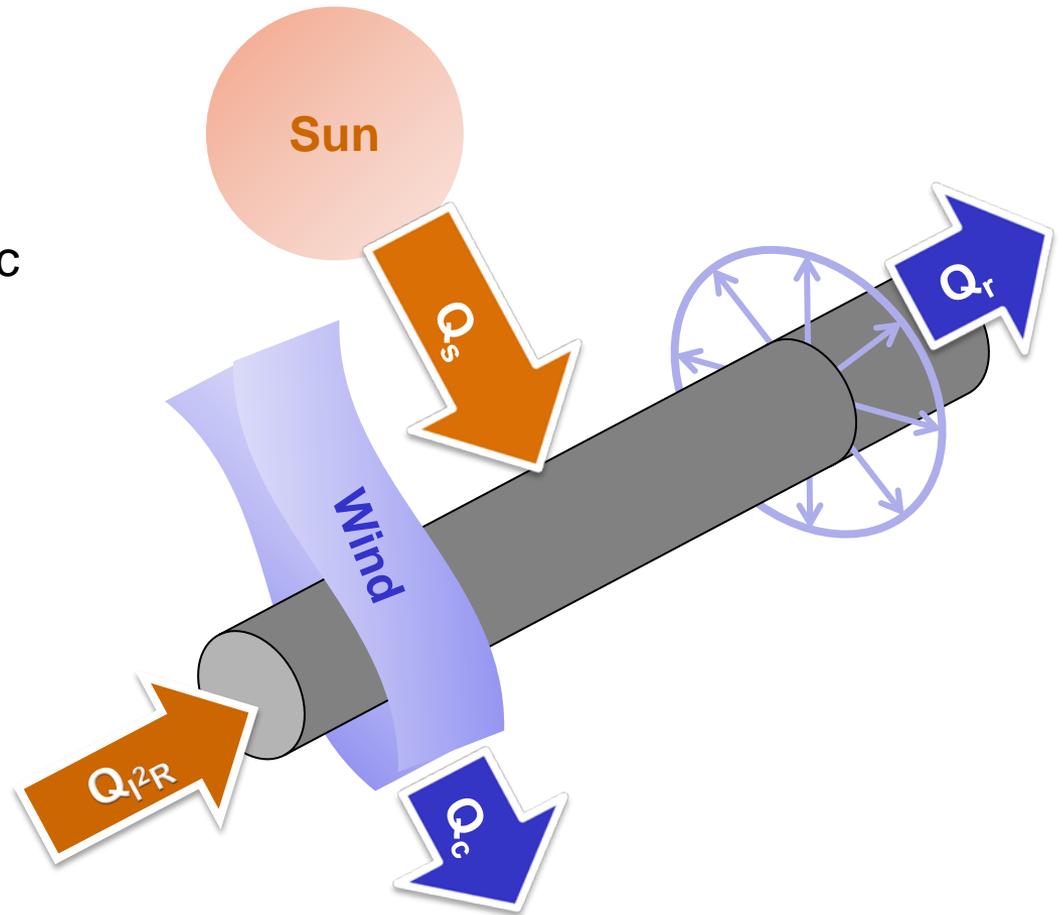
- Dynamic Line Rating (DLR) Concept Review
- Potential applicability of DLR Forecasts
- Case Study
  - Input: geography, line complexity, weather, thresholds
  - Output: binary and confidence
  - Results: usability metrics
- Future market integration of DLR Forecasts

IEEE 738

$$\Delta T = I^2 R + Q_s - Q_r - Q_c$$

$$Q_c = I_{\text{meas}}^2 R - Q_s + Q_r - \Delta T$$

$$I_{\text{max}}^2 R = \Delta T - Q_s + Q_r + Q_c$$

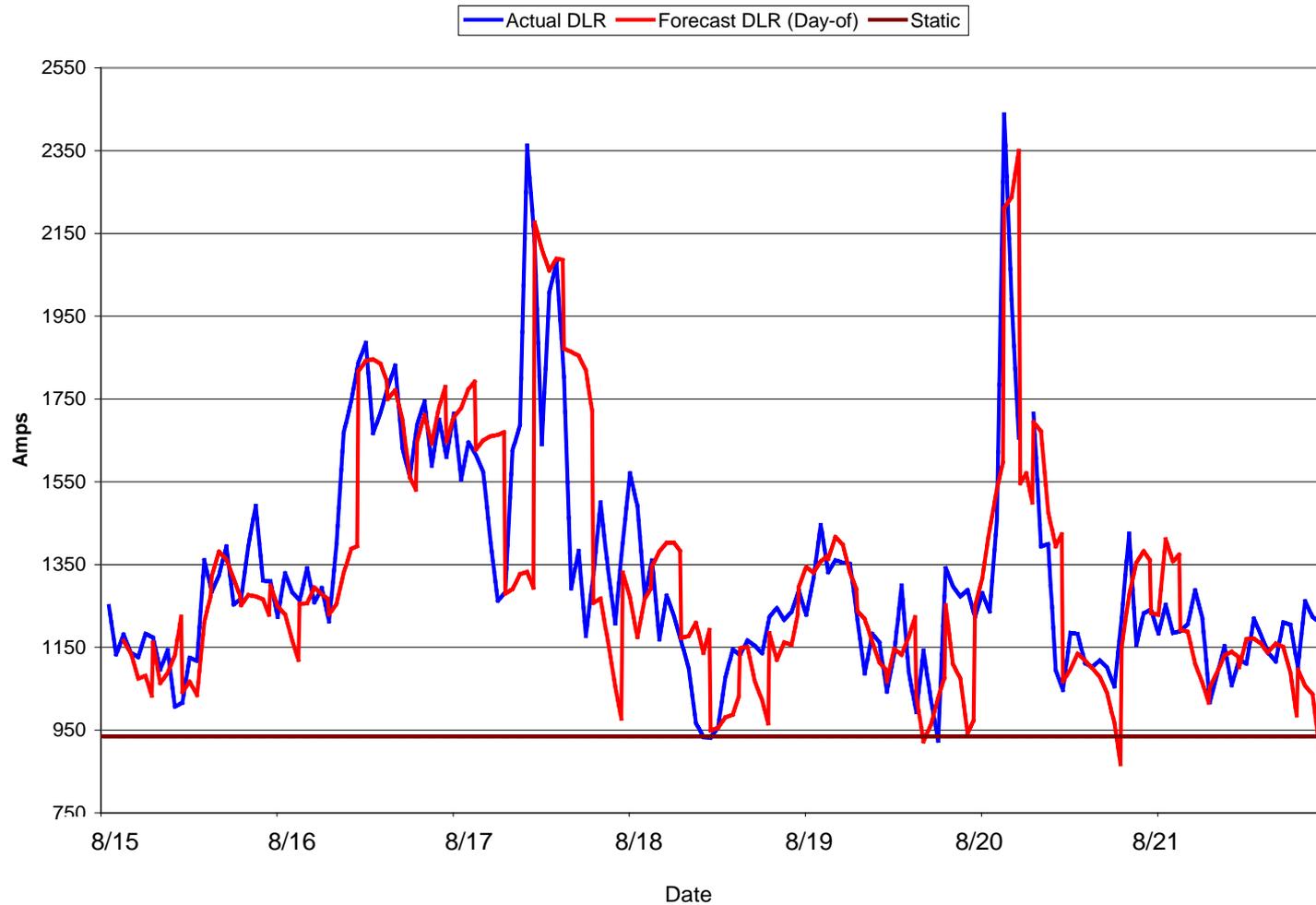


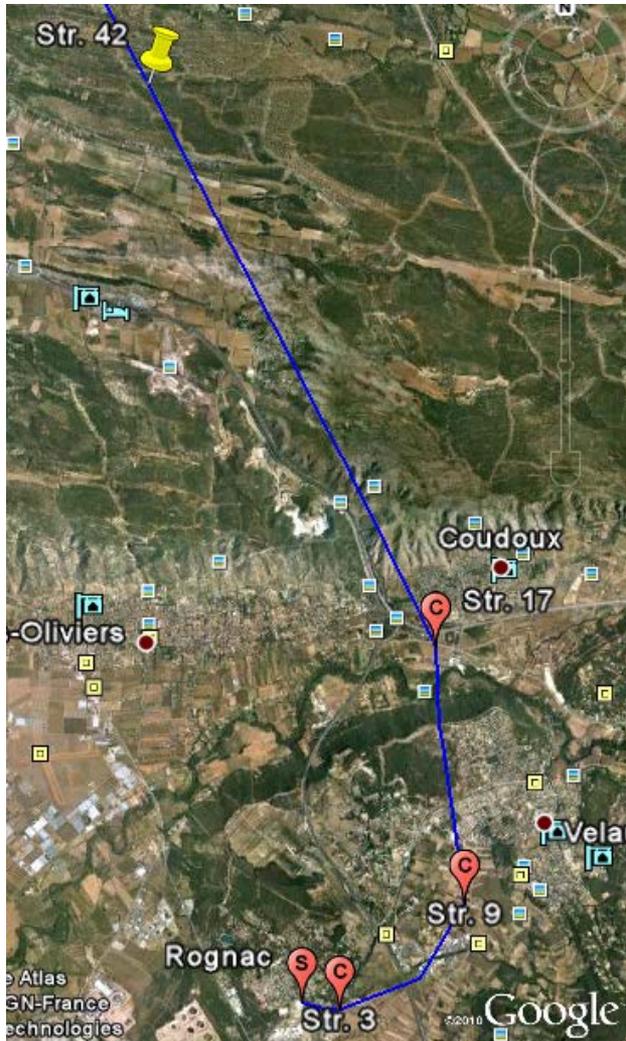
Parameters	Static Ratings	Dynamic Ratings
Solar and Ambient Conditions	Assumed	Measured
Wind Speed	Assumed	Calculated
Tension	Assumed	Measured
Sag or Clearance	Assumed	Calculated
<b>Maximum Rating</b>	<b>Artificially limited to worst case scenario</b>	<b>Calculated based on measured conditions</b>

- DLR Applications
  - KCPL: reduced redispatch on the LaCygne-Stilwell Flowgate
  - Oncor/ERCOT: \$1.46m in single-day congestion savings with 10% incremental capacity on 6 lines
  - Europe: Ice detection
  - Pacificorp: Improve wind deliverability
- Additional Applications with Forecasted DLR
  - Avoid unnecessary or uneconomic dispatch
  - Reduce day ahead congestion and LMPs
- Both
  - Postpone transmission upgrades
  - Bridge between initial capacity need and construction completion
  - Facilitate transmission maintenance

- Provide high accuracy and operationally useful predictions
  - Low Error of 2-3%
  - High Usability of 97-98%
  - Configurable Thresholds and Confidence Levels
  - Integrates with EMS
- Provide timely predictions for markets and operations
  - For day ahead and day of operations
  - For day ahead and day of markets

# Result: Successful Day-of DLR Predictions





- Southeast France
- 225 kV line
- Multi-Week Study
- Multiple forecast algorithms tested



## THE CONSTANT DEVELOPMENT OF TESTS ON THE GROUND

As part of its public-service duties, RTE provides its support to prototype operations whose appropriateness cannot be determined until they have been used under real conditions on the ground.

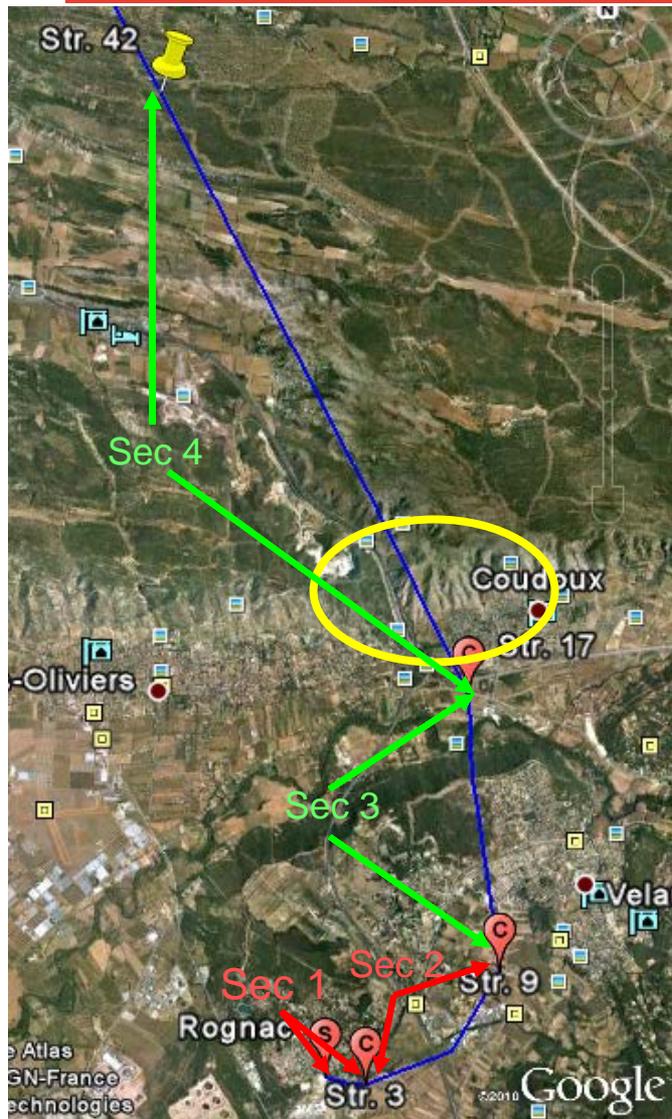
An innovation could allow units within the electrical system to overcome lmap limits (maximum permissible current under steady-state operating conditions), which are strict limits that guide the daily actions

of the dispatchers. This involves a system of real-time monitoring that the teams from the South-East Electrical System have been using for non-operational tests on the 225 kV Rognac-Roquerousse line since last summer.

It is an ongoing measurement of the mechanical tension of the conductor which, from calculations concerning the deflection and the weather conditions, is trans-

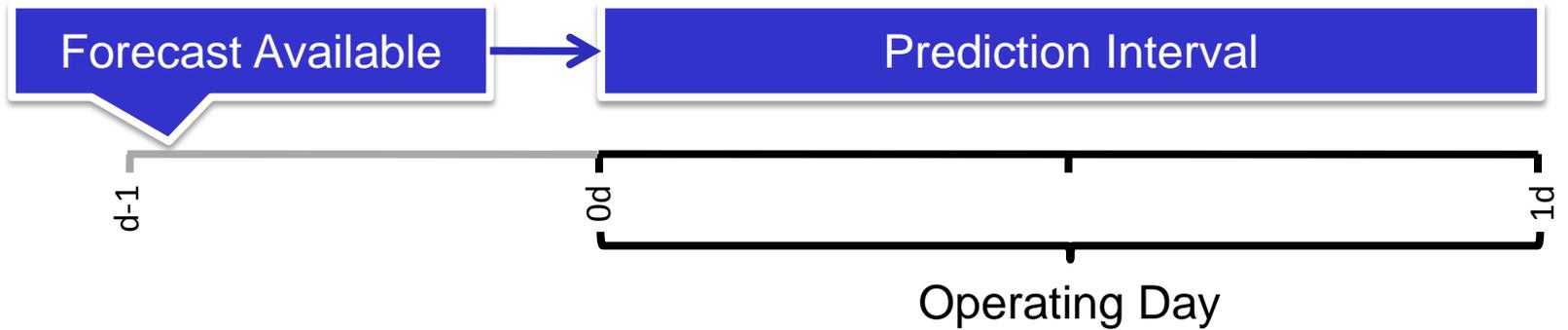
lated into an available transit capacity. In other words, the lmap would no longer be established according to probabilistic calculations, but by taking into account the real distance of the cable from the ground.

The success of these tests could lead to changes in the regulations relative to the control of the network.

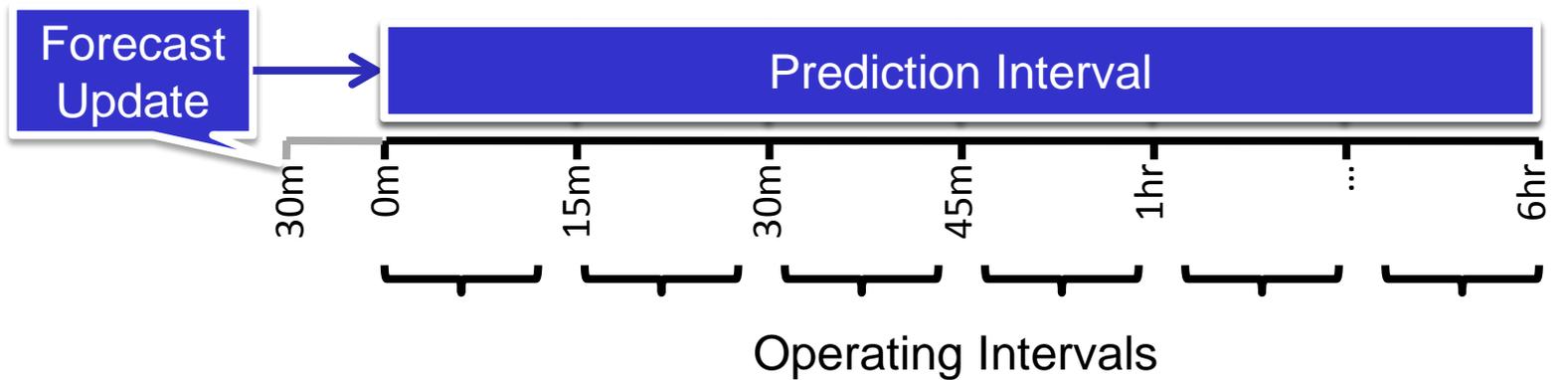


- Green (Sec 3 and 4) shows sections with simple line geometry—Straight with many spans
- Red (Sec 1 and 2) shows sections with complex line geometry. Sec 1 has only 3 spans. Sec 2 has a kink in it and only has 6 spans
- Yellow circle shows where line crosses somewhat abrupt elevation change

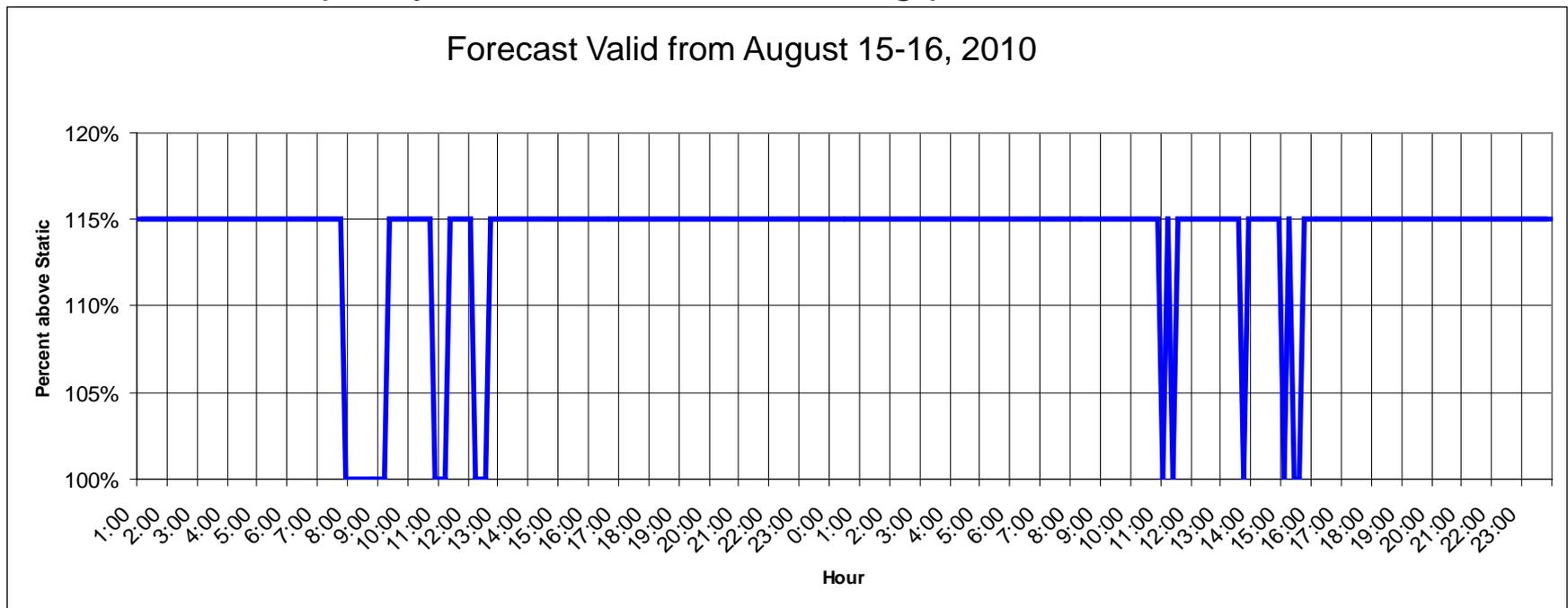
Day Ahead



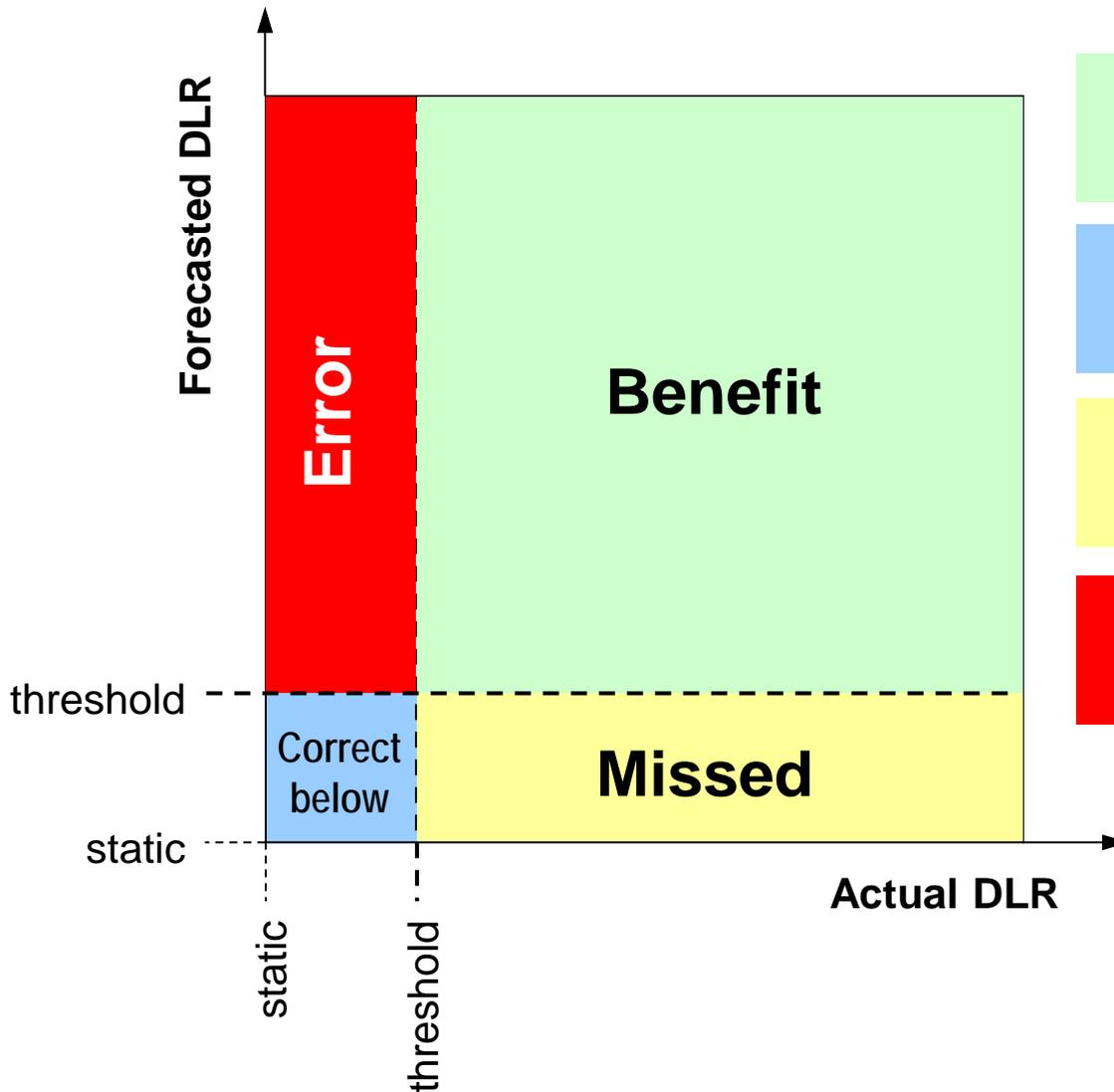
Day Of



- Computationally efficient way to use forecasts.
- One method called the 'Binary Rating Forecast' provides a 'go' or 'no go' decision on future capacity based on a set threshold.
- A threshold is a level set above static by the utility, operator, or ISO.
- The 'Binary Rating Forecast' is a time series of binary outputs showing when increased capacity above threshold is being predicted.



# Output: Binary Rating Forecast Concept



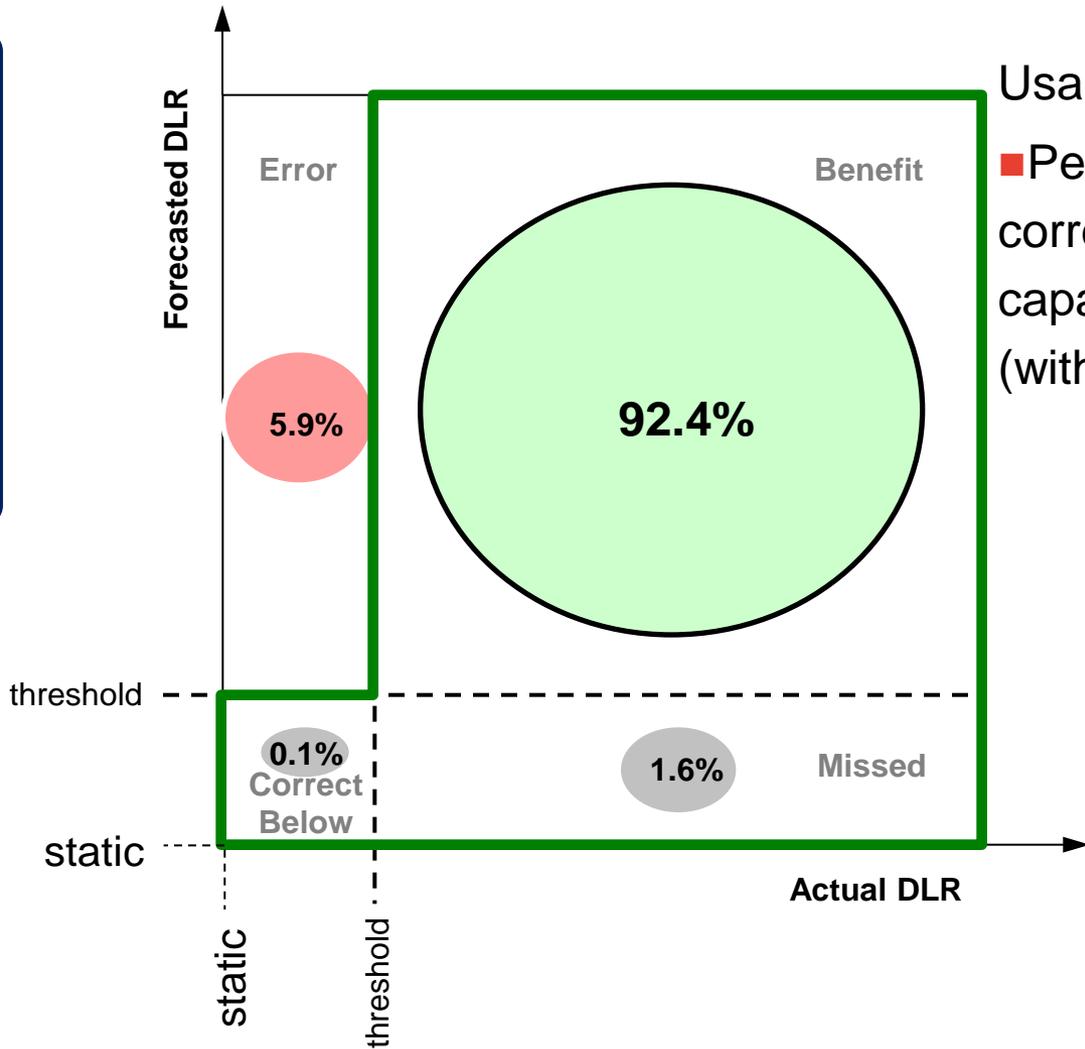
1. Forecast > Threshold  
Actual DLR > Threshold

2. Forecast < Threshold  
Actual DLR < Threshold

3. Forecast < Threshold  
Actual DLR > Threshold

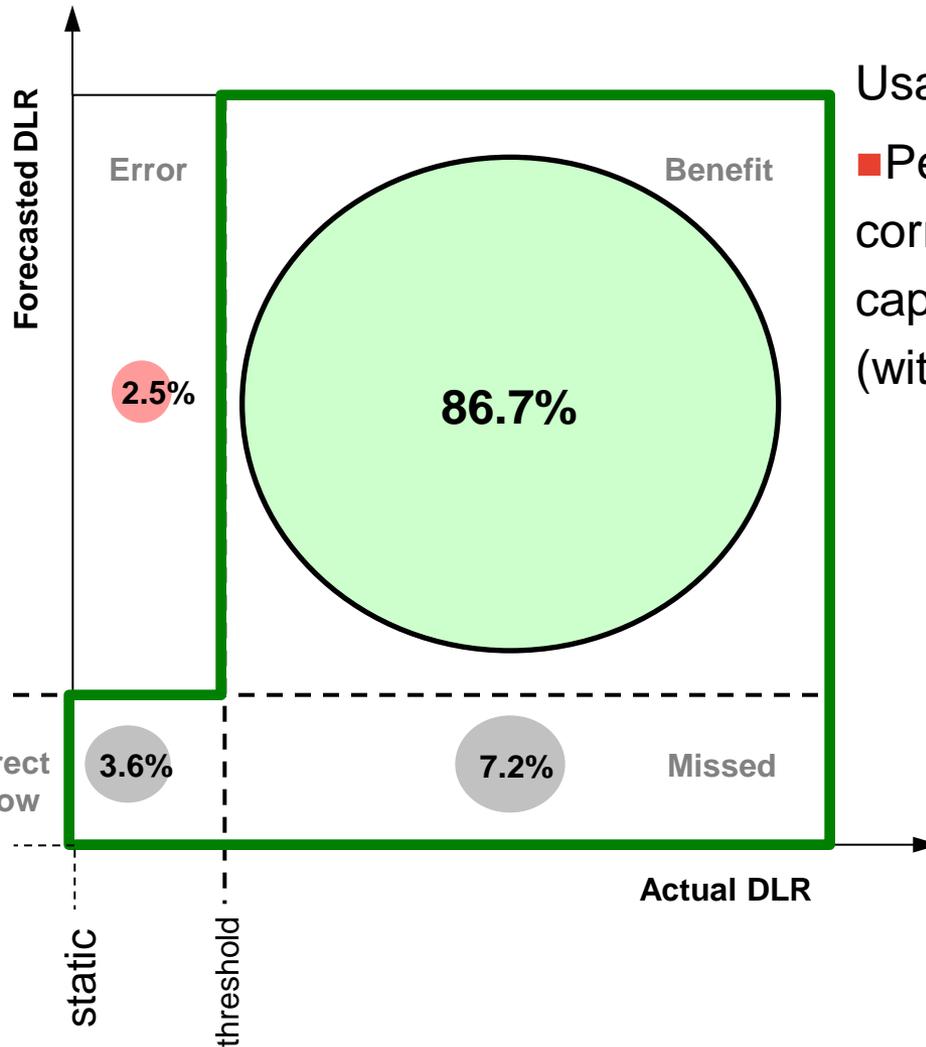
4. Forecast > Threshold  
Actual DLR < Threshold

Day Ahead



Usability = 94.1%

■ Percent of time that forecast is correctly providing increased capacity or not requiring mitigation (within Green Polygon).

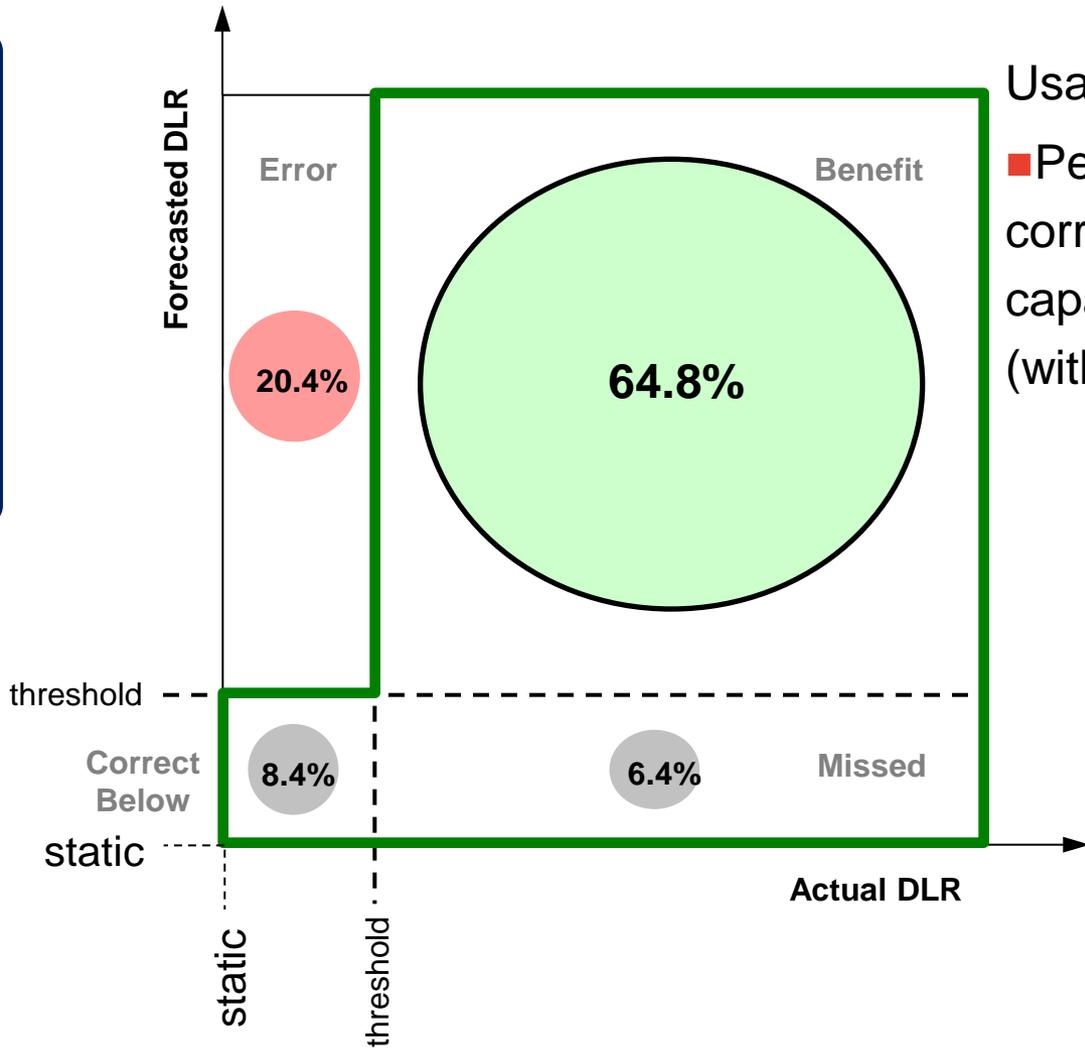


Usability = 97.5%

■ Percent of time that forecast is correctly providing increased capacity or not requiring mitigation (within Green Polygon).

Day Of

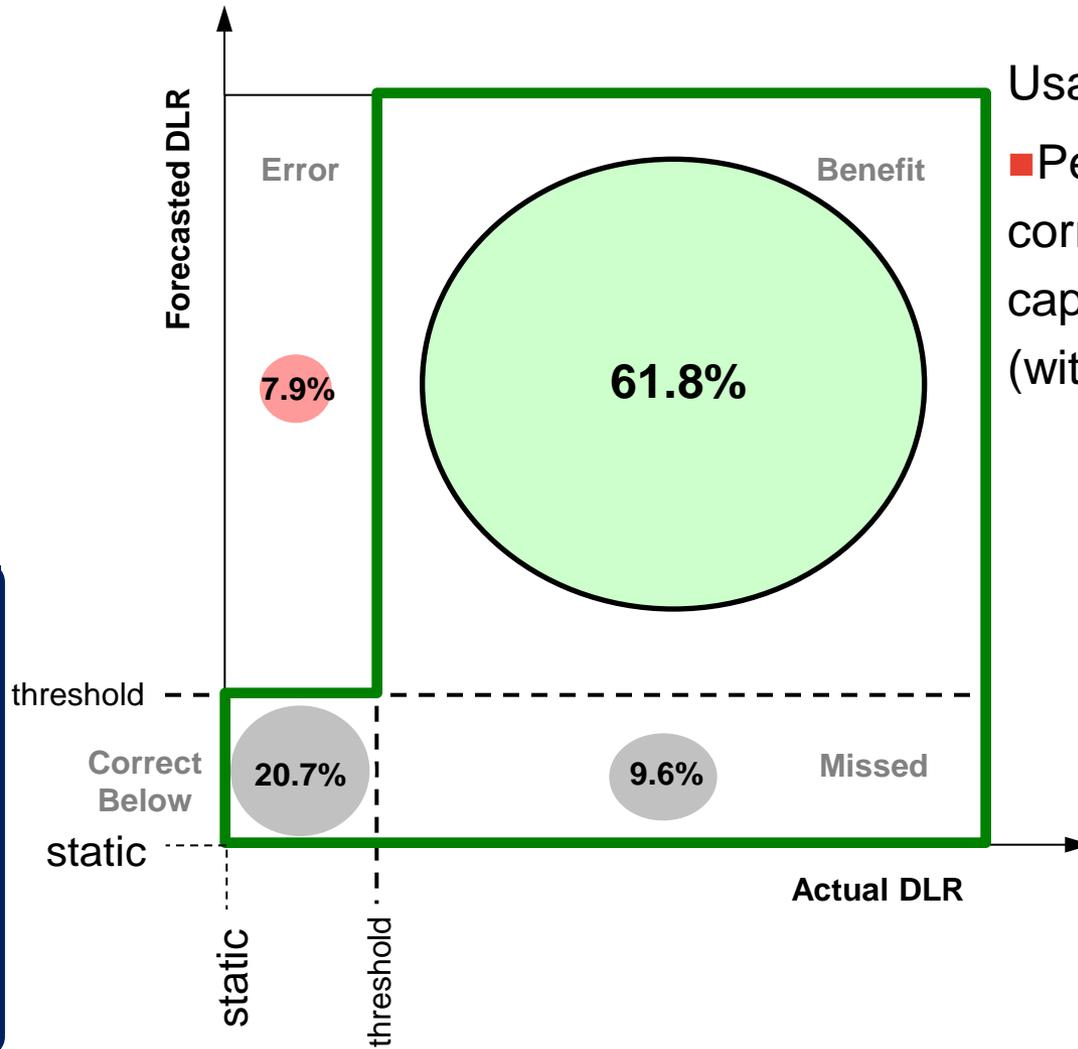
Day Ahead



Usability = 79.6%

■ Percent of time that forecast is correctly providing increased capacity or not requiring mitigation (within Green Polygon).

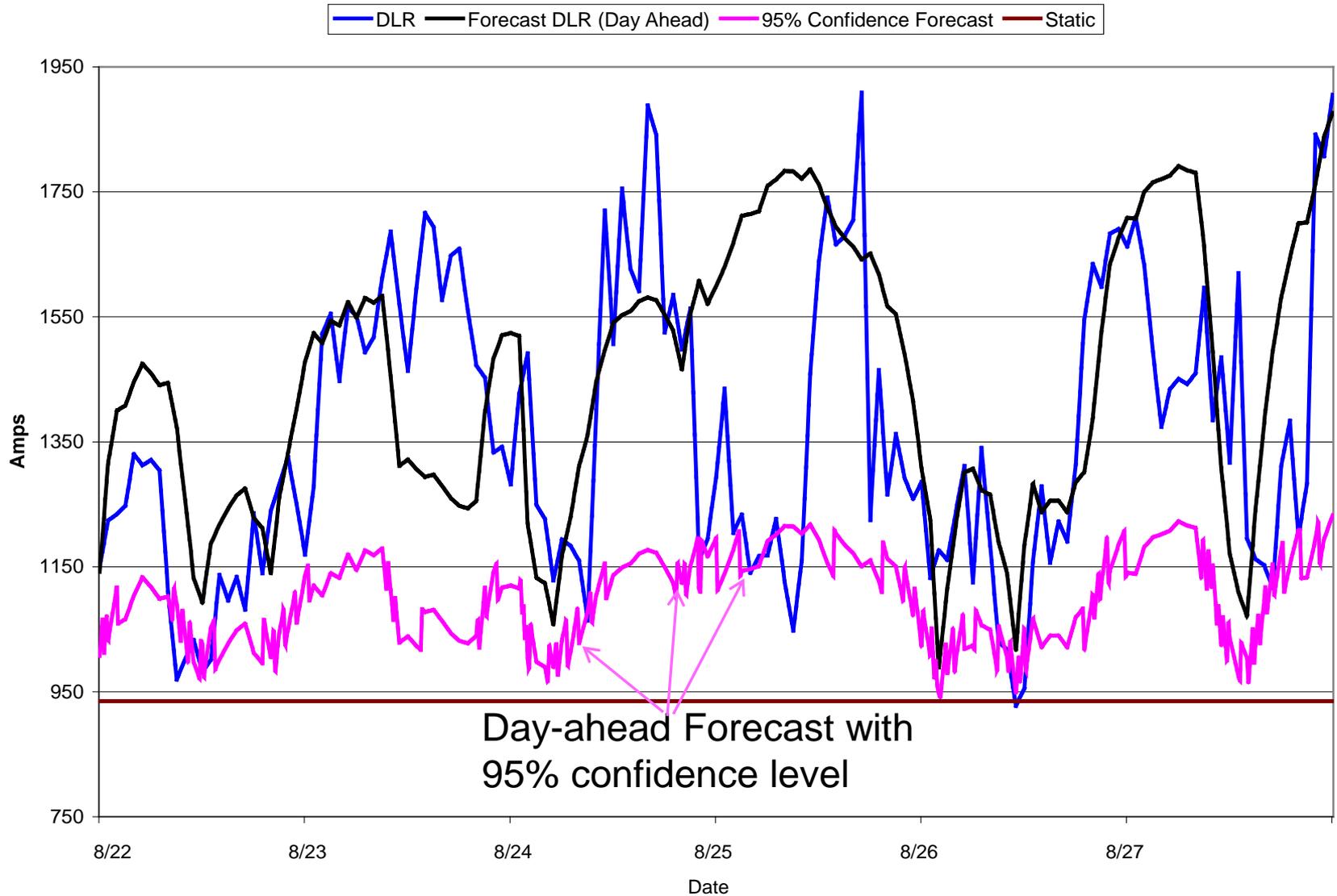
Day Of



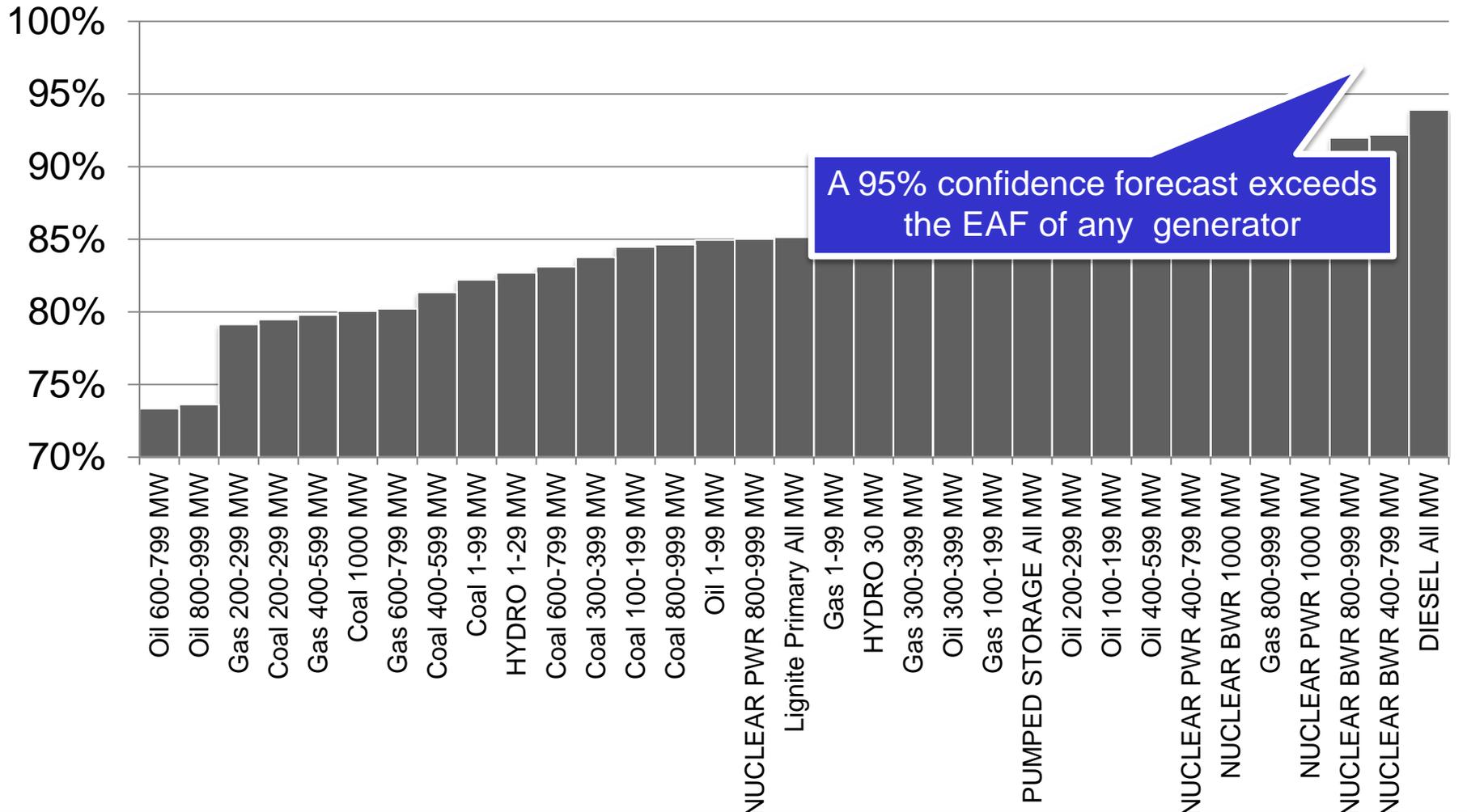
Usability = 92.1%

■ Percent of time that forecast is correctly providing increased capacity or not requiring mitigation (within Green Polygon).

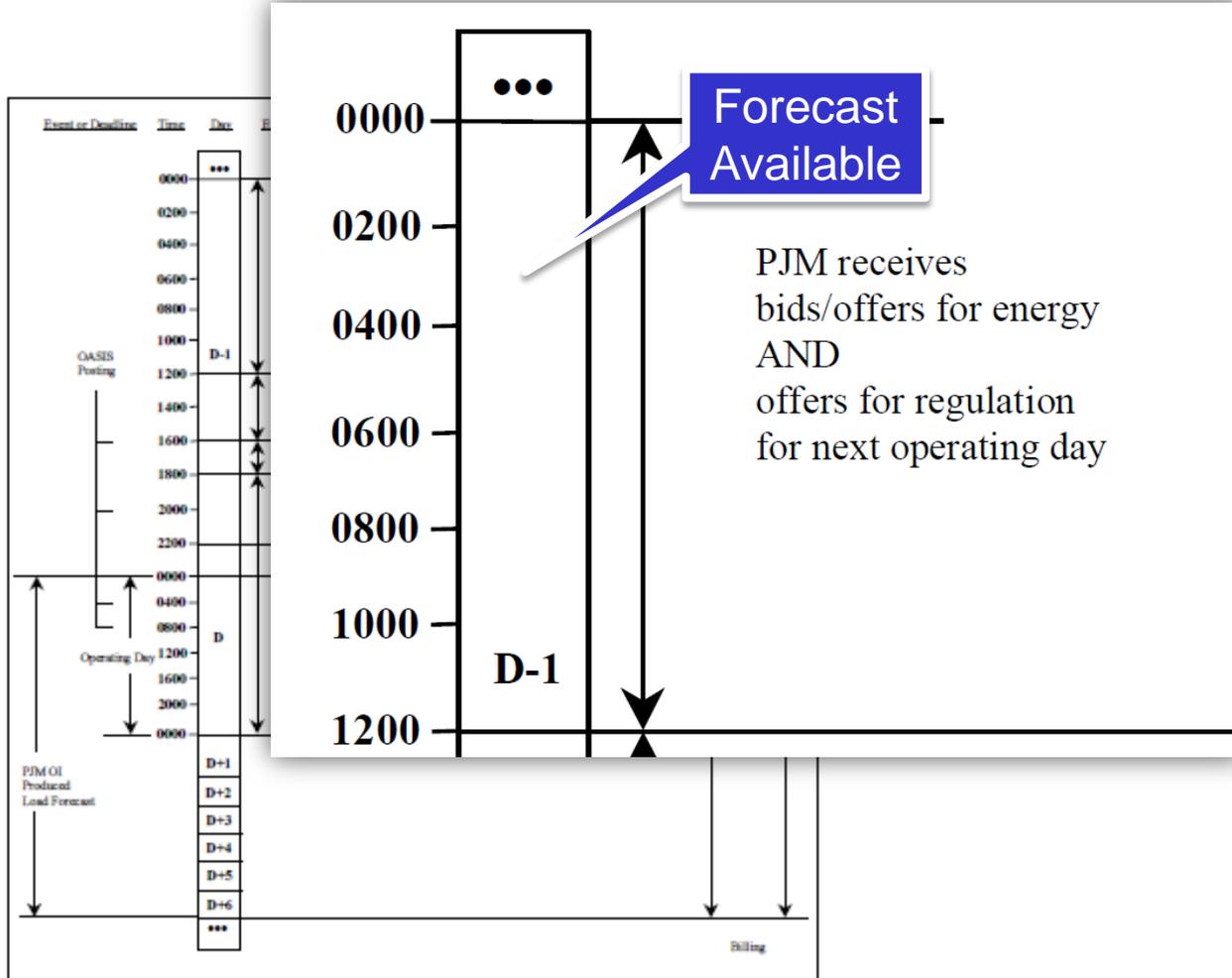
# Result: Ratings Based on Confidence Level

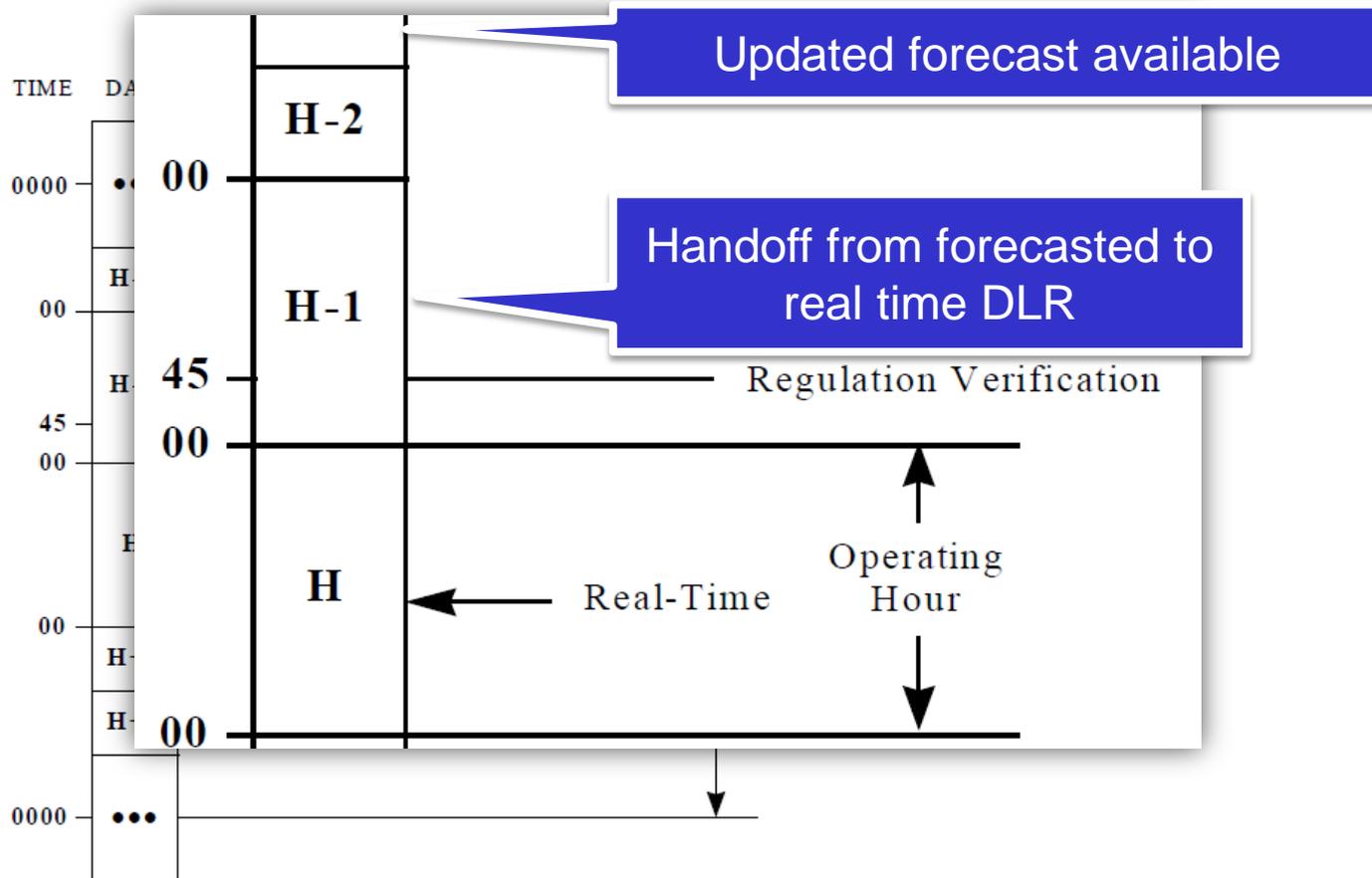


## Generator Equivalent Availability Factor by Fuel and Size



Day Ahead

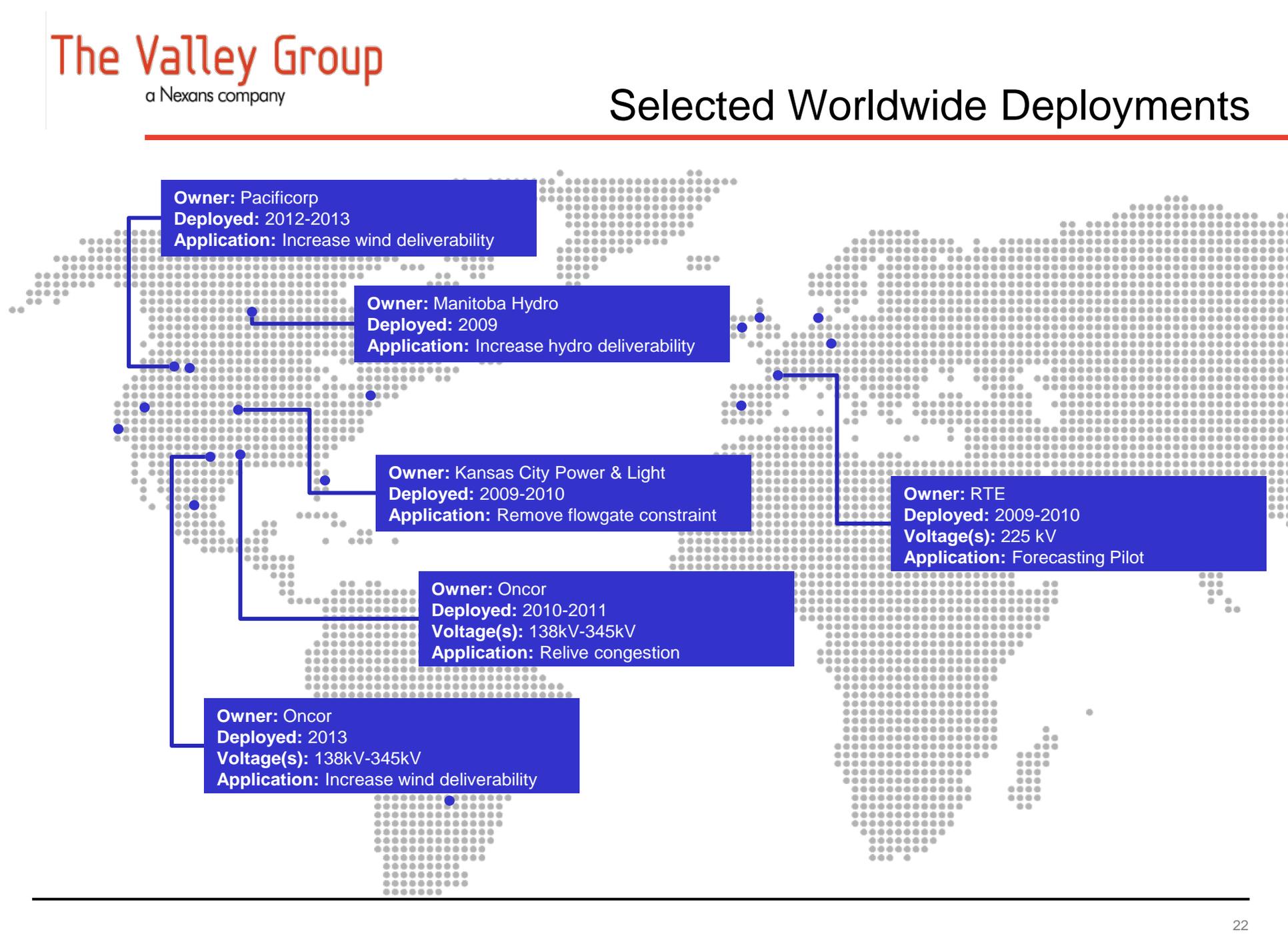




Day Of

- Inter-temporal integration of DLR through forecasts
  - Low Error of 2-3%
  - High Usability of 97-98%
  - Confidence Level configurable
  - Integrates with EMS
- DLR: software and sensors that improves market efficiency
  - Derive economic value from otherwise unused transmission
  - Requires integration from sensor to SCADA for maximum benefit
  - Forecasting provides additional flexibility

## Selected Worldwide Deployments



**Owner:** Pacificorp  
**Deployed:** 2012-2013  
**Application:** Increase wind deliverability

**Owner:** Manitoba Hydro  
**Deployed:** 2009  
**Application:** Increase hydro deliverability

**Owner:** Kansas City Power & Light  
**Deployed:** 2009-2010  
**Application:** Remove flowgate constraint

**Owner:** RTE  
**Deployed:** 2009-2010  
**Voltage(s):** 225 kV  
**Application:** Forecasting Pilot

**Owner:** Oncor  
**Deployed:** 2010-2011  
**Voltage(s):** 138kV-345kV  
**Application:** Relieve congestion

**Owner:** Oncor  
**Deployed:** 2013  
**Voltage(s):** 138kV-345kV  
**Application:** Increase wind deliverability