

Transmission ITP

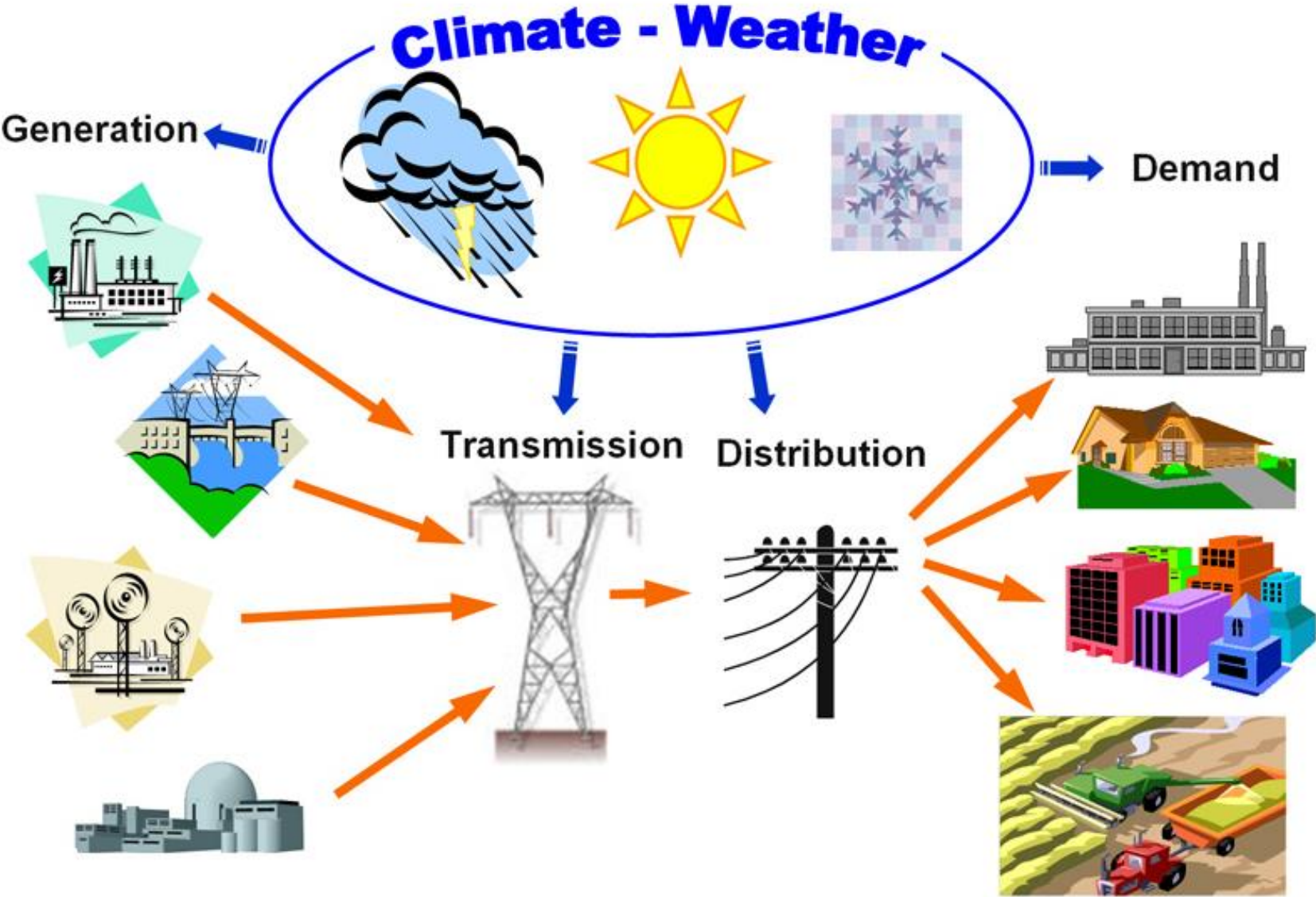
Load Forecasting & Weather

PJM State & Member Training Dept.

Students will be able to:

- Identify the relationship between load and weather
- Describe the load pattern impacts based on the duration of the weather conditions
- Identify possible effects of human behavior on the load

Weather and Load



Weather and Load

- Weather conditions interact to affect the loading and performance of the transmission system
- Some of the most impacting conditions include:
 - Temperature: Minimum/maximum
 - Humidity: Temperature Humidity Index (THI)
 - Wind: Direction/Speed/Wind Chill Index (WCI)
 - Storms: Lightning/Precipitation
 - Cloud cover
- During hot weather, temperature and humidity have greatest impacts
- During cold weather, temperature and wind speed have greatest impacts

Temperature

- Exceedingly hot or cold temperatures will cause the efficiency of system to decrease at or near maximum capacity
- Significant temperature swings will increase system loading
- Overloads on the transmission system
- Unavailability or tripping of transmission facilities



Humidity

- Percentage of water vapor present in a given quantity of air compared to the amount it can hold at its temperature
 - Does not change the temperature
 - Does change how much energy is available for cooling
- Temperature Humidity Index (THI) reflects outdoor atmospheric conditions of temperature and humidity as a measure of comfort or discomfort during the warm season of the year
 - Effects of heat and moisture in the air

Temperature Humidity Index (THI)

Temperature (Fahrenheit)	Relative Humidity									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
80°	69	70	72	73	74	75	76	78	79	80
81°	70	71	72	73	75	76	77	78	80	81
82°	70	72	73	74	75	77	78	79	81	82
83°	71	72	73	75	76	78	79	80	82	83
84°	71	73	74	75	77	78	79	81	83	84
85°	72	73	75	76	78	79	80	82	84	85
86°	72	74	75	77	78	80	81	83	84	86
87°	73	74	76	77	79	81	82	84	85	87
88°	73	75	76	78	80	81	83	85	86	88
89°	74	75	77	79	81	82	84	86	87	89
90°	74	76	77	79	81	83	85	87	88	90
91°	75	76	78	80	82	84	85	87	89	91
92°	75	77	79	81	83	85	86	88	90	92
93°	76	78	80	81	83	85	87	89	91	93
94°	73	78	80	82	84	86	88	90	92	94
95°	77	79	81	83	85	87	89	91	93	95
96°	77	79	81	84	86	88	90	92	94	96
97°	78	80	82	84	86	88	91	93	95	
98°	78	80	83	85	87	89	91	94	96	
99°	79	81	83	85	88	90	92	95		
100°	79	82	84	86	89	91	93	95		
101°	80	82	84	87	89	91	94	96		
102°	80	83	85	88	90	92	95			
103°	81	83	86	88	91	93	96			
104°	81	84	86	89	91	94	96			
105°	82	84	87	90	92	95				
106°	82	85	87	90	93	96				
107°	83	85	88	91	94	96				
108°	83	86	89	92	95					
109°	84	87	89	92	95					
110°	84	87	90	93	96					

- Developed by National Weather Service
- Provides a single numerical value reflecting outdoor atmospheric conditions of temperature and humidity as a measure of comfort or discomfort during warm weather
- Electricity use increases as a heat wave lingers

 **Warning Zone**

 **Danger Zone**

THI ≤ 70 Relatively few people uncomfortable

THI @ 75 Half will be uncomfortable

THI @ 79 Almost all are uncomfortable

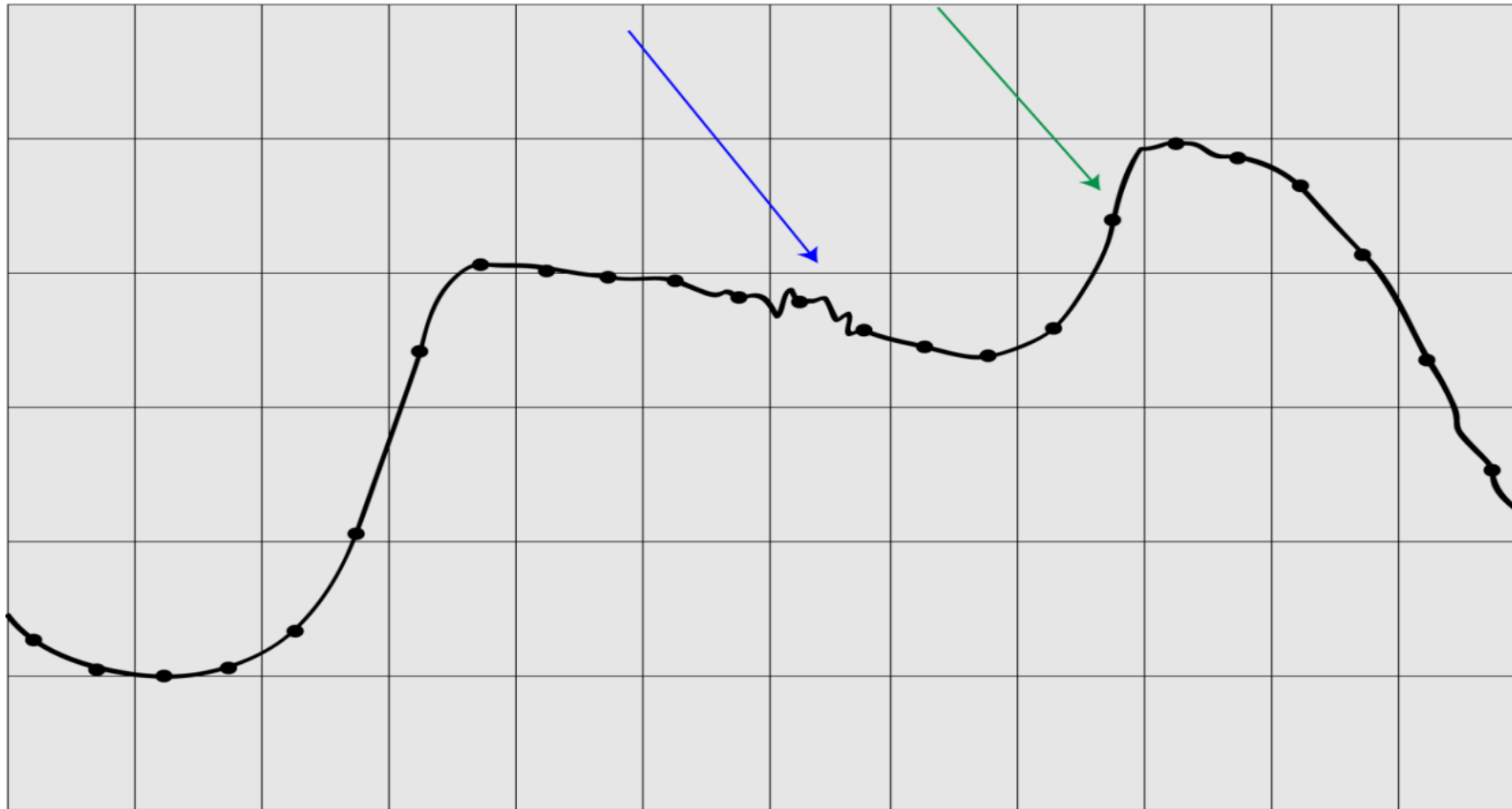
Wind

- Caused as temperature/pressure from one weather system replaces the temperature/pressure of another weather system
 - Commonly associated with fronts and storms
 - Cool air is dense and heavy, circulating strongly over the earth's surface
 - Warm air is lighter, rising above cooler air
- Can flatten afternoon valleys or increase peak loading
- Wind Chill Index (WCI) reflects the “felt” air temperature on exposed skin due to the wind

Wind

PJM EAST LOAD FORECAST

Effects of wind & dropping temperatures:
Limited drop off in valley
Large Evening Pick-up



Storms

- Power outages and loss of customer demand
 - Thunderstorms cause wind and lightning damage
 - Lightning-related outages cause the nation's utility industry over \$100 million annually in materials and labor costs
- Precipitation can decrease temperatures
 - Snow can decrease loading due to facility closings
 - Blizzards can increase loading on weekends

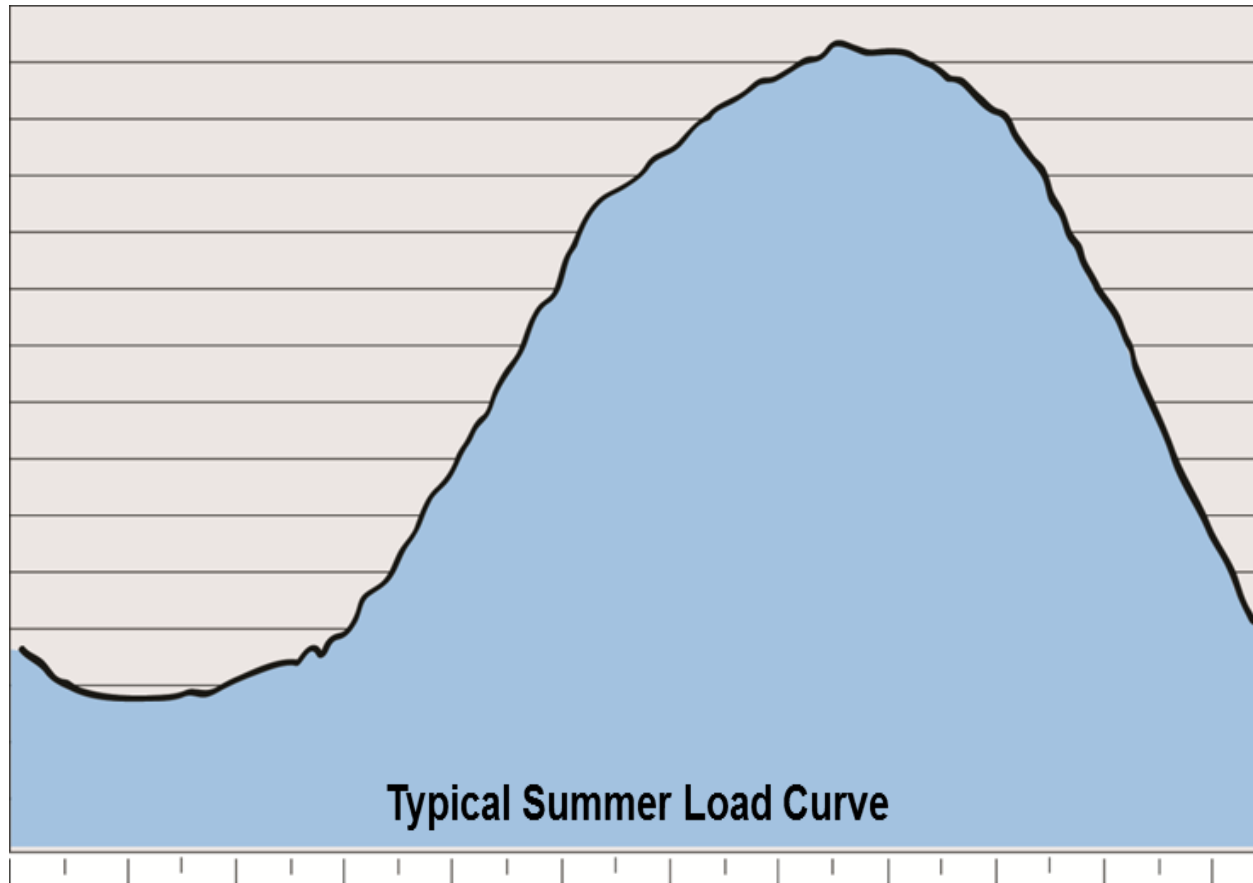


Cloud Cover

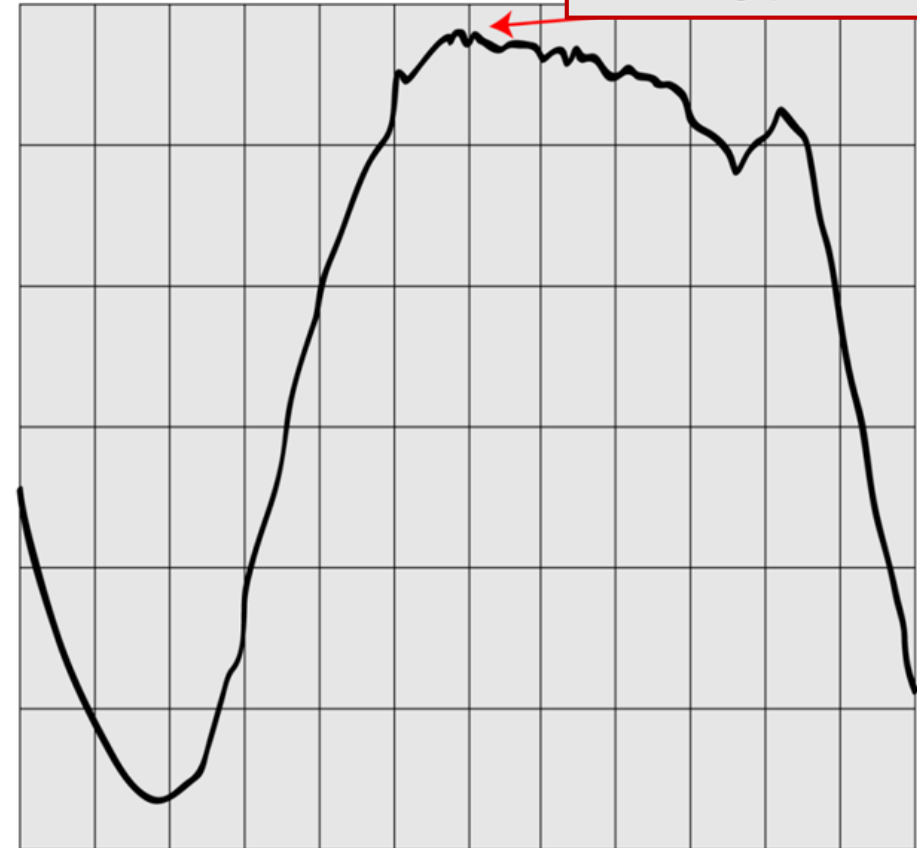
- Associated with fronts and storms
- Can flatten load curves
- Can cause afternoon valleys to be shallow or non-existent
- Increase “lighting” load during the day or afternoon



Cloud Cover



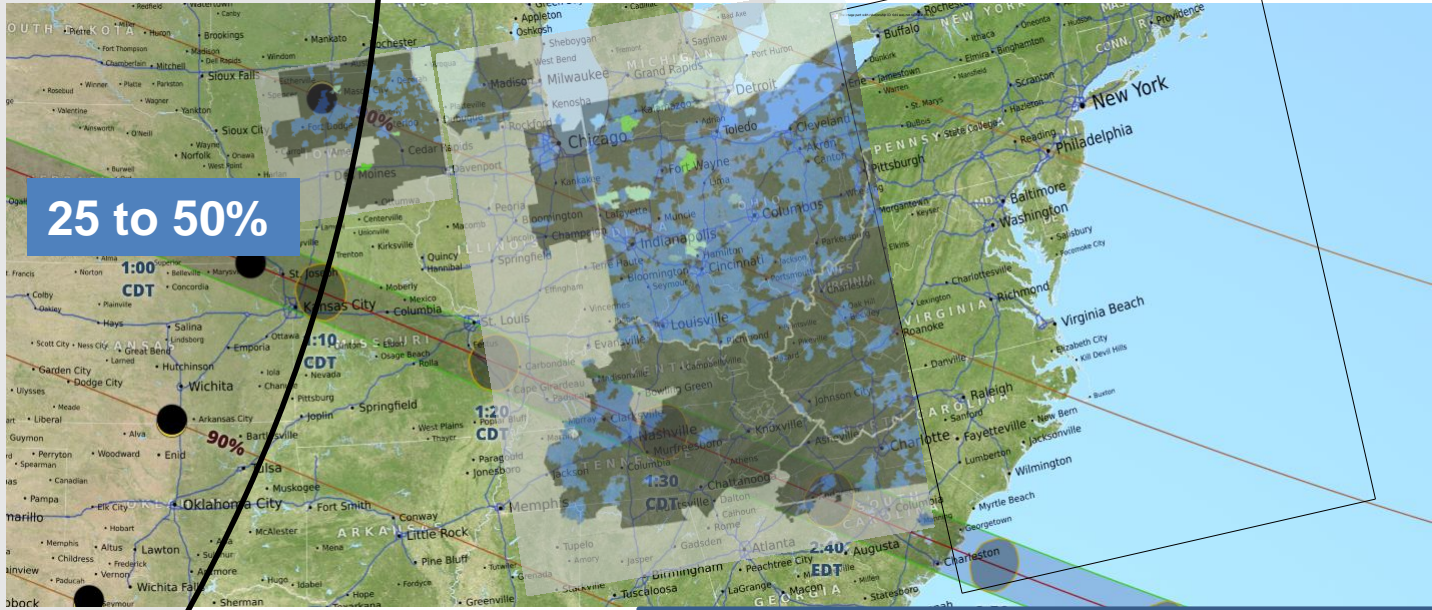
8/15/2005 - PJM LOAD



Flattened Peak resulting from heavy cloud cover in PHIL & DCA area in morning period

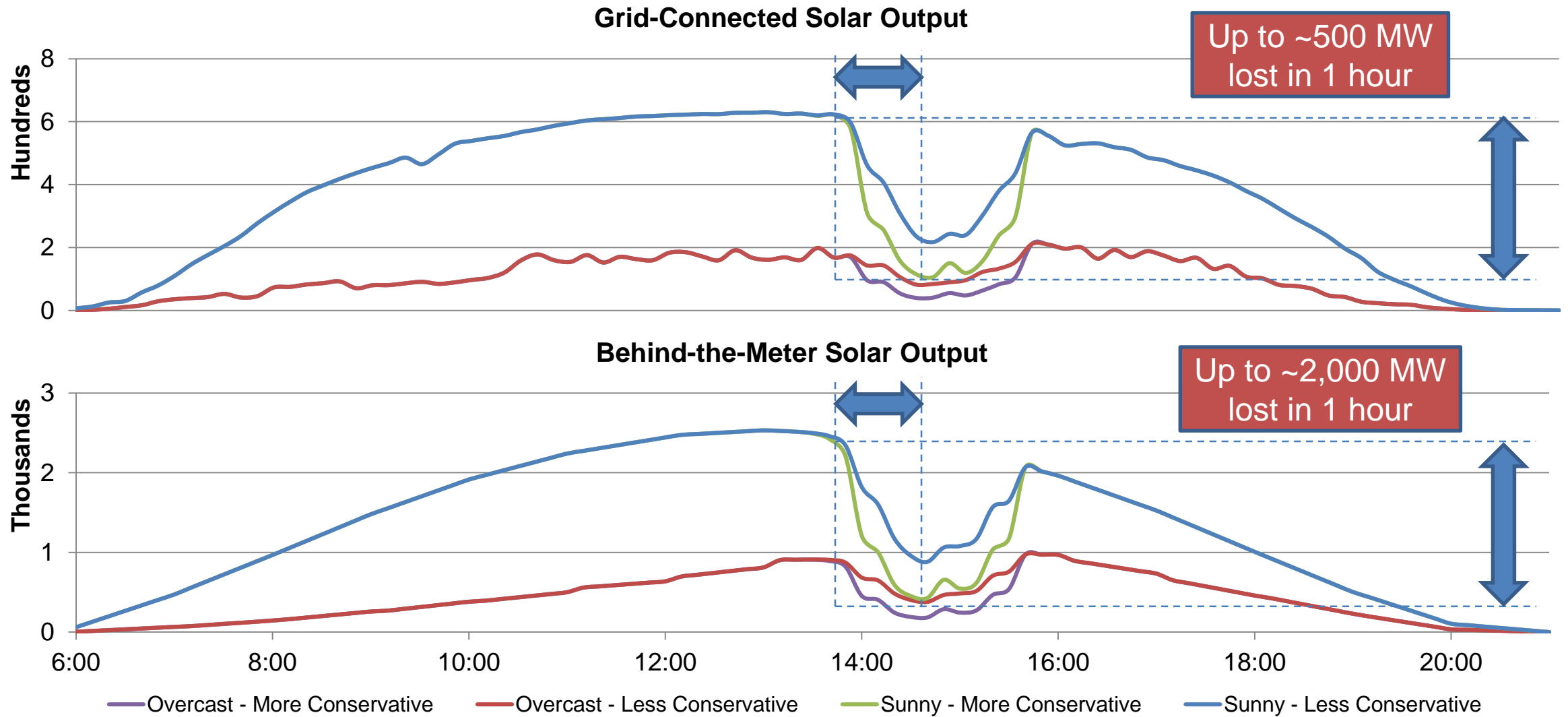
13:30 13:40 13:50 14:00 14:10 14:20 14:30
14:40 14:50 15:00 15:10 15:20 15:30 15:40

50 to 75%



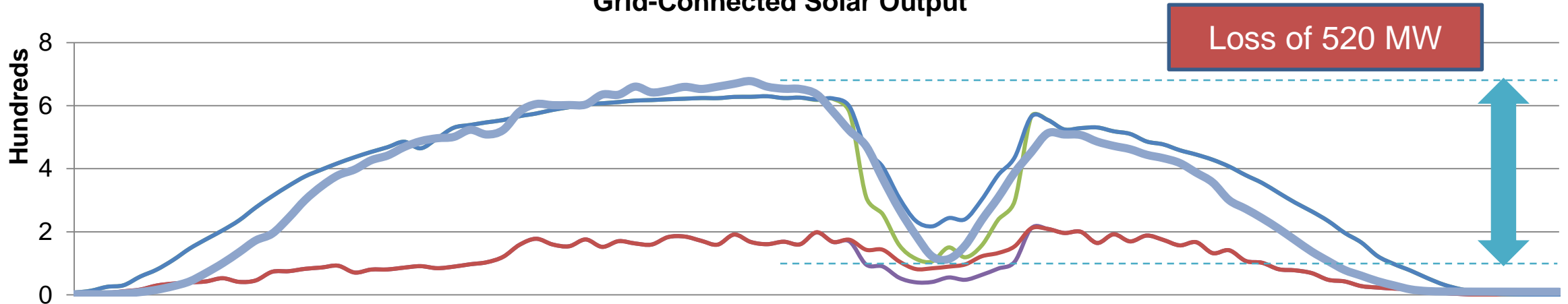
Source of eclipse map: [NASA](#) | Source of PJM solar map: PJM Environmental Information Services

Estimated Solar Output on August 21, 2017

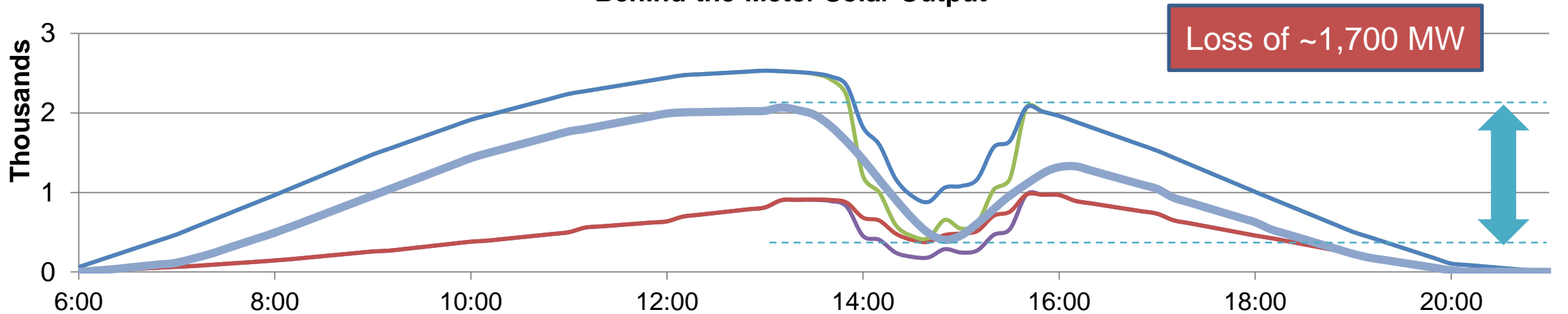


Estimated and Actual Solar Output on August 21, 2017

Grid-Connected Solar Output



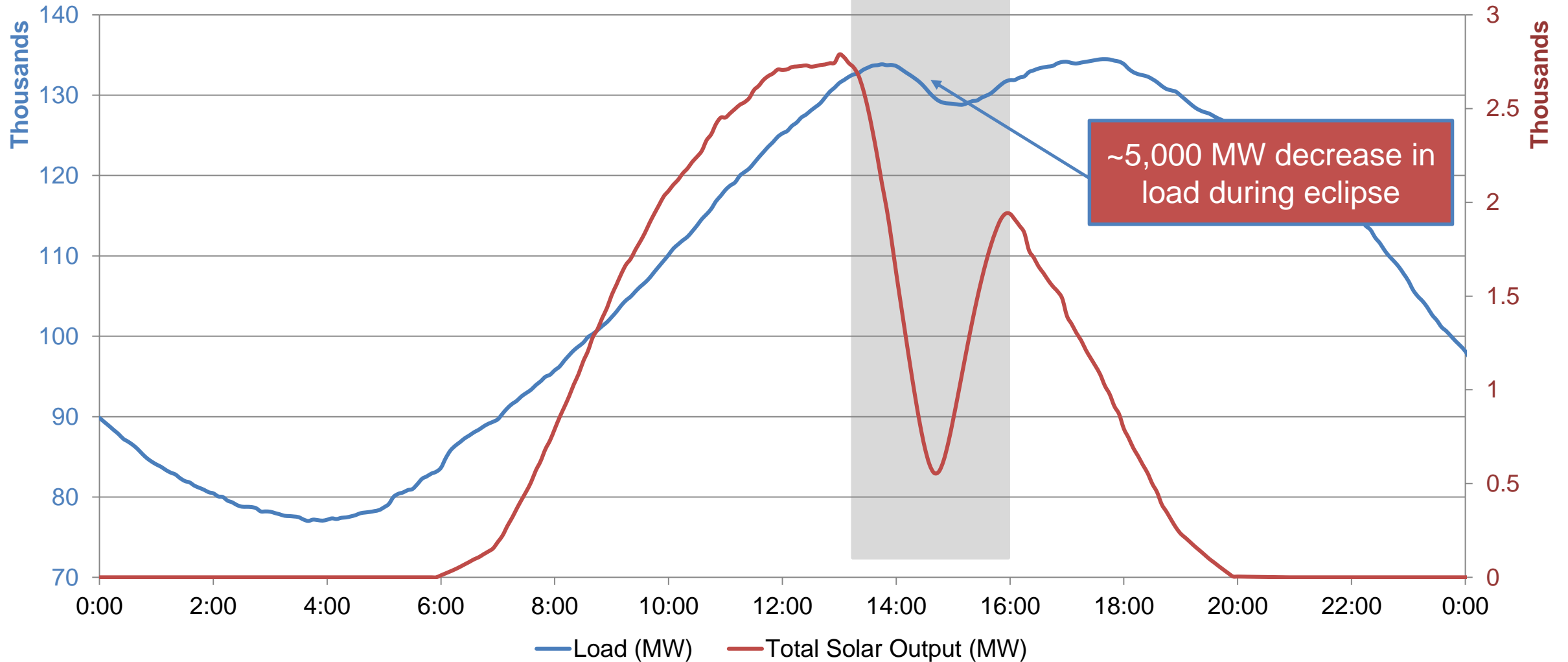
Behind-the-Meter Solar Output



— Low - More Conservative
 — Low - Less Conservative
 — High - More Conservative
 — High - Less Conservative
 — Estimated Actual

RTO Load and Total Solar Output During Eclipse

RTO Load and Solar Output on August 21, 2017

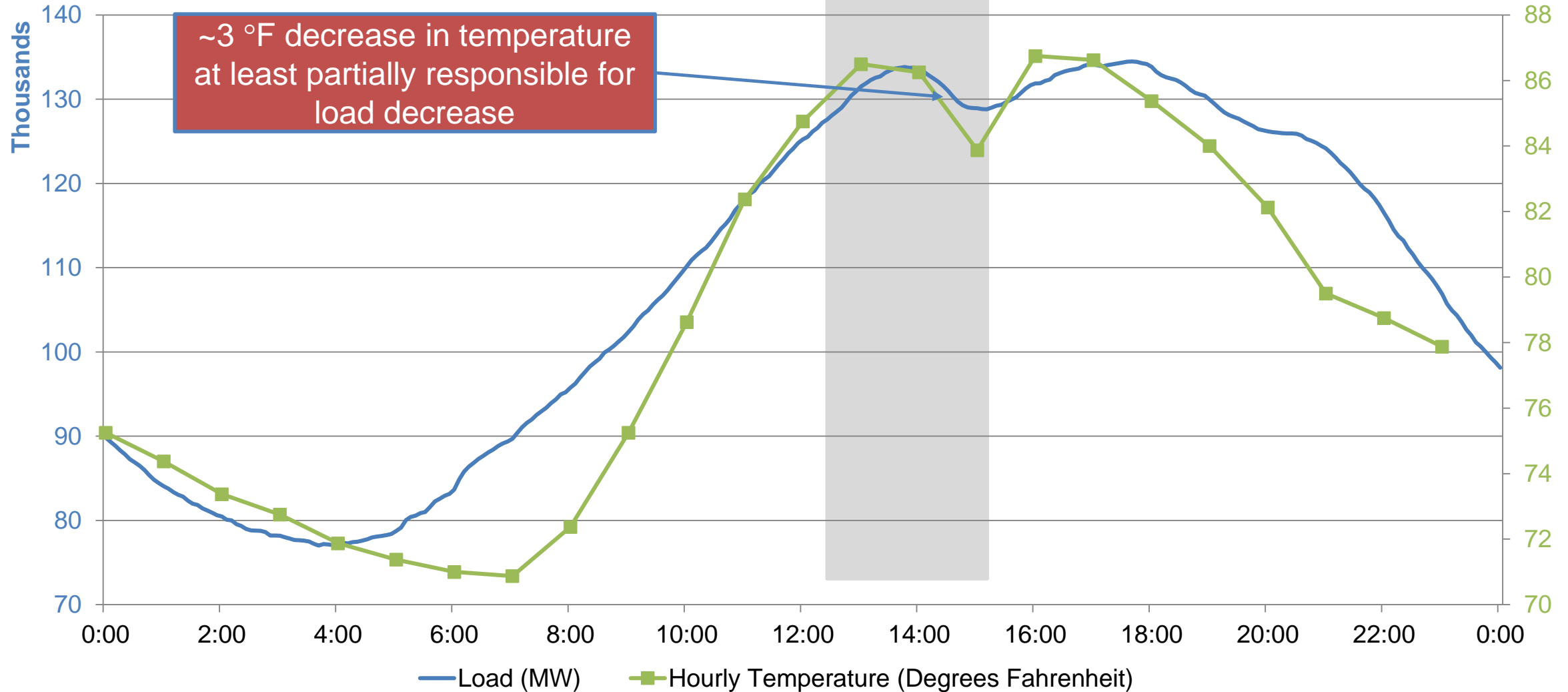


Factors Contributing to Load Changes

Factor that Impacted Load	Direction of Impact	Expected Amount of Impact
Reduced behind-the-meter solar	+	~1,700 MW
Increased lighting load	+	Low
Human behavior	—	Inconclusive – not quantifiable
Decreased temperature	—	Probable, though forecast models not trained on intra-hour values

Temperatures and Load During Eclipse

RTO Load and Temperature on August 21, 2017



Lessons Learned from Solar Eclipse

- Projections of solar output during eclipse were largely accurate
- Load decreased by twice amount that solar output decreased
 - May be different in 2024 with additional installed solar
 - Human behavior is important factor that is not well understood
 - Behind-the-meter assumptions will be difficult to verify
- Current load forecast models are not trained to reflect significant intra-hour temperature changes
- Coordination with forecast vendors is critical

Effects from the Duration of Weather Conditions

- If a hot spell extends to 2-3 days or more:
 - Nighttime temperatures do not cool down
 - Homes and buildings retain heat from the previous days
 - Air conditioners to turn on earlier and stay on later in the day
- During cold weather, portable heaters and strip heaters are among the highest sources of electrical demand

Human Effects on Load

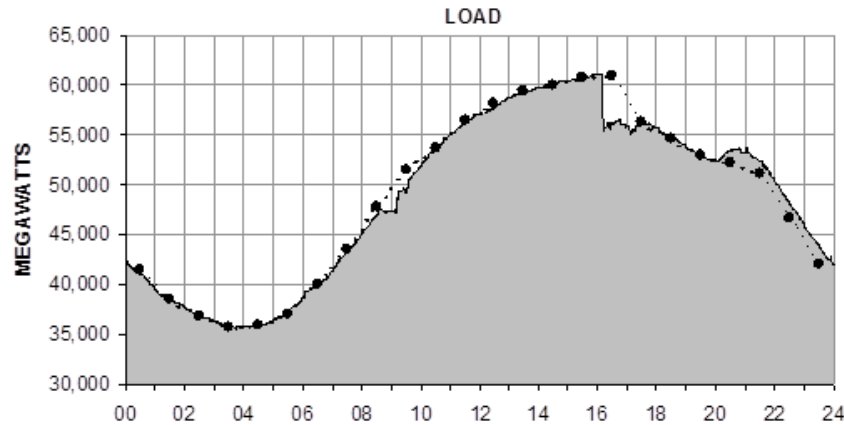
- Day of the week
 - Large load differences between weekends and weekdays
 - Smaller load differences exist even on different weekdays!
 - Monday and Fridays are adjacent to weekends and have structurally different loads than Tuesday, Wednesday, and Thursday
 - On average, Sundays have the lowest demand followed by Saturday
 - The rest of the weekdays have small load variations
- Holidays
 - They have decreased load demand based on the duration and length
 - More difficult to forecast due to infrequent occurrence

Human Effects on Load

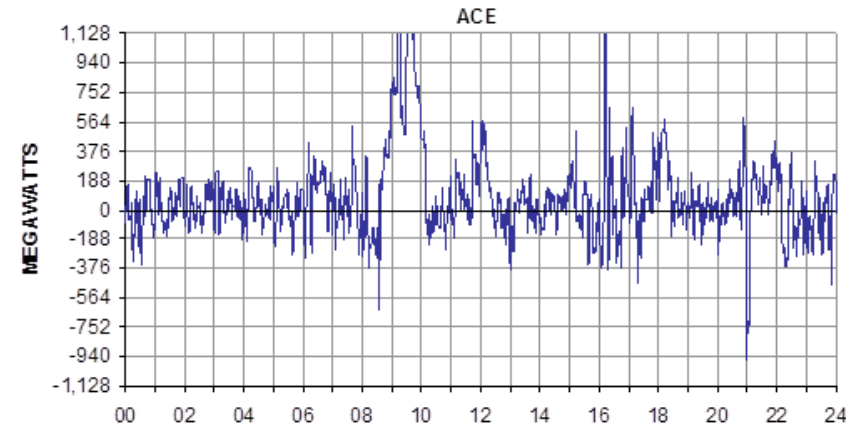
- Hour of the day
 - Load pattern follows the activities of the consumers
 - Demand steadily increases from 9 am to 12 noon with a decrease during midday picking up again until 4 pm in the afternoon
 - Demand steadily decreases from 4 pm to 7 pm increasing again around 8 pm to 9 pm
 - After 9 pm, demand decreases gradually to the lowest load demand in the early morning
- Events
 - Depending on the event, it can have either an increasing or decreasing effect on the overall load demand

August 14, 2003

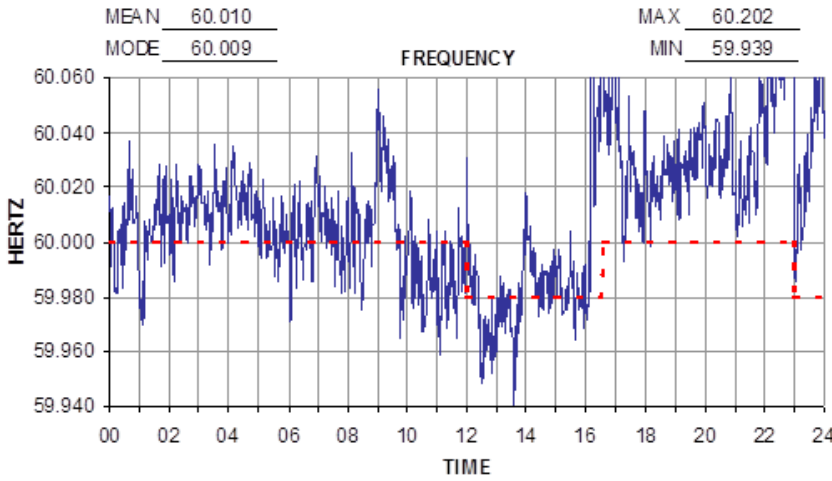
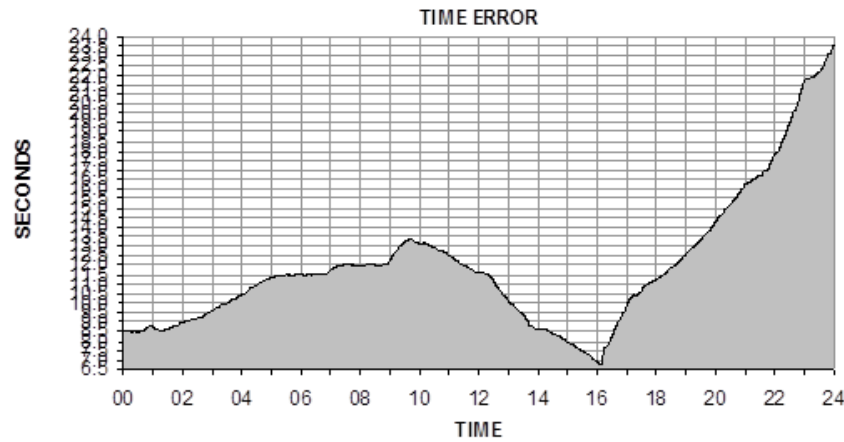
PJM RTO CONTROL DATA 8/14/2003



LOAD	VALLEY	DAY (P)	EVE
HOUR	5	16	21
ACTUAL	35893	60740	53176
GDB FORECAST	35938	60740	52215



COMPLIANCE	22:30 - 06:30	6:30 - 14:30	14:30 - 22:30	Solid Daily
CPS - 1	155.37	139.86	124.88	141.70
CPS - 2	97.92	68.75	72.92	79.86



MEAN	60.010	MAX	60.202
MODE	60.009	MIN	59.939

GENERATED AT: 8/15/2003 6:05

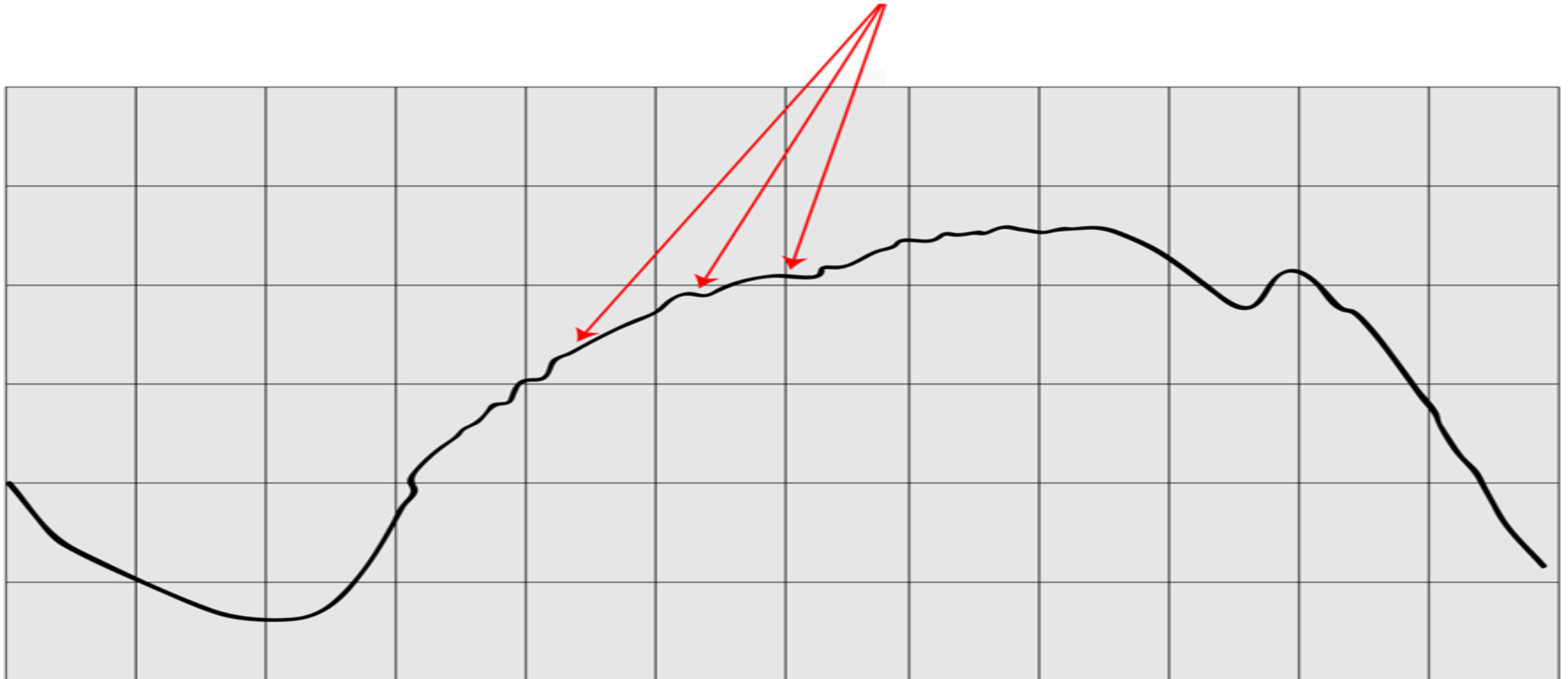
October 3, 1995

- Example of erratic / unusual load shape during and after the televised announcement of the verdict in trial of O.J. Simpson



September 11, 2001

- Effects of the attacks on the World Trade Center and Pentagon

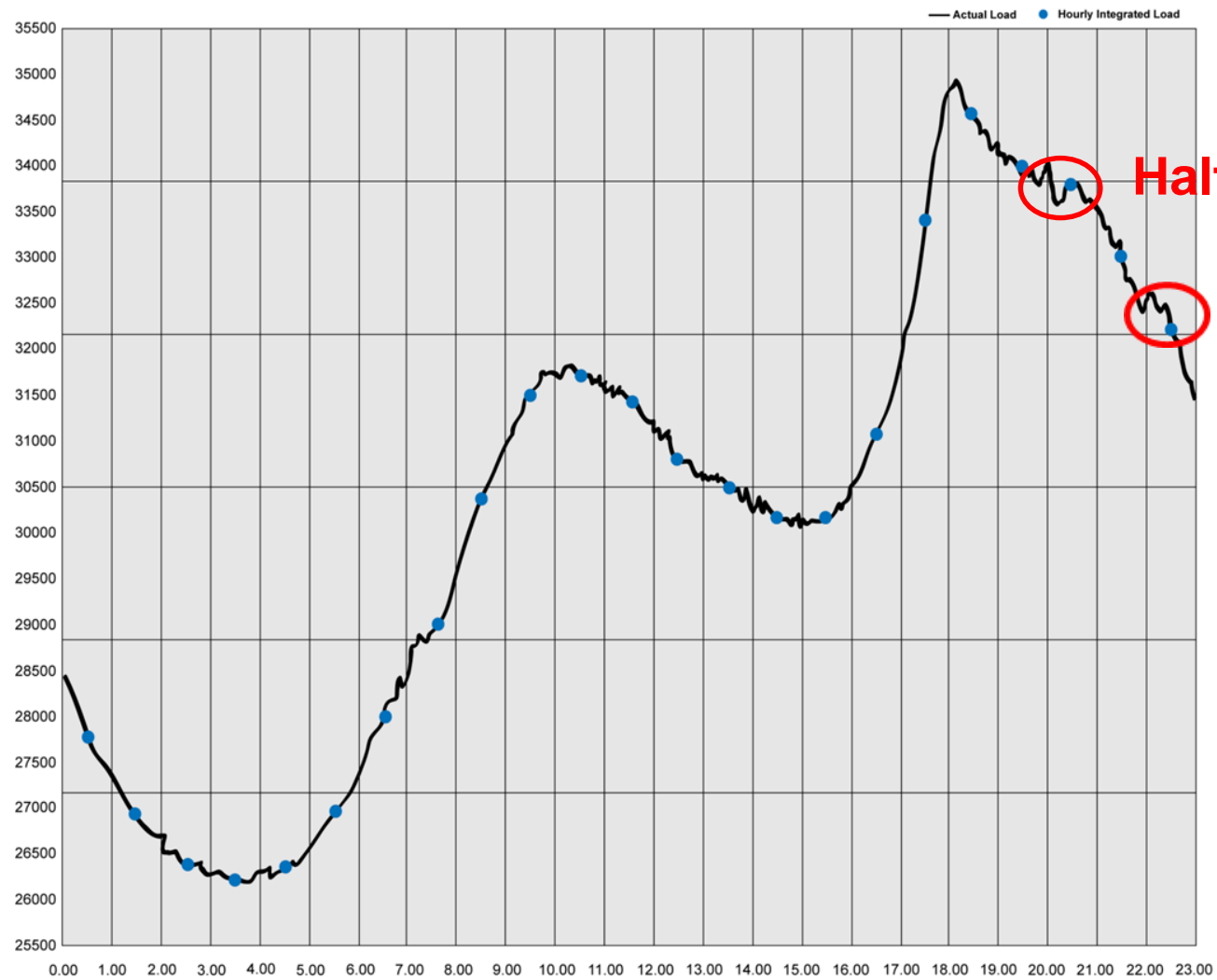


2012 Superbowl

2/5/2012 - PJM LOAD

Super Bowl Sunday

Sunday

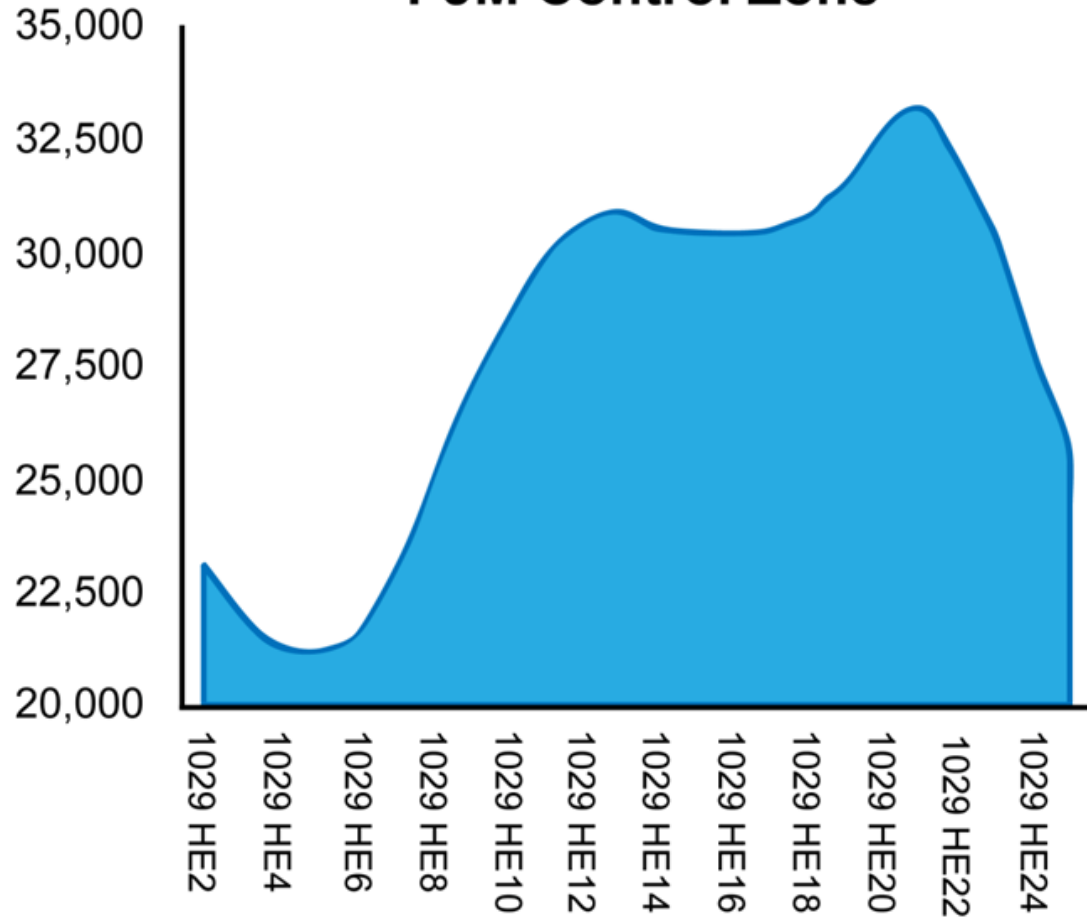


Half Time

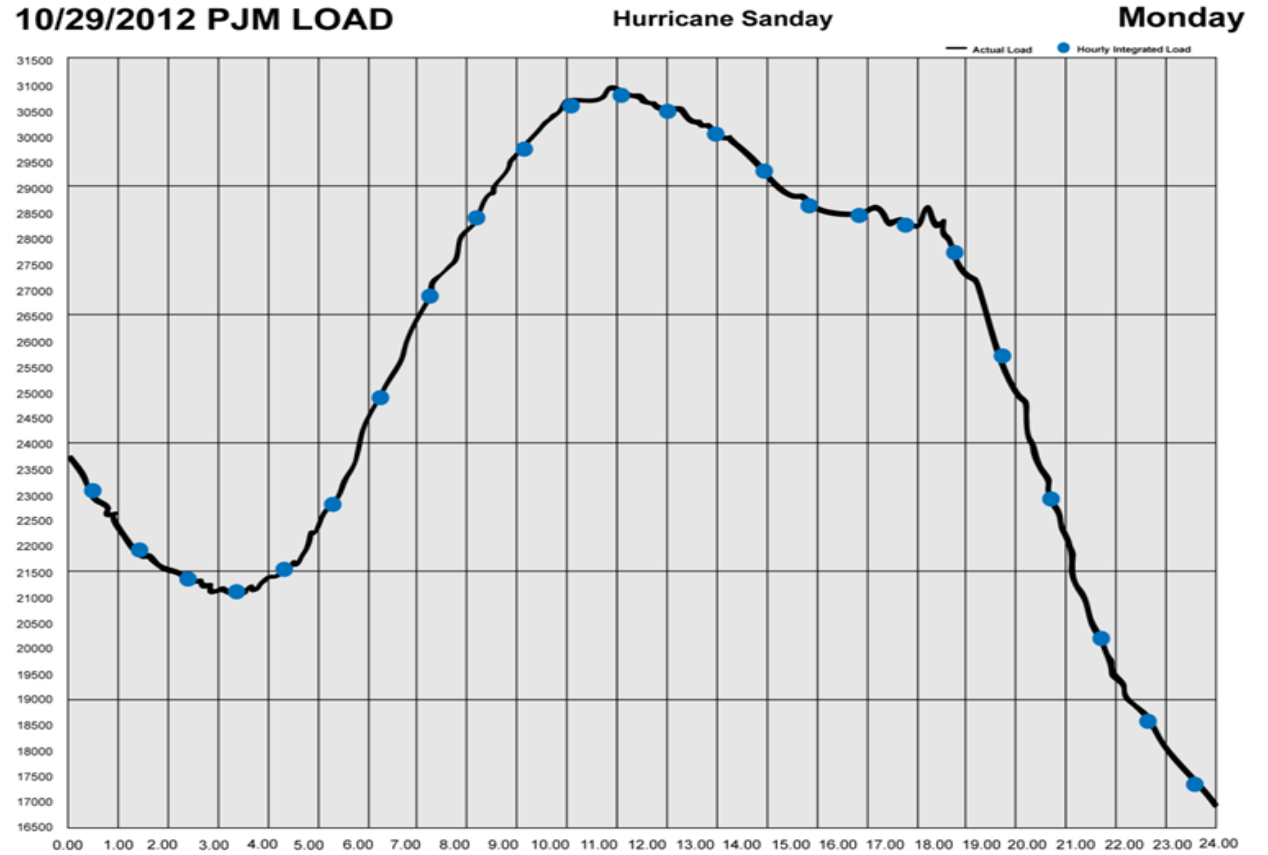
End of Game

Hurricane Sandy, 2012

PJM Control Zone



10/29/2012 PJM LOAD



Questions?

PJM Client Management & Services

Telephone: (610) 666-8980

Toll Free Telephone: (866) 400-8980

Website: www.pjm.com



The Member Community is PJM's self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services

Resources & References



Climate Change Impacts on the Electric Power System in the Western United States. Decision and Information Sciences, www.dis.anl.gov/index.html

Feinberg, E.A. *Load Forecasting.* Eugene.Feinberg@sunysb.edu

Keener, Jr., R.N. *The Estimated Impact of Weather on Daily Electric Utility Operations.* www.sciencepolicy.colorado.edu/socasp/weather1/keener.html