Updates To Load Forecast Methodology

Load Analysis Subcommittee

September 2, 2015

Outline

- Weather History Used in Forecast Simulation
- Overview of Changes Since May
- Forecast Discussion
  - Summer and Winter Charts
  - Decomposition of Changes
  - Accuracy
- Next Steps

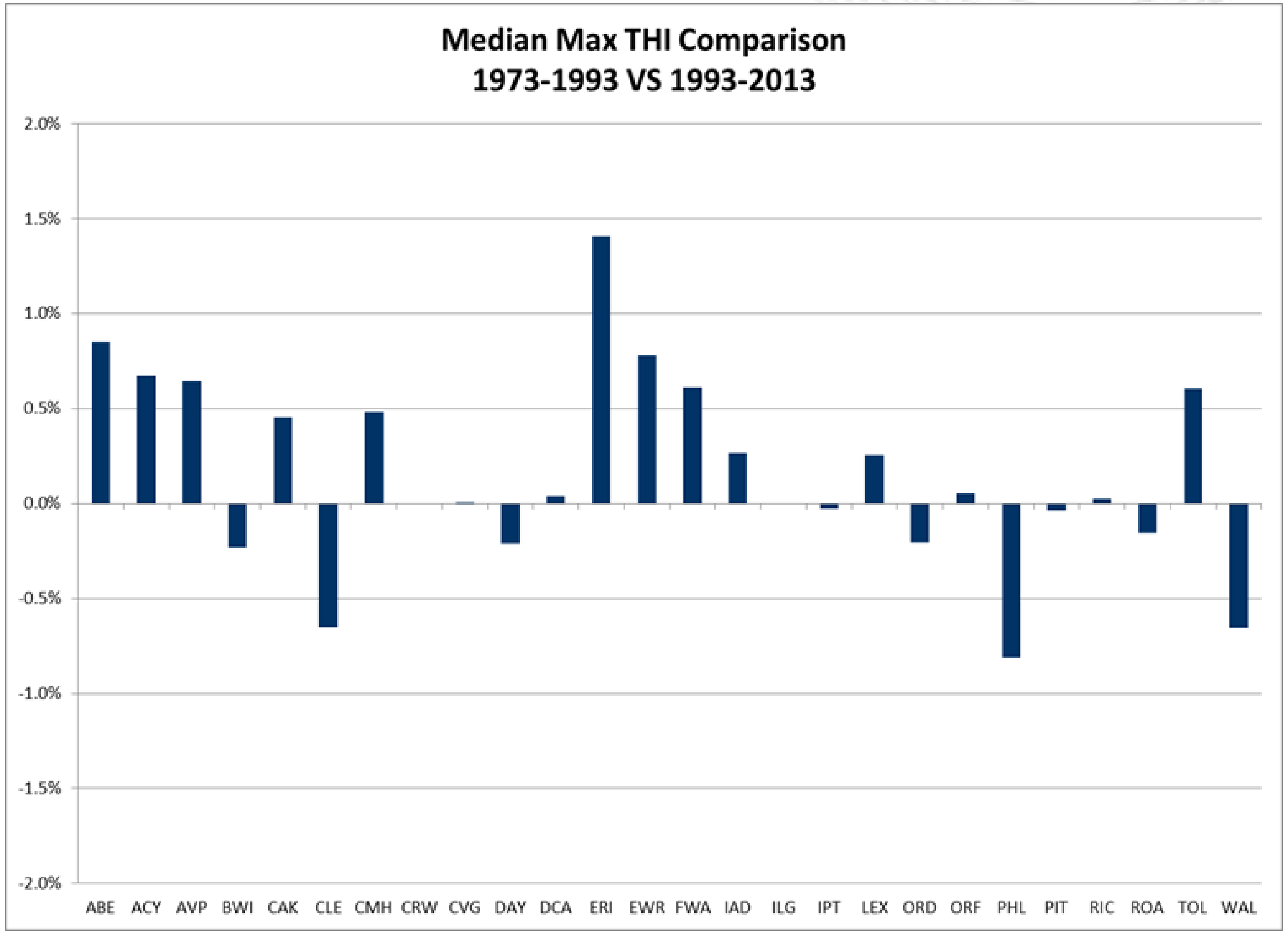
Weather History Used in Forecast Simulation

- PJM establishes parameters for the load forecast by investigating the relationship between load and its drivers (economics, weather, calendar effects, equipment saturation/efficiency) over the time period 1998 to present.
- The results of this model are then simulated across historical weather conditions back to 1973 to get a distribution of possible outcomes for peak load.
  - Values of primary interest are the median result and the 90^{th} percentile result. If weather conditions have changed measurably, then this could have a noticeable impact on forecasted load.

Investigation

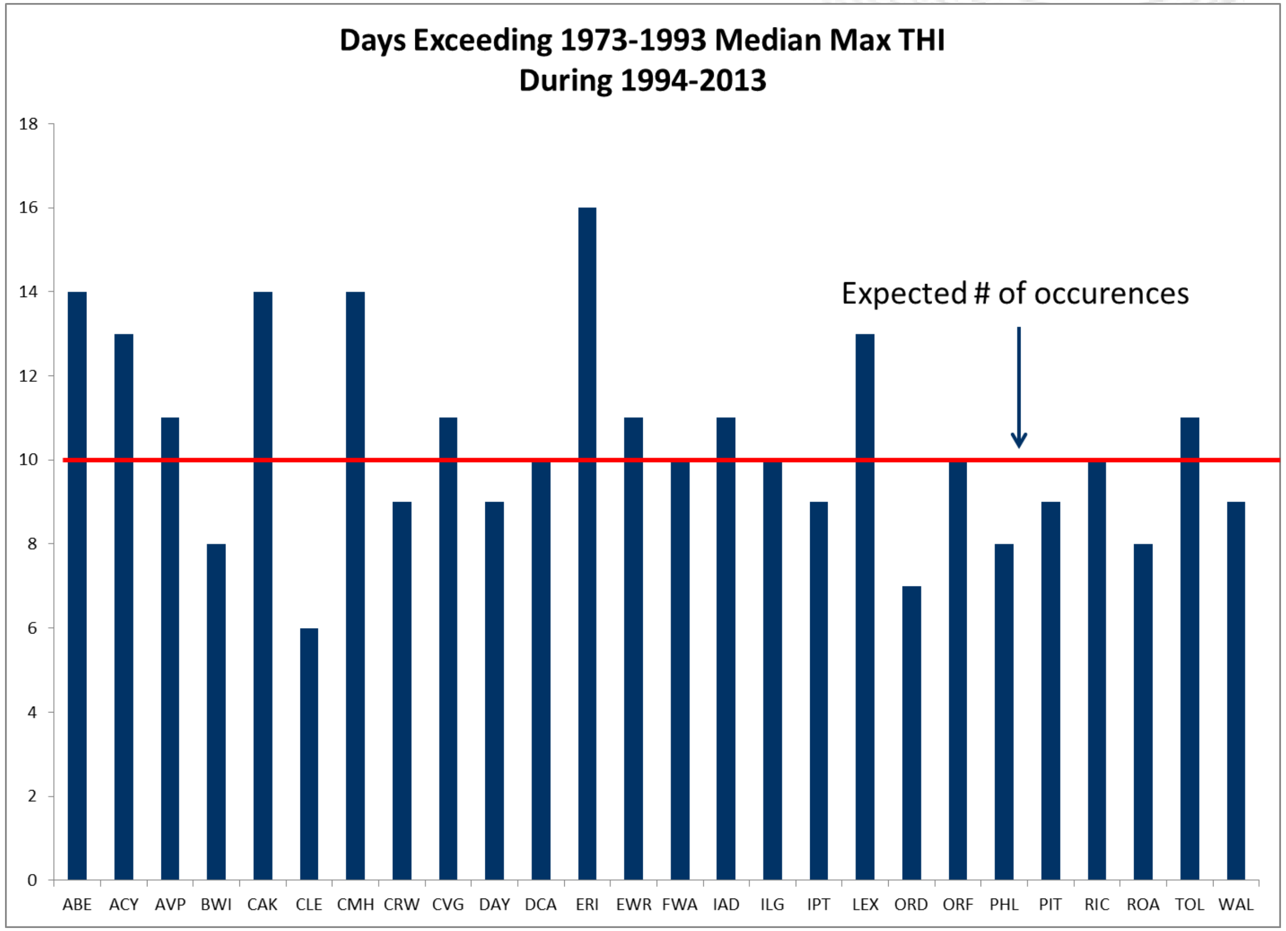
- By taking from the entire pool of available weather data, the implicit assumption is being made that all weather is equally likely. In other words, weather from the 1970s and 1980s is not statistically different from the 1990s and 2000s.

- PJM currently uses 26 weather stations in the long-term load forecast to represent weather conditions across the footprint. Analysis began by comparing results from the overlapping time periods of 1973-1993 and 1993-2013.



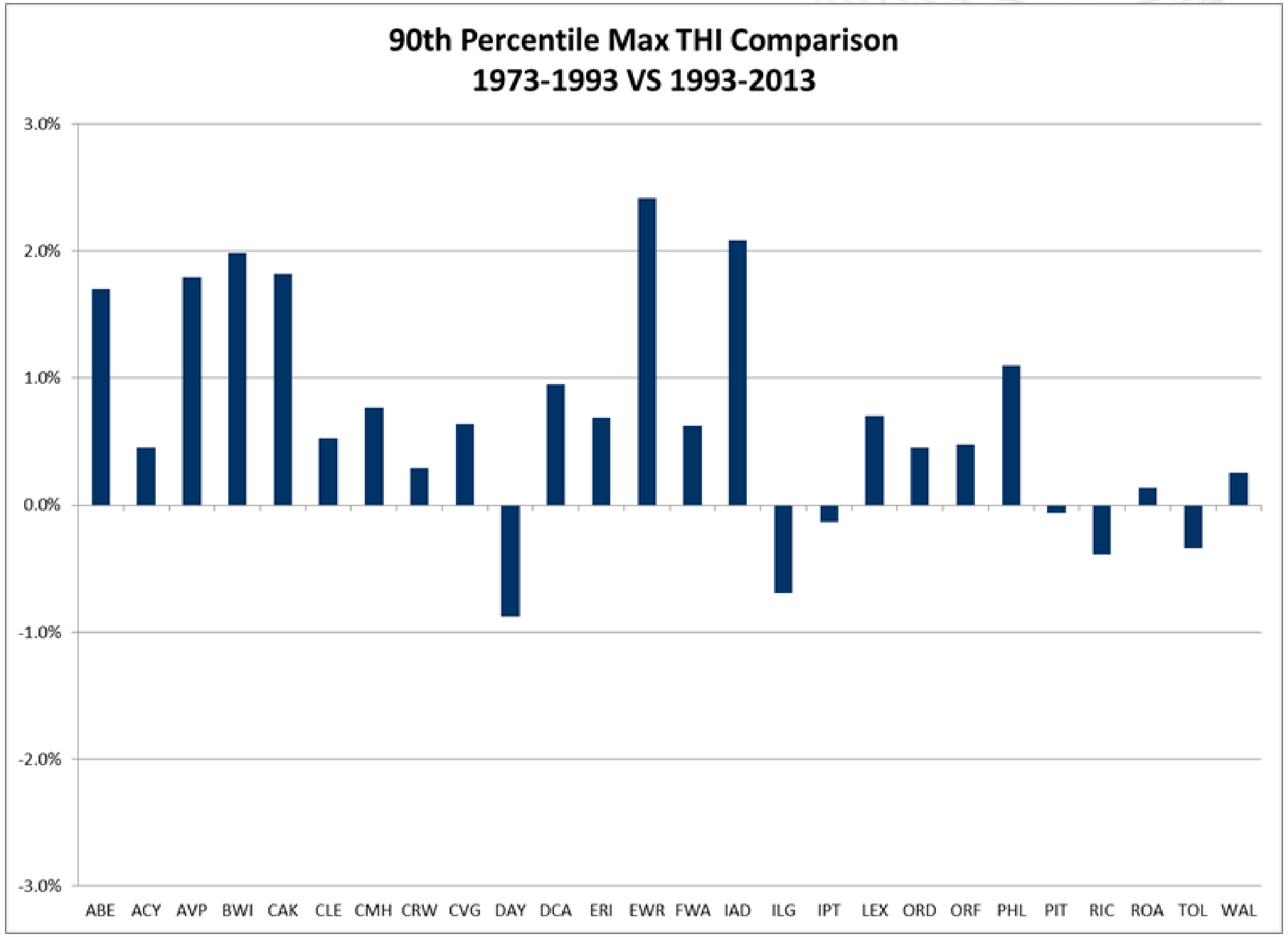
- 15 weather stations had a higher median maximum Temperature Humidity Index (THI) in the latter period

Investigation – *Comparing Medians*



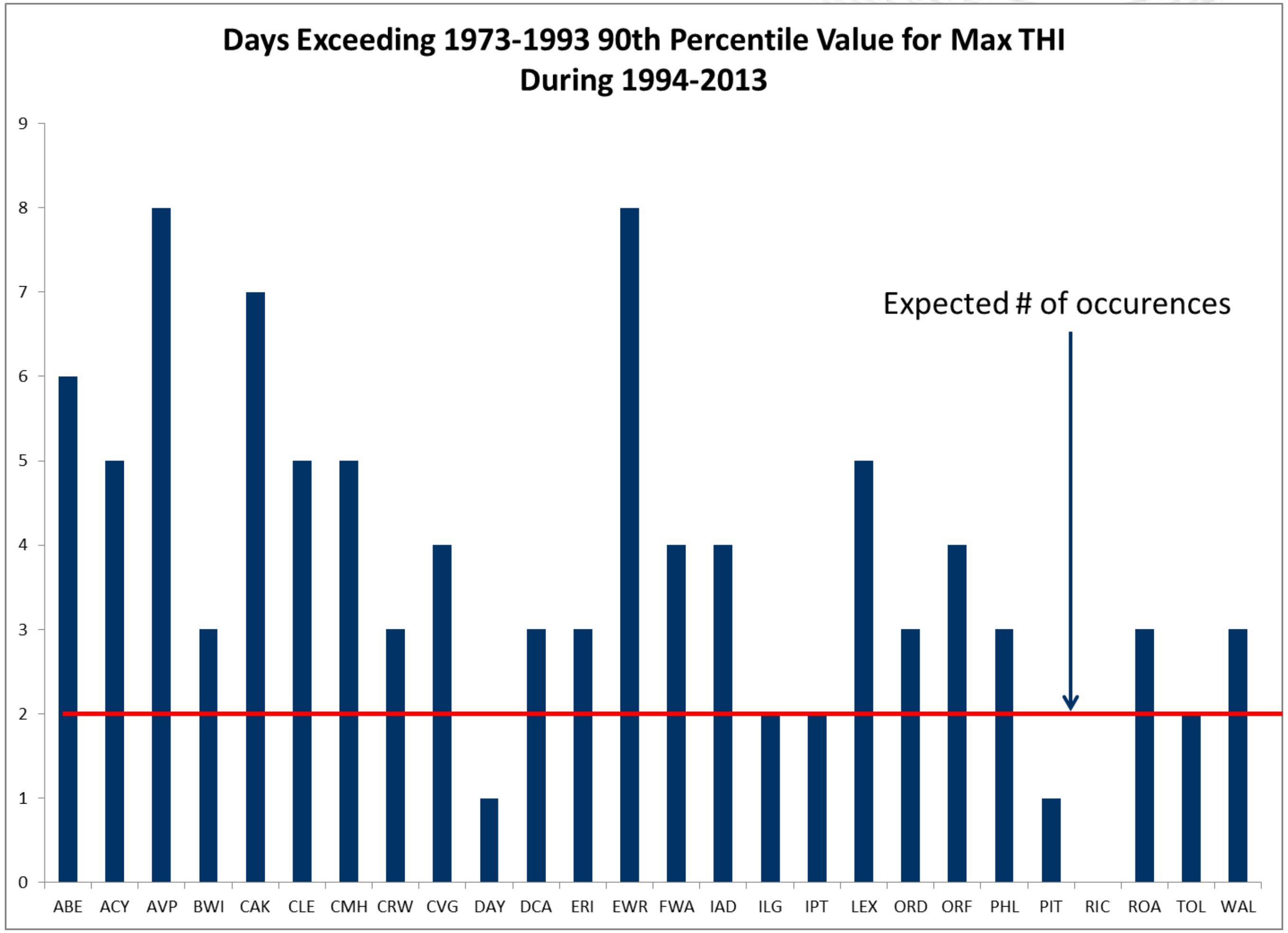
- Six weather stations exceeded their median 13 or more times (as many as 16) out of 20 years.

Investigation – *Comparing at the 90th Percentile*



- 20 of 26 weather stations had a higher 90th percentile value for maximum THI in the latter period

Investigation – *Comparing at the 90th Percentile*



- Twelve weather stations exceeded their 90th percentile value 4 or more times (as many as 8) out of 20 years.

- Observing the medians, there is some indication that more recent THI values are modestly higher. Many weather stations exceeded the median that would have been produced using weather data from 1973-1993 a significant number of times.

- 90th percentile values using a more recent sample are higher across the majority of weather stations. Furthermore, the frequency of exceeding a 90th percentile value from 1973-1993 across weather stations indicates that period is likely not indicative of more recent history.

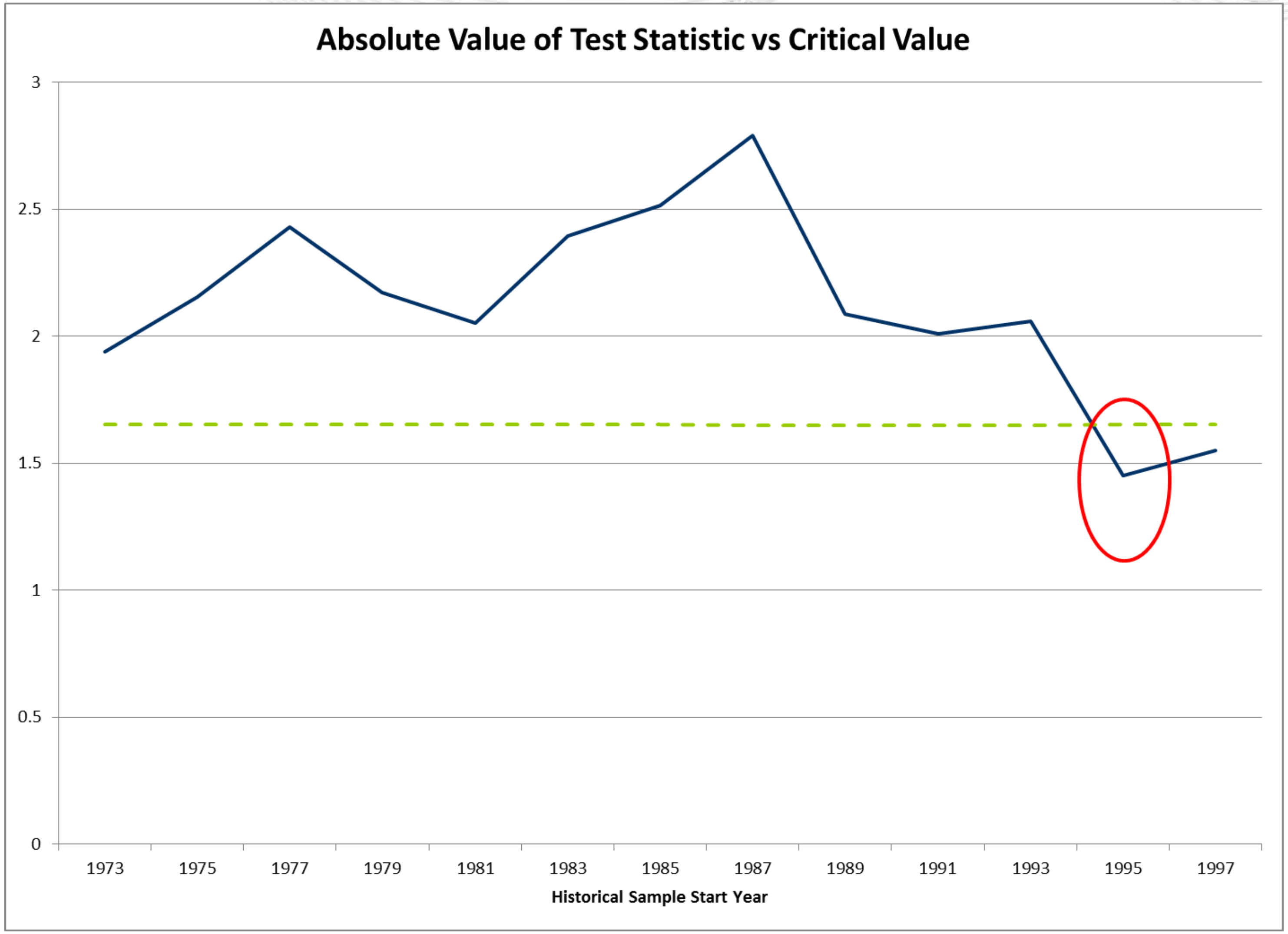
Determining a New Weather Period

- The bulk of the evidence suggests that using all available weather history back to the 1970s may not be a prudent practice going forward as it could contribute to understating peak loads.
- Analysis was performed to determine what would be a more appropriate starting year for the weather simulation.
    - Started with weather data from 2005 to 2014, then compared this time period with samples from historical years to evaluate data consistency. This determined possible start years for final weather period

Determining a New Weather Period – *Method Description*

- Sampled the 13 highest THI days for each year from each weather station for a varying number of years.
- The mean and standard deviation for each test sample was compared to the results to the 2005-2014 time period (control sample).
  - Test samples started with 1973-2004 and then incrementally removed two earlier years (i.e. 1975-2004, 1977-2004, etc.)
- Used a two-sample t-Test to determine if the test sample was consistent with the control sample.

Determining a New Weather Period – *Statistical Results*



Determining a New Weather Period – *Conclusion*

- Recommend shortening to a weather period starting in 1994/1995 depending on the number of years needed to produce an odd number of scenarios. Re-evaluate the decision to use 1994/1995 as a starting point periodically to make sure it remains consistent with evolving weather trends.

- Based on a 2013 survey of North American forecasters, a majority use 20 years or less to define normal weather. Of those changing the number of years, the majority are choosing a shorter number of years.

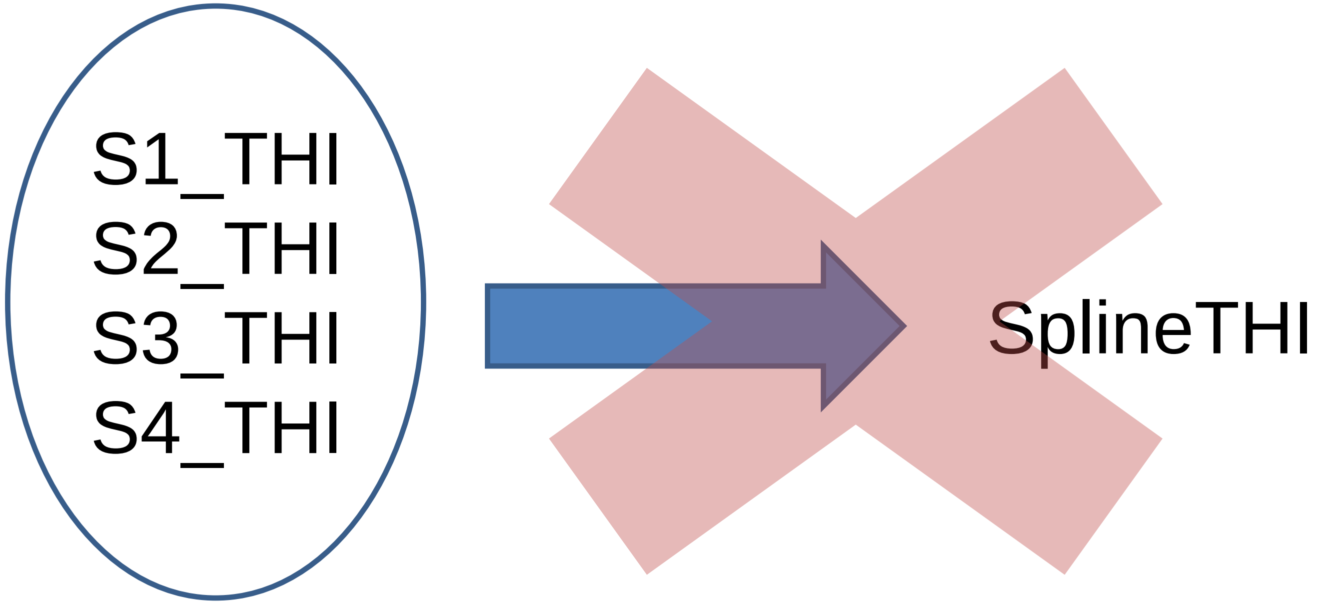
Changes Since Last Update

Overview

- Shortened weather simulation
- Modifications to splines
- Economics updated
  - Using July 2015 economics for analysis
    - New metro area definitions
  - Using Virginia economics for Dominion
- Updated Weather Stations (AEP, PL)
- Using Cooling Saturation figures from Dominion
- New Load Adjustments

- At the last update, PJM described an approach of pre-processing to create two variables *SplineTHI* and *SplineWWP*. This approach is described in Appendix B from the April LAS meeting here. Upon consideration, this has been re-thought for the following reasons:
  - Presumes that cooling/heating equipment have the same behavior at different ranges of THI and WWP
  - Slopes in different ranges that eventually get used as weights may be influenced by day-of-week or holiday factors.

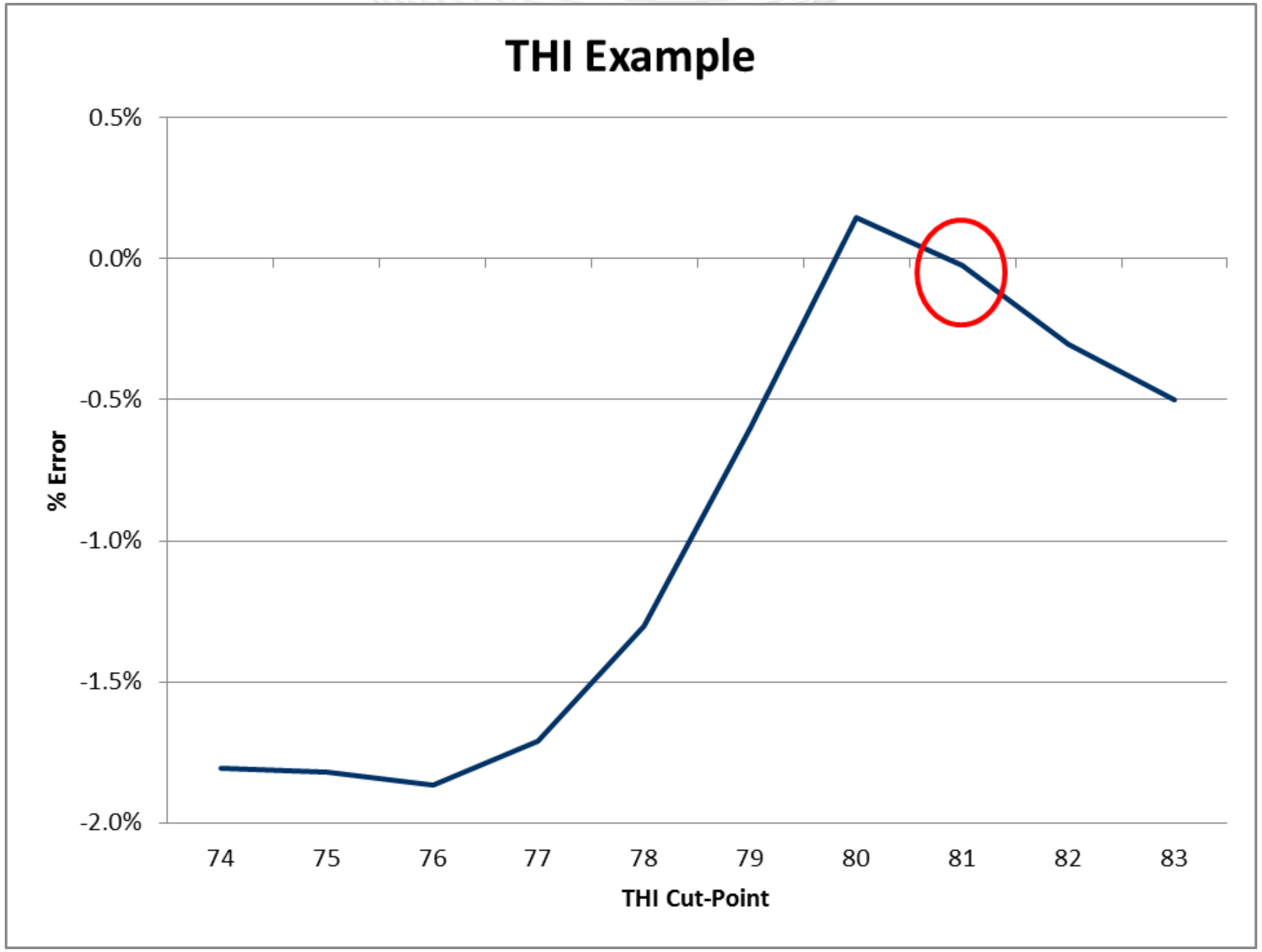
- Splines are split up, such that now each range of THI or WWP is represented as an individual variable rather than aggregated into a single weather measure.



Spline Modifications

- PJM also examined whether a single range definition used for each zone for THI and WWP was the best solution as zones have different weather characteristics.
- To analyze where the ranges should be defined, PJM conducted an analysis looking for the most appropriate cut-point for the extreme range (i.e. highest THI or lowest WWP).
- Controlling for load growth, weekends and holidays, analysis was conducted to see which cut-point would minimize error on the highest load days.

Spline Modifications – *THI example*



Spline Modifications – *THI ranges*

	S1_THI	S2_THI	S3_THI	S4_THI
AE	<=65	65-74	74-82	>82
AEP	<=65	65-73	73-81	>81
APS	<=65	65-73	73-81	>81
ATSI	<=65	65-73	73-81	>81
BGE	<=65	65-74	74-83	>83
COMED	<=65	65-73	73-81	>81
DAYTON	<=65	65-73	73-81	>81
DPL	<=65	65-74	74-82	>82
DQE	<=65	65-73	73-80	>80
DUKE	<=65	65-73	73-81	>81
EKPC	<=65	65-74	74-82	>82
JCPL	<=65	65-73	73-81	>81
METED	<=65	65-73	73-81	>81
PECO	<=65	65-74	74-82	>82
PENLC	<=65	65-72	72-78	>78
PEPCO	<=65	65-74	74-83	>83
PL	<=65	65-72	72-79	>79
PS	<=65	65-73	73-81	>81
RECO	<=65	65-73	73-81	>81
UGI	<=65	65-72	72-79	>79
VEPCO	<=65	65-74	74-82	>82

Spline Modifications – *WWP ranges*

	S1_WWP	S2_WWP	S3_WWP	S4_WWP
AE	>=40	32-40	24-32	<24
AEP	>=40	32-40	24-32	<24
APS	>=40	31-40	22-31	<22
ATSI	>=40	29-40	18-29	<18
BGE	>=40	34-40	28-34	<28
COMED	>=40	28-40	17-28	<17
DAYTON	>=40	30-40	21-30	<21
DPL	>=40	34-40	29-34	<29
DQE	>=40	30-40	21-30	<21
DUKE	>=40	32-40	25-32	<25
EKPC	>=40	32-40	25-32	<25
JCPL	>=40	33-40	27-33	<27
METED	>=40	31-40	23-31	<23
PECO	>=40	33-40	27-33	<27
PENLC	>=40	30-40	20-30	<20
PEPCO	>=40	35-40	30-35	<30
PL	>=40	31-40	23-31	<23
PS	>=40	34-40	28-34	<28
RECO	>=40	33-40	27-33	<27
UGI	>=40	29-40	18-29	<18
VEPCO	>=40	36-40	32-36	<32

- New Summer Seasonal Variables
  - S1_THI
  - Cool * S2_THI
  - Cool * S3_THI
  - Cool * S4_THI
- New Winter Seasonal Variables
  - Heat * S1_WWP
  - Heat * S2_WWP
  - Heat * S3_WWP
  - Heat * S4_WWP

- Analysis is now using Moody’s Analytics July 2015 Economic Forecast
  - Includes re-definition of metro areas
- Dominion
  - Previously had used metro areas Richmond VA, Virginia Beach VA and Roanoke VA.
  - Now uses Virginia
    - Findings show more accurate results (previous metro grouping misses some of the high growth in Northern Virginia)
    - Findings show it produces a higher forecast than with the metro grouping

Economics – *Zonal Representation*

AE	Atlantic City - Hammonton, NJ
	Ocean City, NJ
	Vineland-Millville-Bridgeton, NJ
AEP	Elkhart-Goshen, IN
	Fort Wayne, IN
	Muncie, IN
	South Bend-Mishawaka, IN-MI
	Niles-Benton Harbor, MI
	Canton-Massillon, OH
	Columbus, OH
	Lima, OH
	Kingsport-Bristol-Bristol, TN-VA
	Blacksburg-Christiansburg-Radford, VA
	Lynchburg, VA
	Roanoke, VA
	Beckley, WV
	Charleston, WV
	Huntington-Ashland, WV-KY-OH
	Weirton-Steubenville, WV-OH
APS	Cumberland, MD-WV
	Hagerstown-Martinsburg, MD-WV
	Chambersburg-Waynesboro, PA
	State College, PA
	Winchester, VA-WV
	Morgantown, WV
	Parkersburg-Marietta-Vienna, WV-OH

ATSI	Akron, OH
	Cleveland-Elyria-Mentor, OH
	Mansfield, OH
	Springfield, OH
	Toledo, OH
	Youngstown-Warren-Boardman, OH-PA
	Pittsburgh, PA
BGE	Baltimore-Towson, MD
COMED	Chicago-Joliet-Naperville, IL (Division)
	Elgin, IL (Division)
	Kankakee-Bradley, IL
	Lake County-Kenosha County, IL-WI (Division)
	Rockford, IL
DAYTON	Dayton, OH
DPL	Dover, DE
	Wilmington, DE-MD-NJ (Division)
	Salisbury, MD
DQE	Pittsburgh, PA
DUKE	Cincinnati-Middletown, OH-KY-IN
EKPC	Bowling Green, KY
	Elizabethtown, KY
	Lexington-Fayette, KY
	Louisville-Jefferson County, KY-IN
	Cincinnati-Middletown, OH-KY-IN
	Huntington-Ashland, WV-KY-OH

Economics – *Zonal Representation cont.*

JCPL	Camden, NJ (Division)
	Newark-Union, NJ-PA (Division)
	Trenton-Ewing, NJ
METED	Allentown-Bethlehem-Easton, PA-NJ
	East Stroudsburg, PA
	Gettysburg, PA
	Lebanon, PA
	Reading, PA
	York-Hanover, PA
PECO	Montgomery-Bucks-Chester, PA (Division)
	Philadelphia, PA (Division)
PENLC	Altoona, PA
	Erie, PA
	Johnstown, PA
PEPCO	California-Lexington Park, MD
	Washington-Arlington-Alexandria, DC-VA-MD-WV (Division)

PL	Allentown-Bethlehem-Easton, PA-NJ
	Bloomsburg-Berwick, PA
	East Stroudsburg, PA
	Harrisburg-Carlisle, PA
	Lancaster, PA
	Scranton--Wilkes-Barre, PA
PS	Camden, NJ (Division)
	Newark-Union, NJ-PA (Division)
	Trenton-Ewing, NJ
RECO	Newark-Union, NJ-PA (Division)
UGI	Scranton--Wilkes-Barre, PA
VEPCO	Virginia

Weather Stations – *Zonal Representation*

Zone	Weather Station	Weight
AE	ACY	1.0000
AEP	CAK	0.15058
	CMH	0.23447
	CRW	0.2258
	FWA	0.22685
	ROA	0.1623
APS	IAD	0.3000
	PIT	0.7000
ATSI	CAK	0.4650
	CLE	0.3000
	PIT	0.0850
	TOL	0.1500
BGE	BWI	1.0000
COMED	ORD	1.0000
DAYTON	DAY	1.0000
DPL	ILG	0.7000
	WAL	0.3000
DQE	PIT	1.0000
DUKE	CVG	1.0000

Zone	Weather Station	Weight
EKPC	LEX	1.0000
JCPL	ACY	0.2500
	EWR	0.7500
METED	ABE	0.5000
	PHL	0.5000
PECO	PHL	1.0000
PENLC	ERI	0.5000
	IPT	0.5000
PEPCO	DCA	1.0000
PL	ABE	0.2500
	AVP	0.2500
	IPT	0.2500
	MDT	0.2500
PS	EWR	1.0000
RECO	EWR	1.0000
UGI	AVP	1.0000
VEPCO	IAD	0.3333
	ORF	0.3333
	RIC	0.3334

- If zonal forecasters have questions and/or suggestions about zonal grouping:
  - Email Load_Analysis_Team@PJM.com

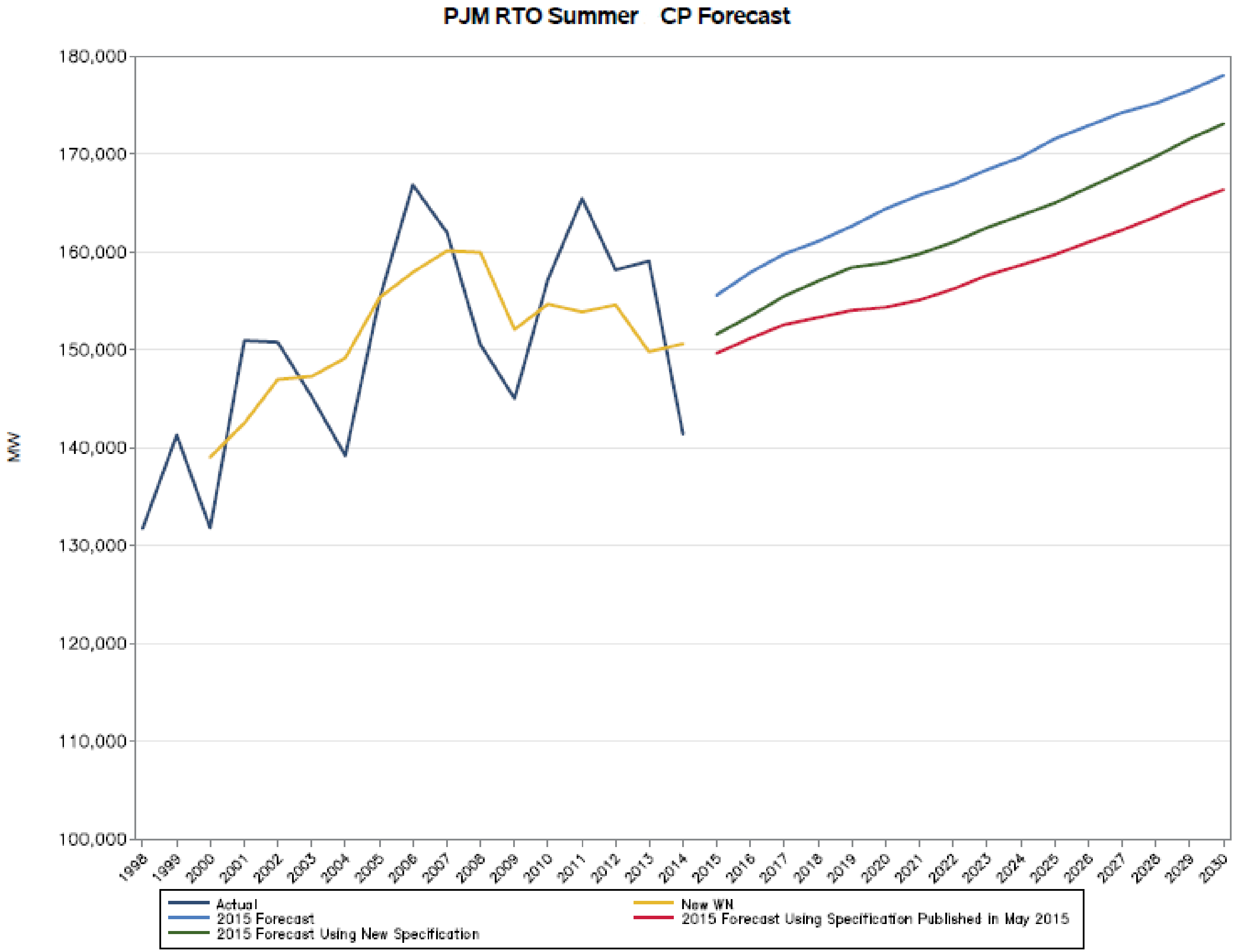
- For the new equipment indexes each zone is assigned to a Census Division. Historical and forecast data for equipment saturation and equipment efficiency are then used to construct the index. Further info on the index construction can be found in Appendix A from the April 2015 LAS meeting here.
- Dominion provided PJM with residential cooling saturation figures. PJM used their history, in place of those in Census Division, for the residential cooling part of the index and appended the forecast from the EIA. Remaining components of the index remain as those from EIA.

- PJM will often include load adjustments to account for large shifts in load caused by a shift in zonal definition, the loss of a large industrial customer, or an otherwise large shift in load not explained by the model parameters.
- A load adjustment is a binary variable in the model. It would be defined as 1 in the specified years and 0 in all other years.

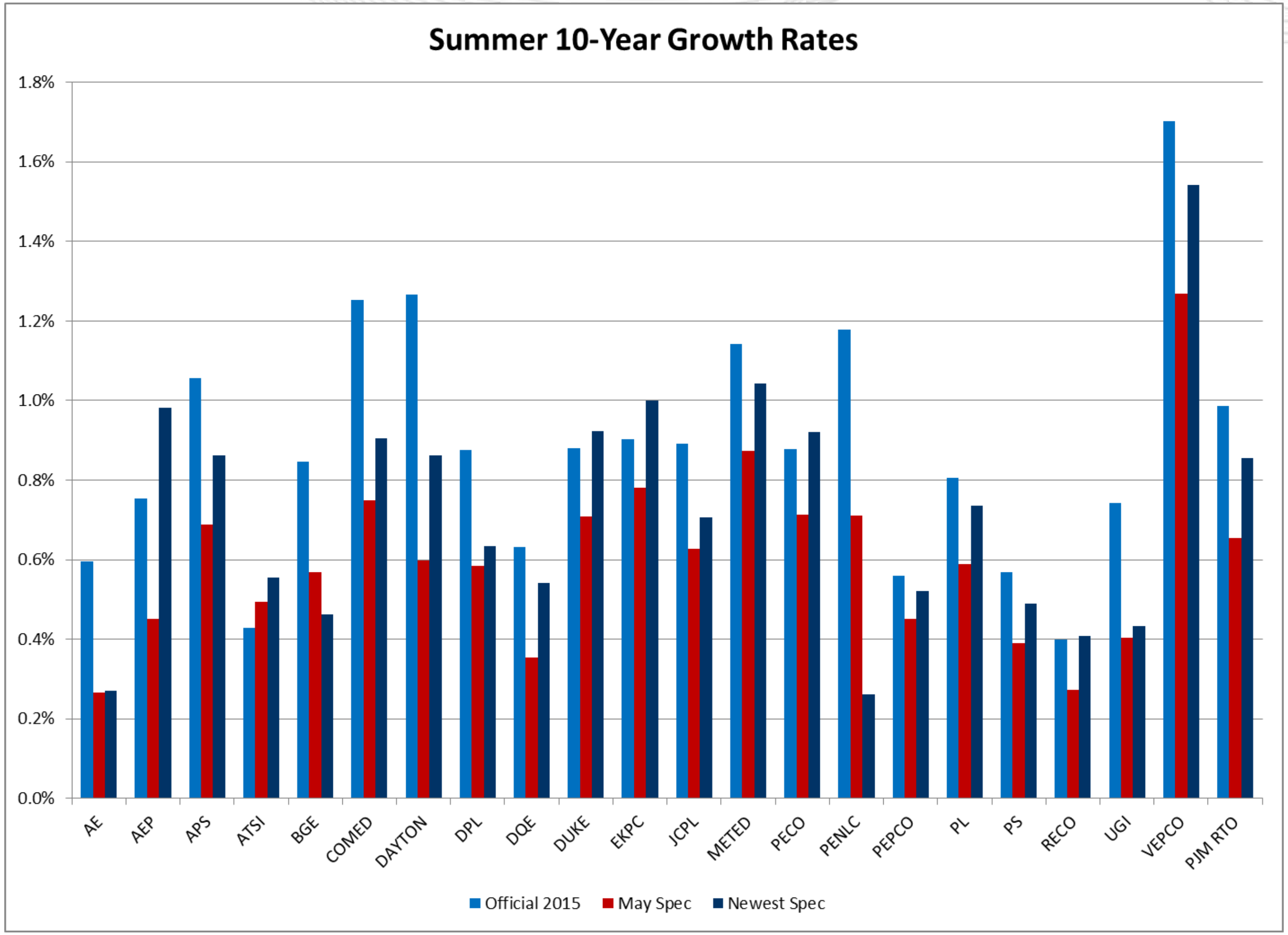
- PJM re-examined existing load-adjustments and revised them by examining trends in base load relative to the Economic Index interacted with the Other Equipment Index (driver for base load in the forecast model specification).

AEP	2005-2006	Load shift and large industrial customer on/off
AEP	2013	Loss of large industrial customer
APS	2006	Load shift
ATSI	2009	Load shift
DUKE	2008	Load shift
EKPC	2013	Load shift (definitional discrepancy pre/post integration)
PENLC	2004	Load shift

Forecast Discussion


PJM RTO Summer CP Forecast
MW
180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Actual
2015 Forecast
2015 Forecast Using New Specification
New WN
2015 Forecast Using Specification Published in May 2015

RTO Summer Forecast



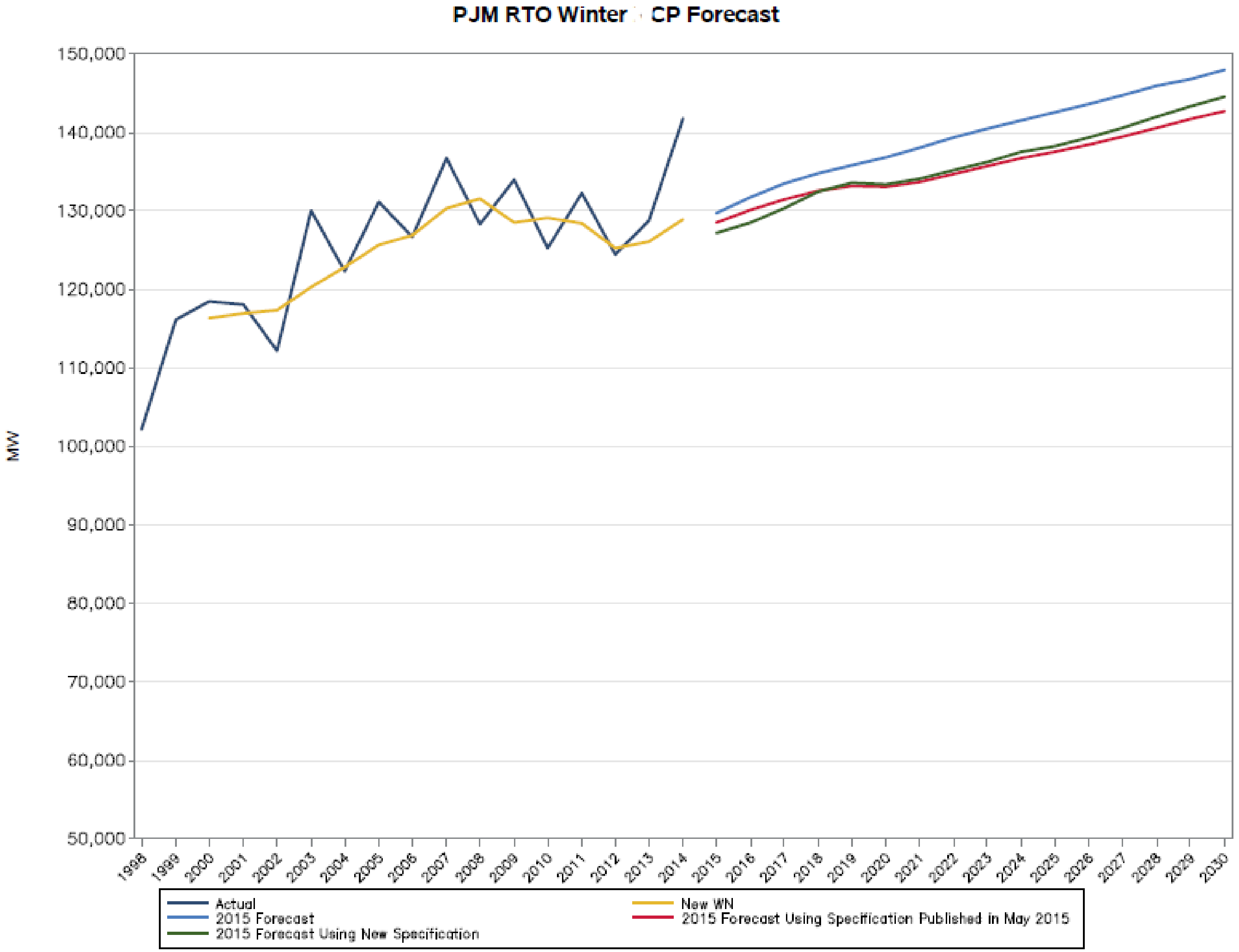
RTO Summer Forecast Summary

- The latest forecast with an updated specification, updated economics, and revised assumptions on the weather simulation period is:
  - 2.6% lower than the official 2015 forecast for 2018
  - 2.4% higher than the forecast posted in May for 2018
- Growth relative to the 2014 WN (150,631 MW)
  - Official 2015: +3.3%
  - May Spec: -0.7%
  - Newest Spec: +0.6%

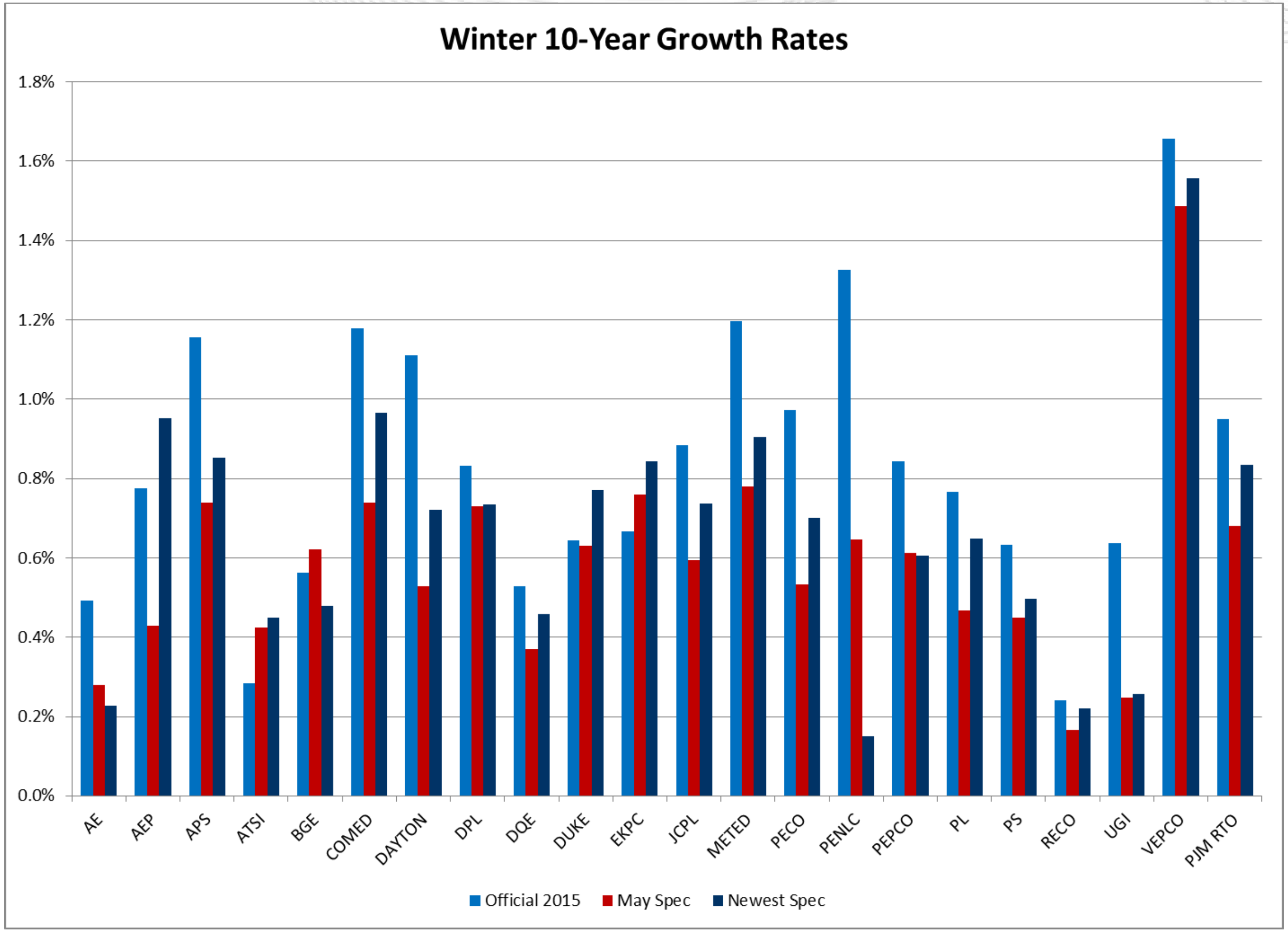
RTO Summer Forecast Summary

- 10-year (2015-2025) growth rates:
  - Official 2015: 0.99%
  - May Spec: 0.65%
  - Newest Spec: 0.85%
- Zonal graphs are available with meeting materials

RTO Winter Forecast



RTO Winter Forecast



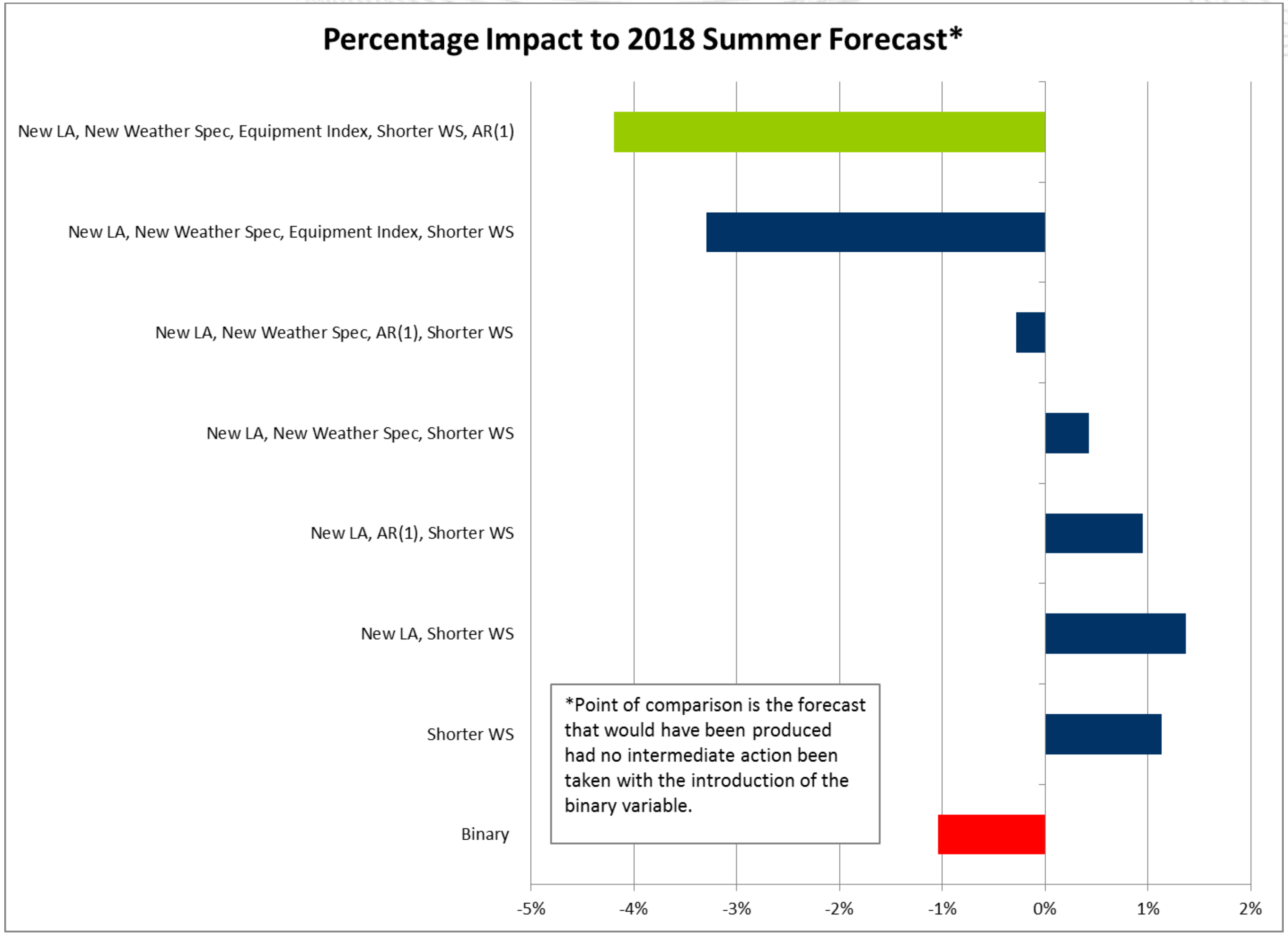
- The latest forecast with an updated specification, updated economics, and revised assumptions on the weather simulation period is:
  - 1.8% lower than the official 2015 forecast for 2018
  - 0.1% lower than the forecast posted in May for 2018
- Growth relative to the 2013/2014 WN (X MW)
  - Official 2015: +0.6%
  - May Spec: -0.3%
  - Newest Spec: -1.3%

- 10-year (2015-2025) growth rates:
  - Official 2015: 0.95%
  - May Spec: 0.68%
  - Newest Spec: 0.83%
- Zonal graphs are available with meeting materials

Decomposition of Forecast Changes

- PJM ran a series of sensitivities to help stakeholders understand what is driving the change to the forecast. Some are abbreviated on the chart on the following slide:
  - Shorter WS: Shorter Weather Simulation
  - New LA: New set of Load Adjustments
  - AR(1): Autoregressive Error term
  - New Weather Spec: Change in weather specification
  - Equipment Index: Cooling, Heating, and Other Equipment Indexes that measure saturation and efficiency

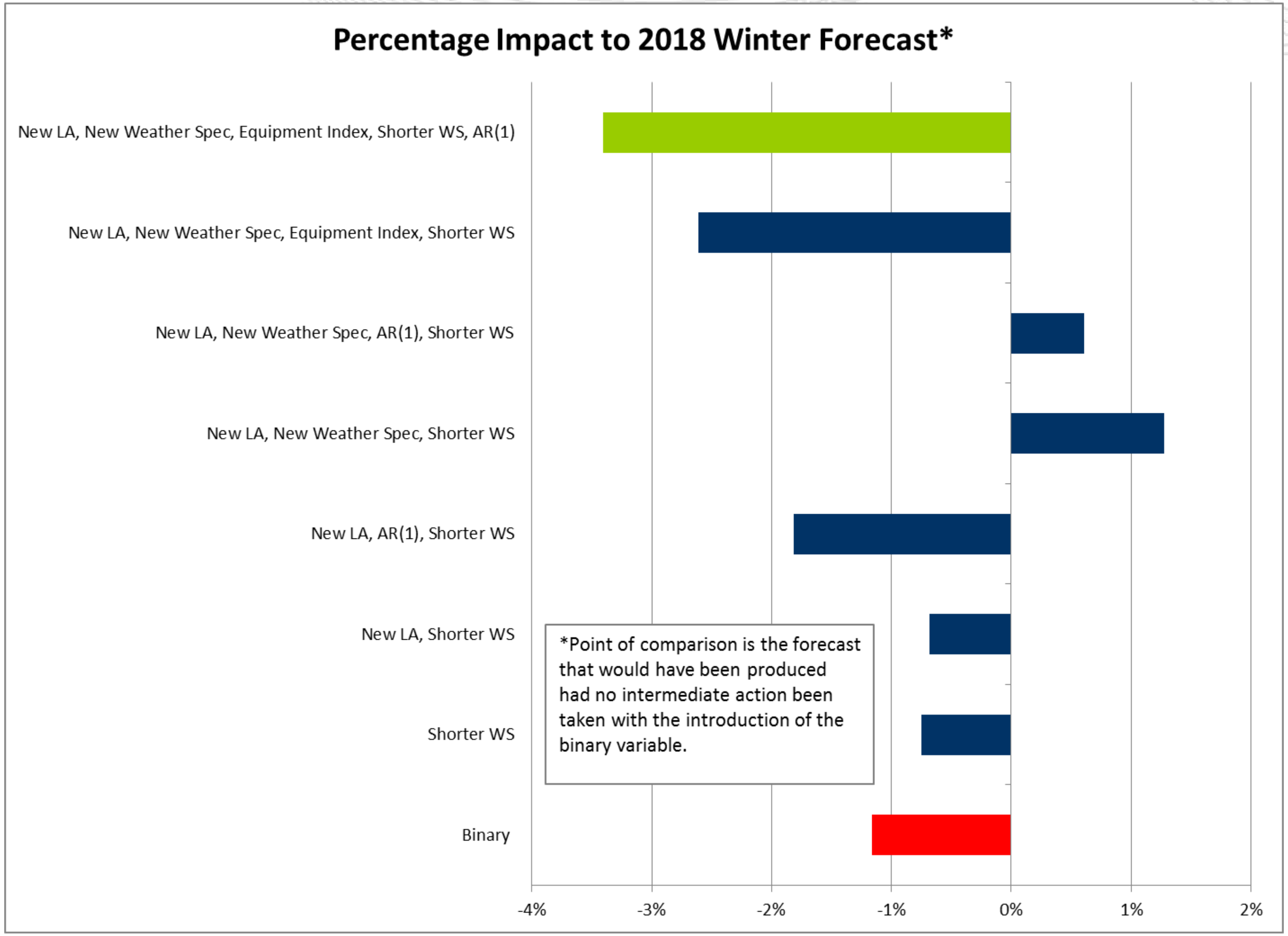
Decomposition of Forecast Changes - Summer



Decomposition of Forecast Changes – Summer Summary

- Equipment index variables both lower the starting point and reduce forecasted growth from that point.
- Weather re-specification has small impact on forecasted growth, most of its impact is through lowering of the starting point.
- Autoregressive Error Term has minimal impact on growth, primarily works to reduce the starting point.
- Shortening the Weather Simulation period raises the starting point

Decomposition of Forecast Changes - Winter



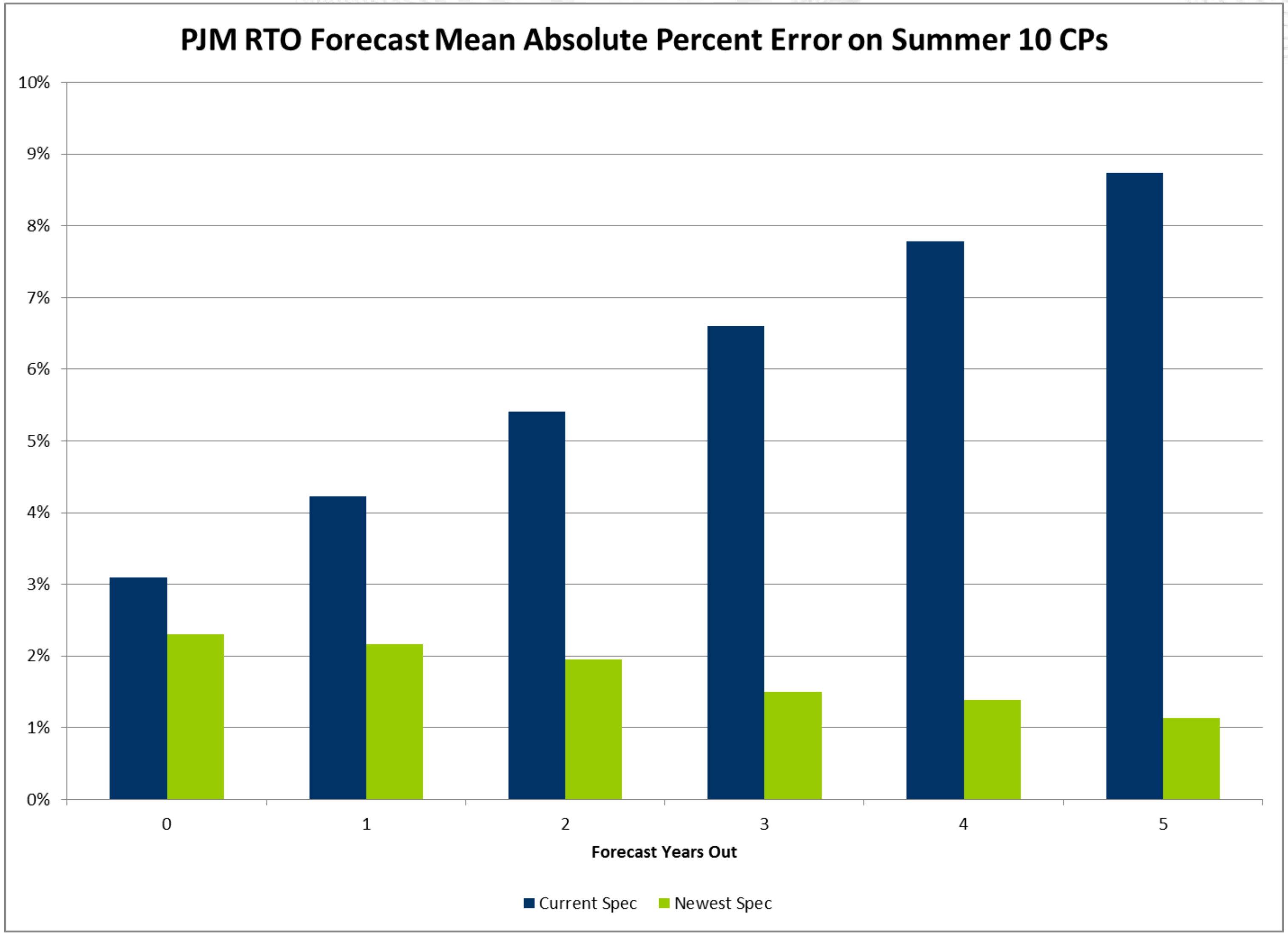
Decomposition of Forecast Changes – Winter Summary

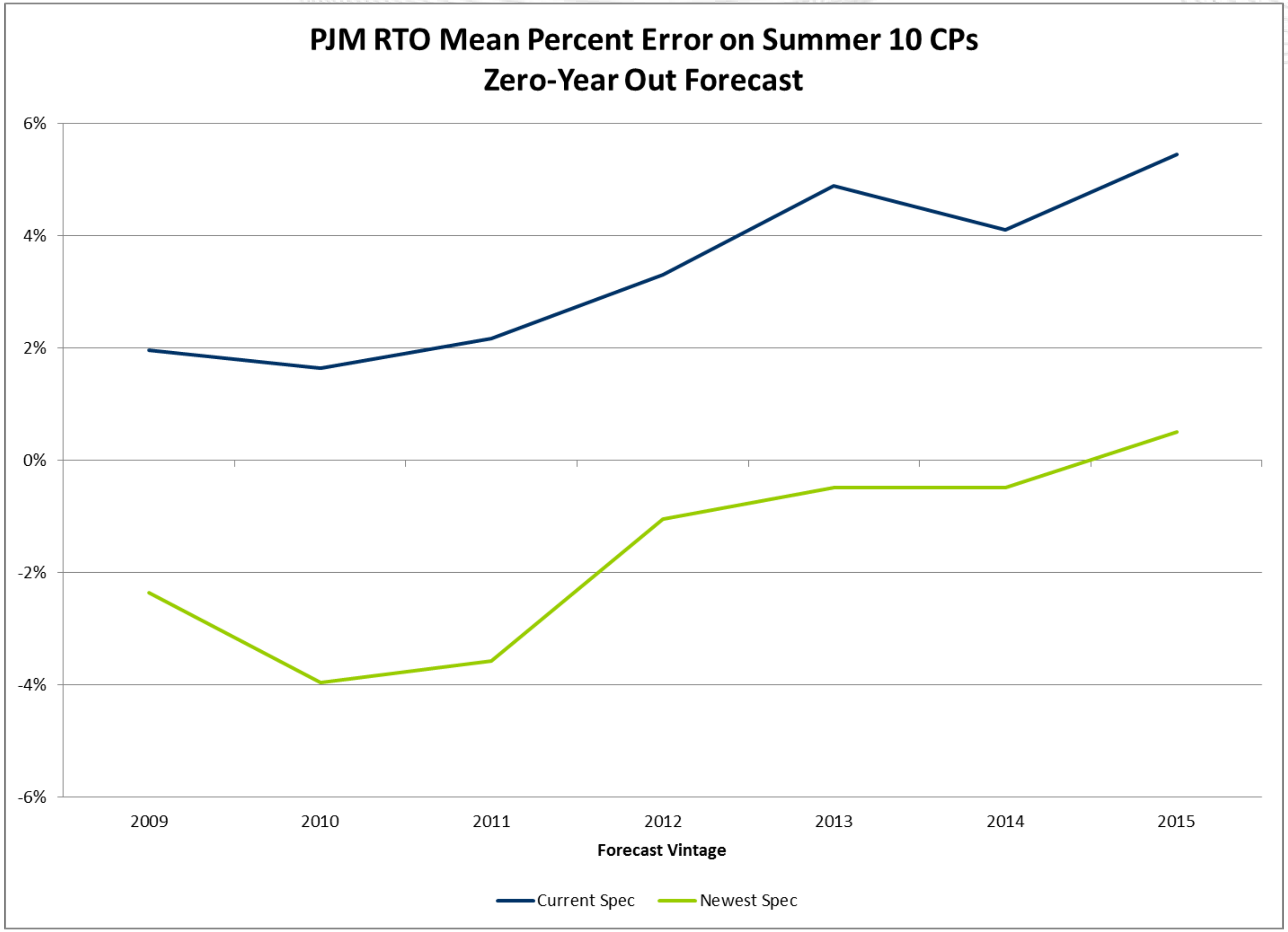
- Equipment index variables both lower the starting point and reduce forecasted growth from that point.
- Weather re-specification has small impact on forecasted growth, most of its impact is through raising of the starting point.
- Autoregressive Error Term has minimal impact on growth, primarily works to reduce the starting point.
- Shortening the Weather Simulation lowers the starting point

Accuracy

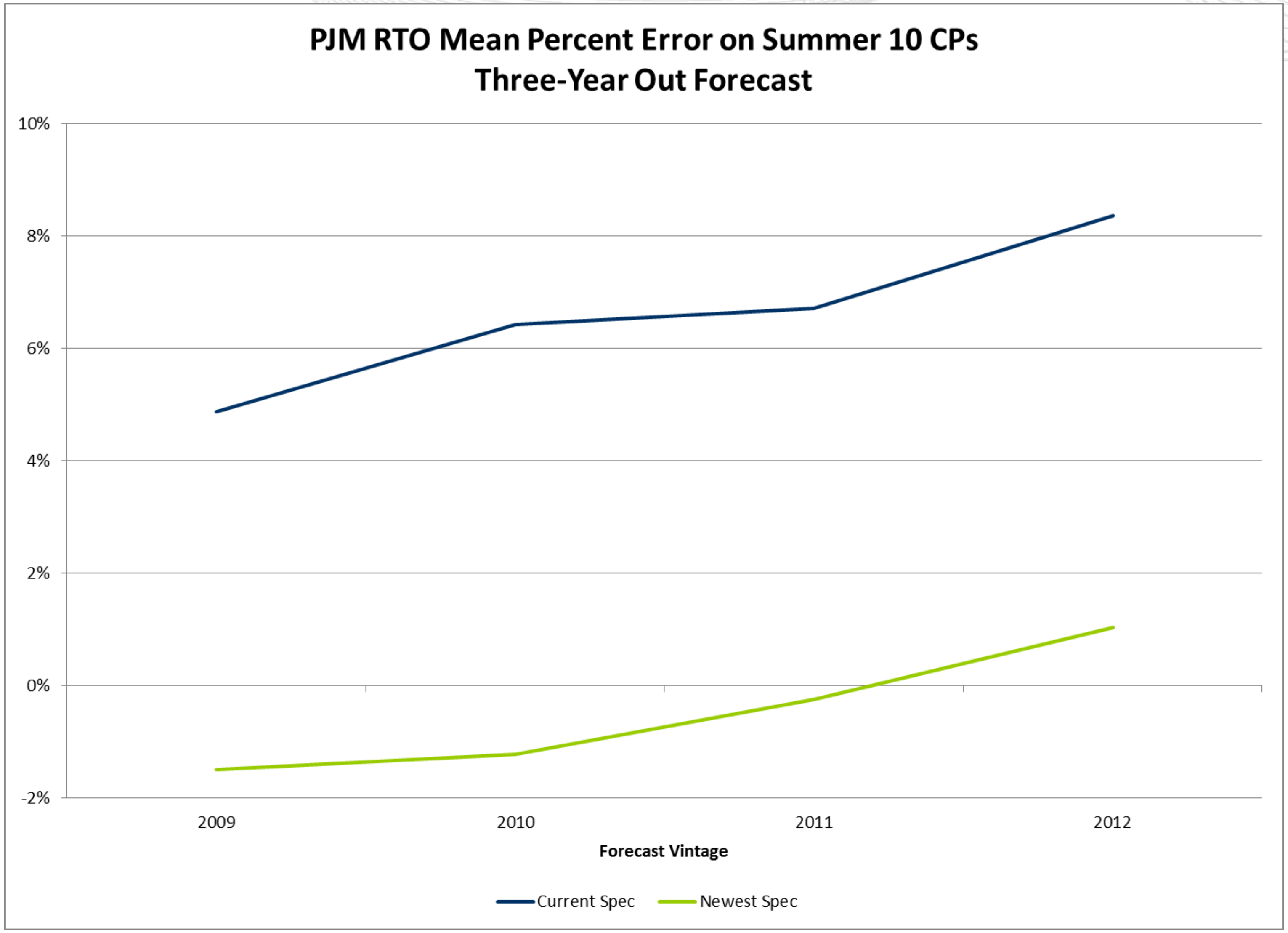
- PJM conducted accuracy analysis on top 10 days from each year using forecasts constructed with July 2015 vintage economics and Equipment Saturation/Efficiency data as of 2014.
- Forecasts were produced with estimation periods ending August 2008 through ending in August 2014
- Analysis was conducted for years 2009 through 2015
  - 2015 analysis conducted using posted metered data and only uses data through July 31, 2015

Accuracy – PJM RTO



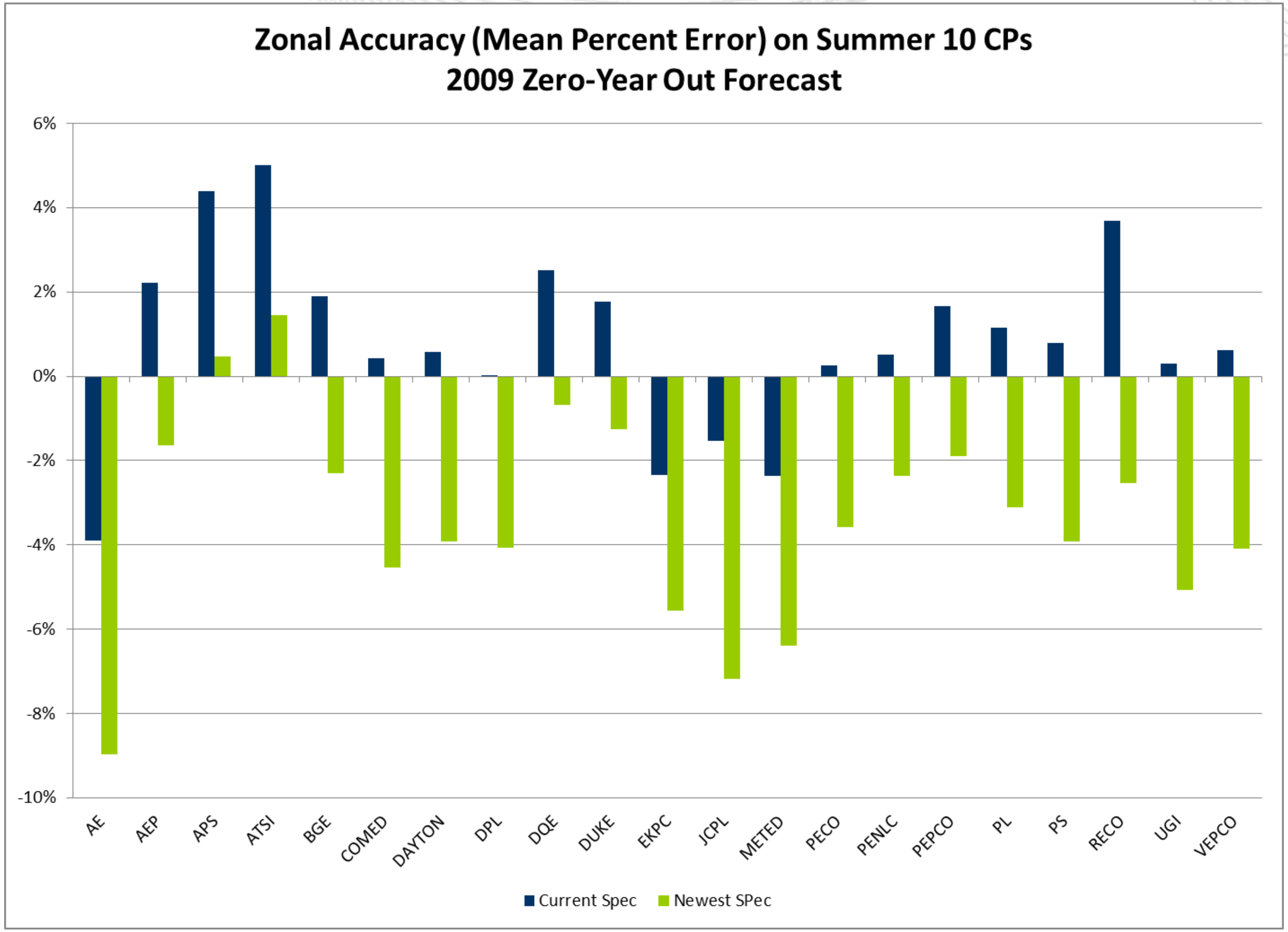

PJM RTO Mean Percent Error on Summer 10 CPs
Zero-Year Out Forecast
6%
4%
2%
0%
-2%
-4%
-6%
2009
2010
2011
2012
2013
2014
2015
Forecast Vintage
Current Spec
Newest Spec

Accuracy – PJM RTO

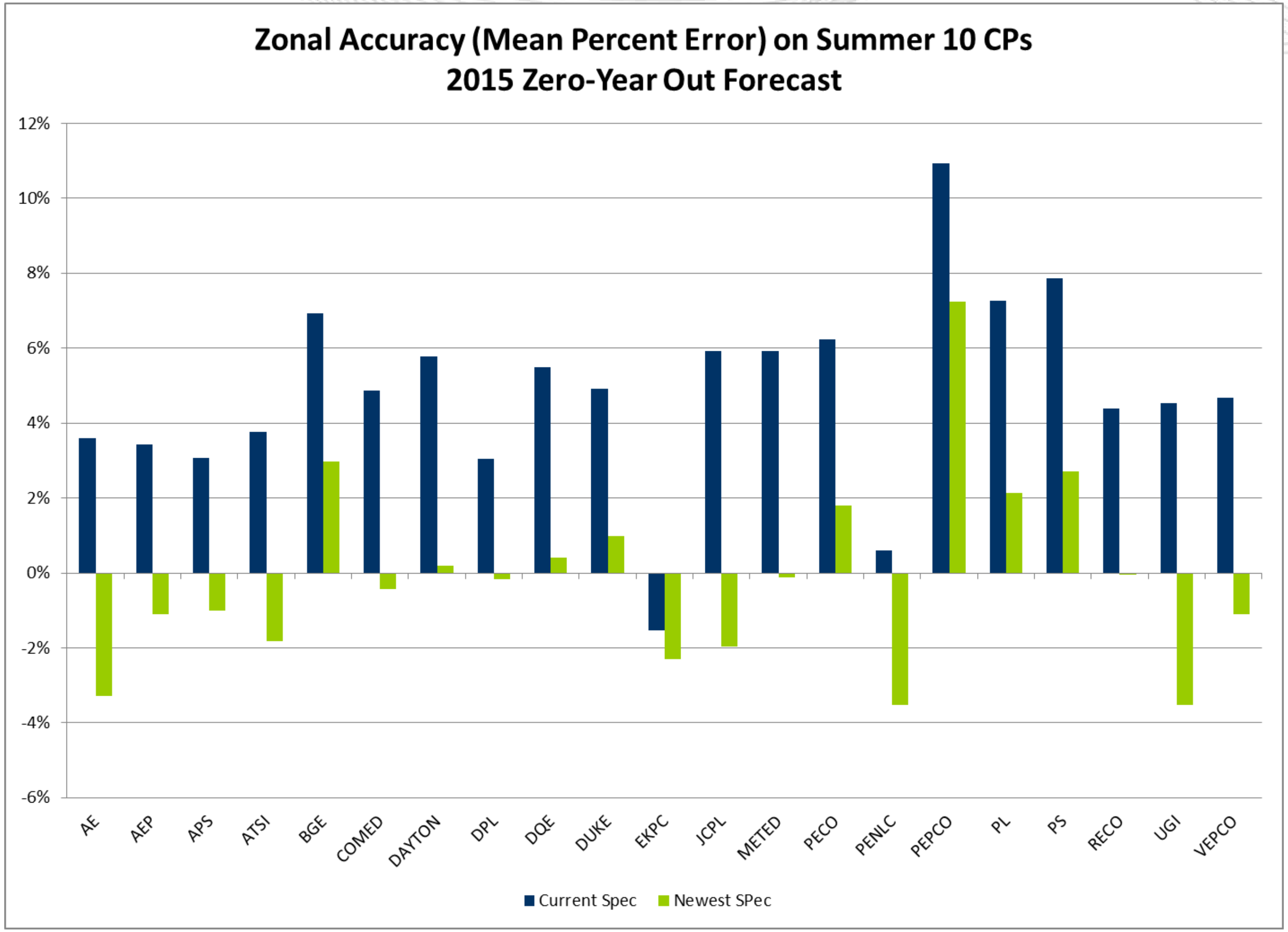


- Developing Equipment Index trends have only recently started to become a valuable tool in the PJM forecasting model. Prior to 2011 or 2012, the model may not have had enough information on equipment trends to make proper forecasting judgments.
- The New Specification has shown a tendency to get better as it gets more information, whereas the Current Specification is getting worse.
- On a three-year out basis the mean absolute percent error of the New Specification is 1.5% versus 6.6% for the Current Specification (an improvement of roughly 75%).
  - This improvement is even more stark in 2015 (85%).

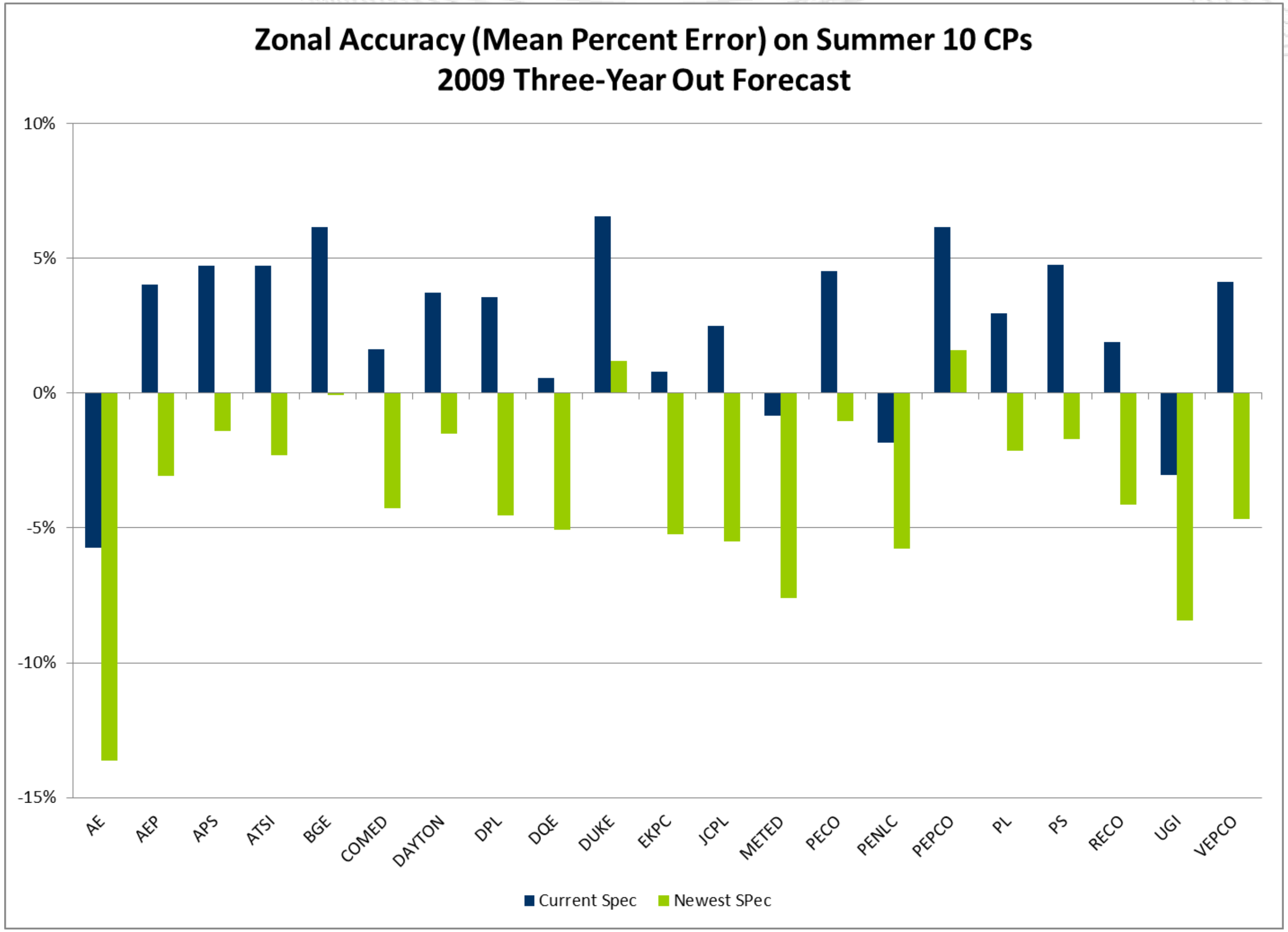
Accuracy – Zones



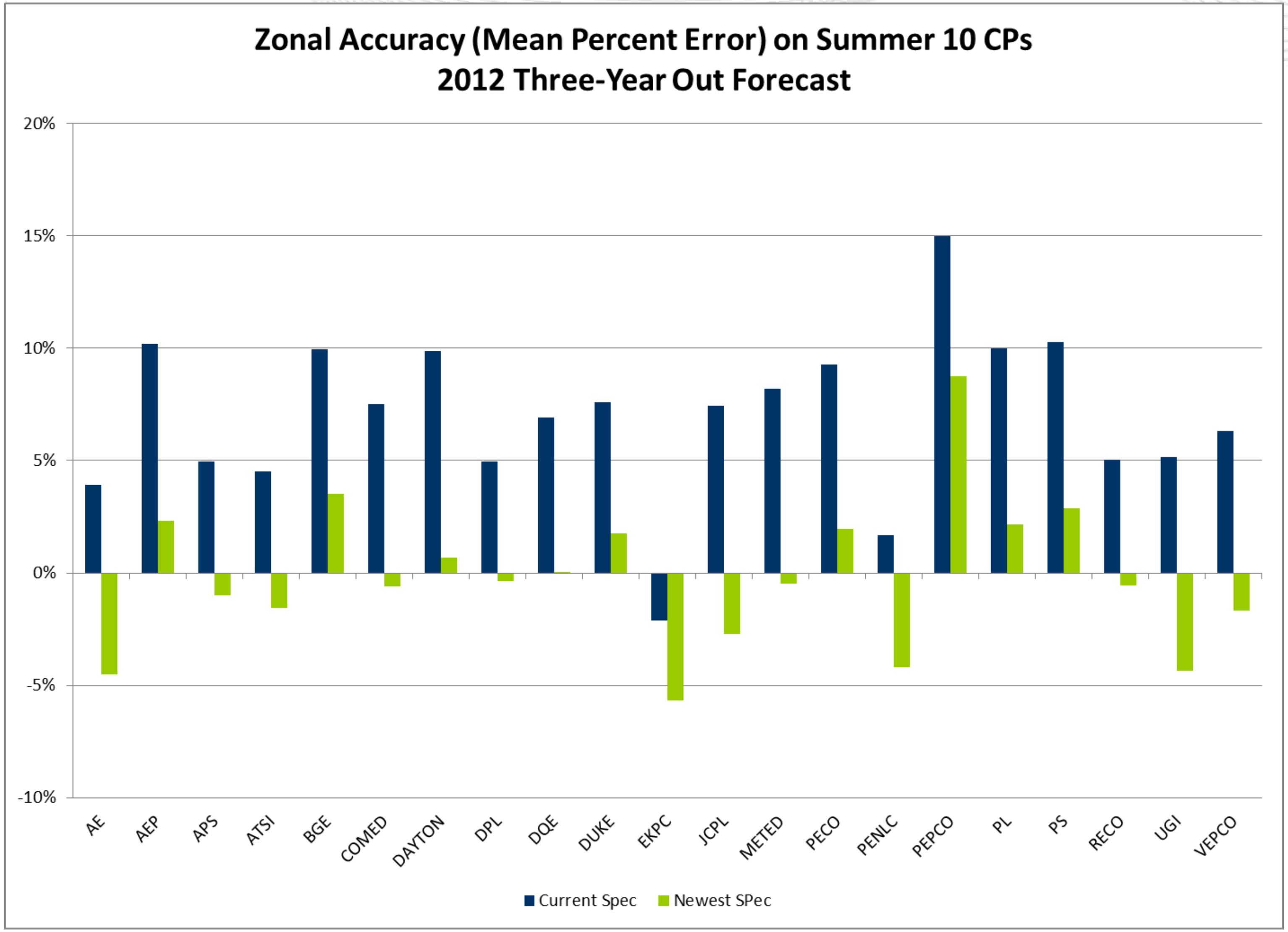
Accuracy – Zones



Accuracy – Zones



Accuracy – Zones



Zonal Accuracy Summary

- The New Specification has shown a tendency to get better as it gets more information, whereas the Current Specification is getting worse.
- For the three-year out forecast, on a zonal-weighted basis, the Mean Absolute Percent Error is 3% in the New Specification. This compares with 6% in the Current Specification.

To Do

- What is presented is ***NOT*** the 2016 Official Forecast
  - Economics will be updated again
  - Equipment index trends will be updated with 2015 data
    - And any additional zonal saturation data if supplied and appropriate
  - Any additional model changes between now and then
  - Add an additional year in the estimation period
  - Potential additional changes to Weather Station mixture
  - Addbacks for 2015
- Manual Language still needs to be developed and presented before PC/MRC