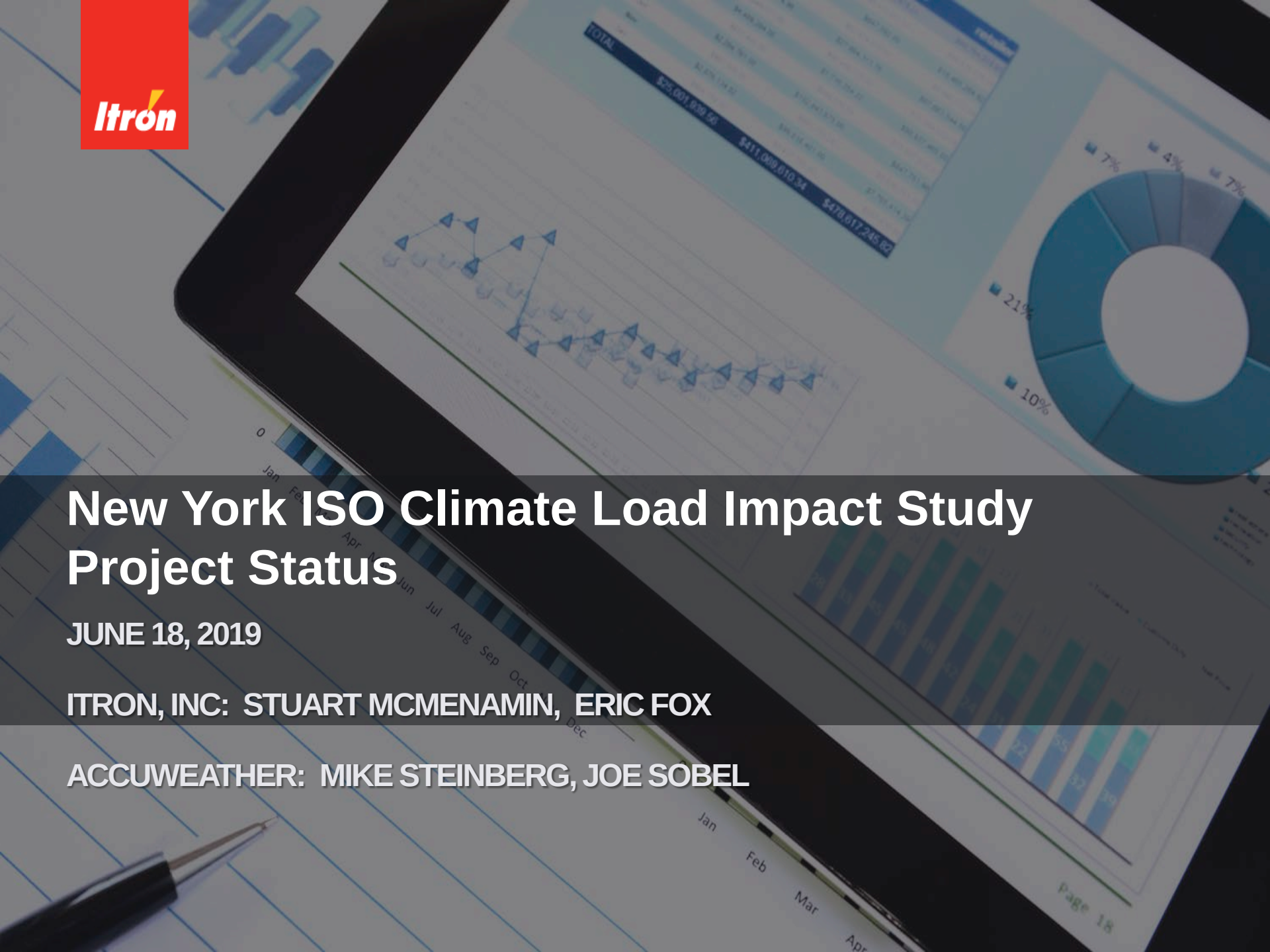


New York ISO Climate Load Impact Study Project Status

JUNE 18, 2019

ITRON, INC: STUART MCMENAMIN, ERIC FOX

ACCUWEATHER: MIKE STEINBERG, JOE SOBEL

AGENDA

1. Introductions

2. Study Objectives

3. Climate Impact and Weather Trend Analysis
   - Building HDD and CDD That Reflect Climate Change

4. Modeling Climate Changes Impact on Transmission Load
   - Baseline Demand, Energy, and Load Model
   - Incorporating New Technologies

5. Questions and LFTF Input

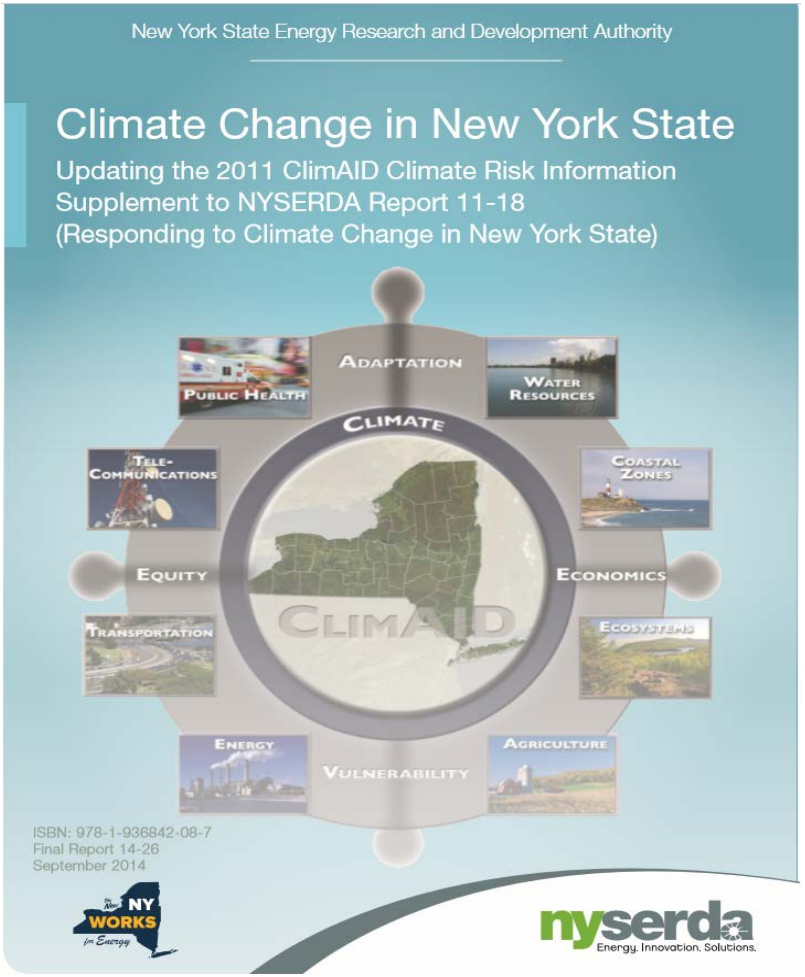
STUDY OBJECTIVES

- First phase of a three phase study

- Develop energy, peak, and 8760 hourly load forecasts for transmission planning areas that reflect the potential impact of climate change
  - Assess current trends and climate change scenarios
  - Leverage off of NYSERDA and ConEdison climate studies

- In addition to weather impacts forecast to account for
  - Population and economic growth
  - End-use saturation and efficiency trends
  - Adoption of new technologies
    - Solar
    - Electric vehicles
    - Electrification programs (e.g., cold climate heat pumps, DER)

NYSERDA CLIMATE IMPACT STUDY



- Increasing temperatures

Table 3. Mean Annual Changes (continued)
Region 4 (New York City) – Temperature

Baseline (1971-2000) 54.6 °F	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
2020s	+ 1.5 °F	+ 2.0 to 2.9 °F	+ 3.2 °F
2050s	+ 3.1 °F	+ 4.1 to 5.7 °F	+ 6.6 °F
2080s	+ 3.8 °F	+ 5.3 to 8.8 °F	+ 10.3 °F
2100	+ 4.2 °F	+ 5.8 to 10.4 °F	+ 12.1 °F

- More heat waves

d. Region 4 – New York City

2020s	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
Days over 90 °F (18 days)	24	26 to 31	33
# of Heat Waves (2 heat waves)	3	3 to 4	4
Duration of Heat Waves (4 days)	5	5 to 5	5
Days below 32 °F (71 days)	50	52 to 58	60
Days over 1" Rainfall (13 days)	13	14 to 15	16
Days over 2" Rainfall (3 days)	3	3 to 4	5

- Rising ocean

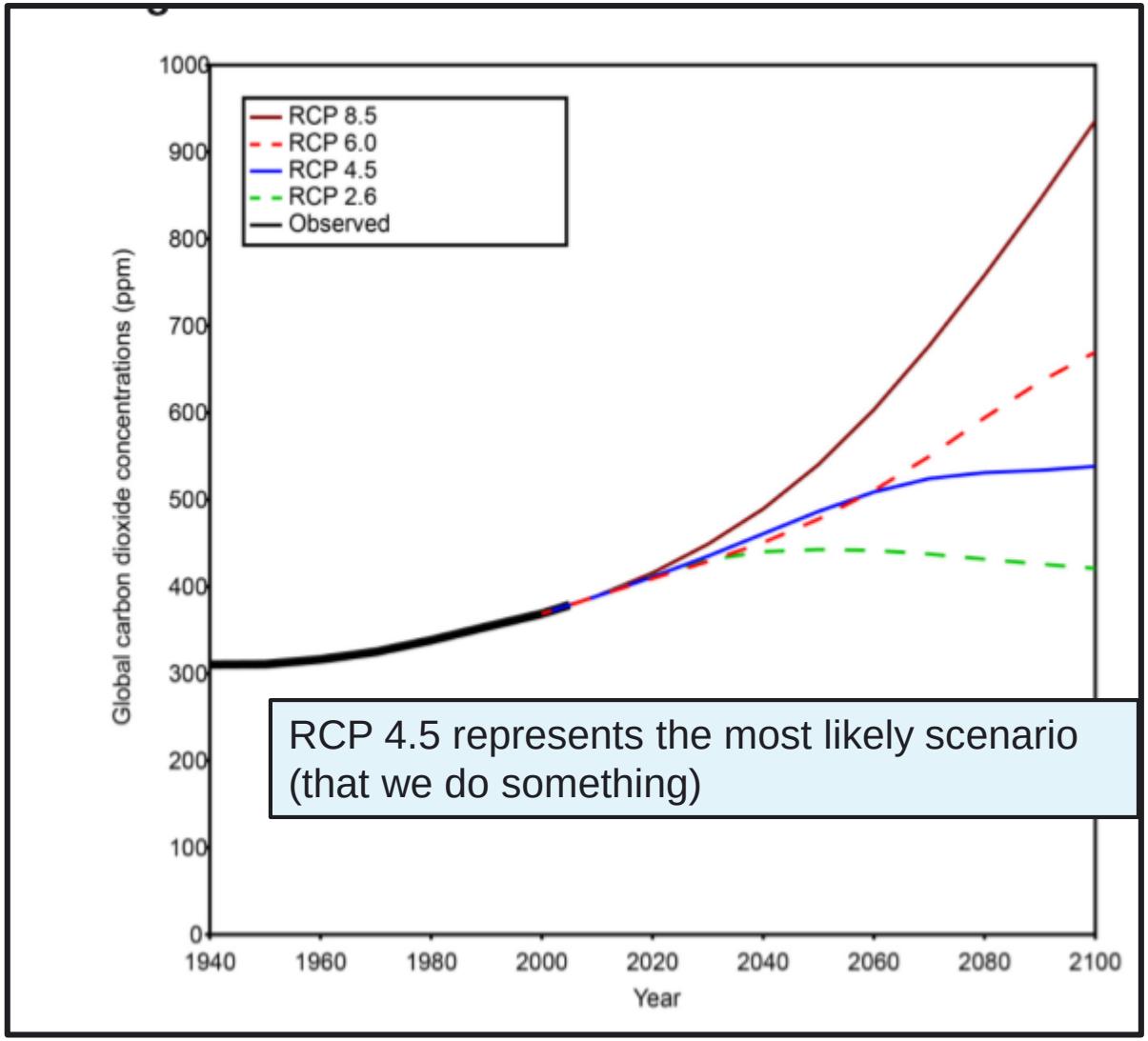
b. Region 4 – New York City

Baseline (2000-2004) 0 inches	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
2020s	2 in	4 to 8 in	10 in
2050s	8 in	11 to 21 in	30 in
2080s	13 in	18 to 39 in	58 in
2100	15 in	22 to 50 in	75 in

Impact of increasing greenhouse gas emissions

September 2014

NYSERDA STUDY CLIMATE SCENARIOS



Comparison with State Climate Study

» NYSERDA Climate Study

Temperature

- Modelling shows that New York should anticipate more warming. Compared to the 1971-2000 period, average temperature will be
  - **up to 3°F warmer by the 2020s**.
  - **up to 6°F warmer by the 2050s**.
  - **up to 10°F warmer by the 2080s**.
- The most warming is expected to occur in northern NYS.
- By 2100, our growing season could be about a month longer, with intense summers (extreme heat and heat waves) and milder winters.

- Based on equally weighting RCP 4.5 and RCP 8.5 and multiple Global Climate Models
- Implies 1.0 degree increase per decade

OTHER FACTORS IMPACTING DEMAND GROWTH

- Factors *mitigating* load impact from climate change
  - End-Use efficiency gains
    - Standards
    - Energy efficiency programs
  - Solar market penetration
  - Slower population growth

- Factors *contributing* to load growth
  - State electrification programs (cold climate heat pumps)
    - But mitigates green house gas concentration
  - Electric vehicle adoption

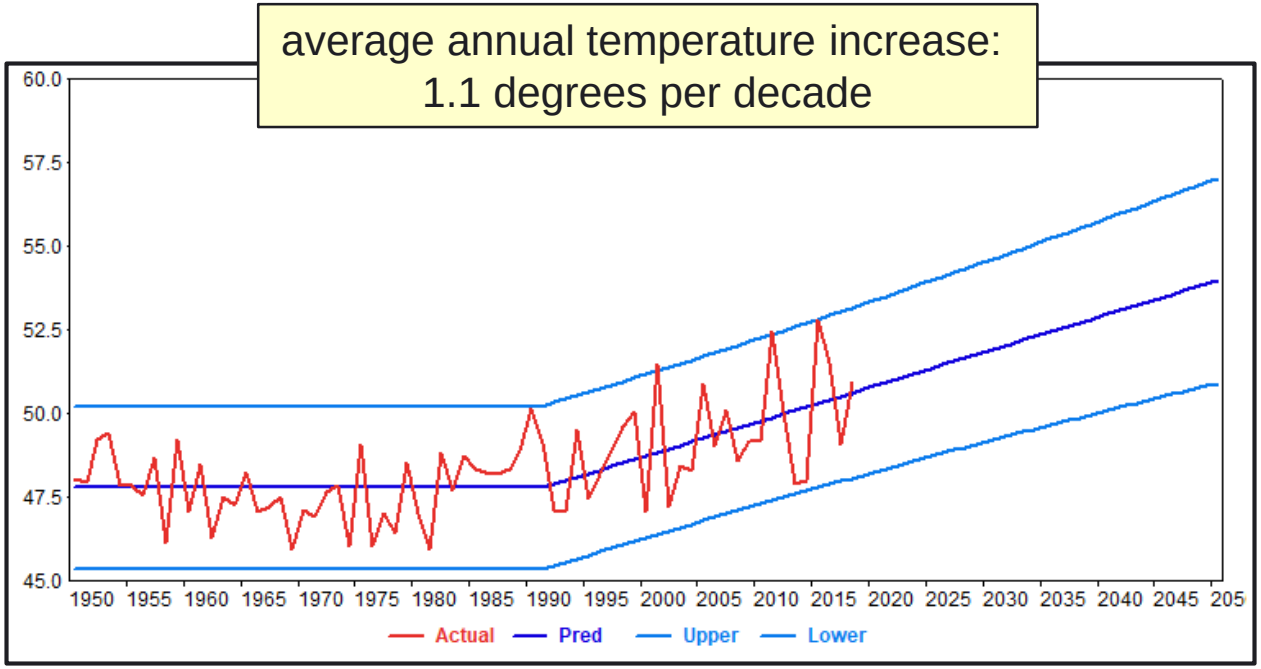
WEATHER TRENDS & SCENARIOS

WEATHER TREND ANALYSIS

» Evaluate annual temperature trends from 1950 to 2018 for 21 Weather Stations

- Temperatures began increasing around 1992
- Average temperature increase has varied across the state
  - From 0.05 degrees to 0.11 degrees per year
    - (0.5 to 1.1 degrees per decade)
- There has been no increase in the maximum summer temperature, but the days are getting warmer
- The minimum temperature during winter has been increasing. It's not getting as cold.
  - Spring is coming earlier and summer is hanging around longer

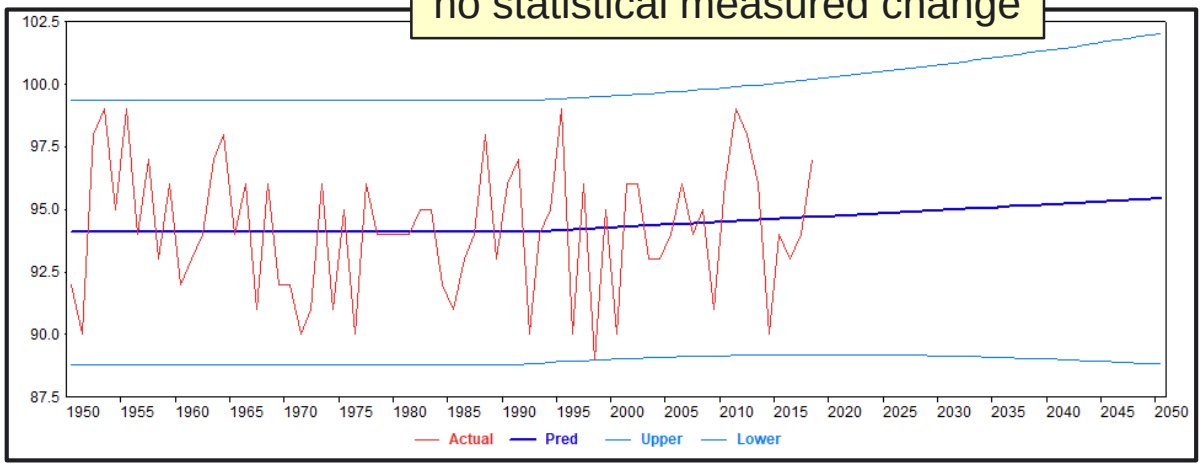
ALBANY WEATHER TRENDS – ANNUAL AVERAGE TEMPERATURE



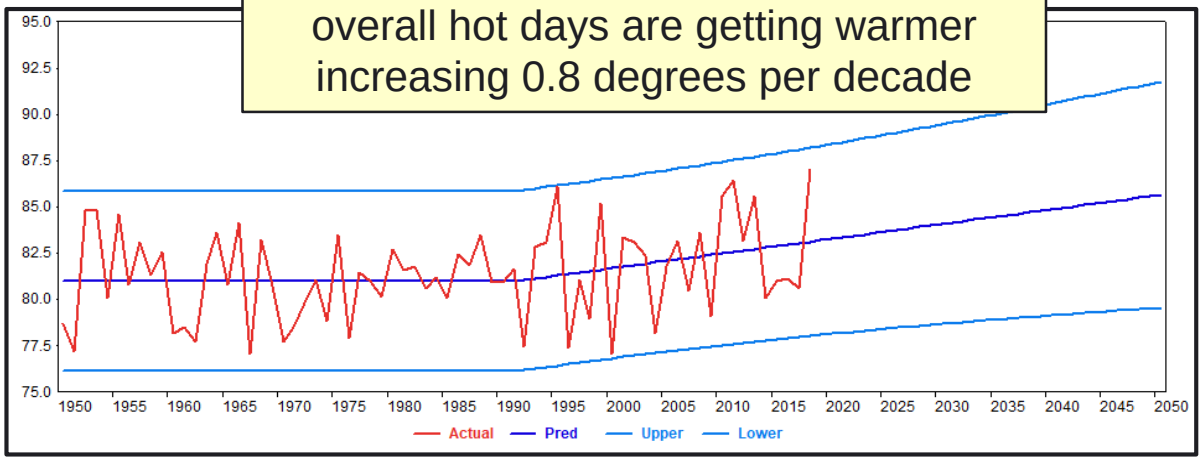
Light blue line shows the 95% confidence interval

ALBANY WEATHER TRENDS – HOTTEST SUMMER DAYS

maximum hourly temperature
no statistical measured change

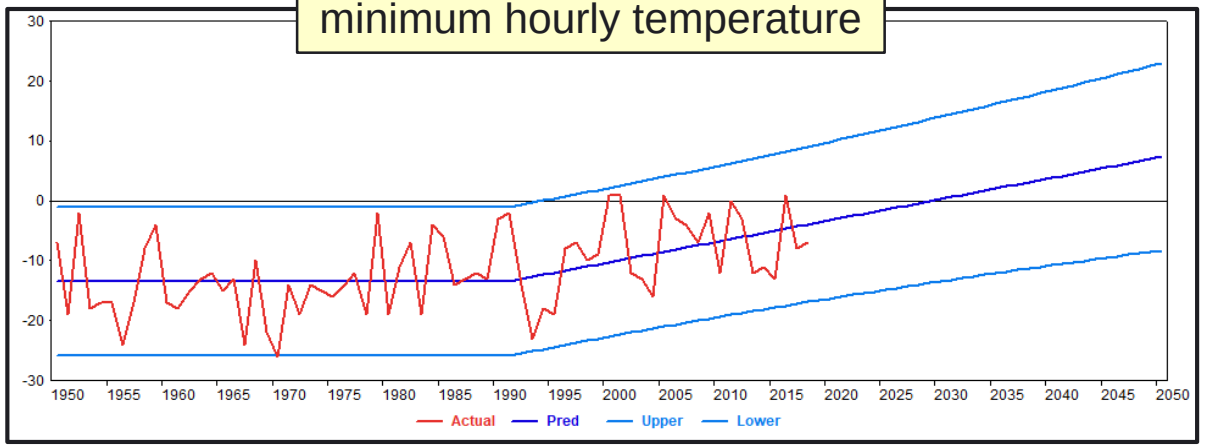


average temperature on hottest days.
overall hot days are getting warmer
increasing 0.8 degrees per decade

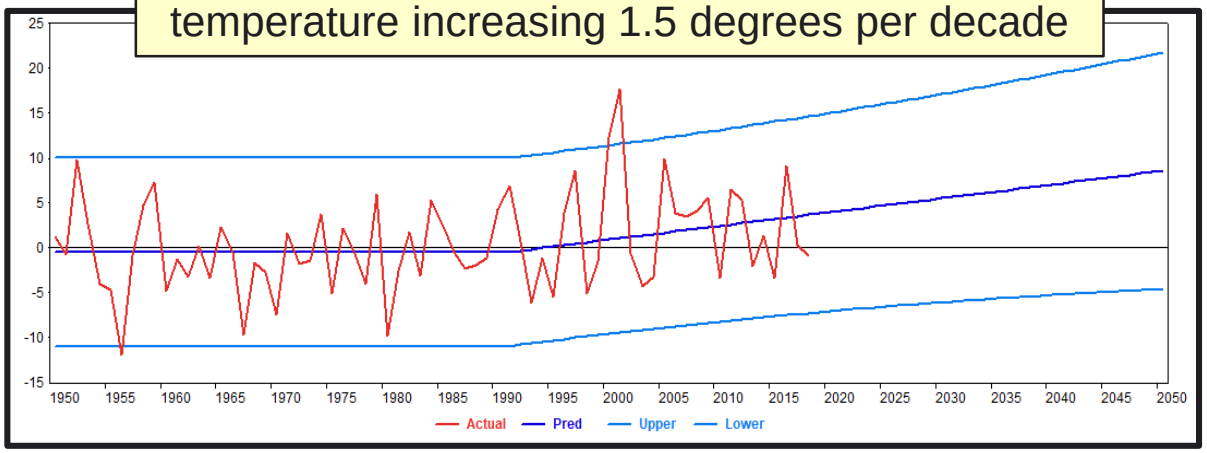


ALBANY WEATHER TRENDS – COLDEST WINTER DAYS

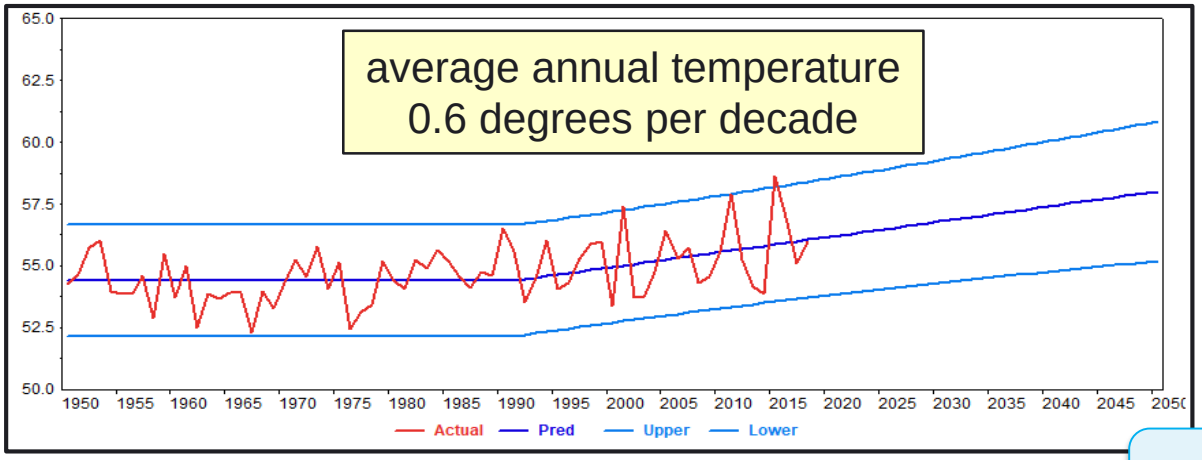
minimum hourly temperature

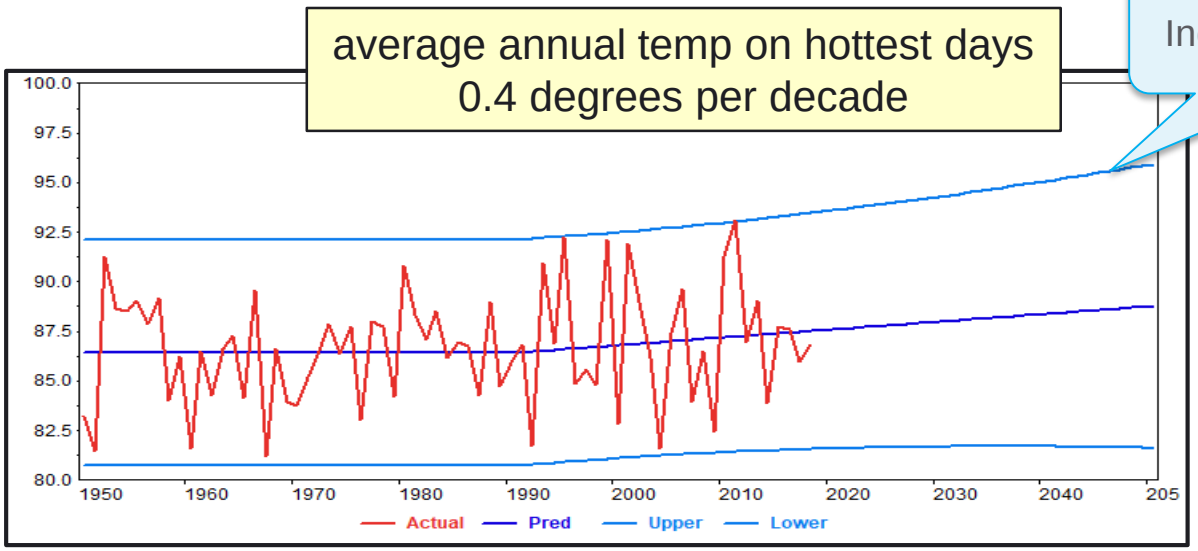


average temperature on coldest days
temperature increasing 1.5 degrees per decade



NEW YORK CITY WEATHER TRENDS

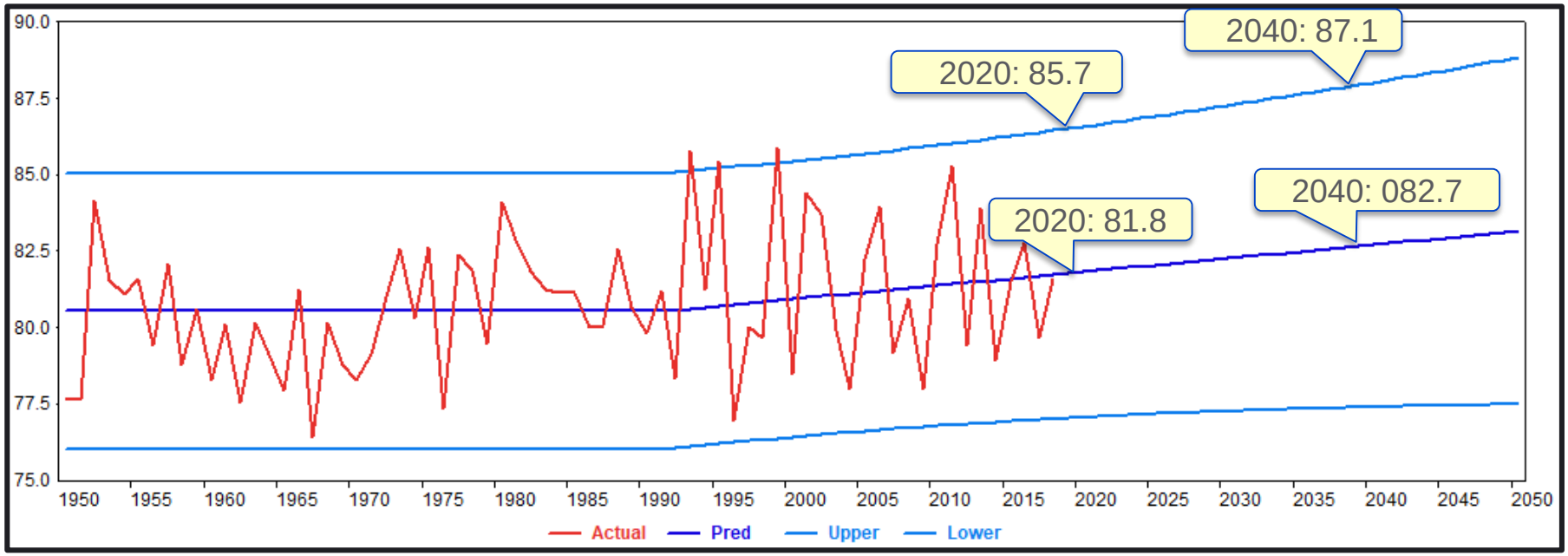




Increasing variance

NEW YORK CITY WEATHER TRENDS - PEAK PRODUCING WEATHER

AVERAGE 3-DAY CUMULATIVE TEMPERATURE-HUMIDITY INDEX



Average peak producing weather increases 0.45 degrees per decade
90th percentile peak producing weather increases 0.74 degrees per decade.

AVERAGE ANNUAL TEMPERATURE TRENDS
SELECTED MODEL RESULTS FOR SEVERAL CITIES

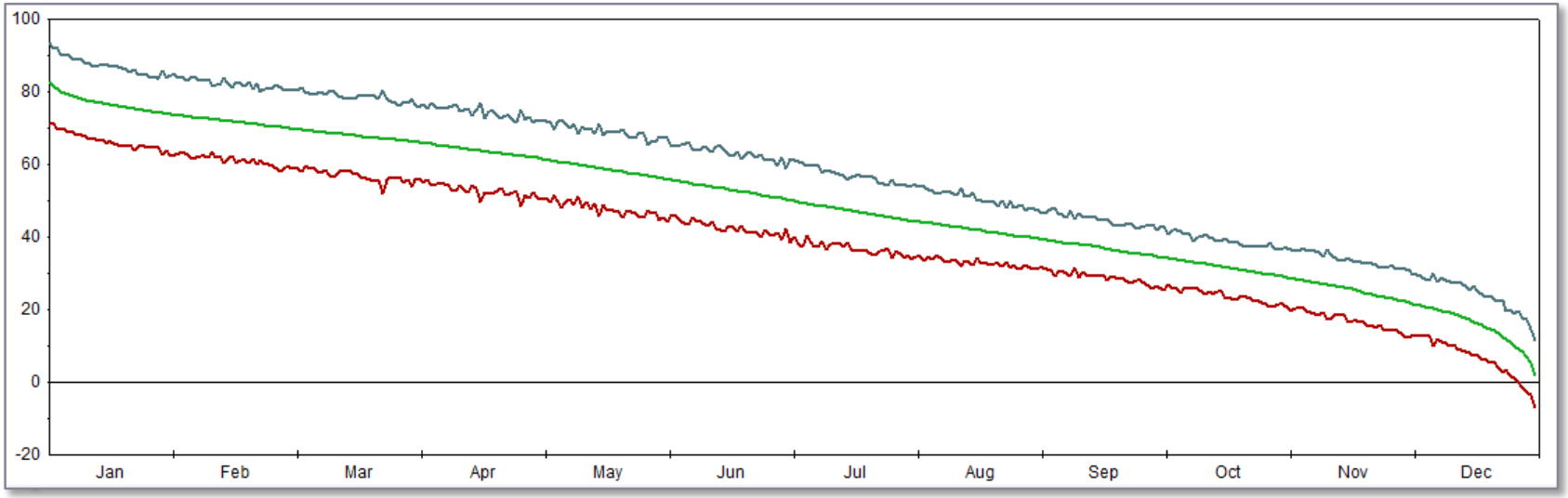
Average Annual Temperature Change Per Decade

Weather Statations	Avg Day	Warmest Day	Coldest Day
Albany	1.10	0.79	1.53
Binghamton	0.53	0.31	0.85
Rochester	0.77	0.36	1.09
Islip	1.00	0.92	1.10
New York (Central Park)	0.61	0.40	0.71
Average	**0.80**	**0.56**	**1.06**

- Temperatures on the warmest days are increasing *slower* than average temperature
- Temperatures on the coldest days are increasing *faster* than average temperature
- Need process to account for differences in temperature trends

Annual Temperature Duration Curve (TDC)

- Start with Ranked and Averaged daily values for AvgDB, MaxDB, MinDB, over 30 year period
- Sort by Average Daily Temperature, ranked highest to lowest
- Max and Min results are also sorted based on the AvgDB values
- This is the base tdc. We will use trend parameters to adjust the TDC curve in future years



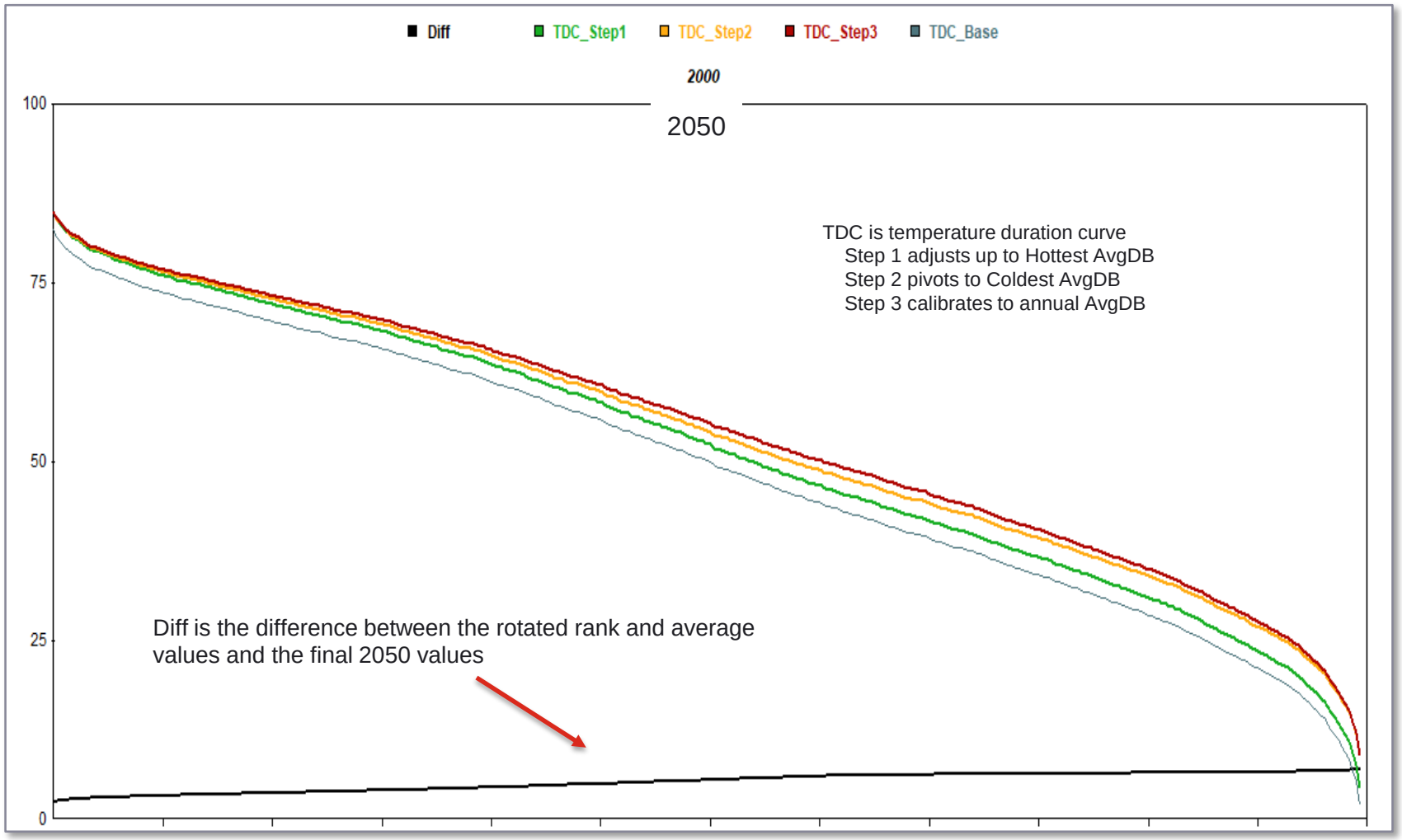
Applying Trend Parameters

- Start with Rank and Average Statistics
  - Annual Average, Hottest Day Avg, Coldest Day Avg
- Apply model trends
  - Hottest Day +.5 degrees per decade
  - Annual Average +1.1 degrees per decade
  - Coldest Day +1.5 degrees per decade
- Adjust for number of years from middle of 30-year R&A
  - Range is 1989 to 2019, so 14.5 years to 2018
  - 26.5 years to 2030, …, 46.4 years to 2050
- Adjust temperature duration curve
  - Step 1: Shift up to match annual maximum temp
  - Step 2: Pivot on max to match annual minimum temp
  - Step 3: Adjust shape to match average annual temp (biggest delta in middle of the TDC)
- Converted ranked days to calendar days
- Compute HDD, CDD, & other concepts by month and year
- Use model standard errors for extreme/mild scenarios

R&A Results	Average	MaxAvgDB	MinAvgDB
By Month	49.05	81.35	4.35
By Season	49.06	82.47	1.97
Adjust to 2050	**Average**	**MaxAvgDB**	**MinAvgDB**
By Season 2050*	49.12	82.47	1.97
Adj/Year	0.11	0.05	0.15
Std Error 2050	1.47	2.90	7.16
Adjustments	**Average**	**MaxAvgDB**	**MinAvgDB**
Adjust to 2018	1.60	0.75	2.16
Adjust to 2030	2.92	1.38	3.95
Adjust to 2040	4.03	1.90	5.44
Adjust to 2050	5.13	2.42	6.93
2050 + 1SE	6.60	5.32	14.09
2050 + 2SE	8.07	8.22	21.25
2050 + 3SE	9.53	11.12	28.41
Adjusted Values	**Average**	**MaxAvgDB**	**MinAvgDB**
Adjust to 2018	50.72	83.22	4.13
Adjust to 2030	52.04	83.85	5.91
Adjust to 2040	53.15	84.37	7.40
Adjust to 2050	54.25	84.89	8.89
2050 + 1SE	55.72	87.79	16.05
2050 + 2SE	57.19	90.69	23.22
2050 + 3SE	58.65	93.59	30.38

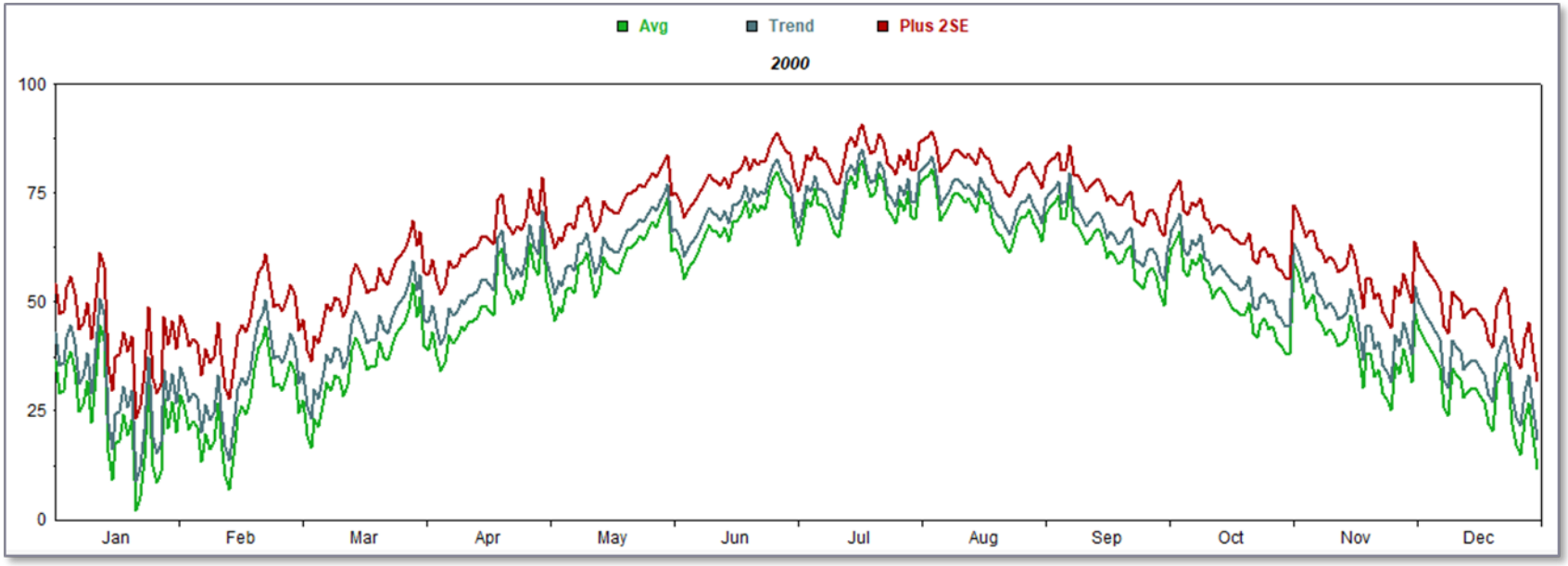
* R&A results are for a leap year. 2050 is not a leap year
Standard error gets bigger for later years. 2050 value is shown.

Depiction of Adjustment Process – Projected Temperature Duration Curve for 2050



CALCULATE DAILY NORMAL WEATHER

» Daily normal temperature mapped to a weather pattern for a calendar year



» Calculate monthly and annual HDD and CDD

Albany			
	Avg Temp	CDD65	HDD60
2020	50.9	775.2	4,731.6
2040	53.1	947.5	4,154.7
Chg	4.3%	22.2%	-12.2%

ADDITIONAL WEATHER SCENARIOS

- Trend analysis is consistent with the NYSERDA climate study. More importantly it provides a confidence interval for evaluating extreme temperatures
- Nevertheless, climate scenarios based on historical trends may not reflect future temperatures
- Additional scenarios will be developed based on work by NYSERDA and ConEdison

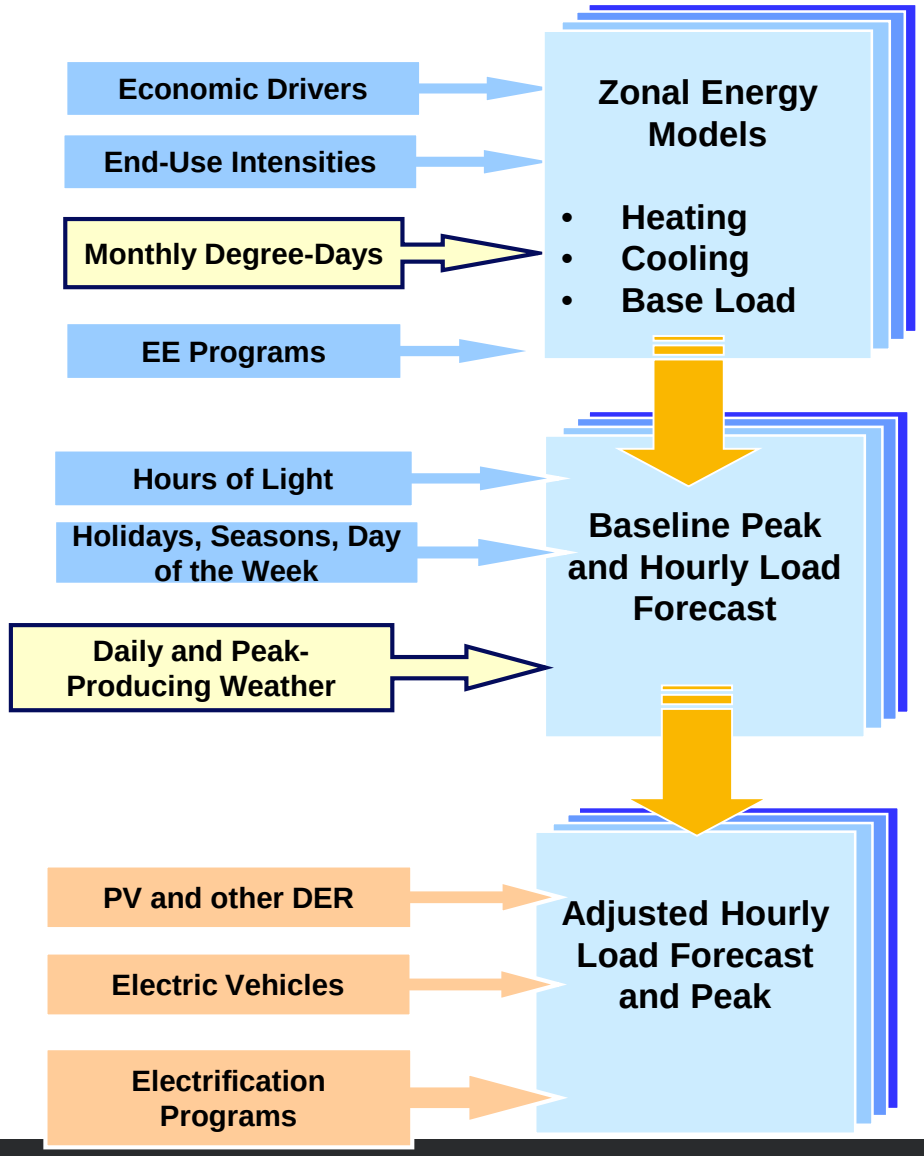
ENERGY & LOAD MODELING APPROACH

ENERGY & LOAD MODELING APPROACH

- Forecast derived for each transmission planning area
  - Baseline models estimated with twelve-years of historical hourly load data (adjusted for solar load impacts)
    - Monthly energy and peak
    - Hourly load
  - Forecast to incorporate current population, economic projetions, and EIA 2019 residential and commercial end-use intensity trends
  - Develop adjusted forecast by layering hourly load forecast for new technologies including
    - Solar
    - Electric Vehicle
    - Electrification program activity – cold climate heat pumps

MODEL OVERVIEW

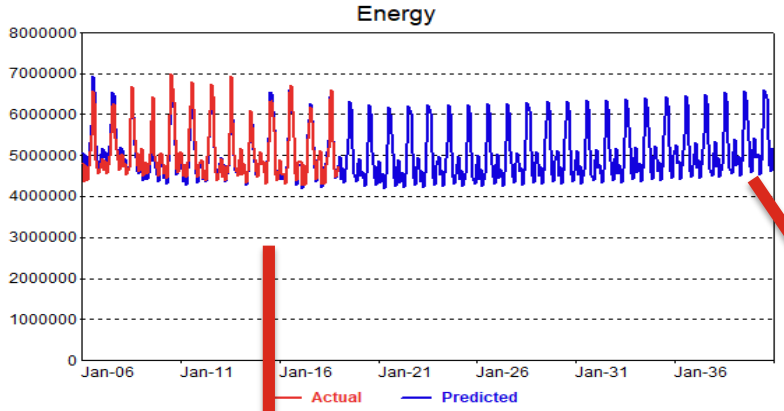
Climate Change impacts
daily and monthly CDD, HDD, and Peak-Day THI

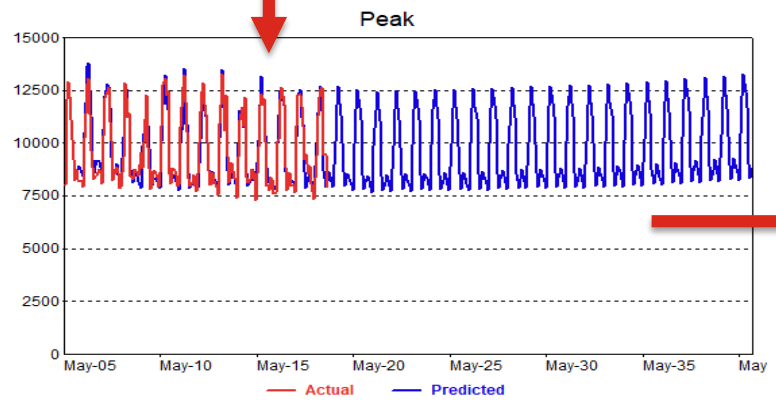


Impact of peak producing weather depends on cooling and heating load requirements.

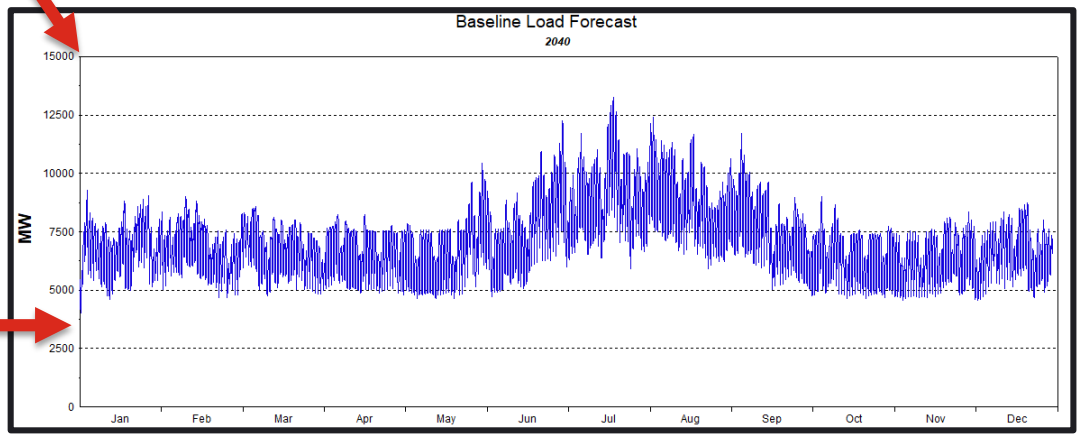
Technologies that reshape load

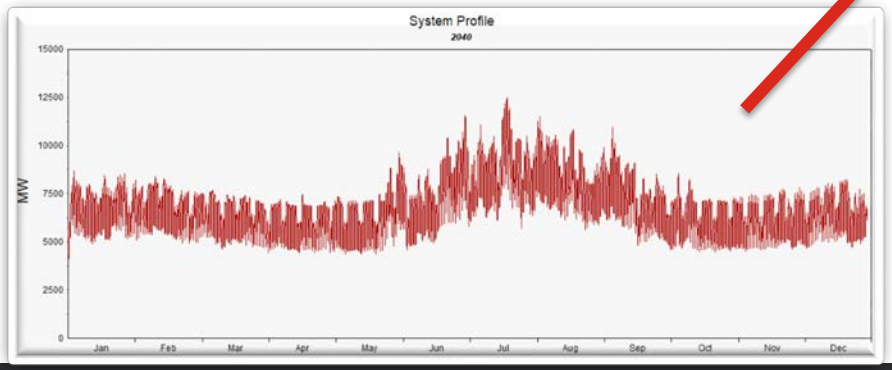
BASELINE ZONAL HOURLY LOAD FORECAST





Combine energy, peak, and profile forecast

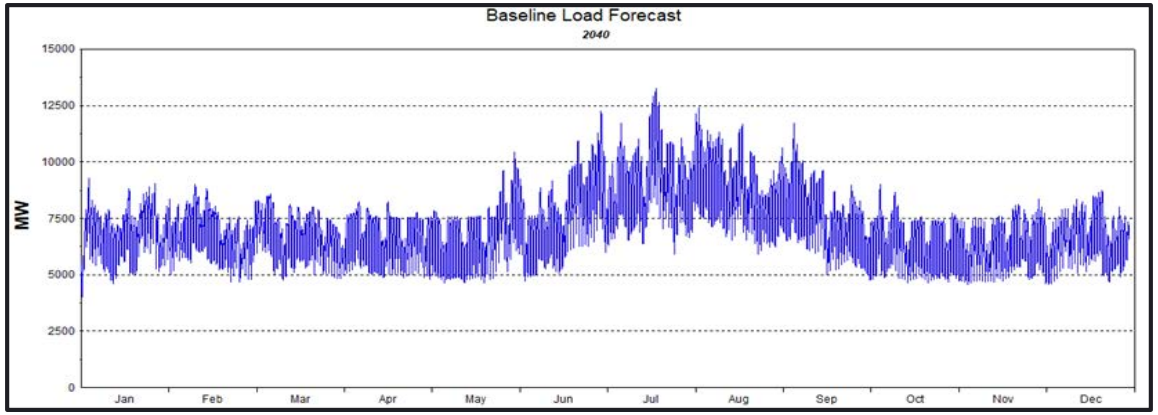




Energy, peak, and shapes estimated with *MetrixND*. Calibrated hourly load forecast generated with *MetrixLT.*

LAYERING NEW TECHNOLOGIES

Baseline



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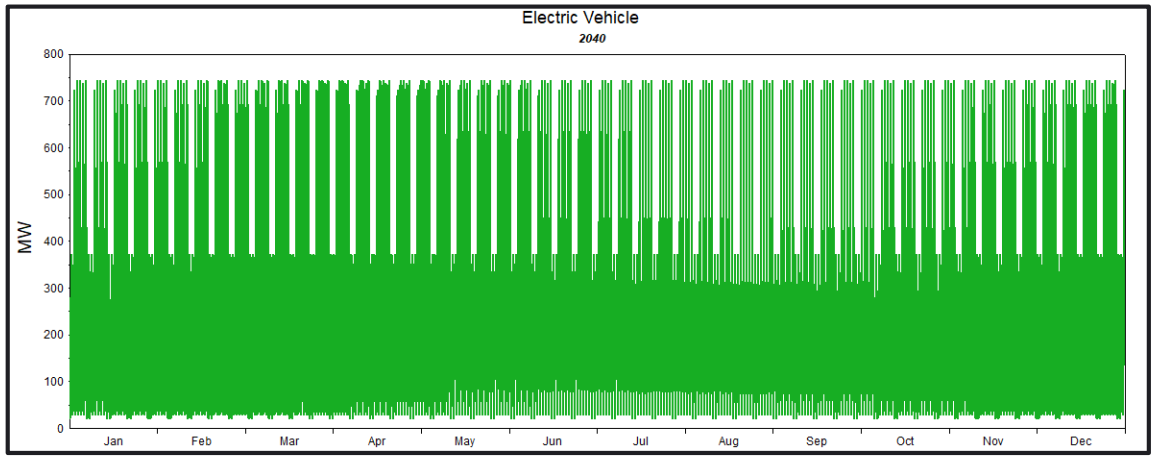

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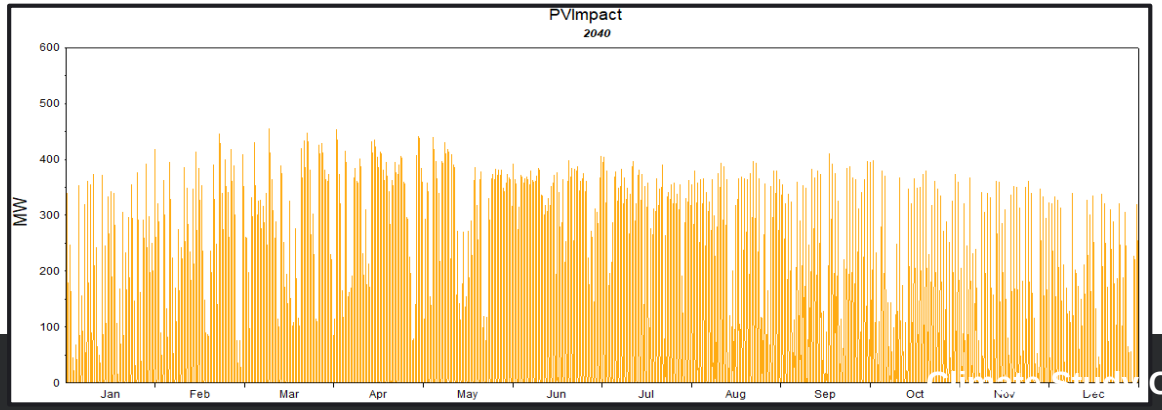
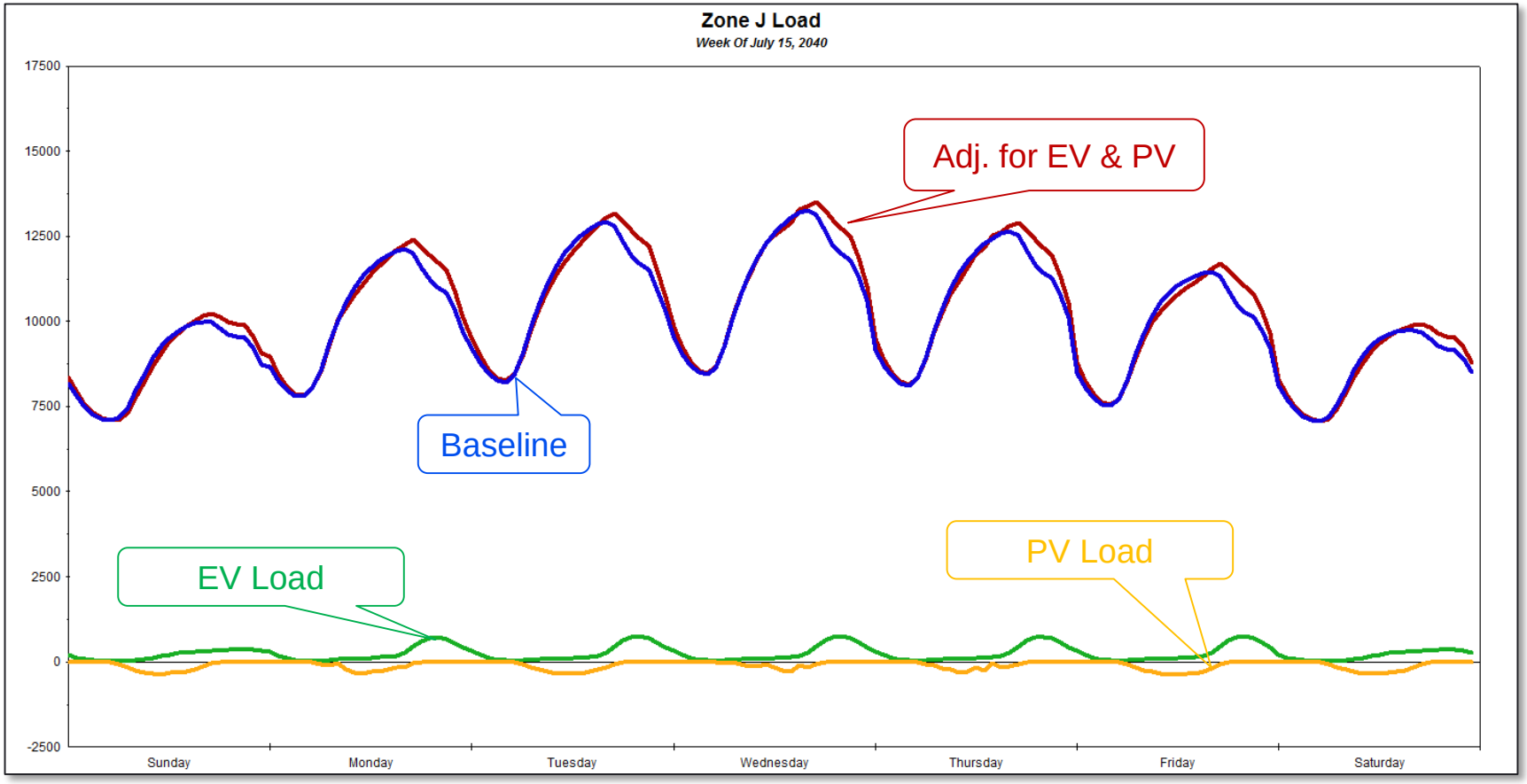
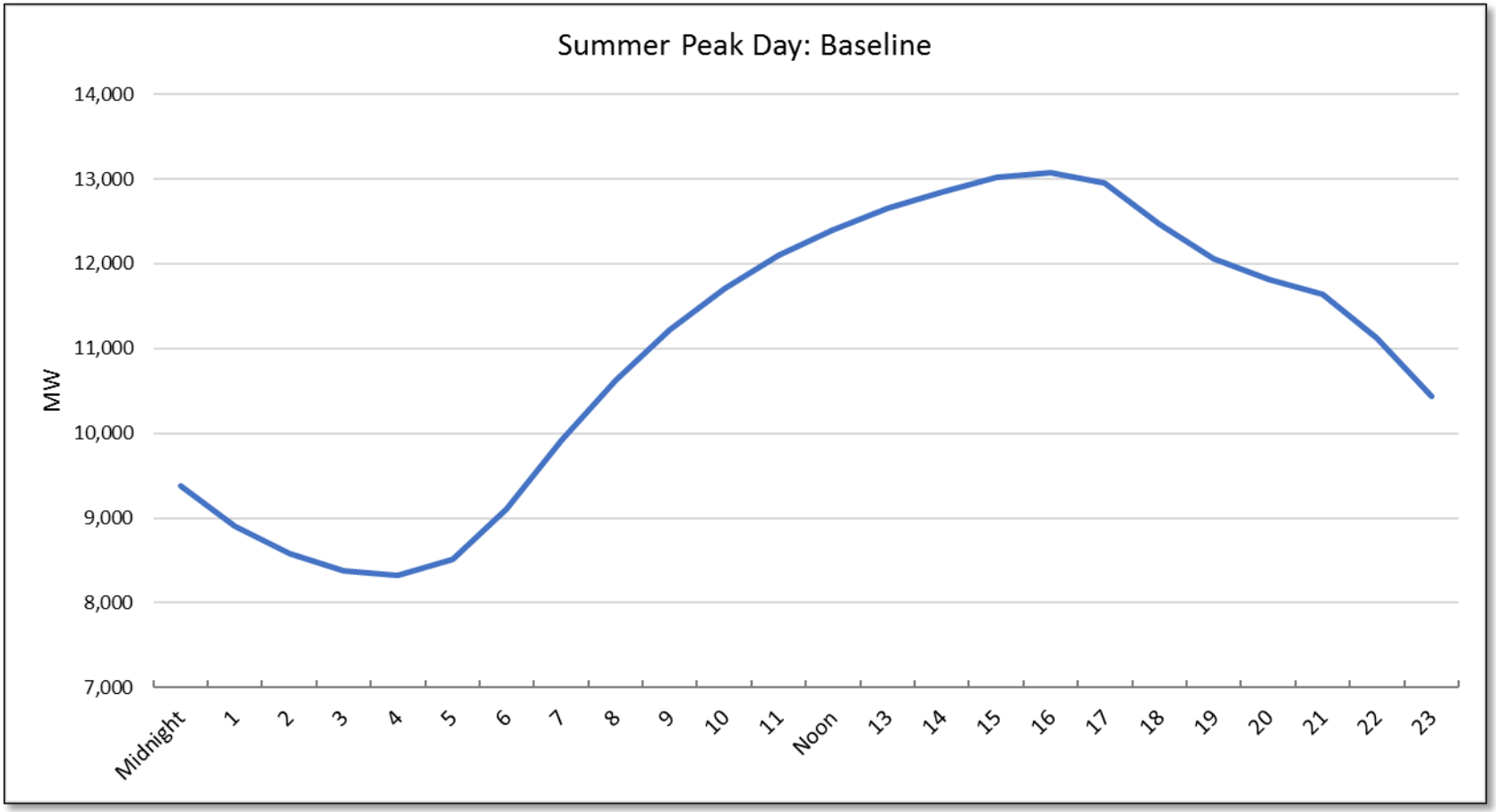


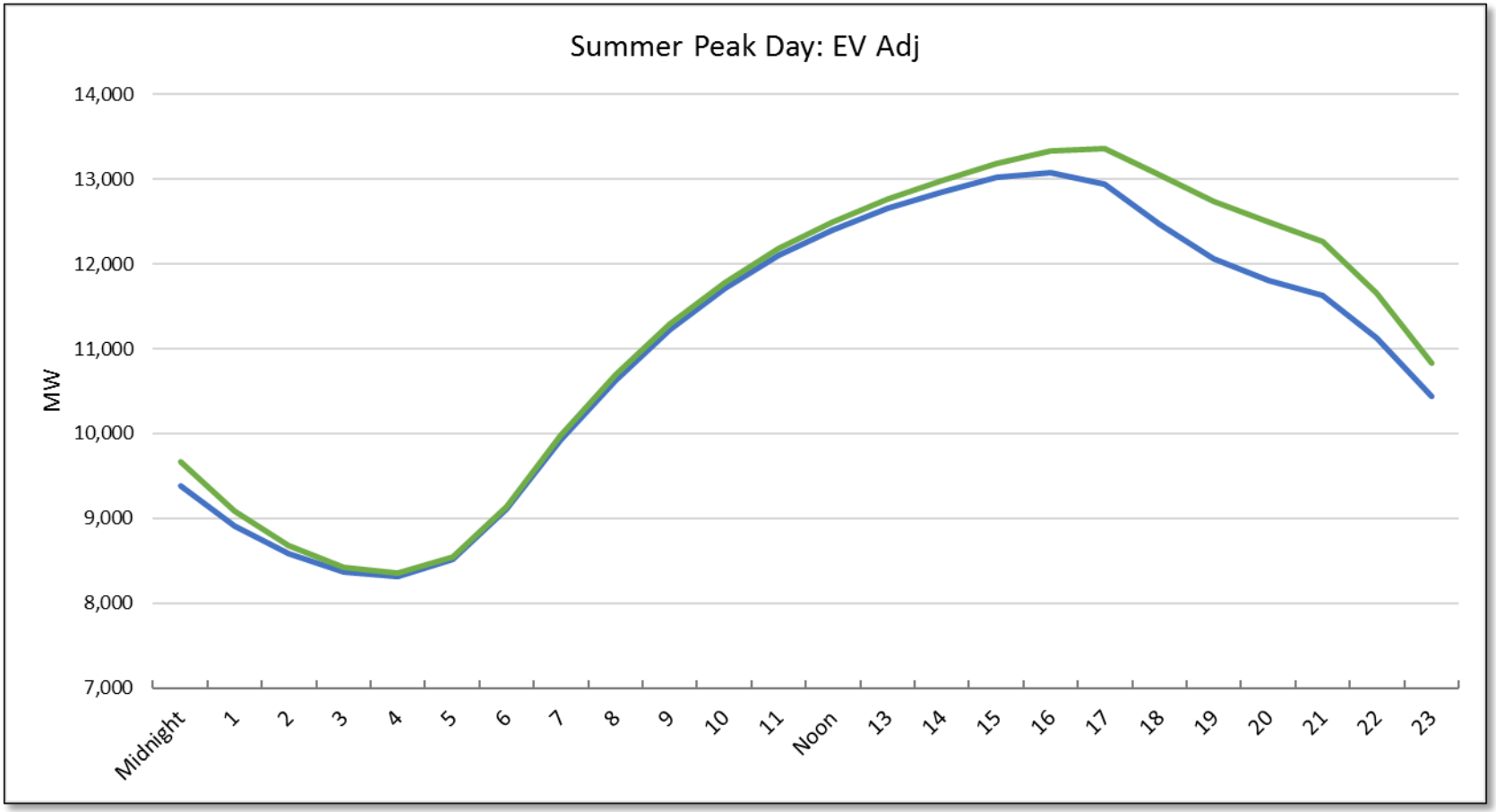
ADJUSTED ZONAL HOURLY LOAD FORECAST



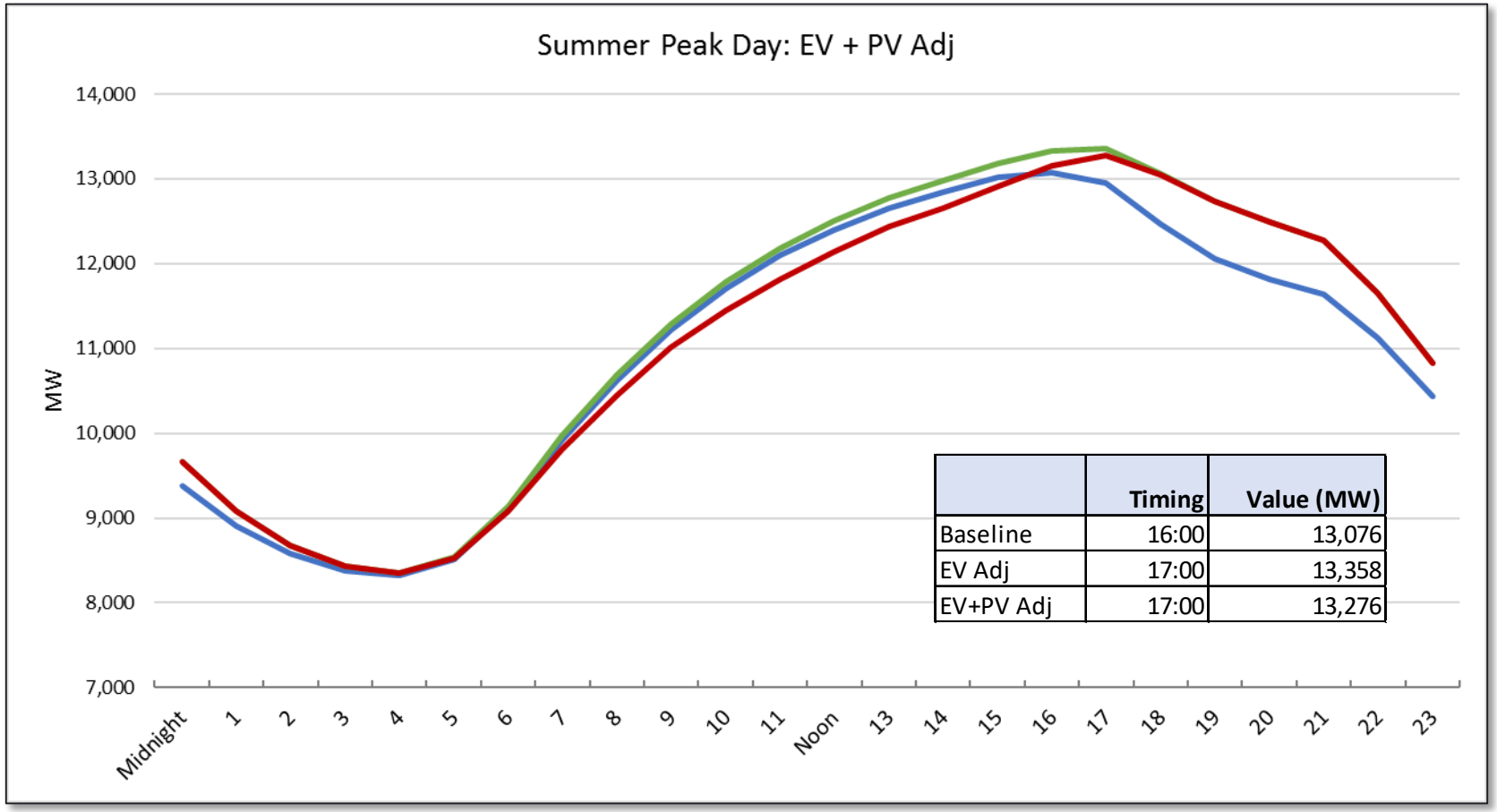
LAYERING NEW TECHNOLOGIES: PEAK DAY 2040



LAYERING NEW TECHNOLOGIES: PEAK DAY 2040



LAYERING NEW TECHNOLOGIES: PEAK DAY 2040



	Timing	Value (MW)
Baseline	16:00	13,076
EV Adj	17:00	13,358
EV+PV Adj	17:00	13,276

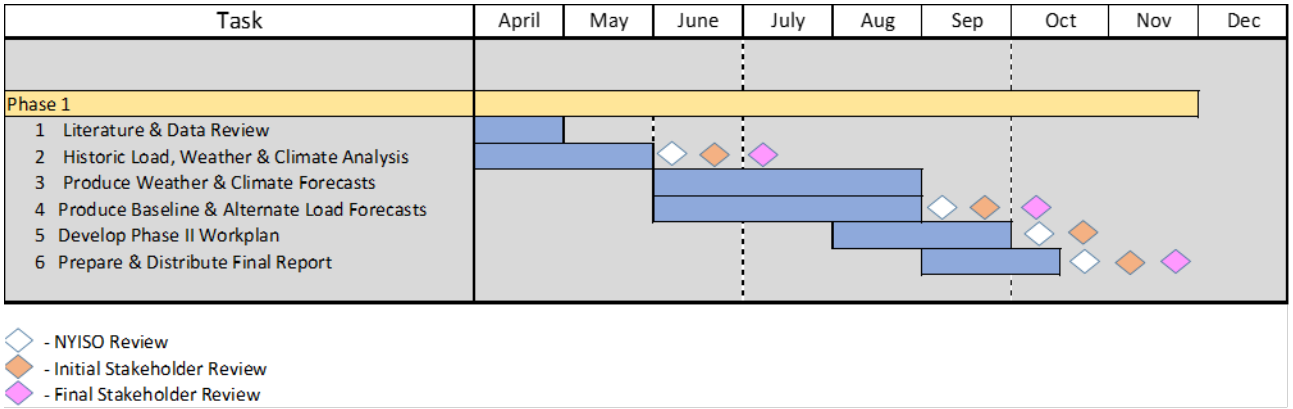
POTENTIAL TECHNOLOGIES TO INCORPORATE

- Solar (Behind the Meter)
- Other DER
- Electric Vehicles
  - Cars
  - Buses & Other Mid-sized vehicles
- Battery Storage
- Electrification Program Impacts
  - Cold climate heat pumps
  - Commercial and industrial processes?

LOAD FORECASTING TASK FORCE INPUTS

- Development of additional weather and load scenarios
  - More aggressive climate change impact
  - Electrification assumptions
    - Technologies, market penetration, load characteristics
  - Historical and projected EE program savings
  - Behind-the-meter Solar PV adoption rates
  - Electric vehicle penetration
- Inputs needed by end of July to maintain schedule

NEXT STEPS



- Continue weather station trend analysis and incorporate trends into construction of expected daily, monthly, and peak weather drivers (21 weather stations)
  - June through July
- Identify and collect data to support scenario development
  - June through July
- Develop zonal energy, peak, and load models and baseline forecast
  - Currently working on zone J (ConEdison)
  - June through September