New York ISO Climate Change and Resilience Study – Phase 1

DECEMBER 17, 2019

ERIC FOX

DIRECTOR, FORECAST SOLUTIONS

AGENDA

» Study Objective
» Recent New York Climate Studies
» Weather Trend Analysis
» Modeling Climate Changes Impact on Load
» Scenarios and Results

STUDY OBJECTIVE

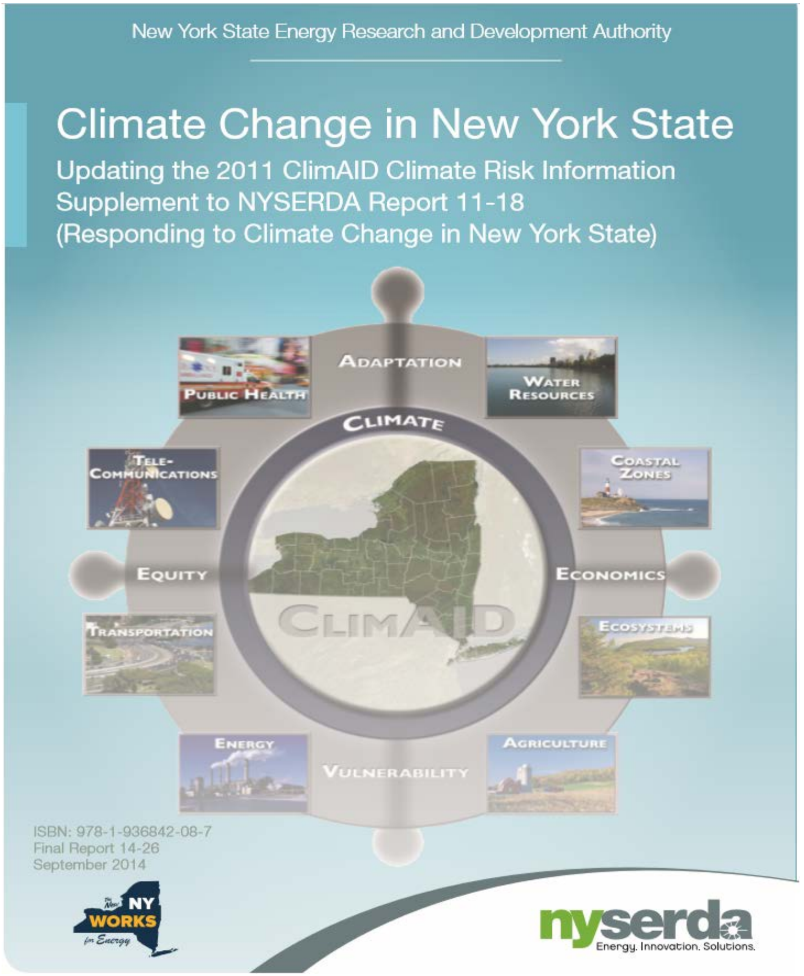
» Develop long-term energy, peak, and 8,760 hourly load forecasts that reflect the potential impact of climate change
  - System forecast
  - TO and zonal level forecast

» Evaluate temperature trends and state climate impact studies
  - Develop long-term HDD, CDD, and peak producing weather that reflect these trends

» Construct scenarios that reflect state policy goals with climate change impacts
  - Policy Case
    - Accelerated energy efficiency savings and BTM solar adoption
  - CLCPA Case
    - State electrification to meet targeted greenhouse gas emission targets

CLIMATE CHANGE STUDIES

RECENT CLIMATE STUDIES



» 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

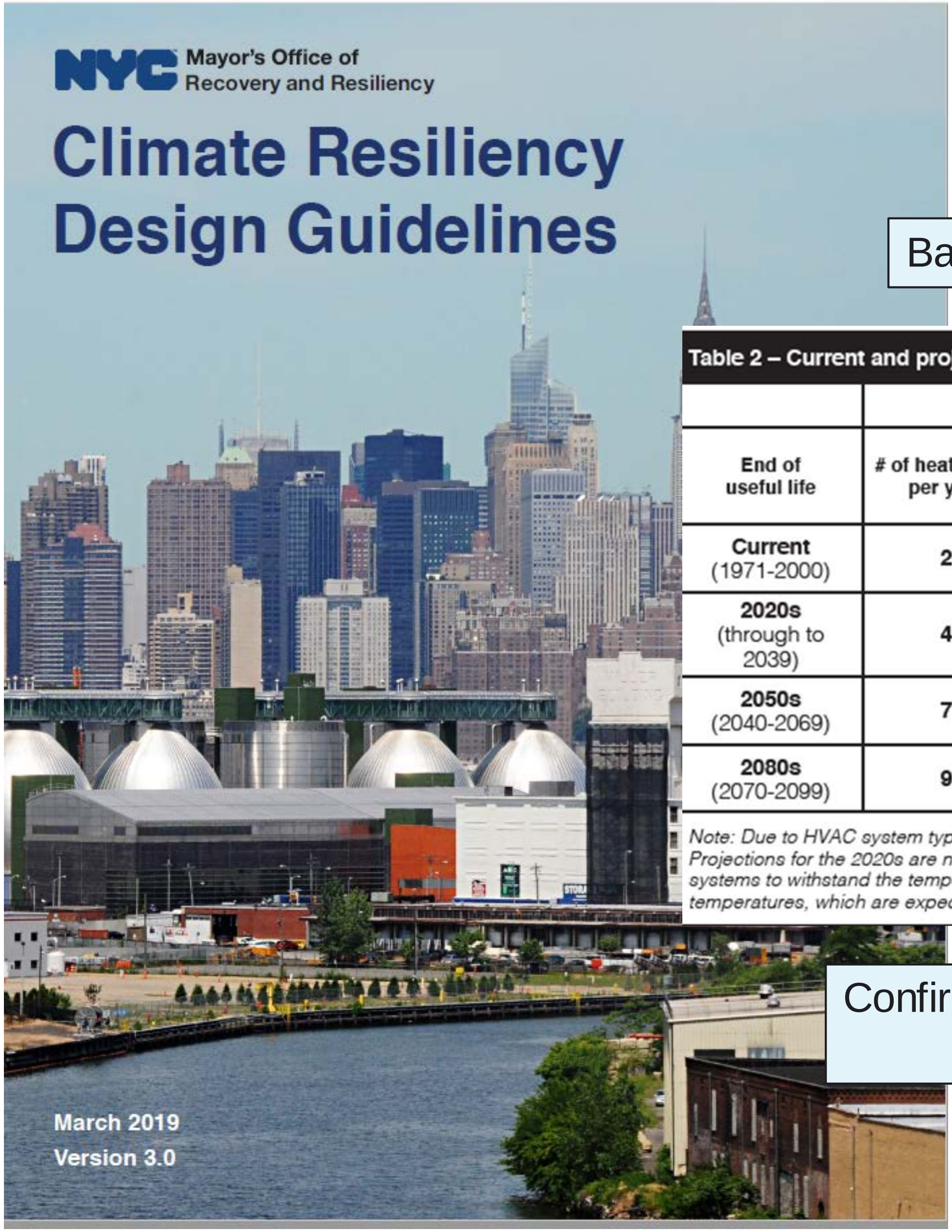
2020s	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
Days over 90 °F (18 days)	24	26 to 31	33
# of Heat Waves (2 heat waves)	3	3 to 4	4
Duration of Heat Waves (4 days)	5	5 to 5	5
Days below 32 °F (71 days)	50	52 to 58	60
Days over 1" Rainfall (13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



Base year 1990 (1971 to 2000)

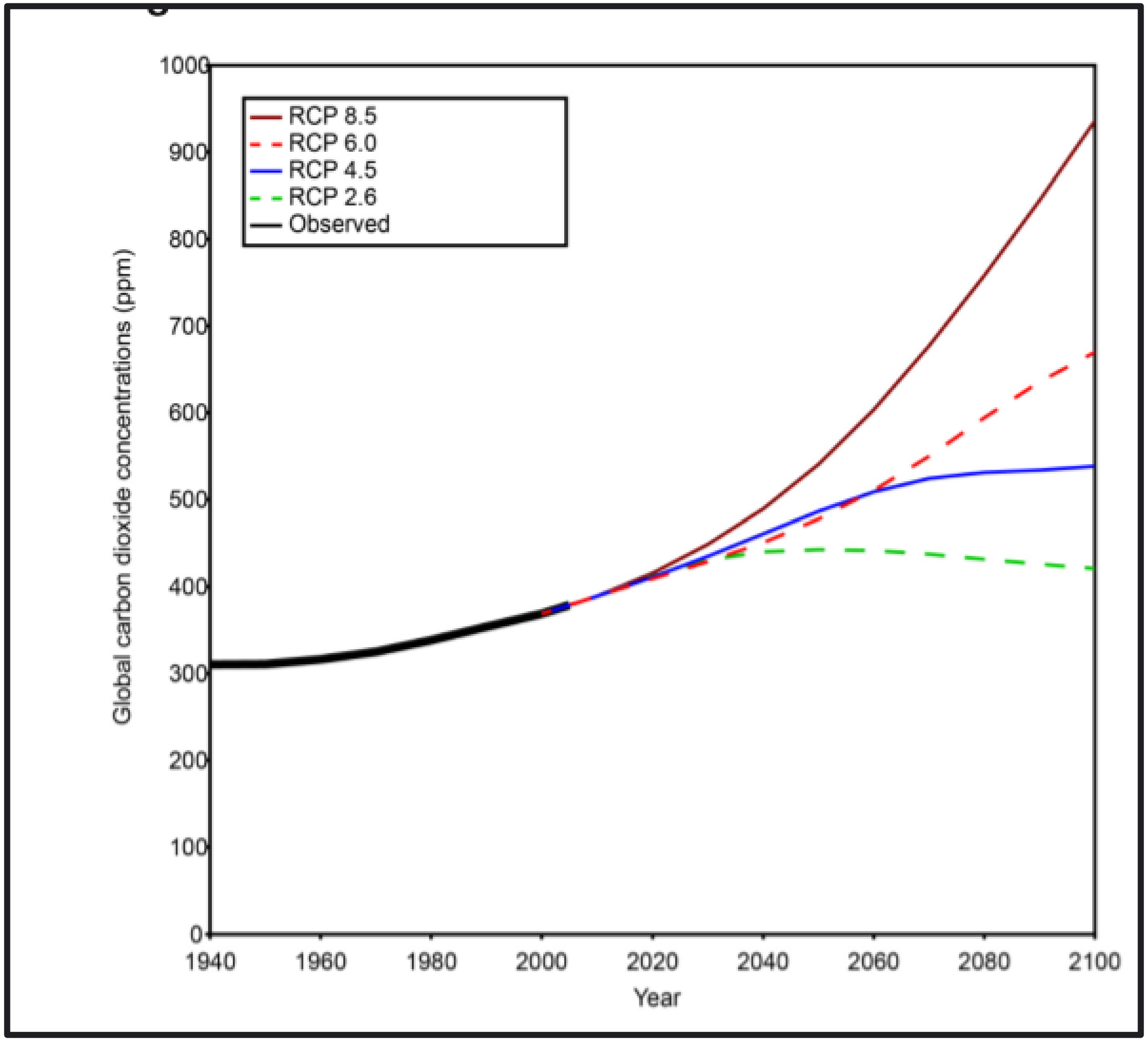
Table 2 – Current and projected extreme heat events and design criteria[27]

	Extreme heat events			*Design criteria*	
End of useful life	**# of heat waves per year**	**# days at or above 90°F**	**Annual average temperature**	**1% Dry Bulb temperature**	**Cooling Degree Days** *(base = 65°F)*
Current (1971-2000)	**2**	**18**	**54°F**	**91°F**	**1,149**
2020s (through to 2039)	**4**	**33**	**57.2°F**	--	--
2050s (2040-2069)	**7**	**57**	**60.6°F**	**98°F**	**2,149**
2080s (2070-2099)	**9**	**87**	**64.3°F**	--	--

Note: Due to HVAC system typical useful life of around 25 years, only design criteria projections for the 2050s are shown. Projections for the 2020s are not shown because it is anticipated that enough of a safety margin is employed already in current systems to withstand the temperature rise expected through the 2020s. The NPCC is developing projections of 1% Wet Bulb temperatures, which are expected to increase. This design criteria will be added in a later version of the Guidelines.

Confirms findings of the 2014 ClimAID update
0.8 to 1.1 degrees per decade

CLIMATE SCENARIOS



REPRESENTATIVE CONCENTRATION PATHS

RCP 2.6

This scenario might be described as the best case for limiting anthropogenic climate change. It requires a major turnaround in climate policies and a start to concerted action in the next few years in all countries, both developing and developed.

RCP 4.5

Emissions peak around mid century at around 50% higher than 2000 levels and then decline rapidly over 30 years and then stabilise at half of 2000 levels. CO2 concentration continues on trend to about 520 ppm in 2070 and continues to increase but more slowly.

RCP 8.5

This is the nightmare scenario in which emissions continue to increase rapidly through the early and mid parts of the century. By 2100 annual emissions have stabilised at just under 30 gigatonnes of carbon compared to around 8 gigatonnes in 2000.

FIFTEEN-CITY TREND ANALYSIS

Trend Analysis of Annual Average Temperature - 1960 to 2017

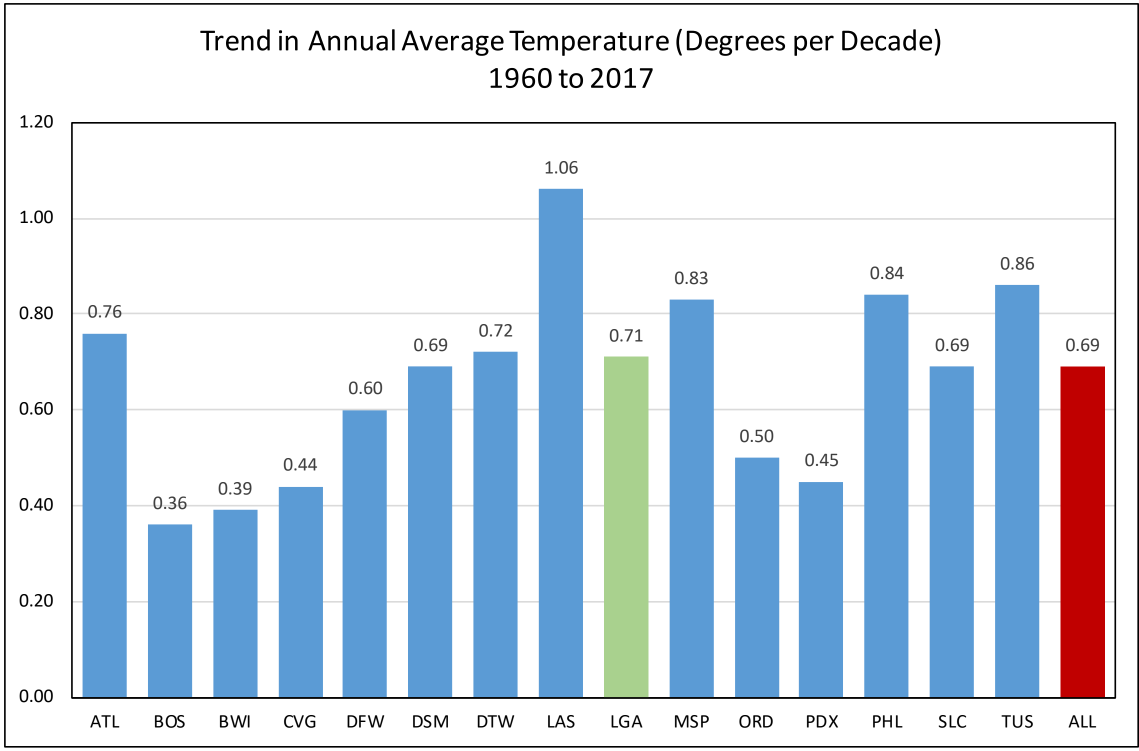
City	Abrev	DTrend	Degrees per Decade
Atlanta	ATL	4.36	0.76
Boston	BOS	2.06	0.36
Baltimore	BWI	2.25	0.39
Cincinnati	CVG	2.53	0.44
Dallas Fort Worth	DFW	3.44	0.60
Des Moines	DSM	3.93	0.69
Detroit	DTW	4.09	0.72
Las Vegas	LAS	6.05	1.06
New York (LGA)	LGA	4.03	0.71
Minneapolis	MSP	4.72	0.83
Chicago	ORD	2.86	0.50
Seattle	PDX	2.55	0.45
Philadelphia	PHL	4.78	0.84
Salt Lake City	SLC	3.92	0.69
Tuscon	TUS	4.89	0.86
All	ALL	3.93	0.69

On the Evolution of
U.S. Temperature Dynamics

FRANCIS X. DIEBOLD
University of Pennsylvania

GLENN D. RUDEBUSCH
FRB San Francisco

July 5, 2019



OTHER STUDIES

- California Fourth Climate Change Assessment
  - Project temperature increases of 0.7 to 1.1 degrees per decade
- Inter Governmental Panel on Climate Change (IPCC)
  - Expect global temperature increases of 0.5 to 0.9 degrees per decade
- Fifteen-city weather trend analysis, 0.4 to 1.1 degrees per decade
- Itron trend analysis for Colorado Springs CO, Evansville IN, Burlington Vt, and Reno NV increasing from 0.5 to 1.2 degrees per decade

FACTORS IMPACTING DEMAND GROWTH

- Mitigating climate change impacts
  - Energy efficiency improvements
    - End-use and building standards
    - Energy efficiency programs
  - Utility scale and behind the meter solar adoption
  - Fuel efficiency standards

- Contributing to load growth
  - Electric vehicle market penetration
  - State electrification programs (cold climate heat pumps)

- Impacts evaluated through constructed scenarios
  - Reference Case – 2019 Gold Book forecast assumptions
  - Policy Case – Higher EE savings and PV market penetration
  - CLCPA Case – Aggressive statewide electrification

WEATHER ANALYSIS

WEATHER TREND ANALYSIS

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

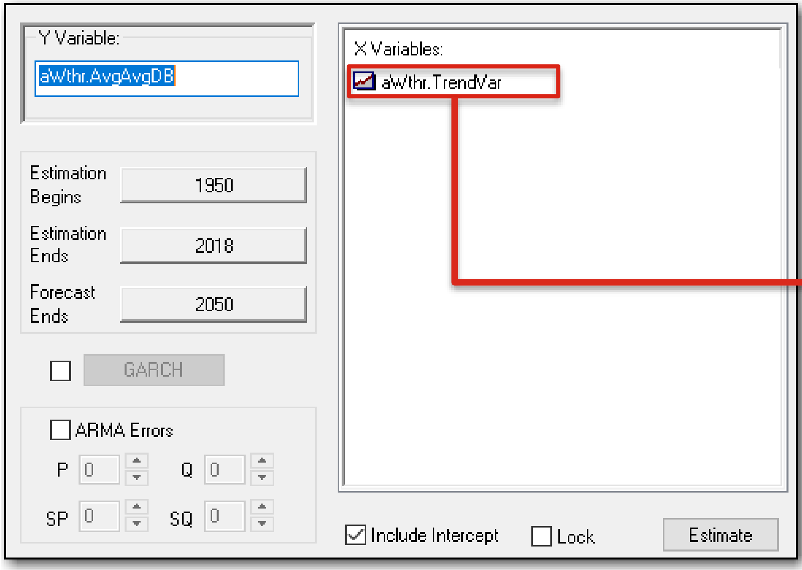
- Temperatures show significant increases starting around 1990
  - Trends are statistically significant – low probability that there is no weather trend (climate change is real)

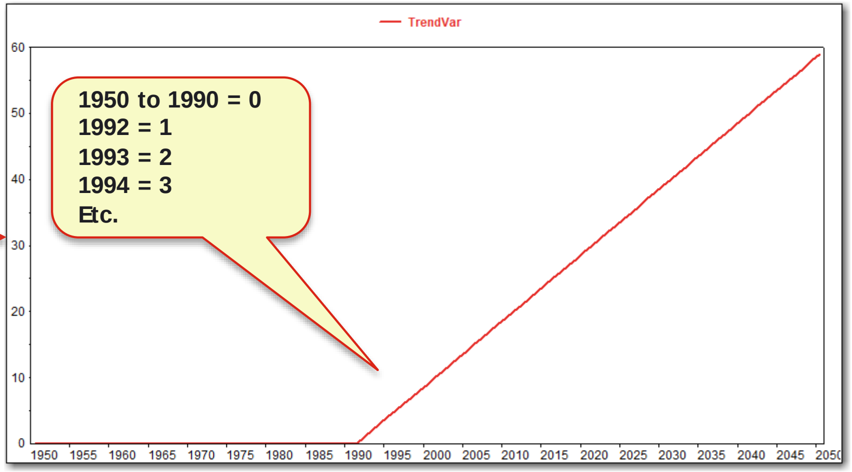
- Average temperature increase has varied across the state
  - From 0.05 degrees to 0.11 degrees per year
    - (0.5 to 1.1 degrees per decade)
  - Consistent with climate change study projections

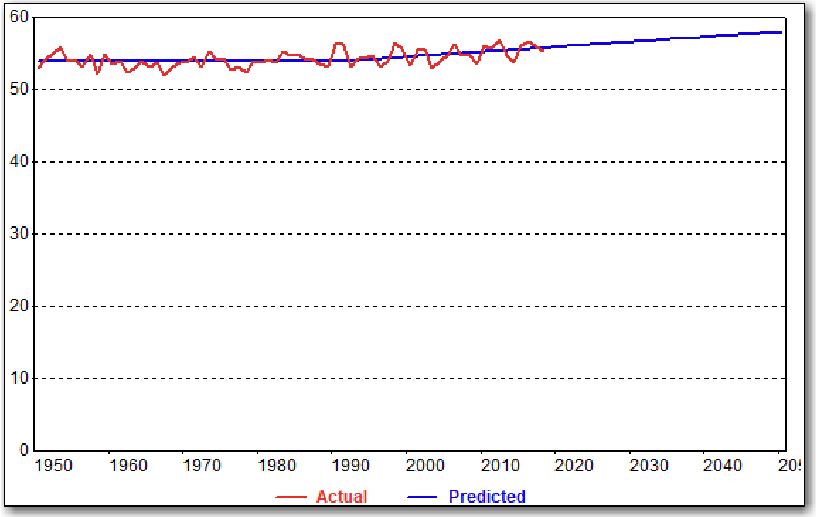
- There has been no statistically significant increase in the maximum temperature, but days are getting warmer

- Most of the temperature change is coming from increasing minimum temperatures. Its not getting as cold at night.

TREND MODELS





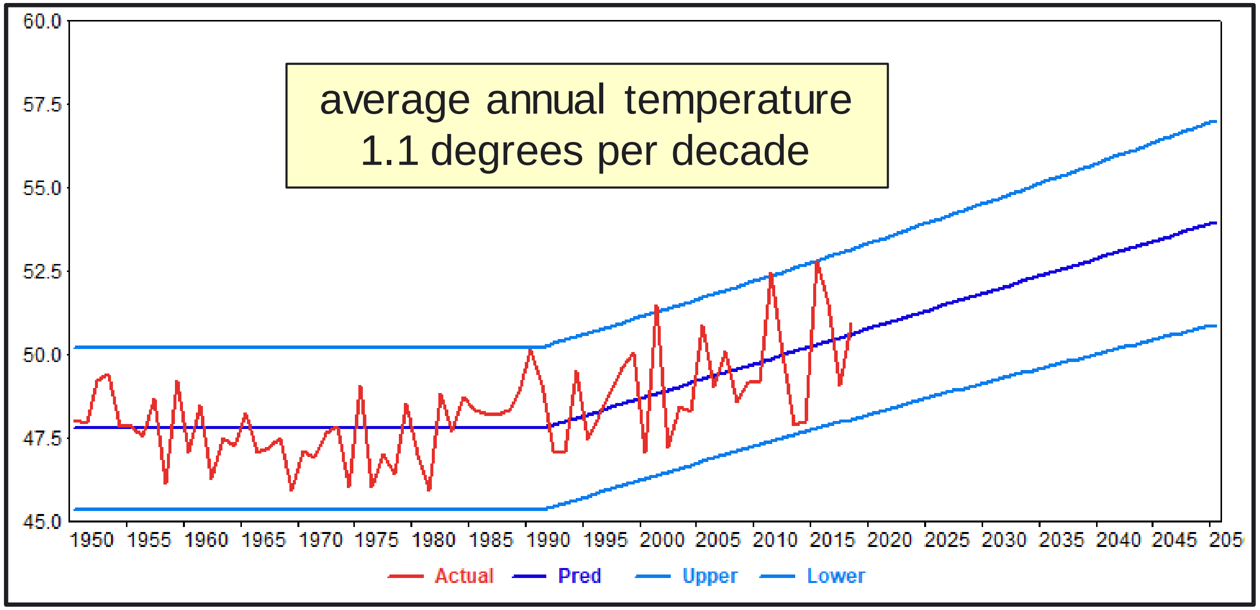


$$AvgAvgDB = f(Trend, Constant)$$

One model for each weather concepts and weather station

Estimated from 1950 through 2018

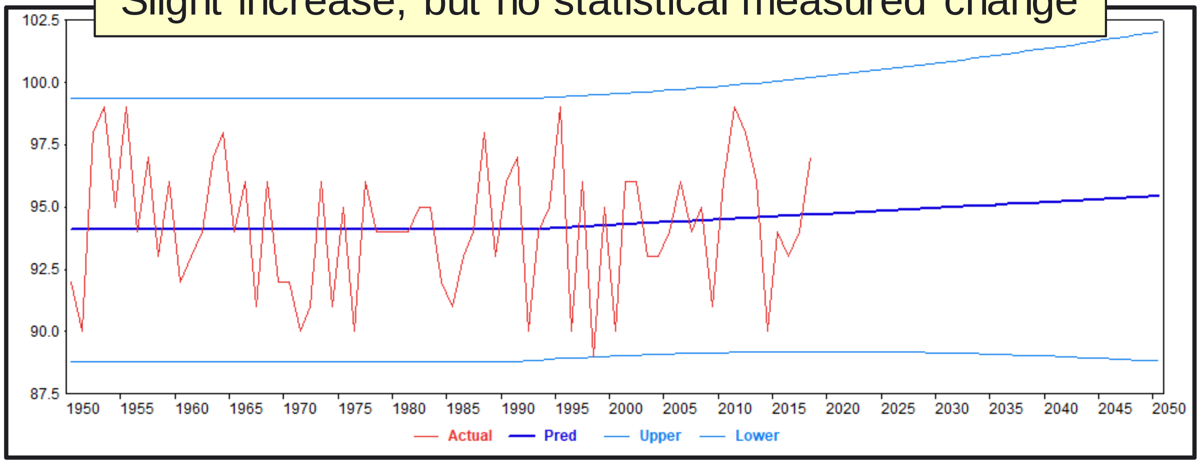
ALBANY WEATHER TRENDS



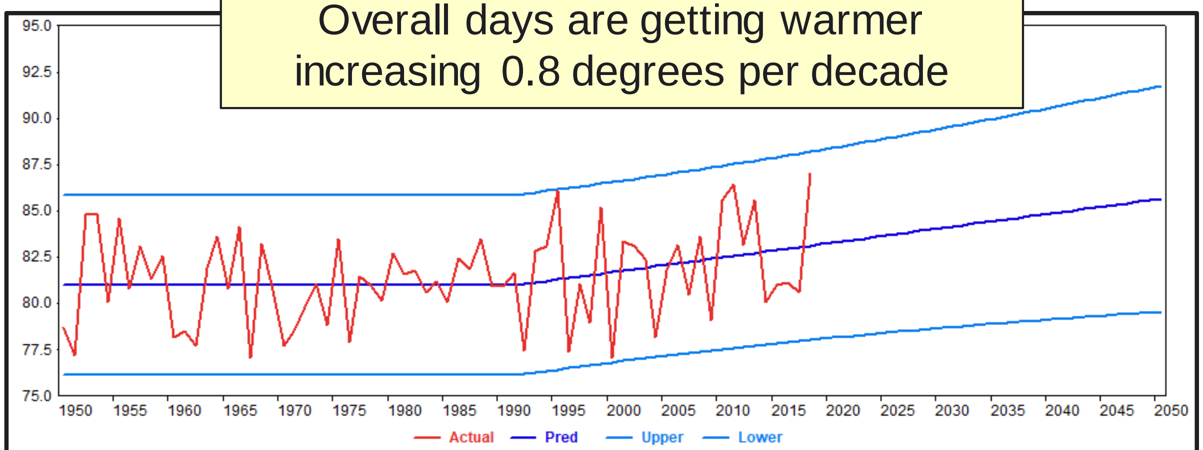
Light blue line shows the 95% confidence interval

ALBANY SUMMER TEMPERATURE TRENDS

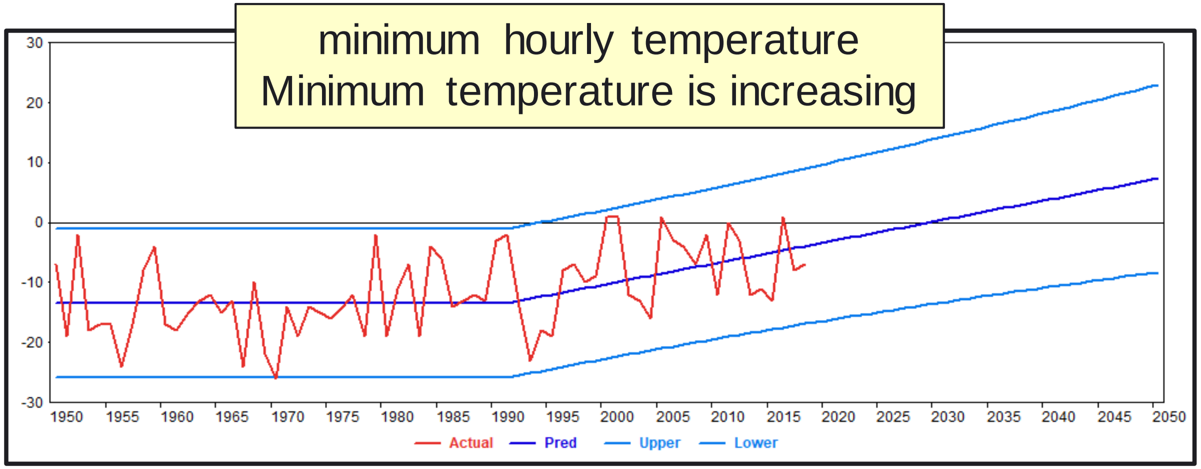
maximum hourly temperature
Slight increase, but no statistical measured change

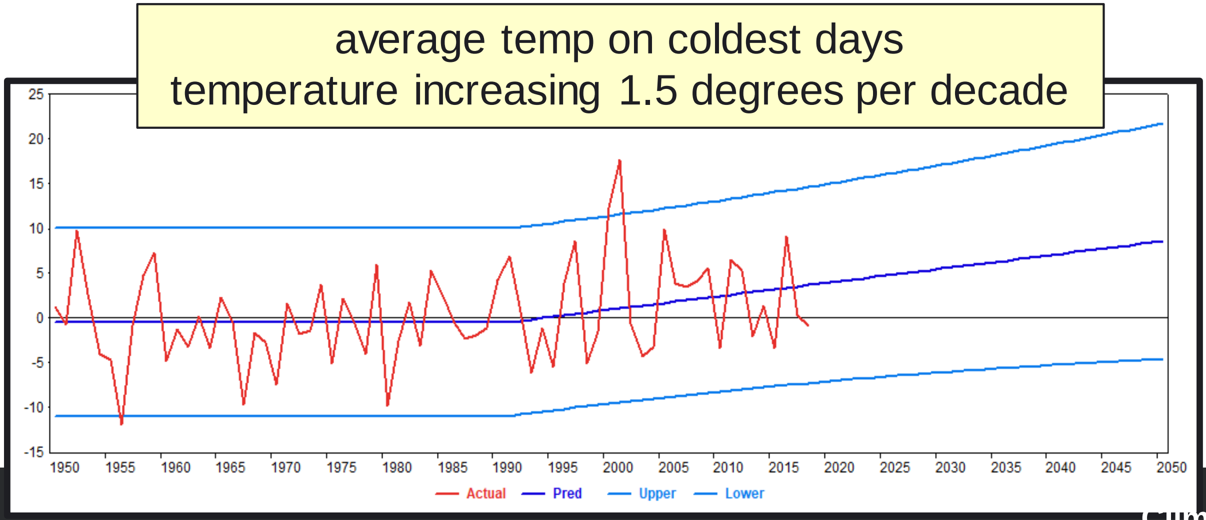


average temperature on hottest days
Overall days are getting warmer
increasing 0.8 degrees per decade

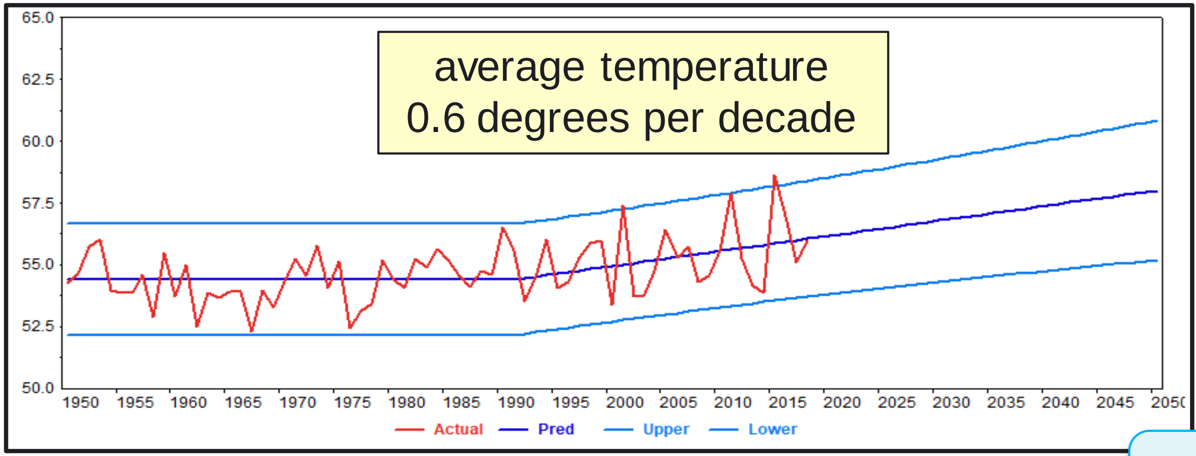


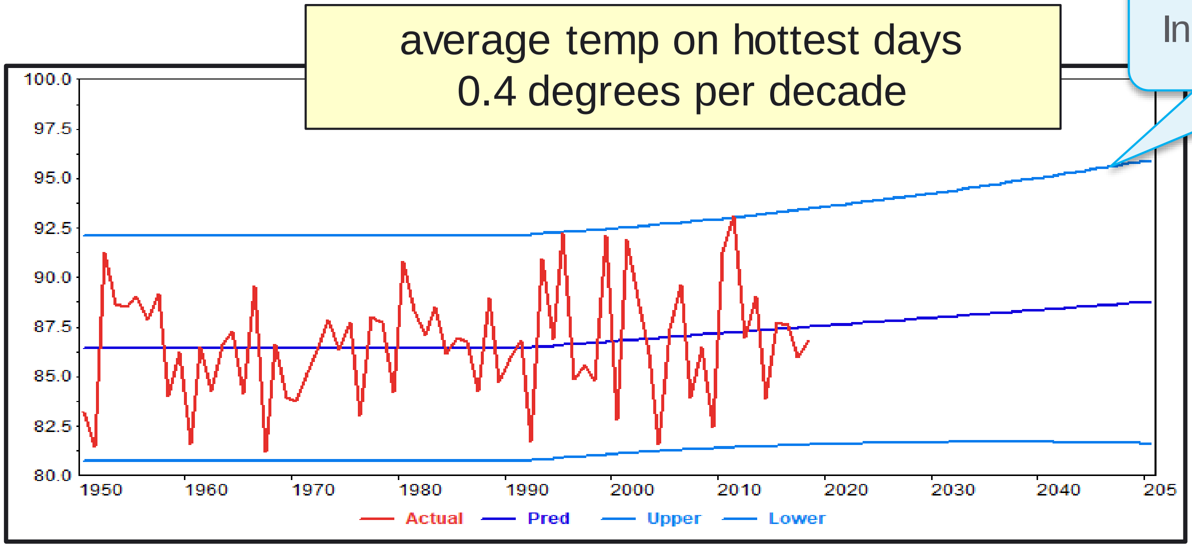
ALBANY WINTER WEATHER TRENDS





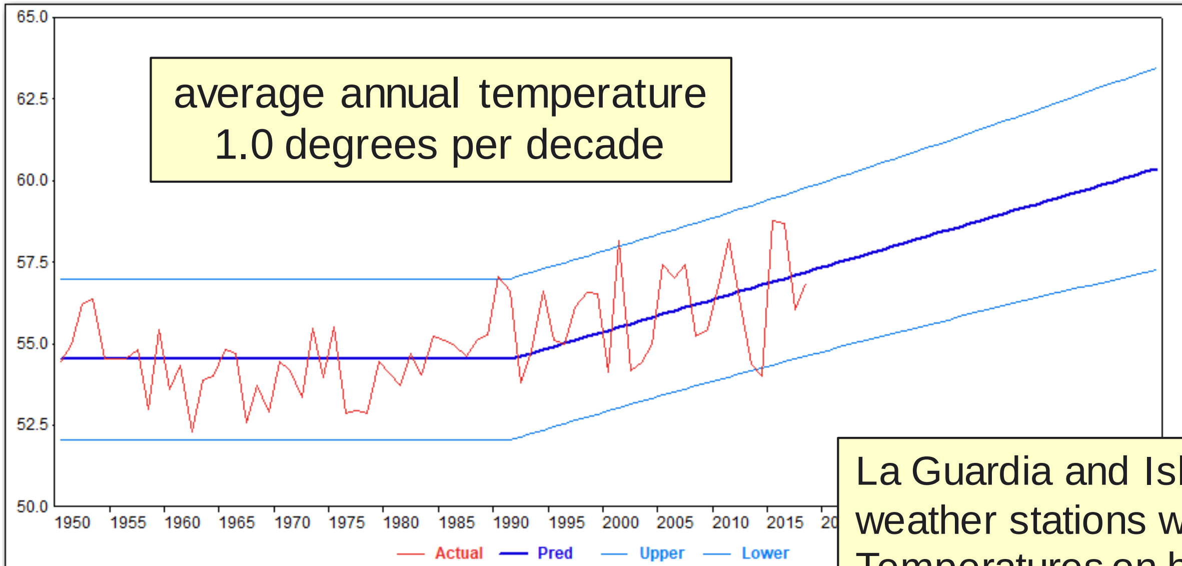
NEW YORK CITY – CENTRAL PARK



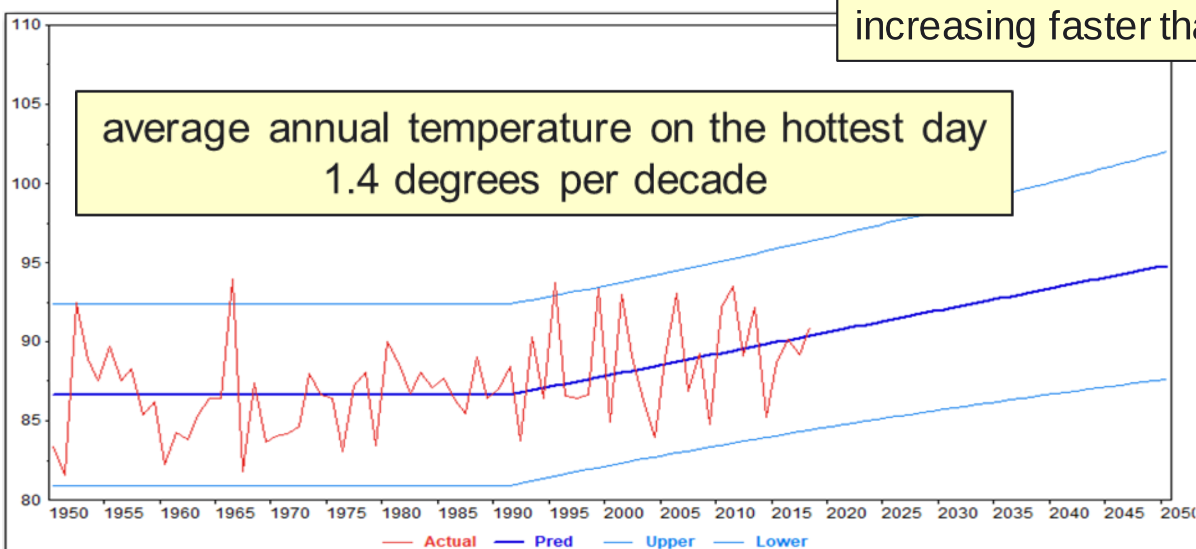


Increasing variance

NEW YORK CITY – LA GUARDIA



La Guardia and Islip are the only two weather stations where it is flipped. Temperatures on hottest days are increasing faster than average temperatures



WEATHER TREND COEFFICIENTS

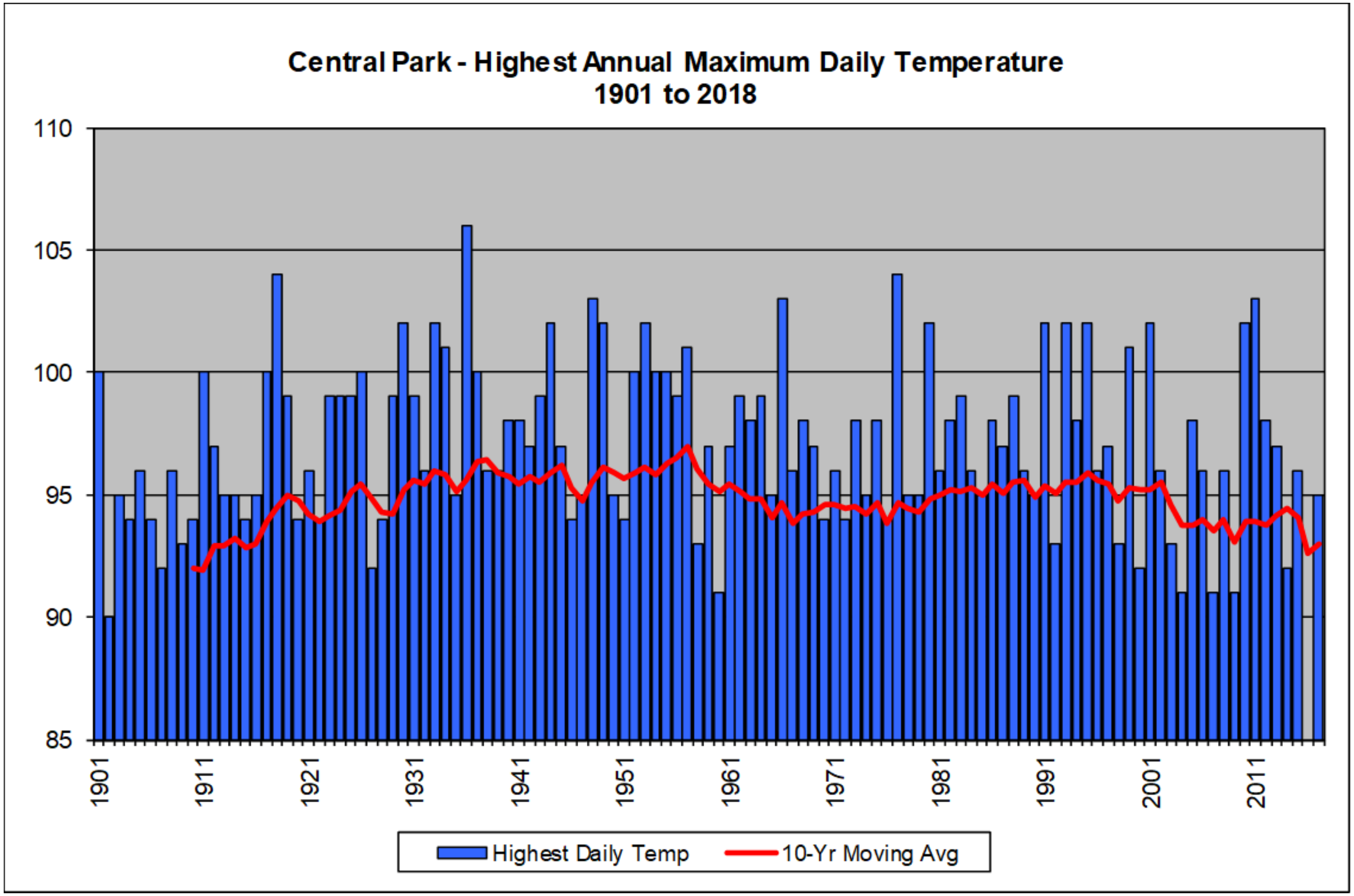
» Average, Max, Min, and CTHI trends estimated for each weather station
  - 21 weather stations

» Station trends weighted to Zones & Transmission Districts based on weather station weights provided by NYISO

TO	AvgTemp	MaxTemp	MinTemp	CTHI
NIMO	0.71	0.52	1.07	0.64
ConEd	0.69	0.56	0.86	0.59
Cen Hudson	0.90	0.78	1.78	0.80
LIPA	0.85	0.93	0.79	0.75
NYSEG	0.60	0.44	1.07	0.55
O & R	0.59	0.41	0.99	0.64
RG&E	0.78	0.45	1.12	0.68
NYCA	**0.71**	**0.58**	**0.98**	**0.63**

» State average temperature trend is 0.71 degrees per decade

» Cumulative hot-day CTHI trend is 0.63 degrees per decade



Little change in maximum temperature – currently tracking a little lower

BUT MORE HOT DAYS
NUMBER OF DAYS AVERAGE TEMPERATURE IS 79 DEGREES OR HIGHER

State

	Normal	Reference	Accelerated
2020	8	9	11
2030	8	11	17
2040	8	13	25
2050	8	17	34

New York City

	Normal	Reference	Accelerated
2020	22	23	27
2030	22	26	36
2040	22	31	49
2050	22	36	60

By 2040, 63% to 93% more hot days for the state
41% to 58% more for NYC

ESTIMATING LONG-TERM WEATHER PROJECTIONS

1. CALCULATE DAILY NORMAL TEMPERATURE AND CTHI

1. For AvgDB and CTHI, calculate average by date from 1/1/1999 to 12/31/2018
   a) Average all January 1st
   b) Average all January 2nd
   c) … (all other days in the year)
   d) Average all December 31st

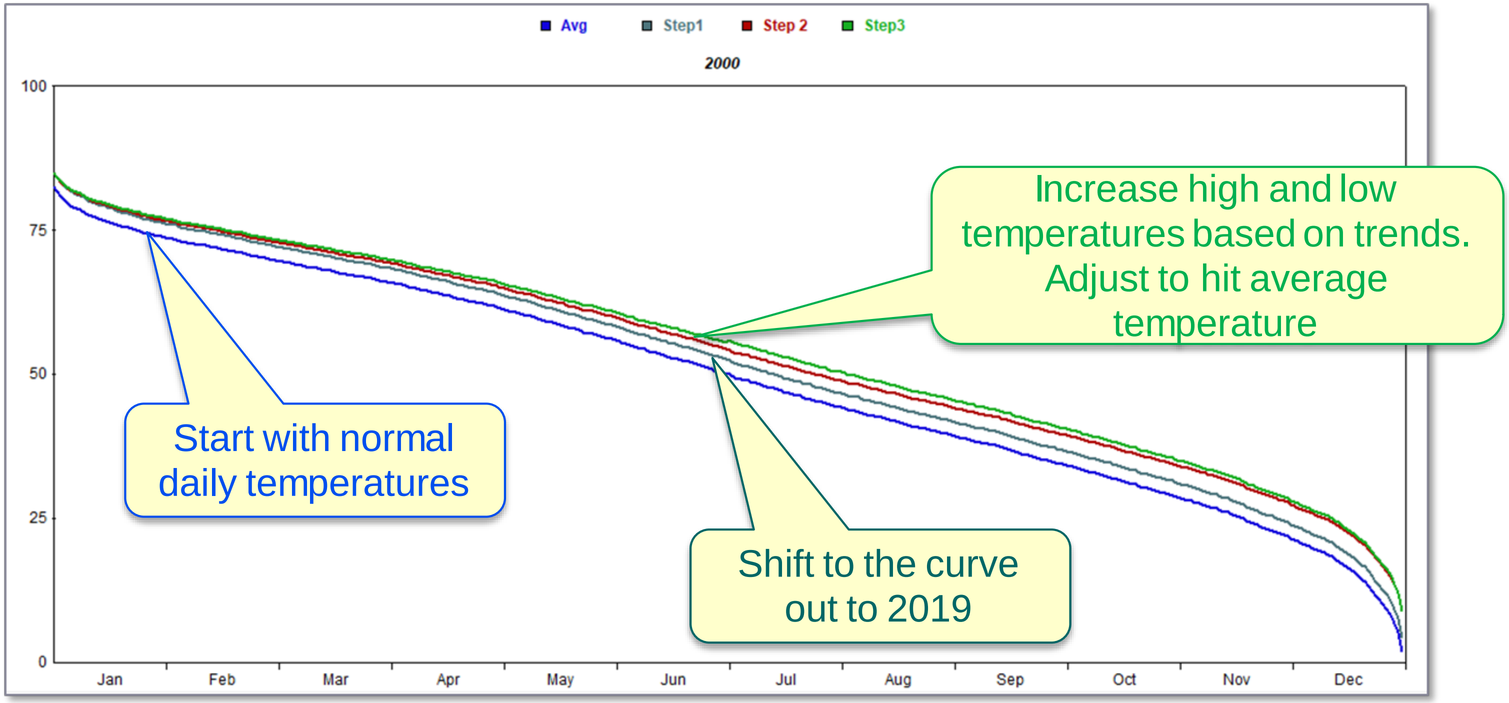
2. Assign the values to a realistic pattern that assures that the peak-producing weather conditions occur on a weekday

2. GENERATE TEMPERATURE DURATION CURVE
SHIFT THE CURVE OUT OVER TIME

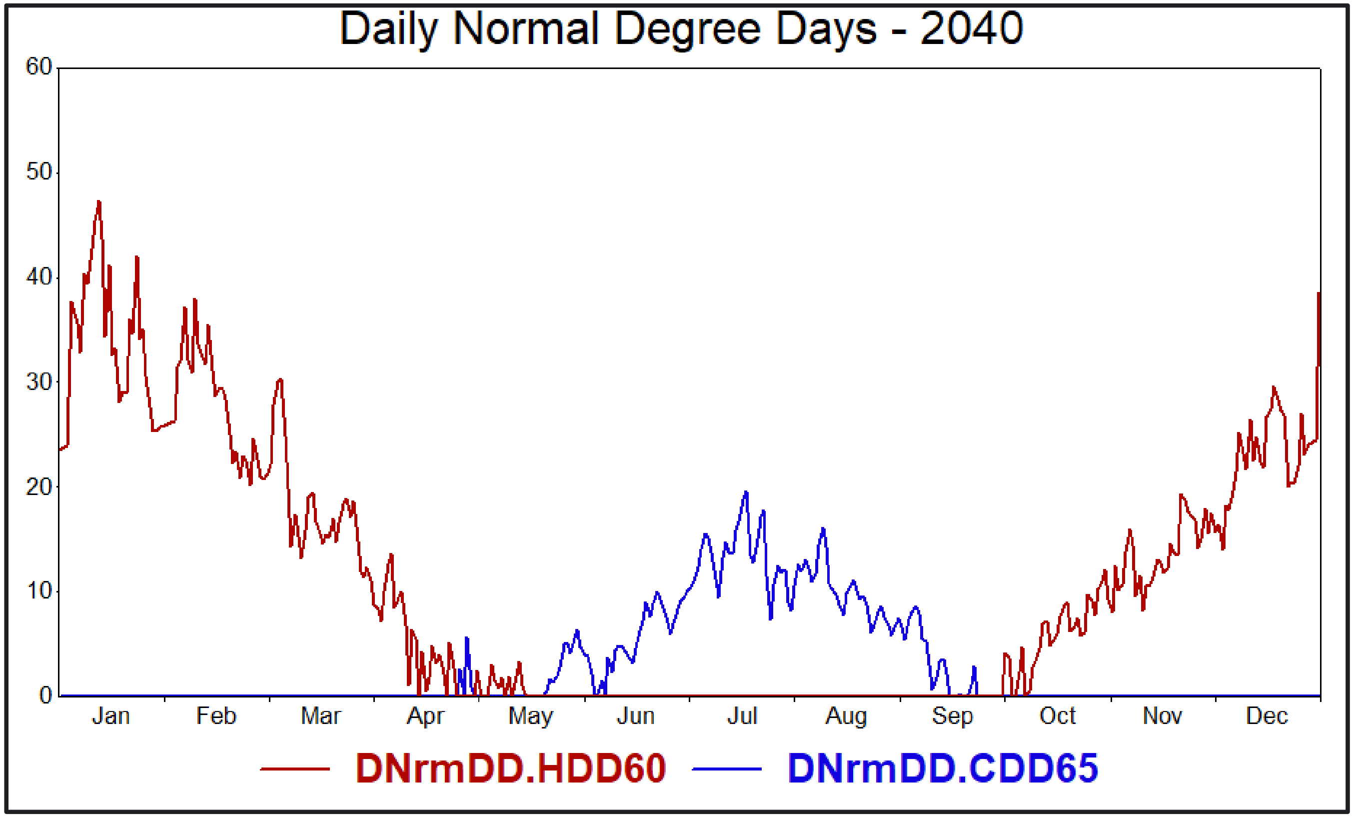
» Temperatures on the hottest days are increasing slower than the average temperature

» Temperatures on the coolest days are increasing faster than average temperature

» The bottom of the temperature duration curve is increasing faster than the top

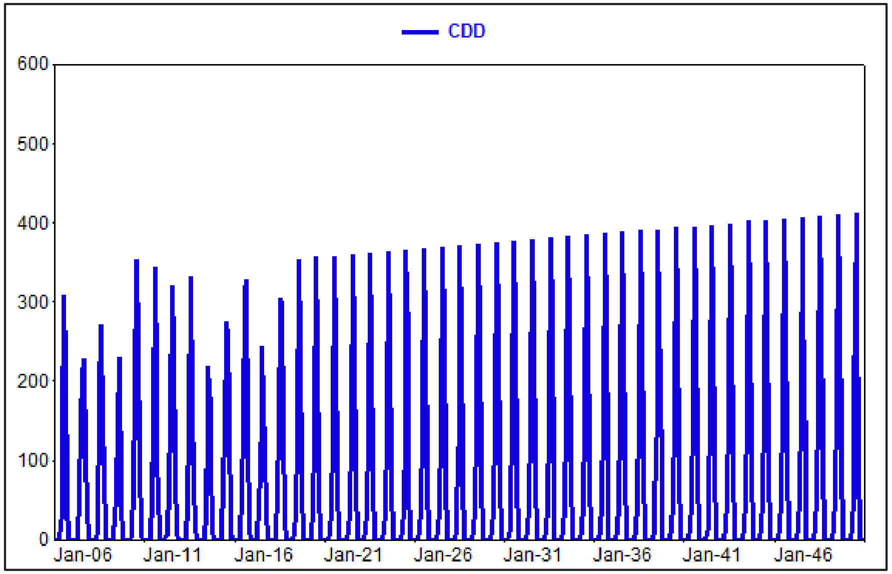


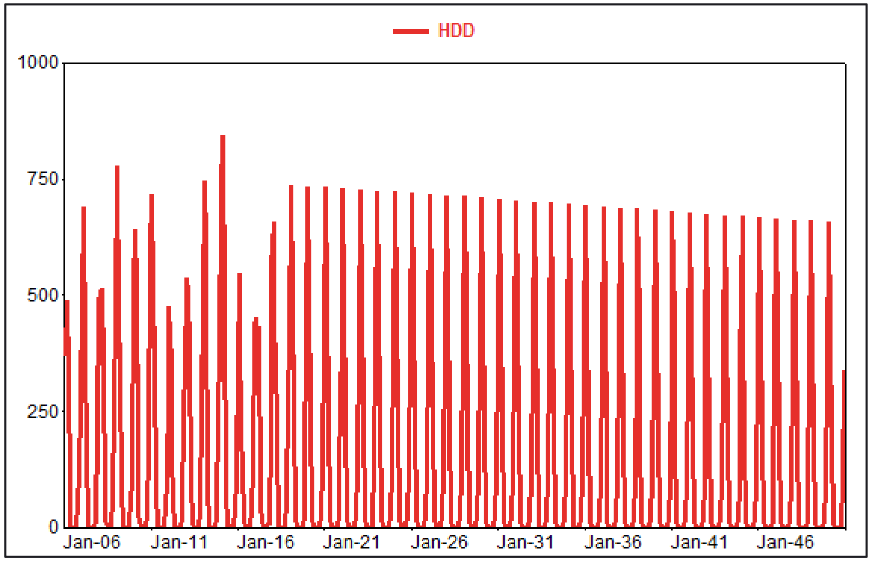
3. CALCULATE DAILY DEGREE-DAYS



4. CALCULATE MONTHLY DEGREE-DAYS
SALES/ENERGY WEATHER DRIVERS

	CDD65	HDD55
Average (1999 to 2018)	766	3,322
Trended to Start Year (2019)	841	3,172
2030	920	3,010
2040	996	2,872
2050	1,070	2,724

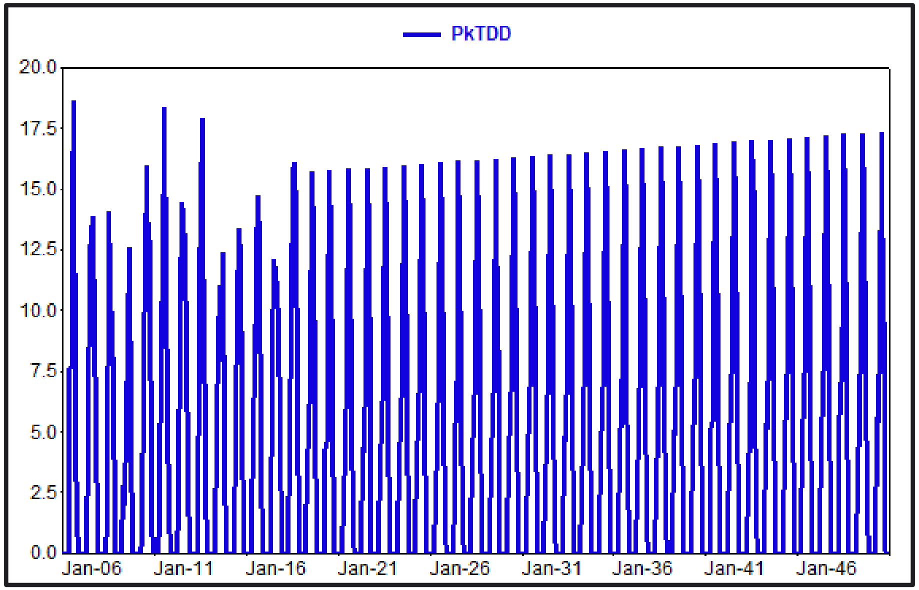


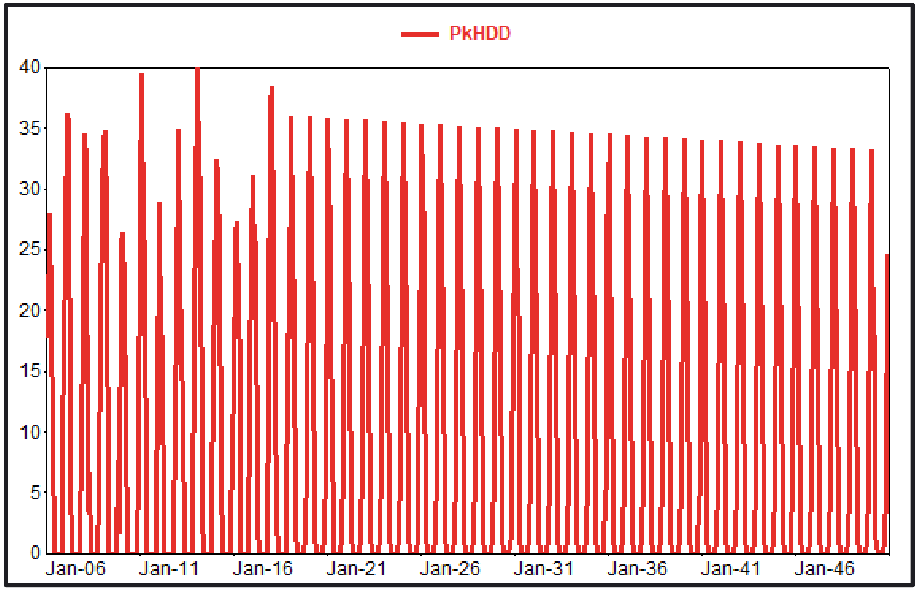


0.8% annual increase in CDD with a faster increase in May than July

And 0.5% annual decrease in HDD

PEAK-DAY WEATHER DRIVERS





Peak-day TDD (CTHI based degree days) increases 0.4% degrees per year

Peak-day HDD decreases 0.3% degrees per year

WEATHER TRENDS BY TRANSMISSION DISTRICT

Peak-Day TDD65

Year	CenHud	ConEd	LIPA	NIMO	NYPA	NYSEG	OR	RGE	NYCA
2020	14.2	16.8	15.8	11.9	12.0	11.5	13.9	12.5	13.9
2030	14.8	17.3	16.8	12.2	12.4	11.8	14.4	12.9	14.5
2040	15.5	17.9	17.7	12.6	12.8	12.1	14.9	13.3	15.0
2050	16.1	18.4	18.7	13.0	13.2	12.5	15.4	13.7	15.5
Avg Change	**0.44%**	**0.32%**	**0.56%**	**0.32%**	**0.31%**	**0.26%**	**0.35%**	**0.30%**	**0.37%**

*** Derived from trended cumulative peak-day THI**

CDD65

Year	CenHud	ConEd	LIPA	NIMO	NYPA	NYSEG	OR	RGE	NYCA
2020	839.9	1,185.2	1,009.6	613.0	471.8	571.6	778.4	644.0	850.6
2030	925.9	1,263.2	1,125.7	669.1	497.1	616.4	827.0	700.7	919.6
2040	1,020.9	1,349.9	1,253.3	731.8	526.4	666.9	882.0	765.2	995.9
2050	1,114.2	1,432.0	1,378.6	792.7	552.9	714.8	933.7	827.6	1,069.5
Avg Change	**0.95%**	**0.63%**	**1.04%**	**0.86%**	**0.53%**	**0.75%**	**0.61%**	**0.84%**	**0.77%**

*** Derived from trended temperatures**

IMPACT ON PEAK DEMAND

	Summer Peak Demand (MW)			Weather Impact (MW)	
	Normal	Reference	Accelerated	Reference	Accelerated
2020	32,652	32,696	33,205	44	553
2030	32,899	33,405	34,393	506	1,494
2040	36,396	37,403	38,911	1,007	2,514
2050	41,700	43,317	45,479	1,617	3,779

Normal – 2019 calculated TDD (Based on THI – combines temperature and humidity)
Reference – 0.6% per decade increase in peak-day TDD
Accelerated – 1.2% per decade increase in peak-day TDD

Expected increase in temperatures and humidity adds a 1,000 MW to 2,500 MW by 2040 and 1,600 to 3,800 MW by 2050

PEAK DEMAND FOR EXPECTED INCREASE IN TEMPERATURE TREND AND 90TH PERCENTILE OF TEMPERATURE TREND

	Gold Book (MW)		Reference Case (MW)		Accelerated (MW)	
	Baseline	90th	50% Prob	90% Prob	50% Prob	90% Prob
2020	32,202	33,990	32,696	34,273	33,205	34,806
2030	31,066	32,776	33,405	34,975	34,393	36,010
2040	33,006	34,810	37,403	38,944	38,911	40,513
2050	35,595	37,539	43,317	44,885	45,479	47,125

*** Gold Book 2050 Extrapolated from 2049 Forecast**

By 2040, design peak demand is between 38,944 MW to 40,513 MW
Compared with the Gold Book forecast of 34,810 MW.

MODELING APPROACH

REFERENCE CASE FORECAST

- Forecast for the system and each NYISO load zone

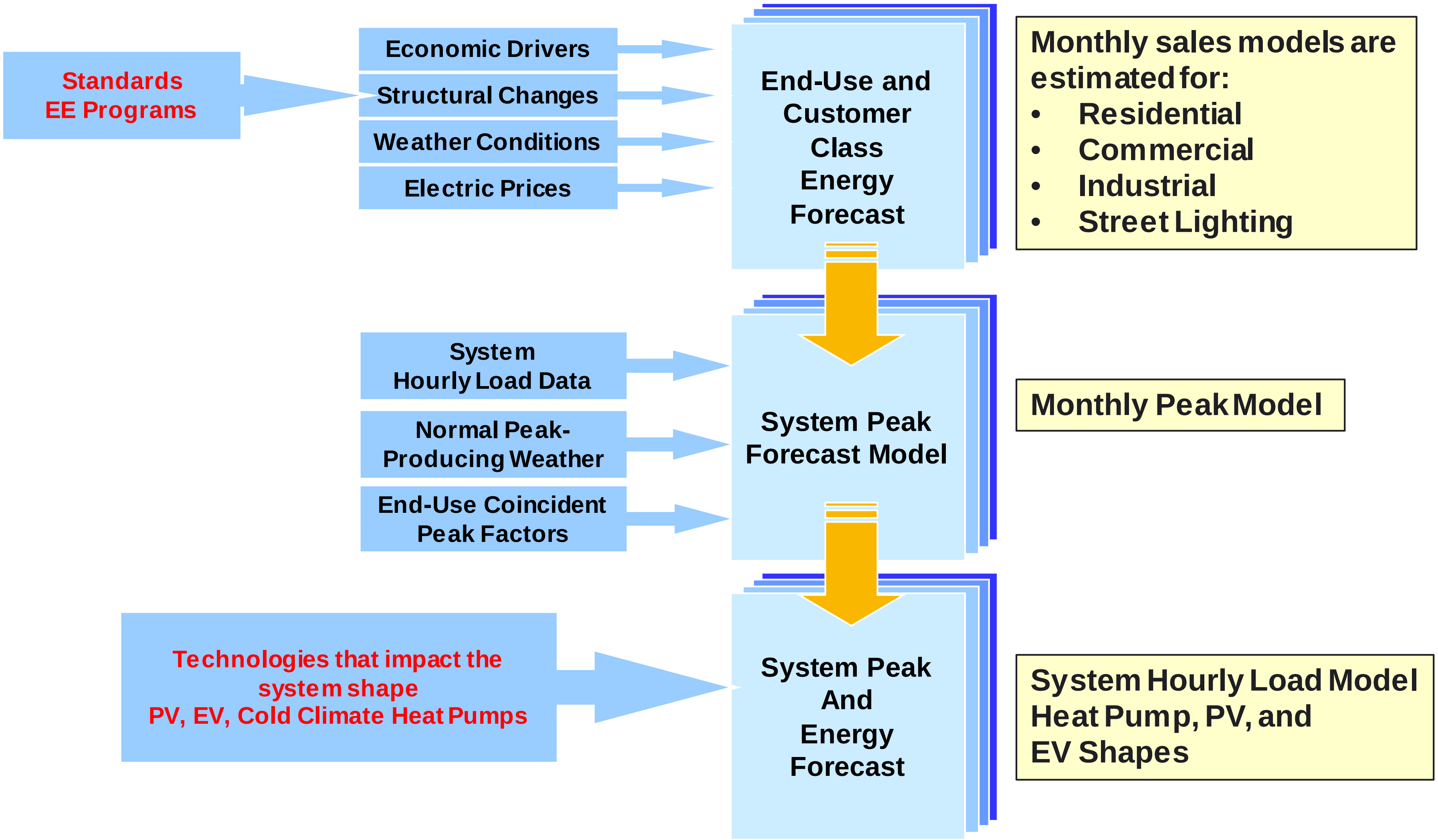
- Estimated with twelve-years of historical hourly load data (adjusted for solar load impacts)
  - Forecast monthly energy, peak, and hourly loads
  - Data through 2018
  - Forecast through 2050

- Assumptions
  - 2018 Moody’s economic forecast
  - EIA 2018 end-use energy intensity projections
  - Average state-wide temperature increases 0.7 degrees per year

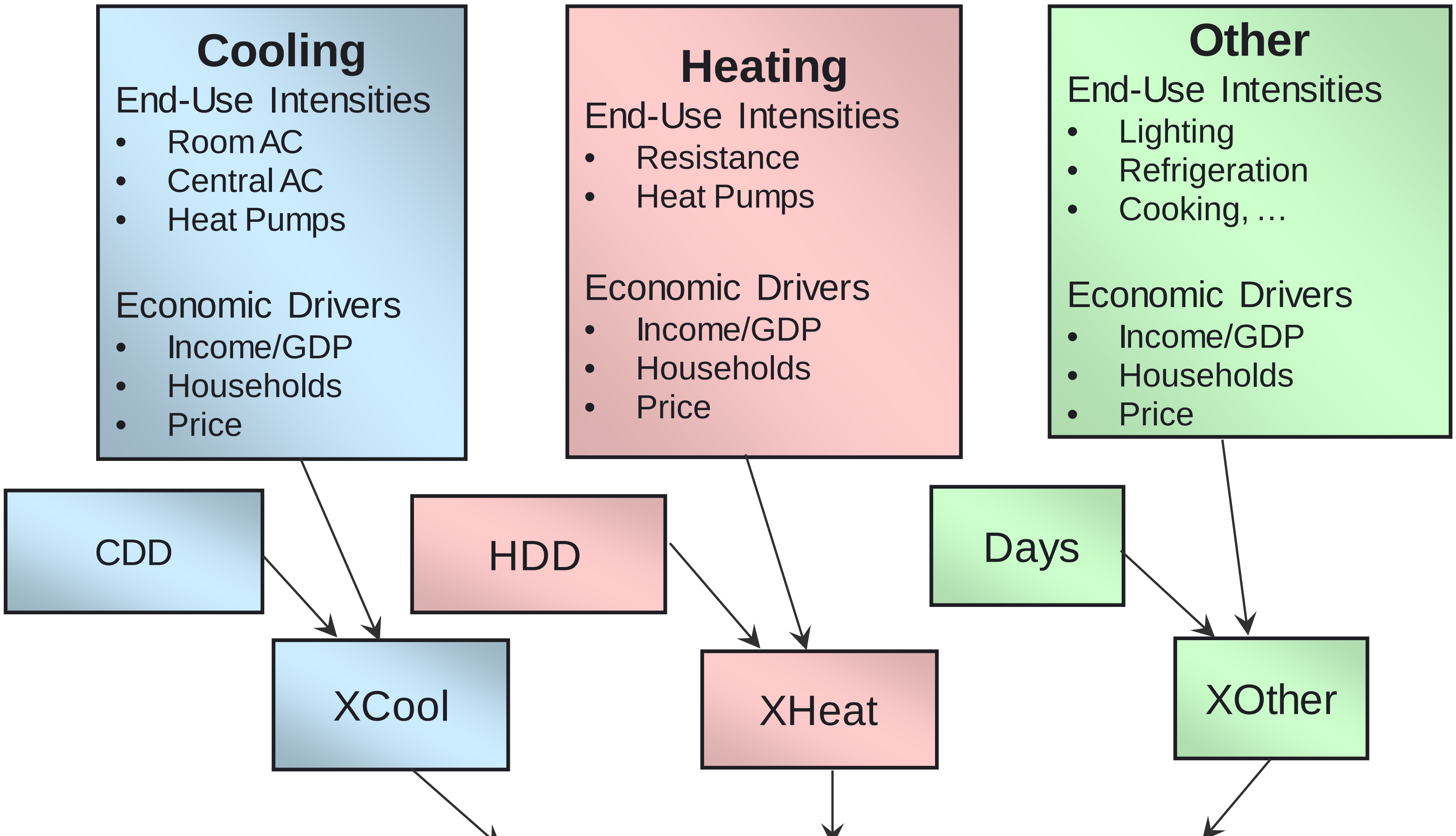
- Gold Book technology projections
  - Solar
  - Electric Vehicles
  - Battery Storage

SYSTEM: BOTTOM-UP FORECASTING FRAMEWORK

CLASS LEVEL END-USE ENERGY DRIVES PEAK DEMAND



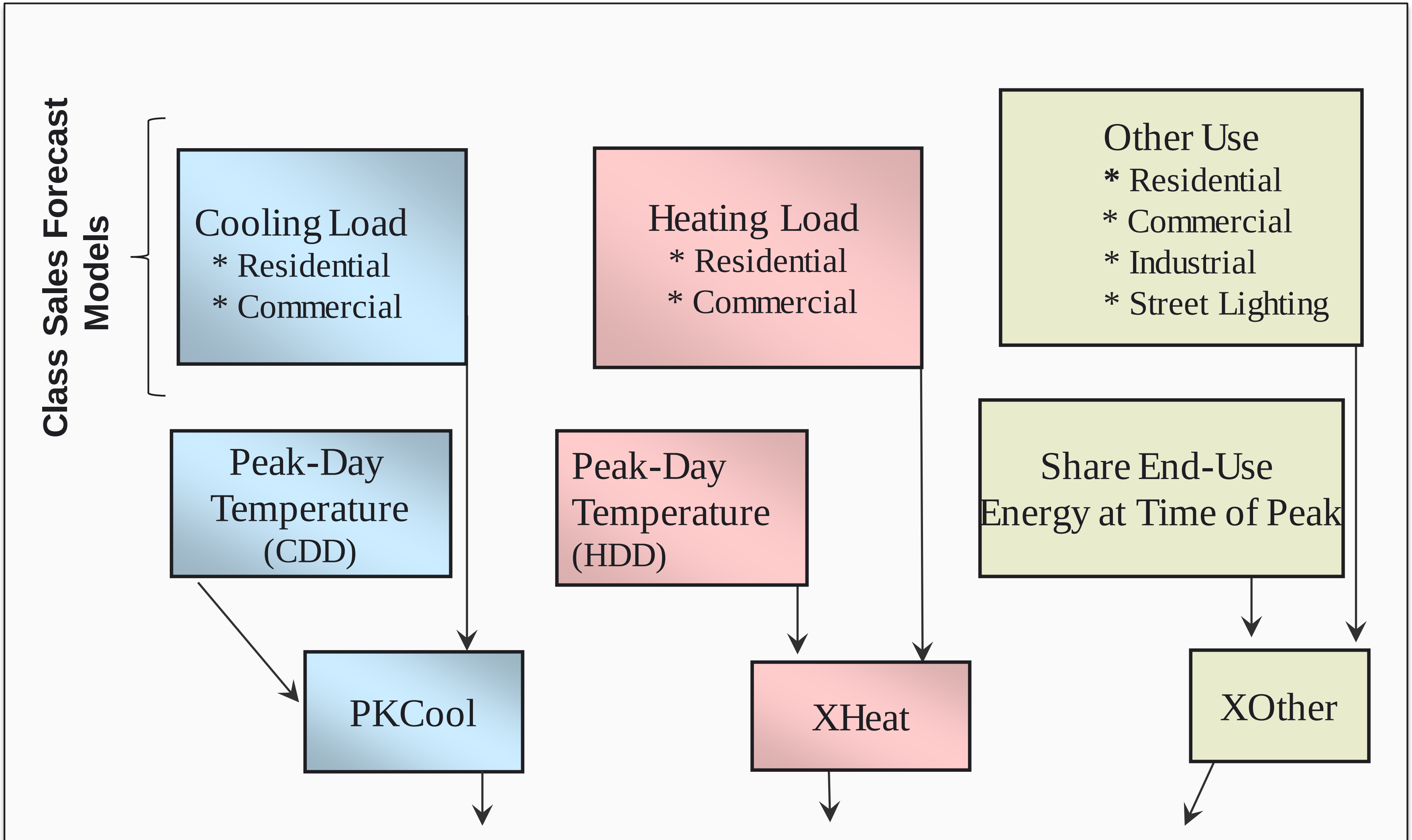
INTEGRATE END-USE INTENSITIES WITH ECONOMICS, PRICE, AND WEATHER



$$Sales_m = a + b_c \times XCool_m + b_h \times XHeat_m + b_o \times XOther_m + e_m$$

Estimate monthly model with historical billed sales data

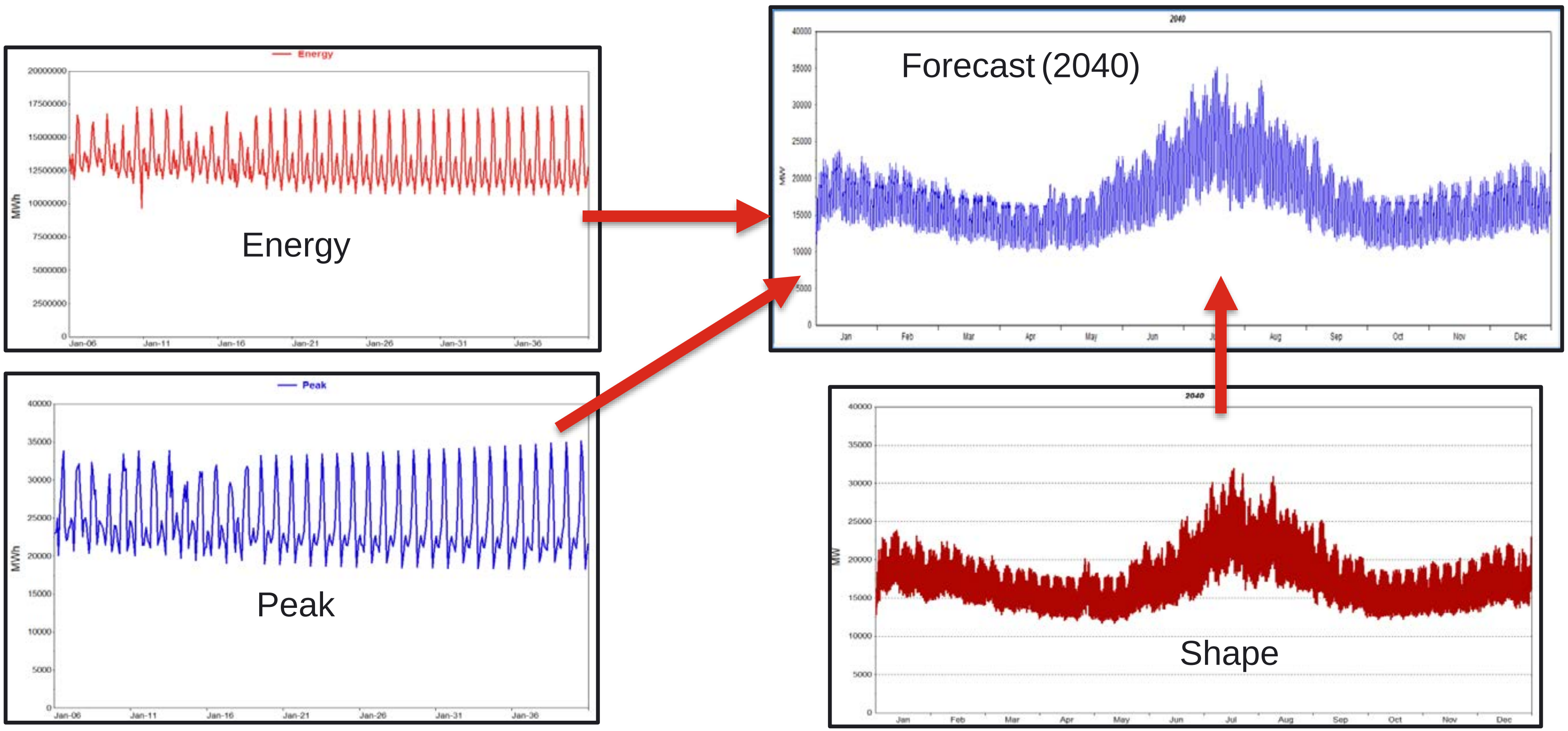
PEAK MODEL



$$Peak_m = a + b_c \times PkCool_m + b_h \times PkHeat_m + b_o \times PKOther_m + e_m$$

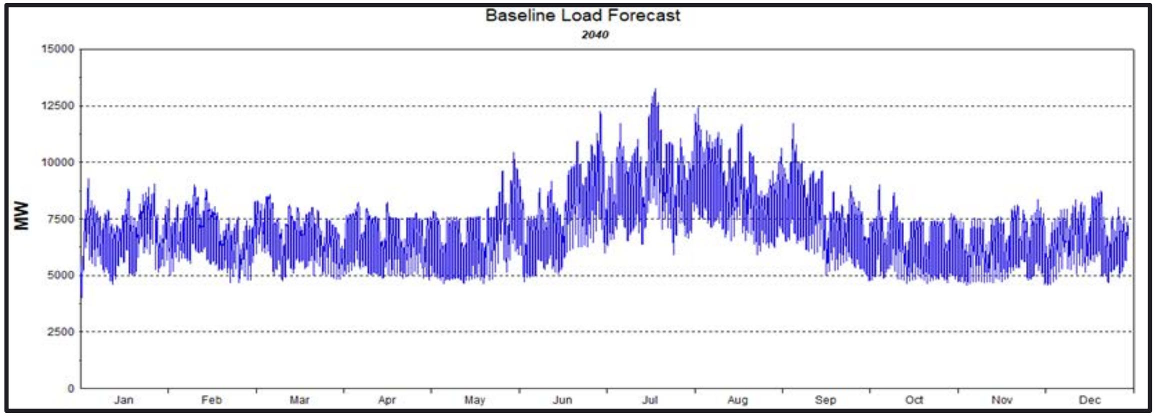
HOW DOES WEATHER ROLL THROUGH?

» Combine energy, peak, and hourly load profile
- Trended monthly CDD and HDD → Sales and Energy
- Trended peak-day CTHI → Peak
- Trended daily CDD and HDD → Shape

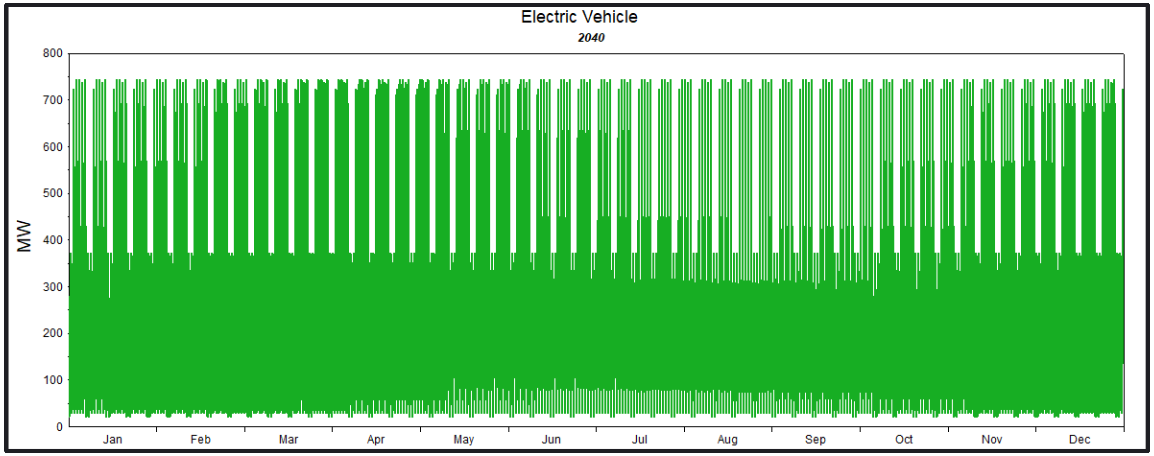


LAYERING NEW TECHNOLOGIES

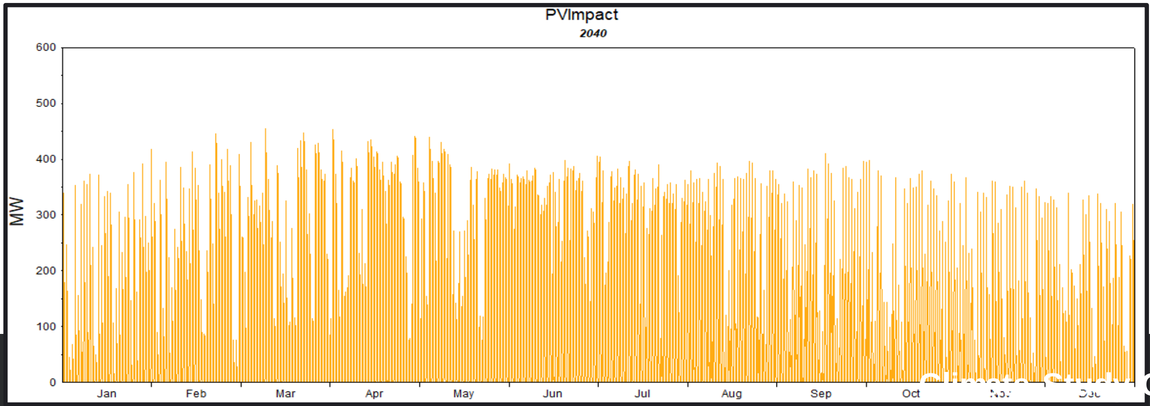
Baseline



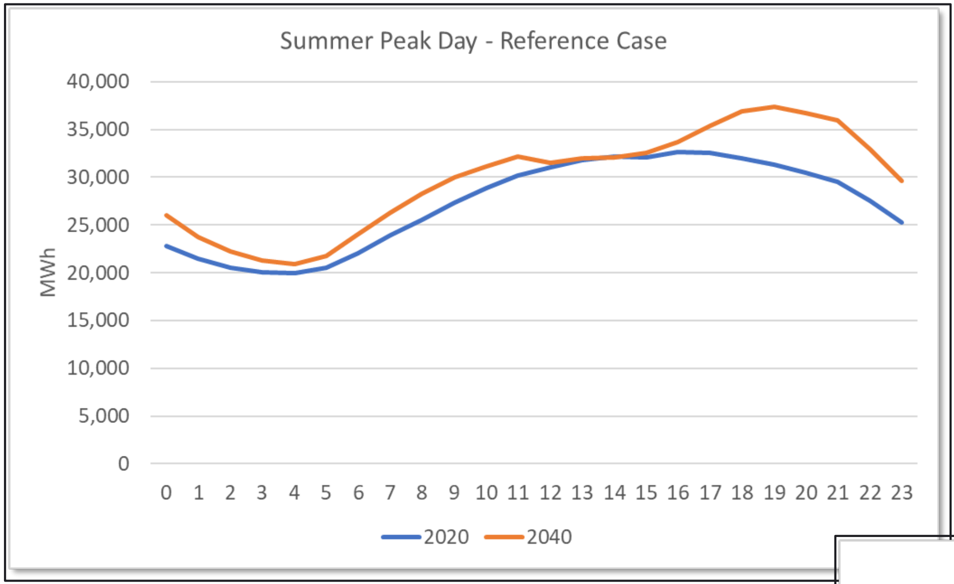
+ EVs

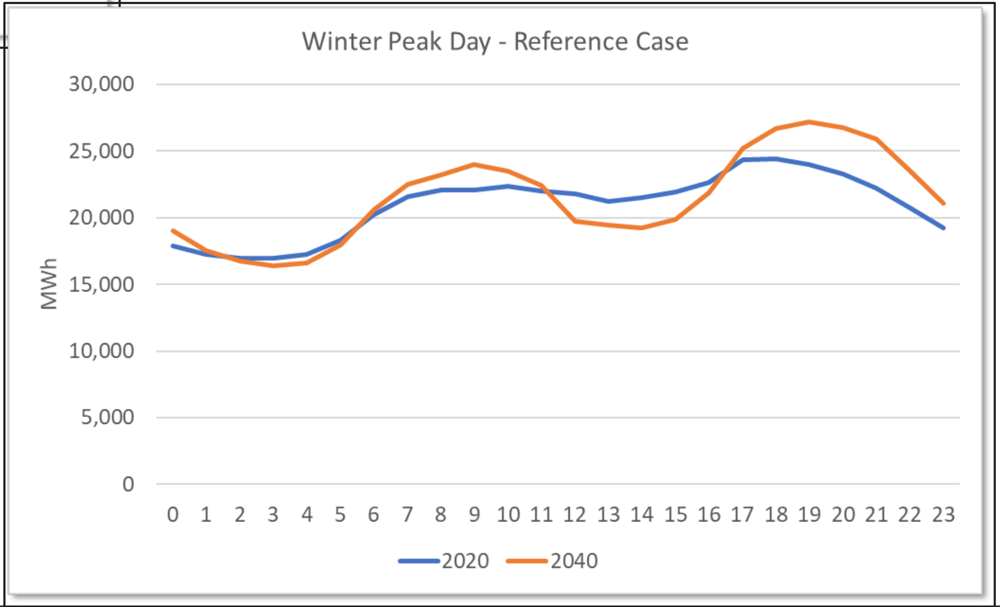


- Solar



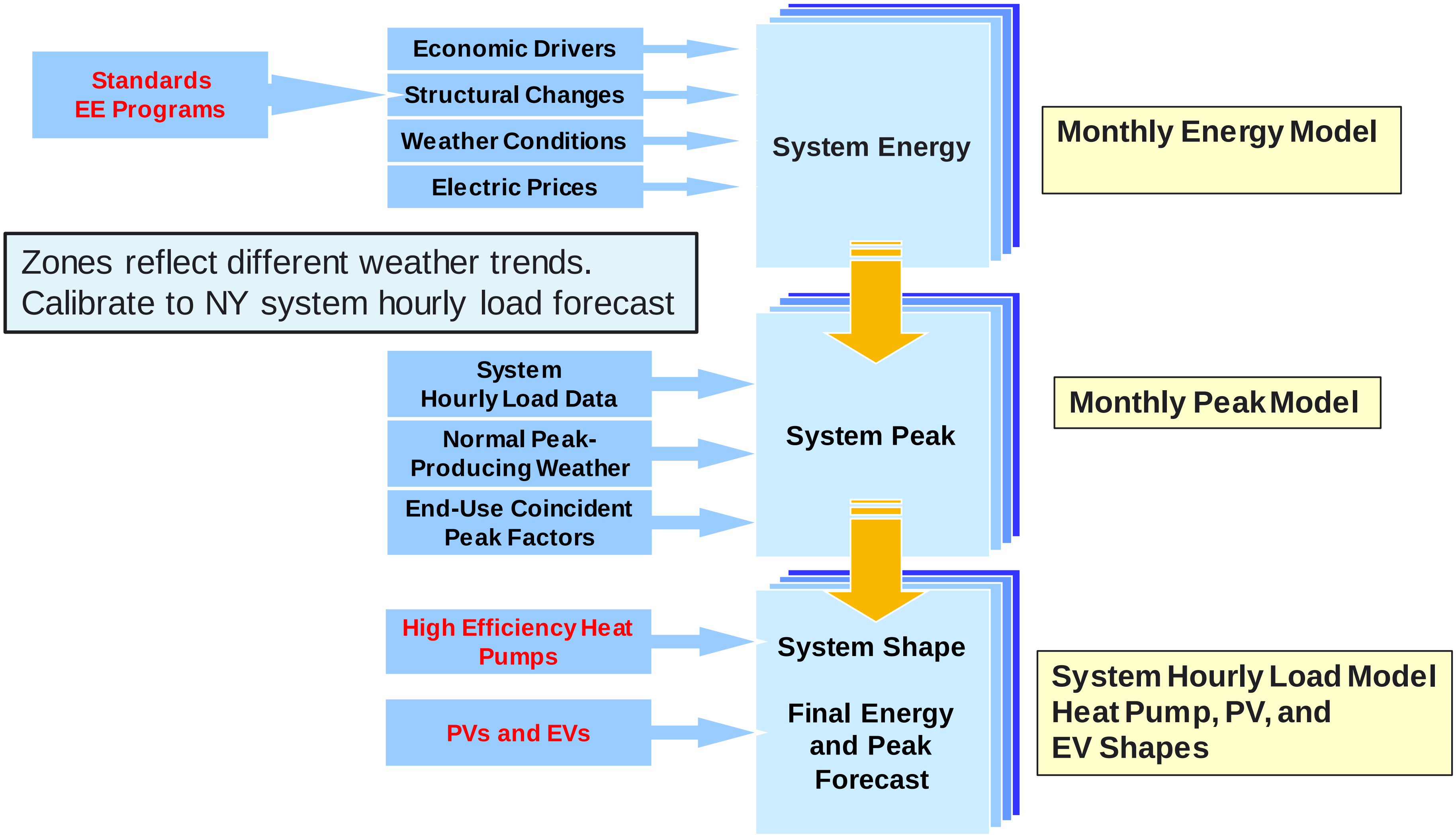
CHANGE IN SYSTEM LOAD





ZONAL LOAD FORECASTS

CONSTRUCT END-USE CONCEPTS AT THE SYSTEM LEVEL



SCENARIOS

RESPONSE TO CLIMATE CHANGE

» Reduce electricity consumption
  - Energy efficiency improvements
    - End-use and building standards
    - Energy efficiency programs
  - Utility scale and behind the meter solar adoption

» Reduce greenhouse gas emissions
  - Electric vehicle market penetration
  - Electrification programs (cold climate heat pumps)

» Impacts evaluated through constructed scenarios
  - Reference Case – 2019 Gold Book forecast assumptions
  - Policy Case – Higher EE savings and PV market penetration
  - CLCPA Case – Aggressive statewide electrification

THE POLICY SCENARIO

- Stronger EE program impacts, State meets the Clean Energy Standard Goals
  - 2,200 GWh of additional savings per year through 2025

- Behind-the-Meter Solar PV: Increased to 6,000 MW by 2025. Thereafter, an additional 3,000 MW through 2050.

- State utilities implement electrification programs. 25% of existing homes convert to cold climate heat pumps 2050.

- 3,000 MW of battery storage by 2030; 5,000 MW by 2050
  - Additional storage treated as a supply option

CLIMATE LEADERSHIP AND COMMUNITY PROTECTION ACT

» Passed July 2019

» Requires
  - Reduction of greenhouse gases of 85% of 1990 levels (209 million metric tons) by 2050
  - Reduce GHG emissions 40% by 2030
  - Obtain fossil-free generation, without use of offsets, by 2040

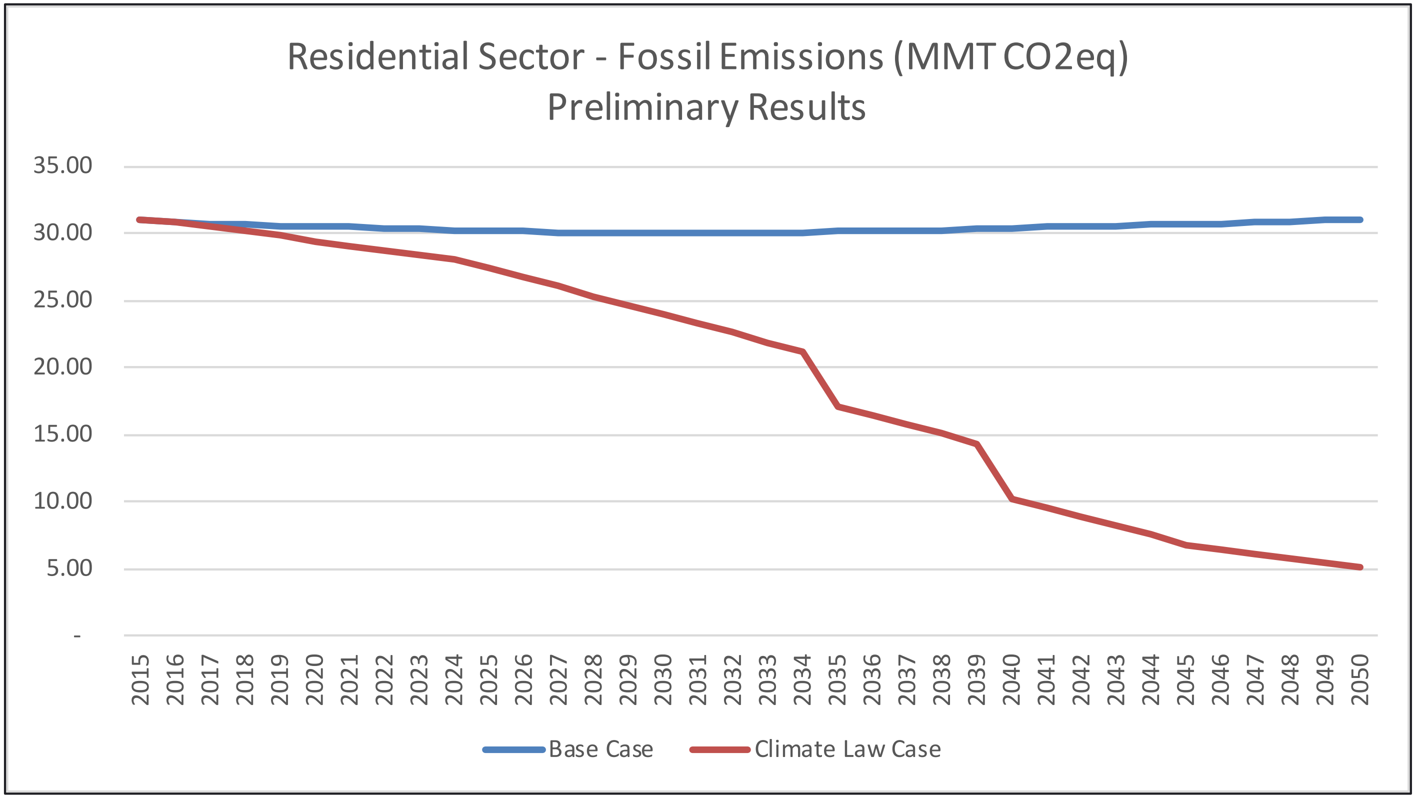
» Achieved through aggressive statewide residential and commercial electrification

NEW YORK STATE GREENHOUSE GAS INVENTORY 1990 – 2016 (NYSERDA)

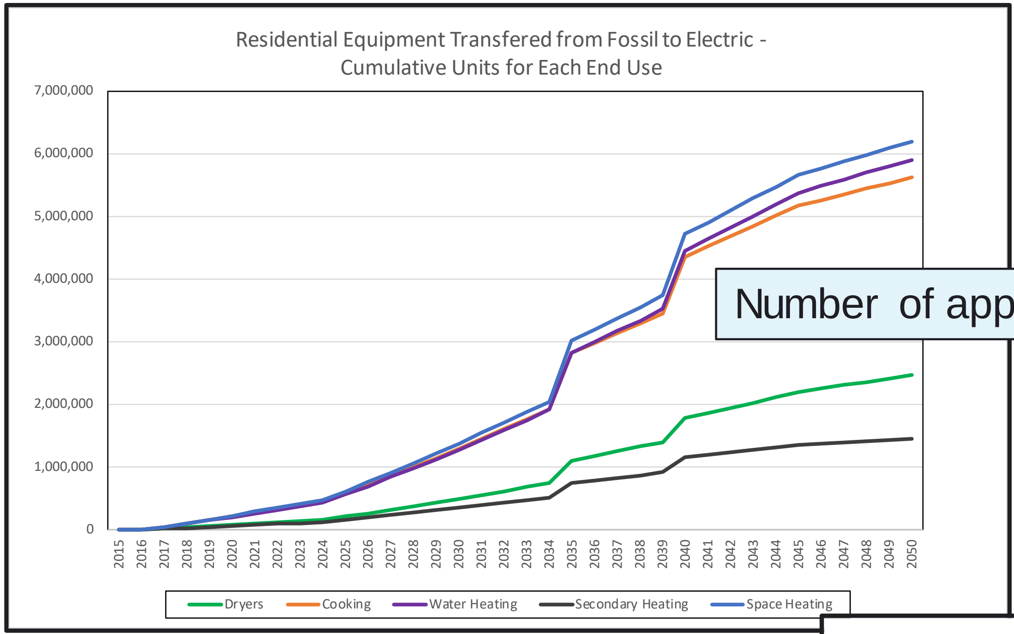
Focus on residential sector

Metric Tons (Millions)	1990	1995	2000	2005	2010	2015	2016
Energy	208.96	206.87	228.2	230.69	193.21	180.69	172.79
Electric Generation	63.02	51.28	55.68	53.58	37.31	29.13	27.72
Residential (Non-Electric)	34.25	34.98	40.28	39.83	31.7	35.64	30.89
Commercial (Non-Electric)	26.55	27.04	32.23	28.66	24.19	21.87	20.66
Industrial (Non-Electric)	20.02	22.54	17.52	14.89	10.27	10.8	10.23
Transportation	59.37	61.82	71.66	79.23	74.93	74.15	73.98
Net Imported Electricity	1.74	4.52	6.04	7.35	9.2	3.37	3.82
Incineration of Waste	1.27	1.96	2.05	3.6	2.35	2.92	2.79
Natural Gas Systems	2.74	2.74	2.73	3.52	3.25	2.82	2.73
Non-Energy Sources	27.22	28.05	30.28	31.19	31.56	32.91	32.82
Agriculture	8.37	7.8	8.55	8.27	8.73	8.86	8.86
Waste	14.86	15.43	15.62	15.62	14.29	13.23	12.8
Industrial Processes & Product Use	3.99	4.83	6.11	7.3	8.54	10.82	11.15
Total	236.19	234.92	258.48	261.88	224.77	213.59	205.61
Fuel Combustion	204.95	202.17	223.41	223.57	187.6	174.95	167.28
NonFuel Combustion	31.24	32.75	35.07	38.31	37.17	38.65	38.33

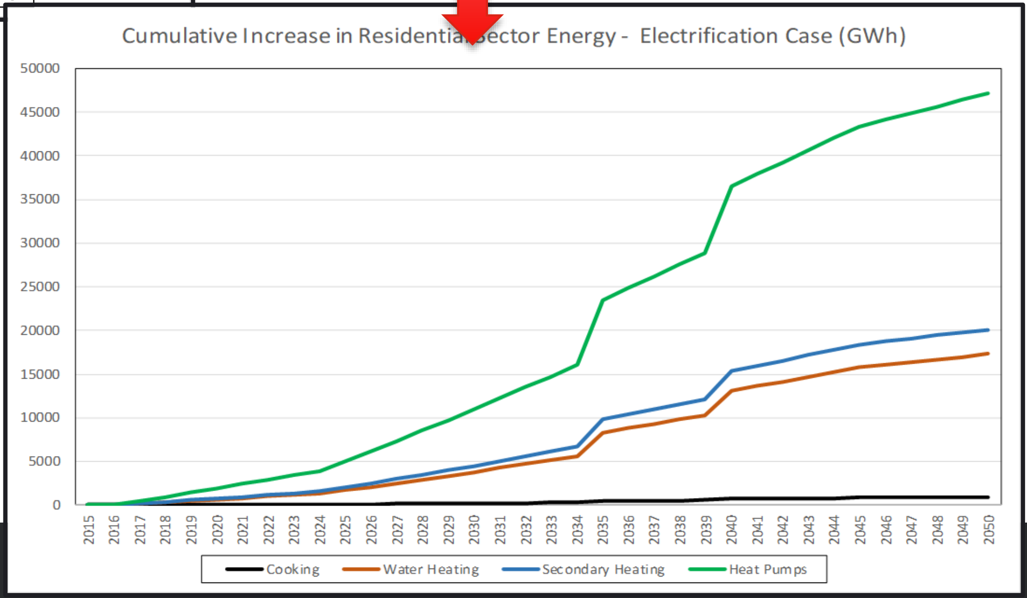
ESTIMATED RESIDENTIAL EMISSIONS REDUCTION



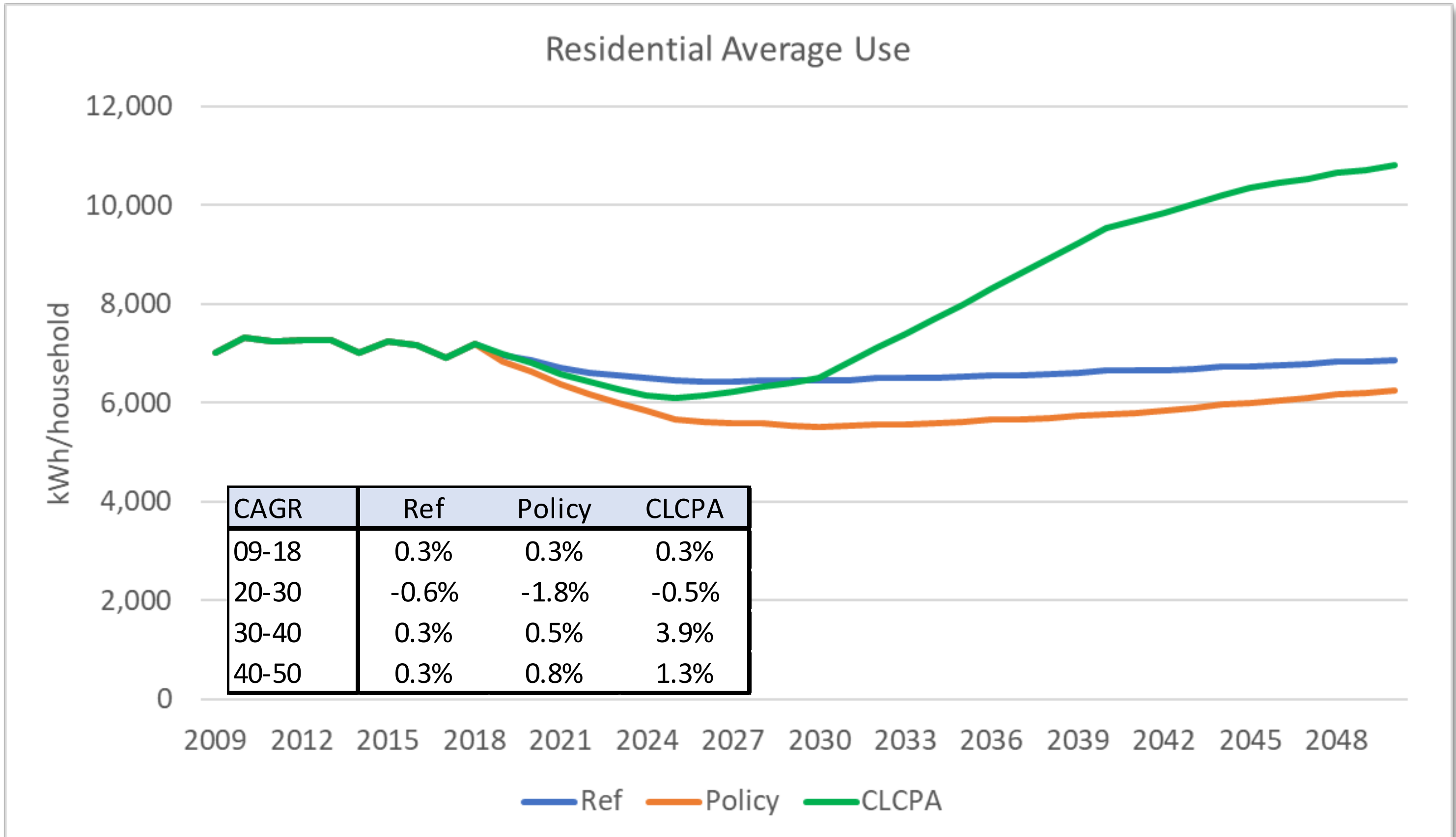
RESIDENTIAL FUEL SWITCHING



Number of appliances replaced x electric appliance use

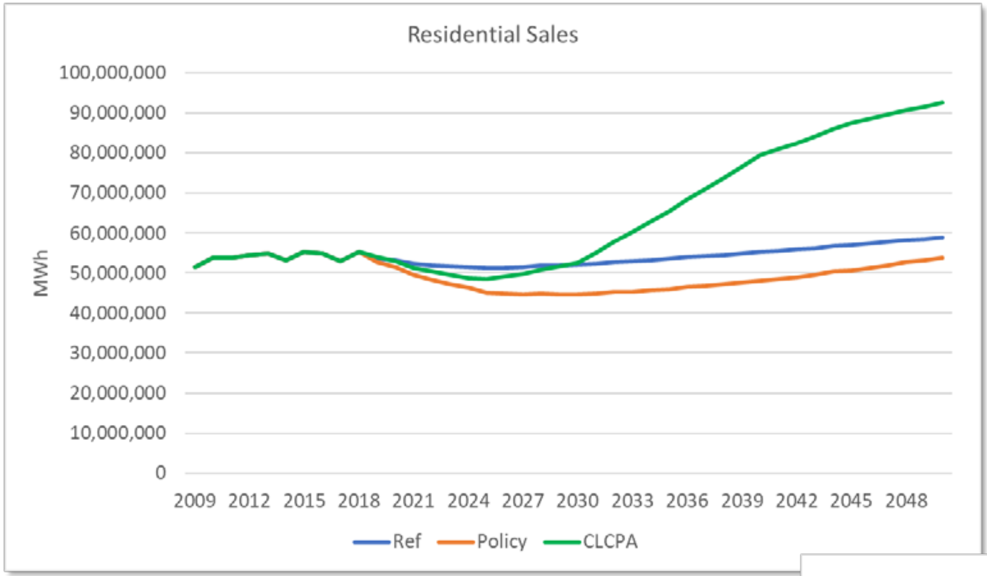


RESIDENTIAL AVERAGE USE



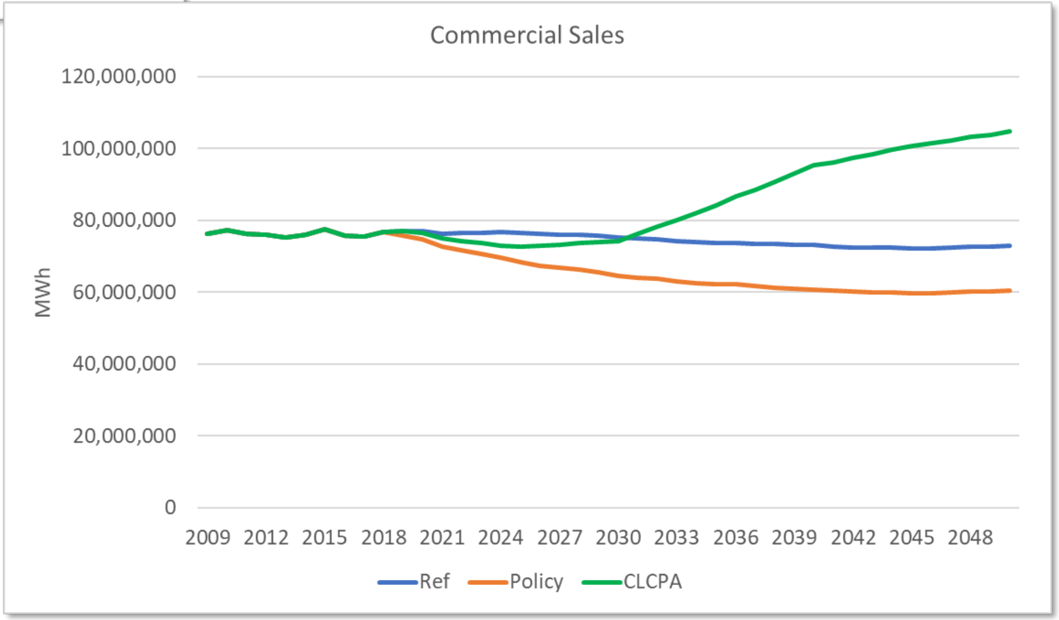
CAGR	Ref	Policy	CLCPA
09-18	0.3%	0.3%	0.3%
20-30	-0.6%	-1.8%	-0.5%
30-40	0.3%	0.5%	3.9%
40-50	0.3%	0.8%	1.3%

RESIDENTIAL AND COMMERCIAL CLASS SALES

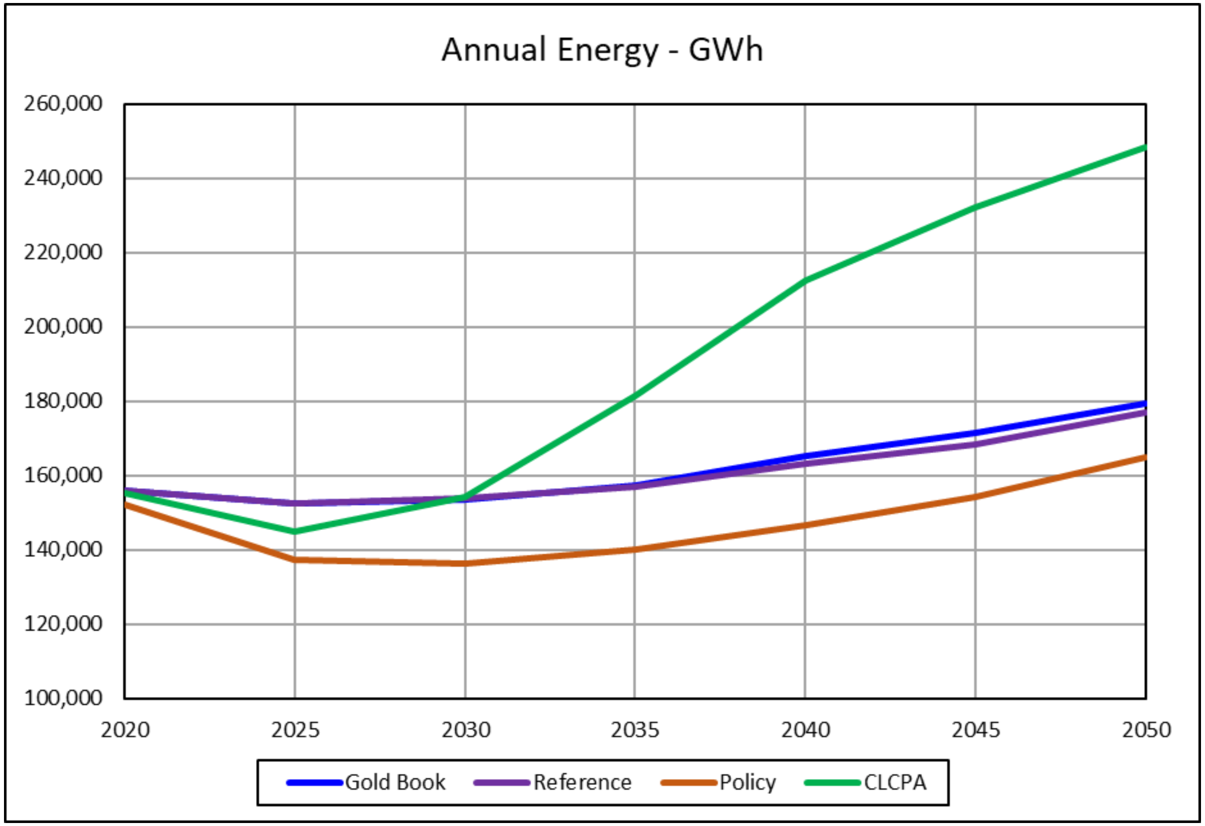


CAGR	Ref	Policy	CLCPA
09-18	0.8%	0.8%	0.8%
20-30	-0.2%	-1.4%	-0.1%
30-40	0.6%	0.8%	4.2%
40-50	0.6%	1.1%	1.6%

CAGR	Ref	Policy	CLCPA
09-18	0.1%	0.1%	0.1%
20-30	-0.2%	-1.4%	-0.3%
30-40	-0.3%	-0.6%	2.5%
40-50	0.0%	-0.1%	0.9%



SYSTEM ENERGY



Policy case is lower than reference case:
Additional EE savings and PV adoption outweigh gains from electric vehicles and electrification.

CLCPA case significantly higher than reference case:
With aggressive statewide electrification

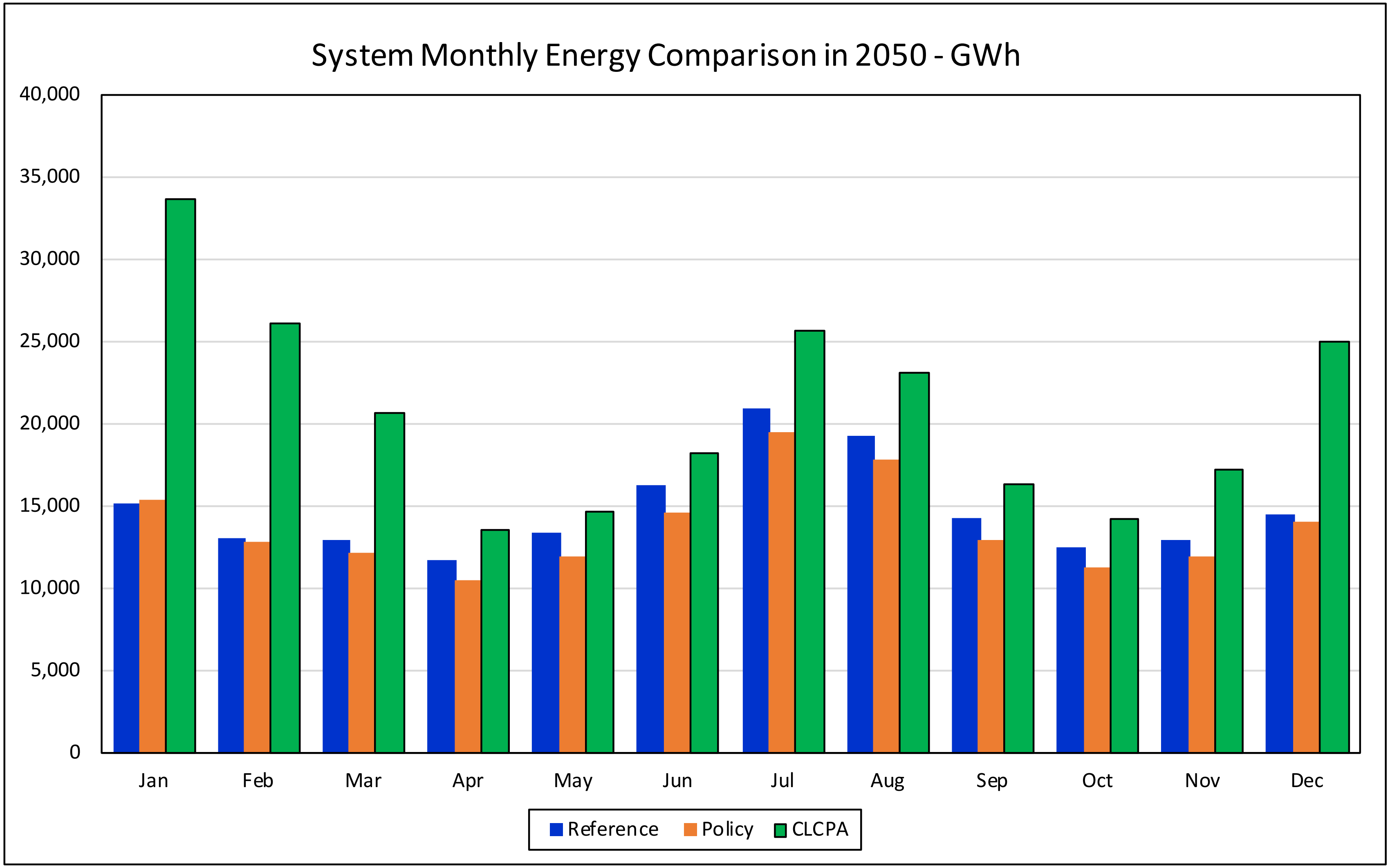
FORECAST COMPARISON (SYSTEM ENERGY)

Reference Case (GWh)						
Year	Base	EV	PV	Electrification	Battery	Adjusted
2020	158,047	371	(2,647)	-	15	155,786
2030	154,756	4,226	(5,223)	-	200	153,959
2040	155,578	13,174	(5,928)	-	346	163,170
2050	158,575	24,360	(6,398)	-	416	176,952

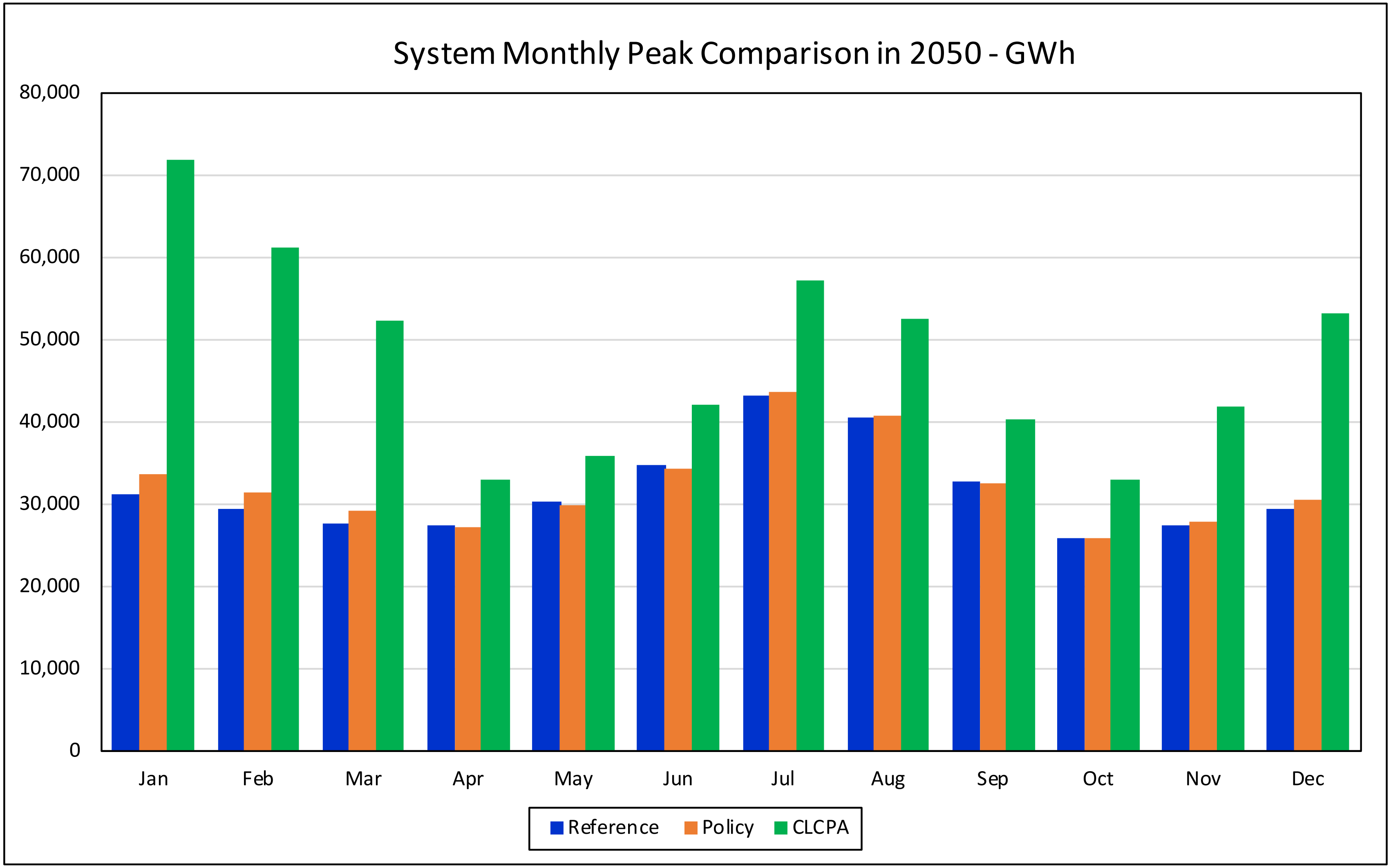
Policy Case (GWh)						
Year	Base	EV	PV	Electrification	Battery	Adjusted
2020	153,647	420	(2,647)	755	15	152,190
2030	133,856	5,488	(8,081)	4,952	200	136,416
2040	129,178	16,361	(8,885)	9,679	346	146,679
2050	129,425	30,253	(9,662)	14,614	416	165,046

CLCPA Case (GWh)						
Year	Base	EV	PV	Electrification	Battery	Adjusted
2020	153,647	420	(2,647)	3,961	15	155,396
2030	133,856	5,488	(8,081)	22,633	200	154,096
2040	129,178	16,361	(8,885)	75,594	346	212,594
2050	129,425	30,253	(9,662)	97,917	416	248,349

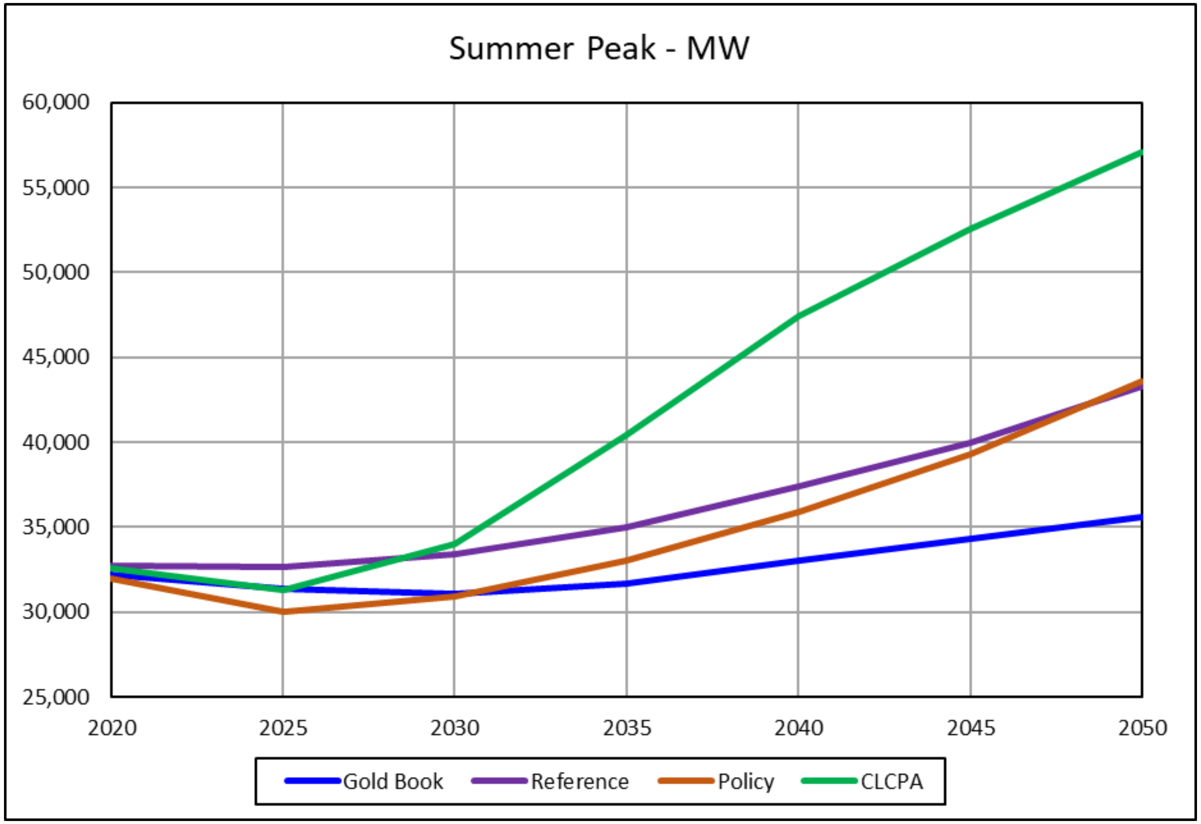
SYSTEM MONTHLY ENERGY COMPARISON IN 2050



SYSTEM MONTHLY PEAK COMPARISON IN 2050

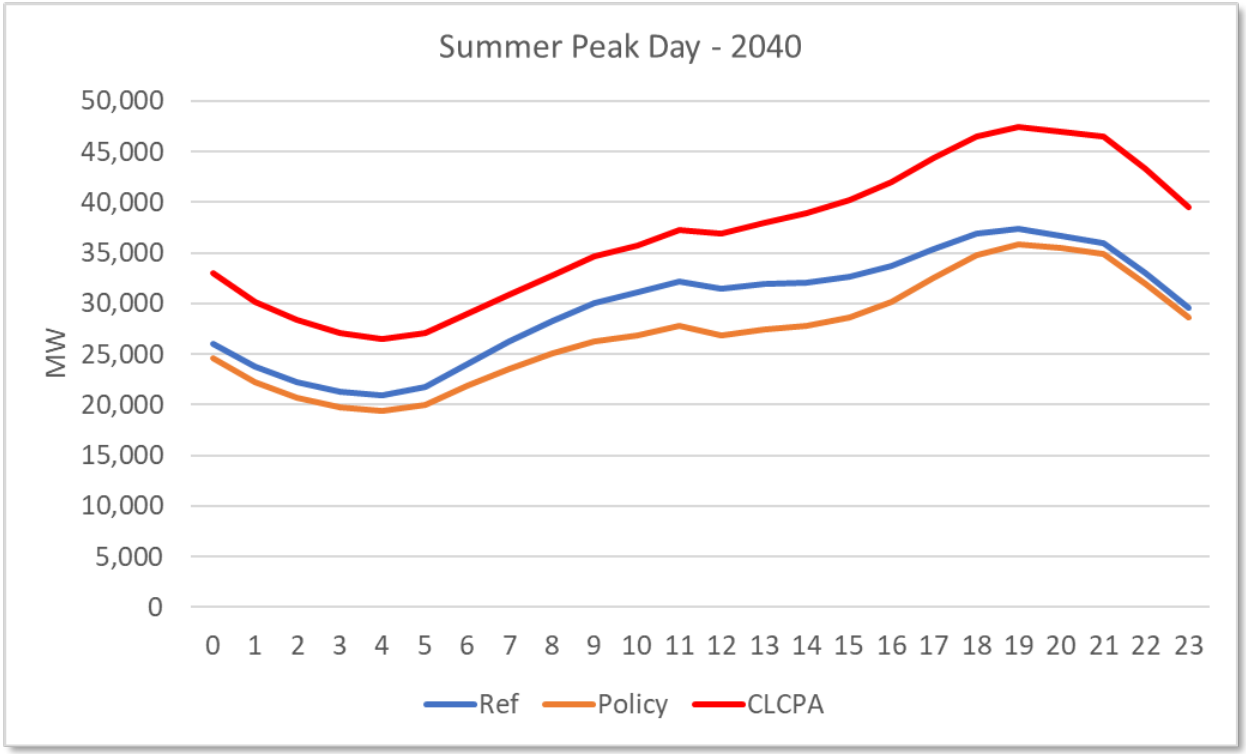


FORECAST COMPARISON – SUMMER PEAK

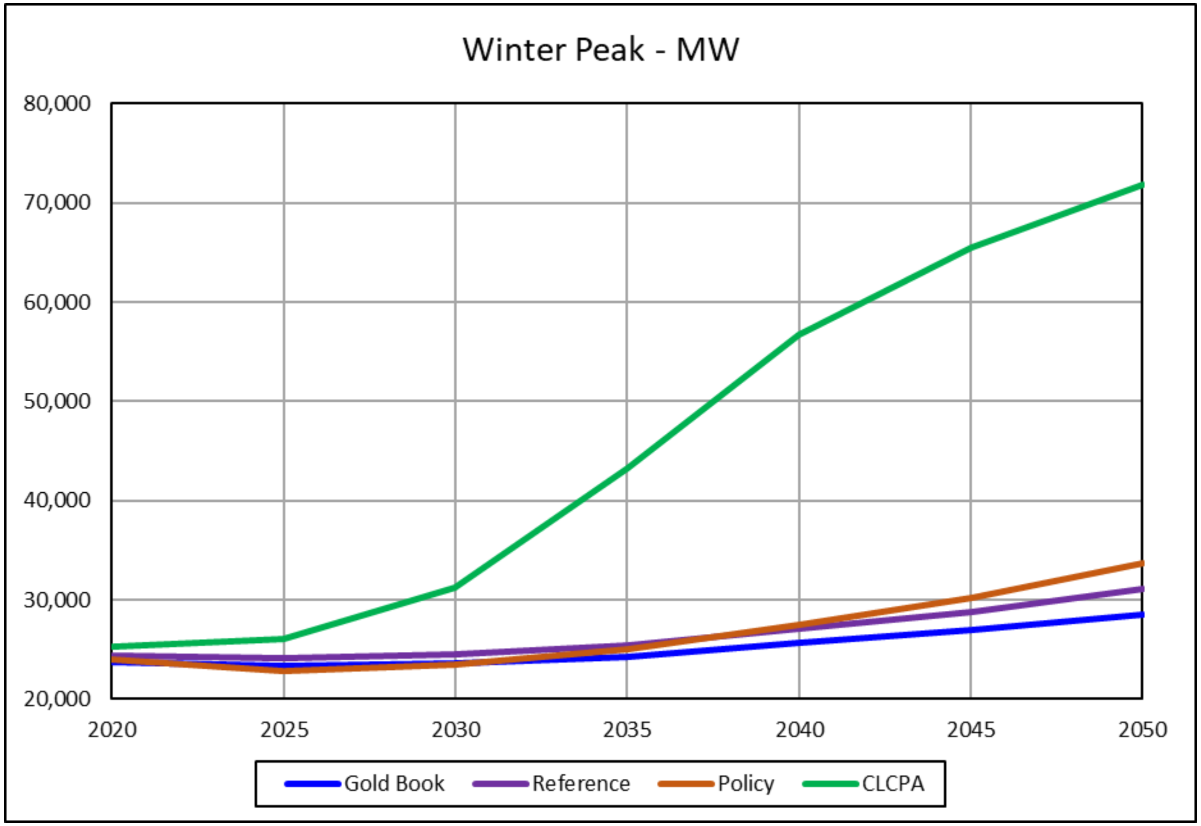


Year	Gold Book	Reference	Policy	CLCPA
2020	32,202	32,696	32,013	32,604
2030	31,066	33,405	30,936	33,978
2040	33,006	37,403	35,866	47,465
2050	35,598	43,317	43,563	57,109

SUMMER PEAK-DAY LOAD FORECAST (MW)

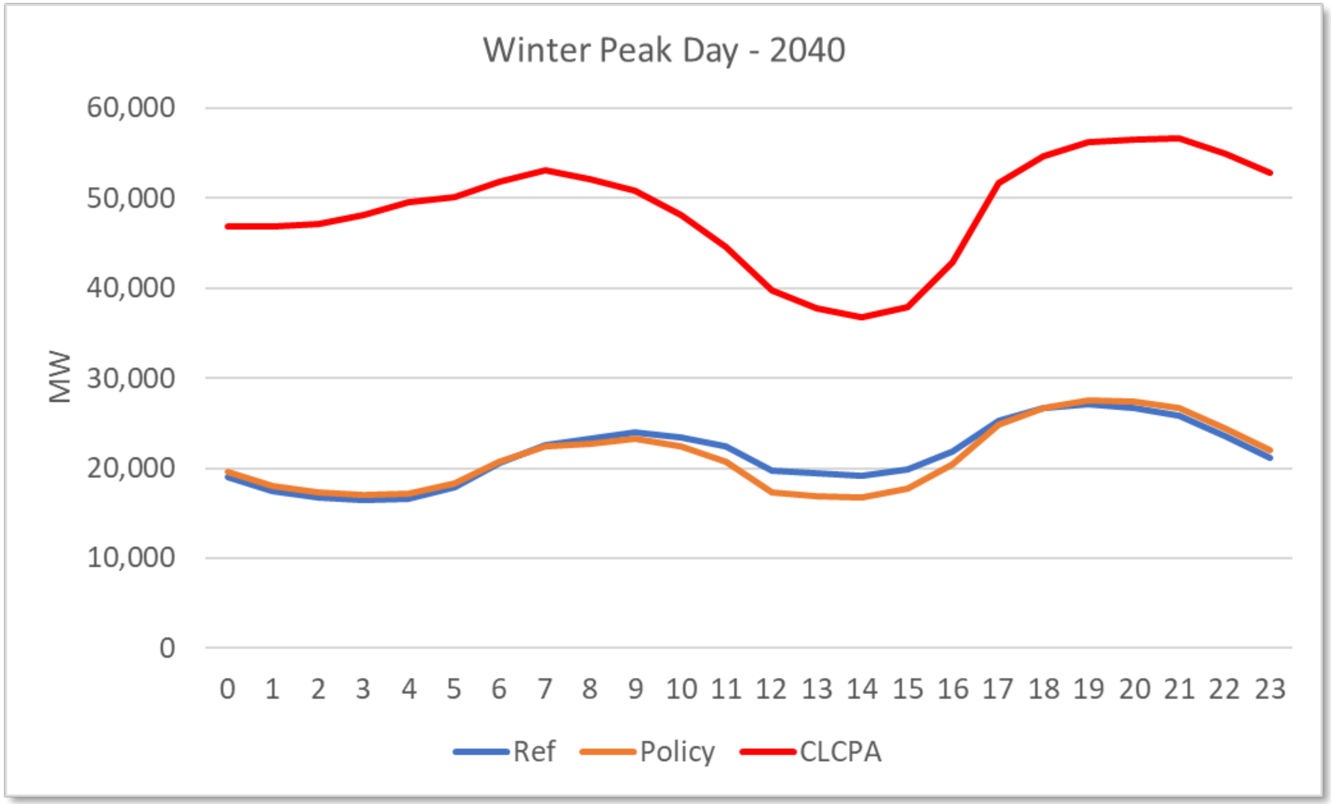


FORECAST COMPARISON – WINTER PEAK

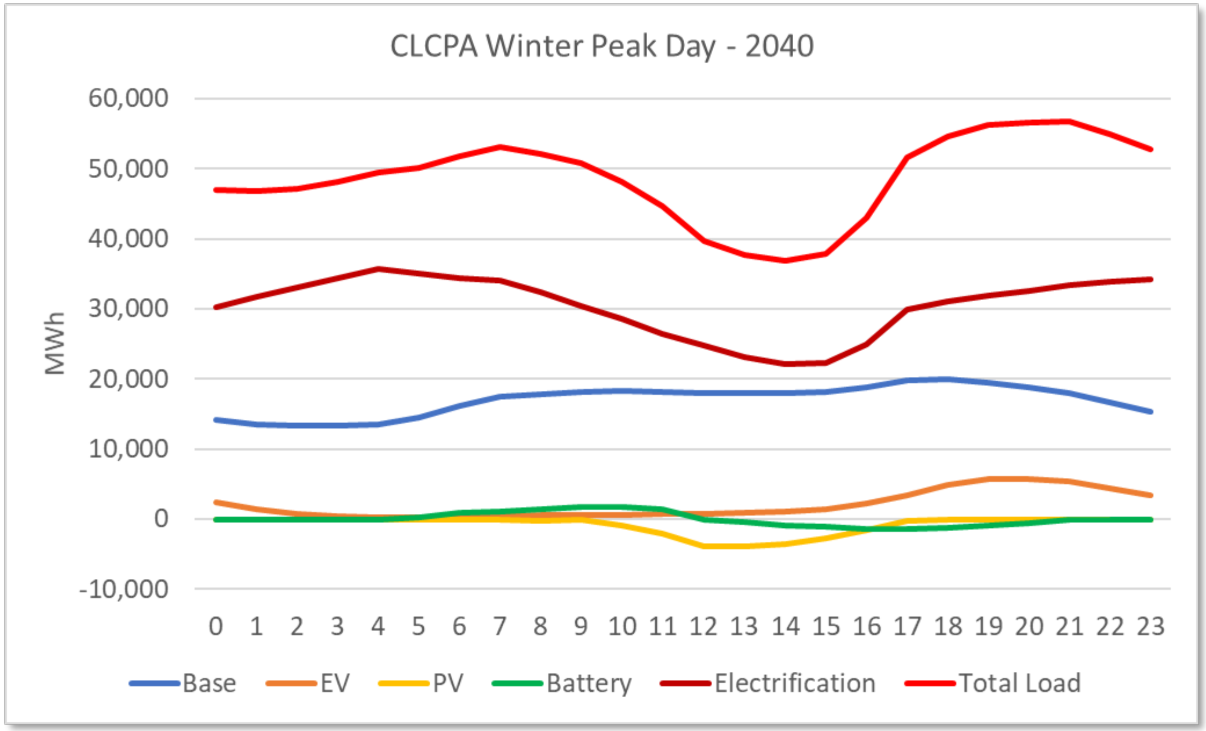


Year	Gold Book	Reference	Policy	CLCPA
2020	23,745	24,395	23,978	25,310
2030	23,586	24,519	23,432	31,219
2040	25,647	27,151	27,549	56,701
2050	28,540	31,131	33,652	71,859

WINTER PEAK-DAY LOAD FORECAST



CLCPA WINTER PEAK DAY LOAD FORECAST



Shapes matter when we start thinking about how policies impact end-use choices and adoption of new technologies

SUMMARY

» Analysis of weather trends across the state show statistically significant increase in average temperatures of 0.5 to 1.1 degree per decade
  - State average 0.7 degrees per decade
  - Temperatures on the coldest days are increasing faster than temperatures on the hottest days
  - Trend likely to continue through the future and could be worse depending on long-term greenhouse gas path
  - Warming trend will contribute to increase in summer peak demand and lower winter peak demands. Increase in cooling energy requirements will partially be offset by declining heating related requirements.

» State policy to address greenhouse gas emissions will have more impact on loads than the impact due to temperature trends. The end-use modeling approach provides a framework for translating energy policy into impacts on energy, hourly loads, seasonal peak demands, and changes in emissions of greenhouse gases.

MORE TO DO

- » Improvement on end-use data – end-use saturation, square footage, building shell integrity, end-use and technology profiles for both electric and non-electric fuel types
- » More detailed data at the Transmission District level
  - Class level sales and customers (e.g, residential, commercial, industrial)
  - Historical and projected EE savings – ideally by end-use
  - Electrification activity – heat pumps, other end-uses
  - Electric vehicle projections
- » More detailed analysis on and forecast of electric vehicles
- » More work on modeling commercial and industrial electrification
- » More work on estimating emissions reductions as a result of increased electrification