Climate Study – Phase 1 Discussion

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Load Forecasting Task Force

March 11, 2020, Rensselaer, NY

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Climate Study – Phase 1: Summary

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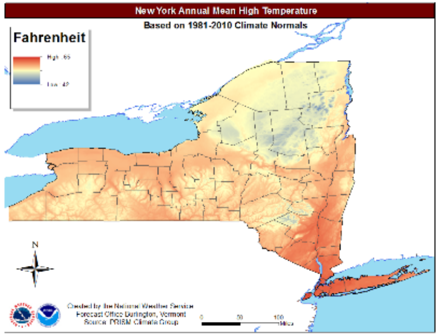
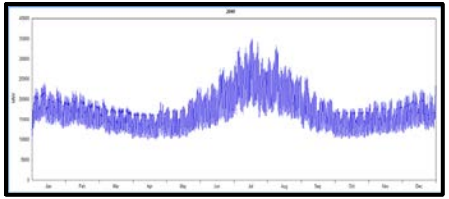
Study Objectives

- **Evaluate temperature trends and state climate impact studies**
- **Develop long-term energy, peak, and 8,760 hourly load shapes that reflect the potential impact of climate change**
    - In addition to the NYCA forecast, also produce Zonal and Transmission District level forecasts
- **Construct additional forecast scenarios that reflect state policy goals that include climate change impacts**
    - Policy Case (Clean Energy Standard)
    - Climate Leadership and Community Protection Act (CLCPA)
- **Apply results to Phases 2 & 3 of Climate Study, and to future Gold Book forecasts, RNA, & other NYISO studies**





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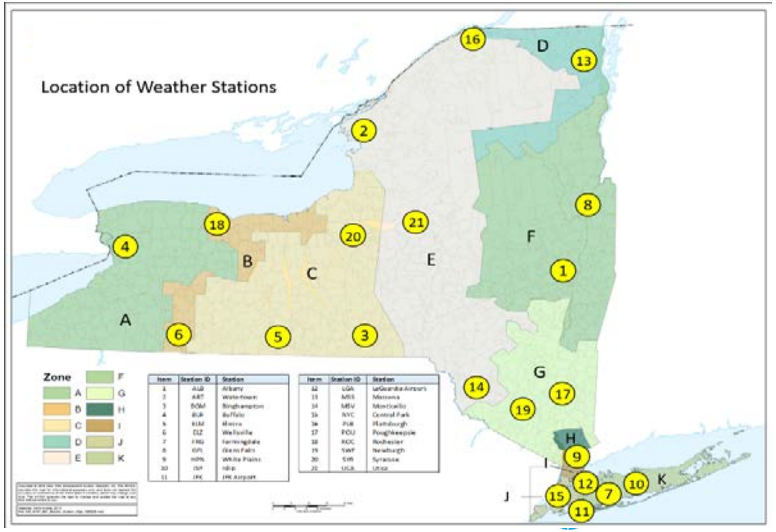
Weather Trend Analysis

- Evaluated temperature trends from 21 NY Weather Stations (1950-2018)
- Average temperature increase has varied across the state (0.5ºF to 1.1ºF per decade)
- No statistically significant increase in the maximum hourly heat index, but the average value of the heat index on the hottest days is getting warmer
- Most of the temperature change is coming from increasing minimum temperatures in winter months

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**



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Forecast Scenarios

- **All forecast scenarios include the following assumptions and projections:**
  - 2018 Moody's Economic Forecast
  - 2018 U.S. Energy Information Administration end use intensities
  - 24,360 GWh of Electric Vehicle (EV) Use by 2050
  - 6398 GWh of Solar (PV) and 29,468 GWh of Energy Efficiency Savings by 2050

Scenario	Temperature Increase	Additional PV / EV (2050)	Additional Energy Efficiency (2050)	Electrification Assumptions
Reference	0.7°F / decade	None	None	None
Reference Accelerated	1.4°F / decade	None	None	None
Policy Case	0.7°F / decade	9,000 MW / 6,000 GWh	2,200 GWh / year	25% of existing homes converting to heat pumps
CLCPA	0.7°F / decade	9,000 MW / 6,000GWh	2,200 GWh / year	Aggressive greenhouse gas reduction goals (85% reduction from 1990 levels)

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Climate Impacts on Summer Peak Forecast

- The Accelerated Trend Case assumes that the hottest temperatures and coldest day temperatures are increasing twice as fast as the Reference Case scenario
- Climate trend accounts for 1,600 MW to 3,800MW increase in Summer Peak

	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

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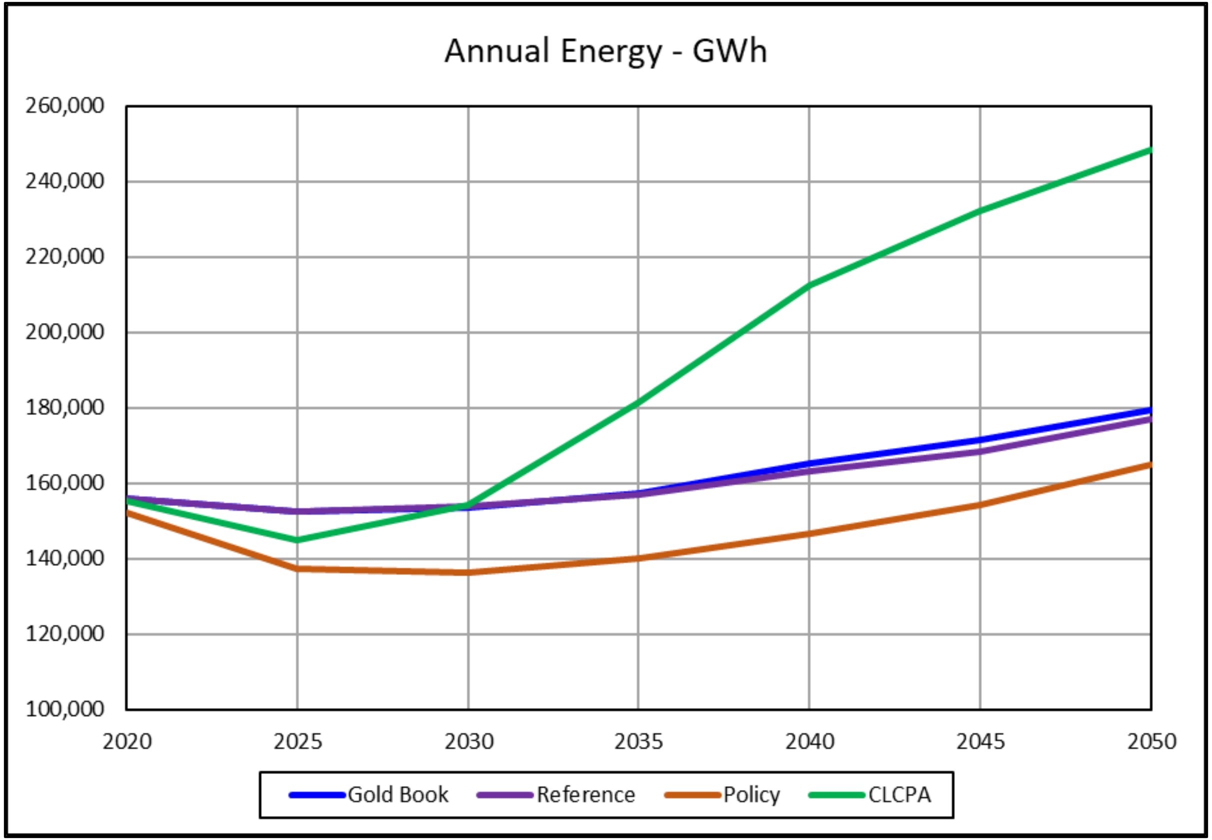
Scenario Comparisons – Annual Energy



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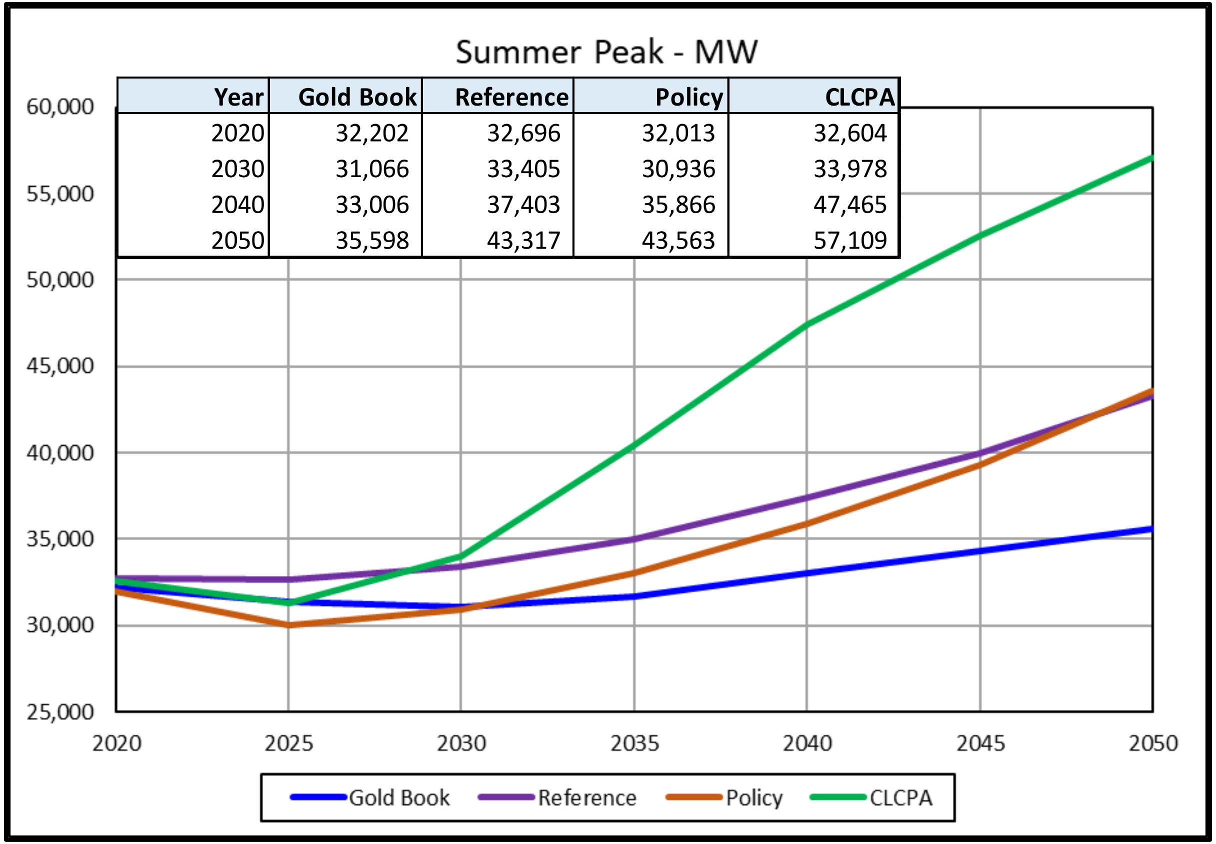
Scenario Comparisons – Summer Peak



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

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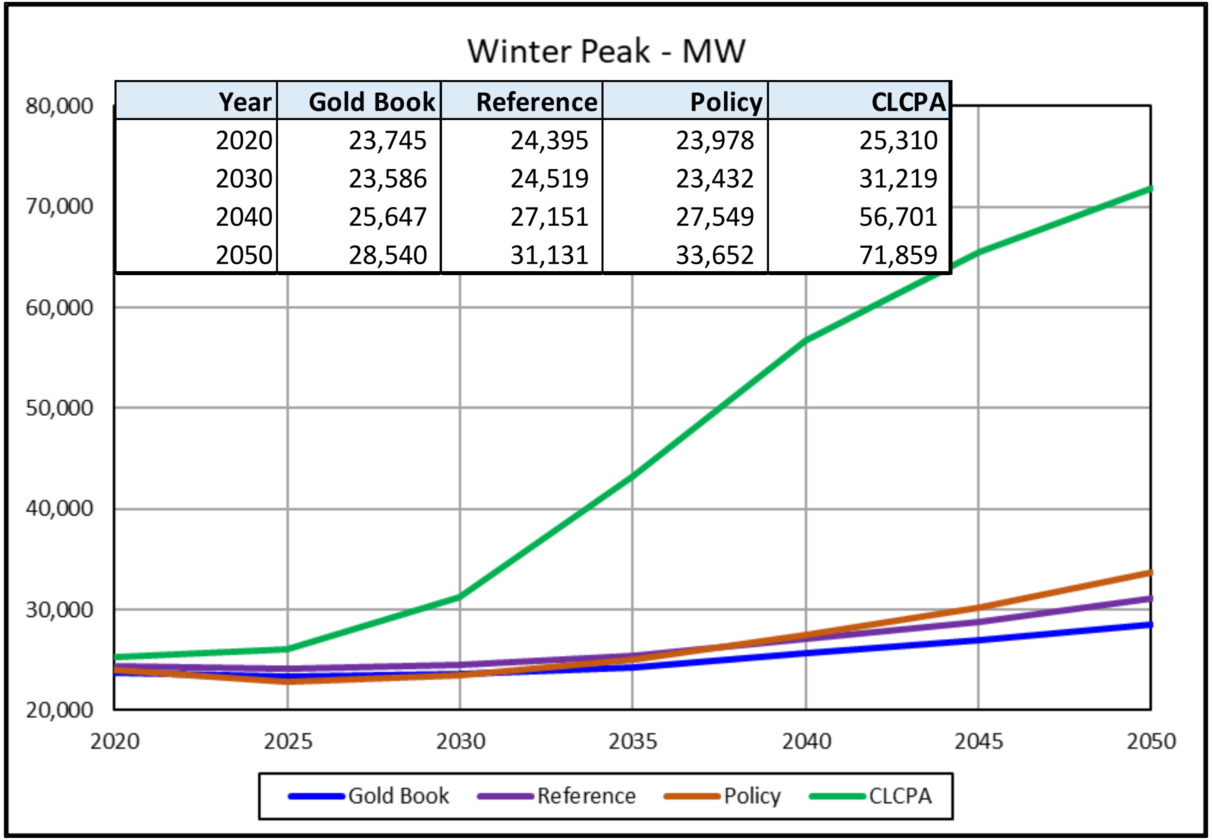
Scenario Comparisons – Winter Peak



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

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CLCPA Scenario - Electrification

- **Goal: Achieve 85% reduction in greenhouse gases by 2050 in residential, commercial, industrial and transportation sectors from 1990 emission levels**
- **Replaces fossil-based technologies with electric technologies**
  - End uses include space heat, water heat, clothes dryers and cooking in residential & commercial sectors. Industrial sector sees modest improvements in energy intensity.
  - Residential electric space heat technology is primarily air source heat pump, with resistance heating for supplemental and secondary heating needs.
- **85% reduction in transportation greenhouse gases via transition to electric vehicles**

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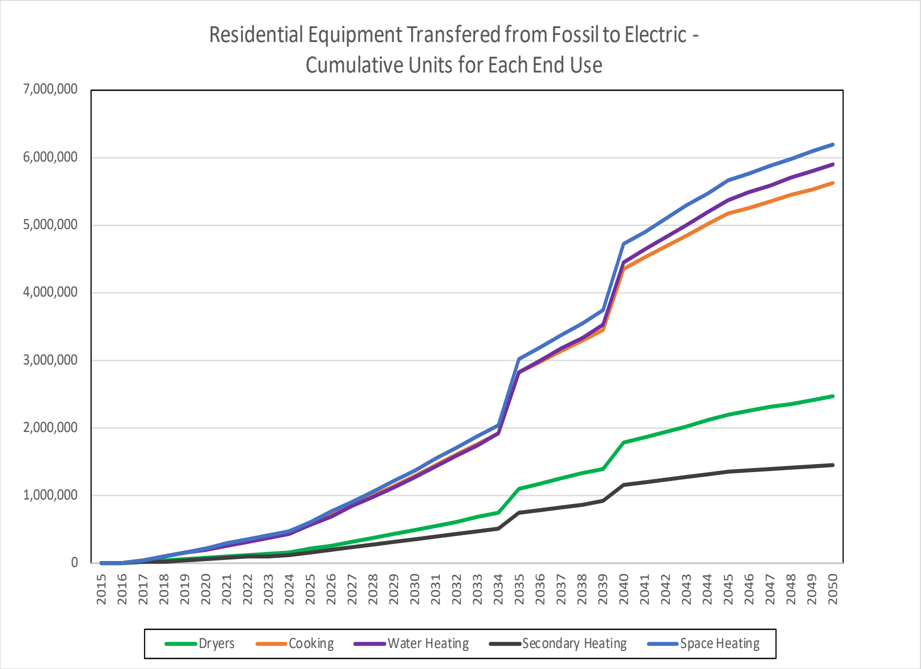
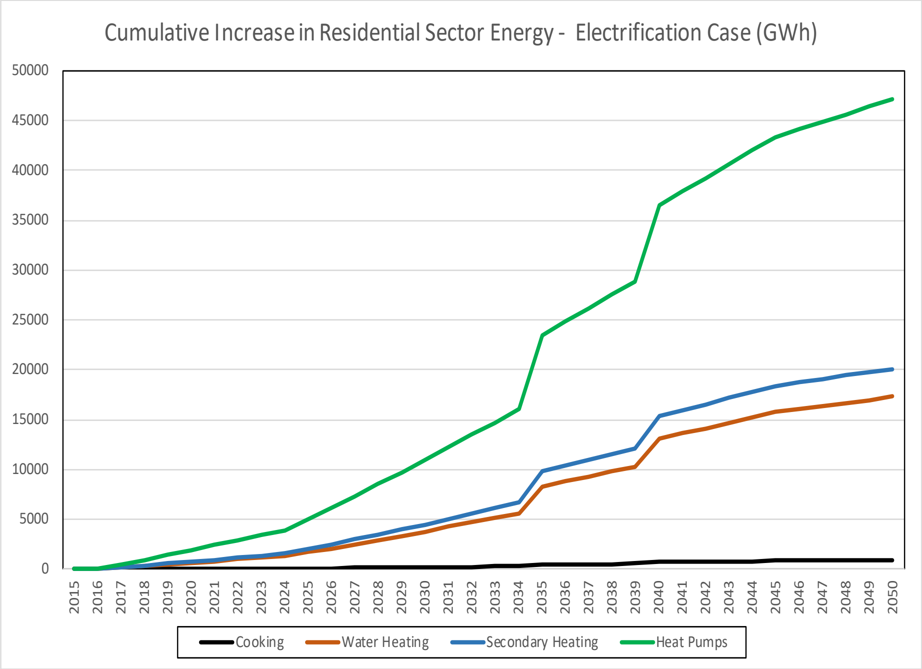
Step 1: Determine the number of residential appliances converting to electricity



Step 2: Multiply by kWh use per appliance, taking future efficiency trends into consideration. In particular, assume heat pumps for heating.



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Summary and Future Work

- **Analysis of weather trends across NY 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 faster or slower depending on long-term greenhouse gas path
- **State policy to address greenhouse gas emissions will have more impact on loads than 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.**
- **Enhancements planned include:**
  - Augmentation of end-use data (increased spatial-temporal resolution)
  - Additional work on modeling commercial and industrial electrification
  - Improving estimates of emission reductions as a result of increased electrification
  - Additional end-use data (saturation, square footage, building shell integrity, technology profiles for both electric and non-electric fuel types) from in-state and national sources

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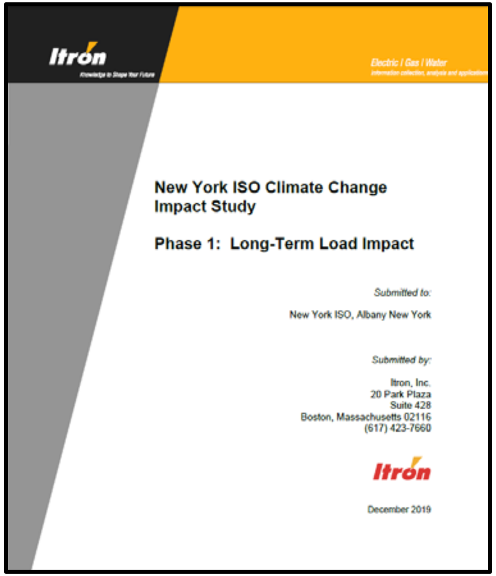
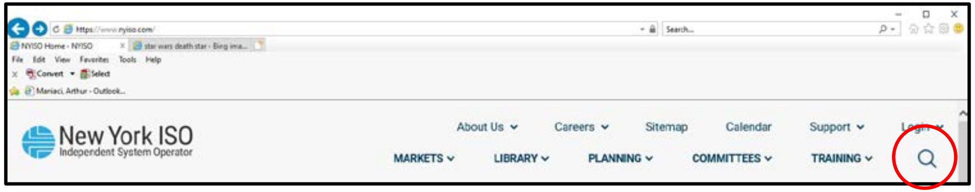
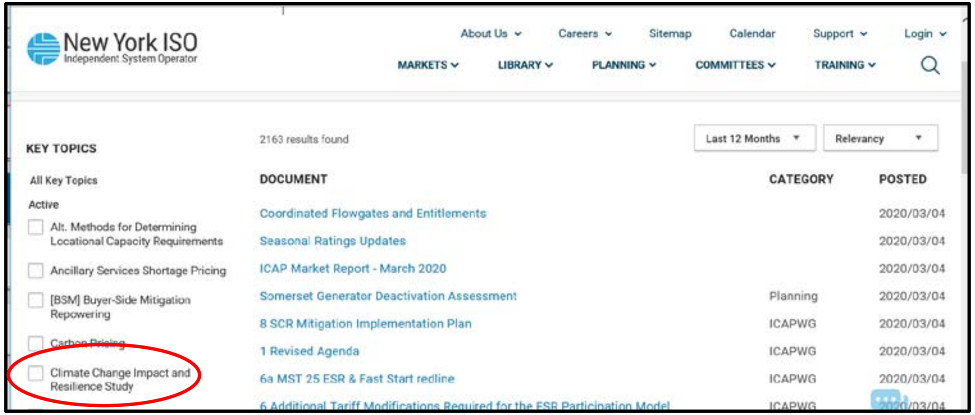
Finding the report on our web page





1. Click the ‘Search’ Icon on our web page.



2. Select “Climate Change Impact & Resilience Study”

Or use the web link below

https://www.nyiso.com/documents/20142/10773574/NYISO-Climate-Impact-Study-Phase1-Report.pdf/01fc1353-38cb-b95d-60c2-af42a78bff50

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Energy & CO_2 Emissions Analysis for 2016 and 2050

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Main Points

- Emissions reductions due to fuel switching from fossil fuel to electricity requires an understanding of energy generation, energy utilization and energy losses for all fuels of interest
- Proper accounting requires knowledge and application of energy efficiency factors for each type of fuel source
- Fuel switching is relatively easy to analyze for thermal processes in the residential, commercial and transportation sectors such as heating, cooling, clothes drying, water heating, cooking and combustion engines
- Industrial processes are much more difficult to analyze for fuel switching and for determining the impacts on greenhouse gas emissions

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New York State Greenhouse Gas Inventory

Millions Metric Tons CO2 equivalent

Category	1990	1995	2000	2005	2010	2015	2016	2050	Y16-Y50
Energy	208.96	206.87	228.2	230.69	193.21	180.69	172.79	31.344	141.45
Electric Generation	63.02	51.28	55.68	53.58	37.31	29.13	27.72	9.45	18.27
Residential (Non-Electric)	34.25	34.98	40.28	39.83	31.7	35.64	30.89	5.14	25.75
Commercial (Non-Electric)	26.55	27.04	32.23	28.66	24.19	21.87	20.66	3.98	16.68
Industrial (Non-Electric)	20.02	22.54	17.52	14.89	10.27	10.8	10.23	3.00	7.23
Transportation	59.37	61.82	71.66	79.23	74.93	74.15	73.98	8.91	65.07
Net Imported Electricity	1.74	4.52	6.04	7.35	9.2	3.37	3.82	0.26	3.56
Incineration of Waste	1.27	1.96	2.05	3.6	2.35	2.92	2.79	0.19	2.60
Natural Gas Systems	2.74	2.74	2.73	3.52	3.25	2.82	2.73	0.41	2.32
Non-Energy Sources	27.22	28.05	30.28	31.19	31.56	32.91	32.82	4.08	28.74
Agriculture	8.37	7.8	8.55	8.27	8.73	8.86	8.86	1.26	7.60
Waste	14.86	15.43	15.62	15.62	14.29	13.23	12.8	2.23	10.57
Industrial Processes & Product Use	3.99	4.83	6.11	7.3	8.54	10.82	11.15	0.60	10.55
Total	236.19	234.92	258.48	261.88	224.77	213.59	205.61	35.43	170.18
Fuel Combustion	204.95	202.17	223.41	223.57	187.6	174.95	167.28	30.74	136.54
NonFuel Combustion	31.24	32.75	35.07	38.31	37.17	38.65	38.33	4.69	33.64

Source: NYSERDA, New York State Greenhouse Gas Inventory: 1990 - 2016

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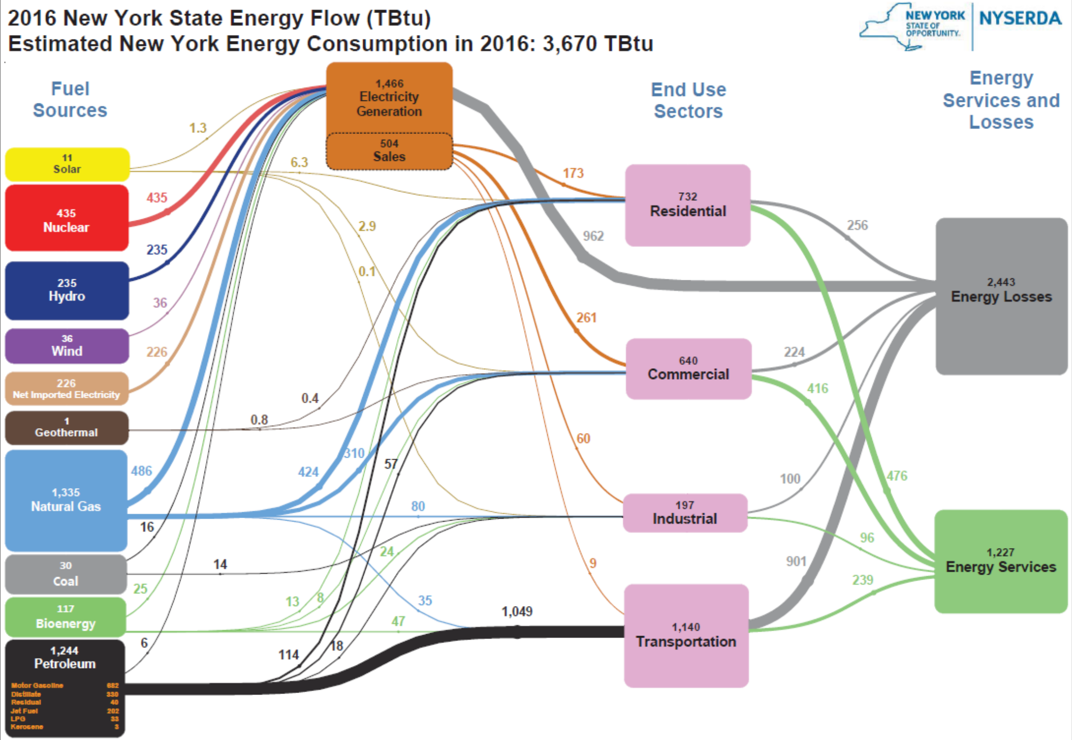
Energy Flow Diagram for New York State



Source: NYSERDA, Patterns and Trends New York State Energy Profiles: 2002-2016 published January 2019. Motor gasoline includes ethanol which is not included in Total Petroleum so sums may differ from the total. Electricity Sales (504 TBtu) are a part of the total Electricity Generation sector (1,466 TBtu). Bioenergy includes ethanol (47 TBtu), wood (38 TBtu), landfill gas (6 TBtu), and waste (26 TBtu). Geothermal energy in this case represents ground source heat pumps. Electricity losses are calculated as the difference between energy input for electricity generation and energy from retail electricity sales. Energy losses for the end-use sectors are based on the following estimated end-use efficiency factors from the Lawrence Livermore National Laboratory, 65% for the residential sector, 65% for the commercial sector, 49% for the industrial sector, and 21% for the transportation sector. Totals may not equal the sum of components due to rounding.

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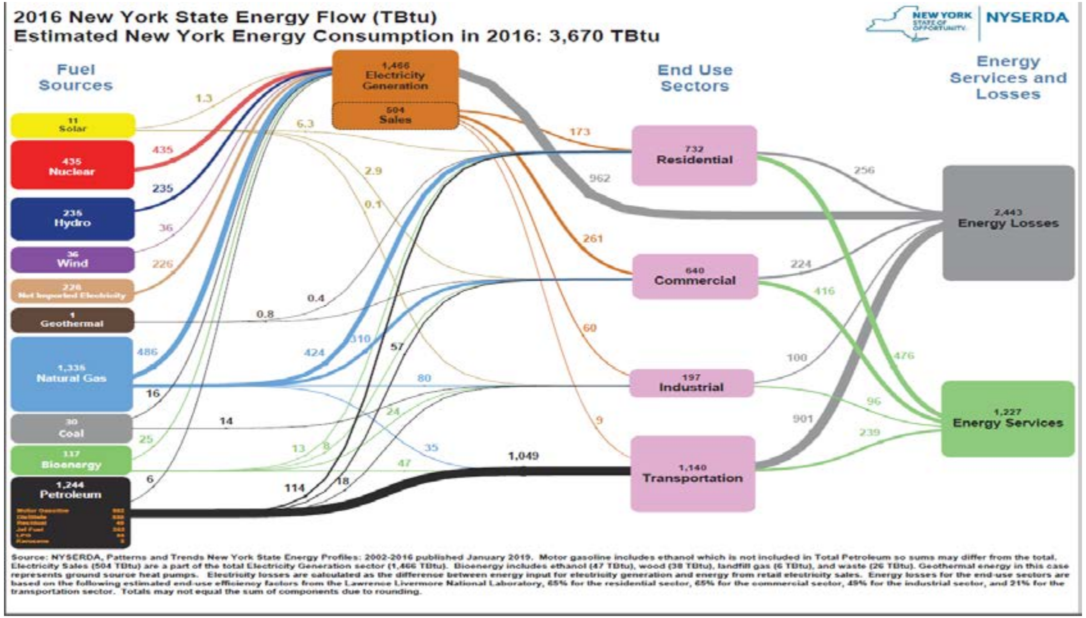
Translation of Process Diagram Data to Energy Accounting Table



Energy sources, utilization and losses by major end use sector provide the data needed to assess the impacts on greenhouse gas emissions due to electrification.

Energy Accounting - 2016 Baseline

2016	Source TBTU =			Utilized TBTU +			Losses - TBTU			Percent Losses		
	(a)	(b)	(c)=(a-b)	(f)=(a)-(d)	(g)=(b)-(e)	(h)=(c)-(f)	(d)	(e)=(b*.08)	(f)=(d)-(e)	(i)=(d)/(a)	(j)=(e)/(b)	(i)=(f)/(c)
Sector	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total	Electric	Fossil
Res	732	173	559	476	159	317	256	14	242	0.35	0.08	0.43
Com	640	261	379	416	240	176	224	21	203	0.35	0.08	0.54
Trans	1140	9	1131	239	8	231	901	1	900	0.79	0.11	0.80
Tot	2512	443	2069	1131	407	724	1381	36	1345	0.55	0.08	0.65

2050 Electrification

2050	Energy Impact	
Sector	GWh	TBTU
Res	49,000	167
Com	42,000	143
Trans	30,250	103
Tot	121,250	413

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Energy Accounting in 2016 and 2050

Energy Accounting - 2016 Baseline

2016	Source TBTU =			Utilized TBTU +			Losses - TBTU			Percent Losses		
	(a)	(b)	(c)=(a-b)	(f)=(a)-(d)	(g)=(b)-(e)	(h)=(c)-(f)	(d)	(e)=(b*.08)	(f)=(d)-(e)	(i)=(d)/(a)	(j)=(e)/(b)	(i)=(f)/(c)
Sector	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total	Electric	Fossil
Res	732	173	559	476	159	317	256	14	242	0.35	0.08	0.43
Com	640	261	379	416	240	176	224	21	203	0.35	0.08	0.54
Trans	1140	9	1131	239	8	231	901	1	900	0.79	0.11	0.80
Tot	2512	443	2069	1131	407	724	1381	36	1345	0.55	0.08	0.65

Energy Accounting - 2050 CLCPA, Differential Impact

2050	Source - TBTU			Utilized - TBTU			Losses - TBTU			Percent Losses		
	(k)=(a)+(j)	(a)	(j)=(e)+(i)	(e)=(c)+(d)	(c)=(a)-(b)	(d)=(c)*k?	(i)=(b)+(h)	(b)	(h)=(dg)/(1-g)		(f)	(g)
Sector	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total =	Electric +	Fossil	Total	Electric	Fossil
Res	-373	167	-540	-154	154	-308	-219	13	-232		0.08	0.43
Com	-201	143	-344	-26	132	-158	-175	11	-186		0.08	0.54
Trans	-927	103	-1030	-103	103	-206	-813	11	-824		0.11	0.80
Tot	-1501	413	-1914	-283	389	-672	-1207	35	-1242		0.08	0.65

Note: 1 TBTU = 3.412/1,000 GWh

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Estimated CO_2 Emissions Reductions From 2016 to 2050

CO_2 Emissions Reductions From 2016 to 2050 Due To Electrification

2050	CO2 Impact - Metric Tons		
Sector	TBTU	MT/MMBTU	CO2 (MMT)
Res	-540	0.05307	-29
Com	-344	0.05307	-18
Trans	-1030	0.07131	-73
Tot	-1914	0.06288	-120

2050	CO2 Impact - Short Tons		
Sector	TBTU	ST/MMBTU	CO2 (MST)
Res	-540	0.05850	-32
Com	-344	0.05850	-20
Trans	-1030	0.07860	-81
Tot	-1914.4	0.06931	-133

Change, 2016 to 2050 (MMT)		
Sector	Target	Study
Res	26	29
Com	16	18
Trans	65	73
Tot	107	120

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An Analysis of Gas Furnace and Air Source Heat Pump Performance

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Main Points

- Impact of air source heat pump (ASHP) performance forecasts can be assessed by forecasters using information that is readily available.
- Comparison of ASHP to gas furnaces can provide key information needed by load forecasters to determine impact of ASHP on winter electric peak demand.
- Key factors will be the design conditions for winter peaks and the sizing of ASHP relative to peak heating requirements currently met by gas furnaces.

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Typical Space Heating Usage Characteristics

Table 4-6. Scaled Annual Site Thermal Load

		Non-Thermal Electricity (kWh)	Space Heating Thermal Load (kWh)	Space Heating Thermal Load (MMBtu)	Space Cooling Thermal Load (kWh)	Space Cooling Thermal Load (MMBtu)
Single-Family	NYC/ LI/HV	11,282	20,058	68	4,095	14
	Upstate	7,875	25,505	87	2,339	8
Small Multifamily	NYC/ LI/HV	16,923	30,087	103	6,142	21
	Upstate	11,812	38,257	130	3,508	12

Source: NYSERDA, New Efficiency: New York
Analysis of Residential Heat Pump Potential and Analysis

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Recent Cost Characteristics for Air Source Heat Pumps

Air-Source Heat Pump Costs Comparison Tool

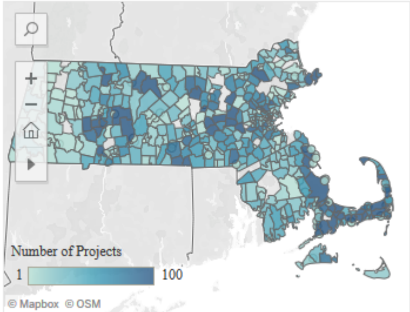
Residents interested in installing air-source heat pumps can use this dashboard to explore recent Massachusetts project prices. The following information was collected as part of MassCEC's Air-Source Heat Pump Rebate Program.

Use the filters to the right to select your county, unit manufacturer, installer, or year of installation to see updated information relevant to your criteria.

Project Snapshot

Median Capacity (Heating Tons)	2.13
Median Cost per Ton	$3,694
Median Cost per Ton (Single head)	$3,224
Median Cost per Ton (Multi head)	$4,153
Number of Projects	20,085

Project Location



Project Volumes

By Installer

NETR LLC	616
Rodenhiser Plumbing, Heating, ..	451
Murphy's Services	387
Orange Oil Company, Inc.	354
The Fuel Company	351
ROBIES HEATING & COOLING	335
Jay Moody LLC	309
ARS/Heating & A/C Services	291
Kerivan-Lane, Inc.	268
128 Plumbing and Heating	258
Pro Heating & Cooling	256

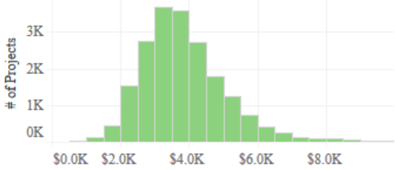
By Manufacturer

Mitsubishi	14,095
Fujitsu	5,241
Daikin	273
Haier	148
Carrier	135
LG	80
Lennox	70
Friedrich	30

Customize Data

Year	(All)
Manufacturer	(All)
County	(All)
Installer	(All)

Pricing Distribution ($/ton)



Consumer tip: Cost per ton is a standard way to compare heat pump pricing. You can likely find the system capacity in tons in the installer proposal. If your proposal lists Btu/hr instead, note 1 Ton = 12,000 Btu/hr. An example for a 24,000 Btu/hr system is below:
24,000 Btu/hr = 2 Tons
$7,000 cost / 2 Tons = $3,500/ton

Source: https://www.masscec.com/cost-residential-air-source-heat-pumps

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Current NYSERDA Rebates for Air Source Heat Pumps

Qualifying Equipment	Participating Installer Incentive	Site Owner Incentive
2-Ton Whole-House Solution ASHP System	$500	$1,500
3-Ton Whole-House Solution ASHP System	$500	$2,500
4-Ton Whole-House Solution ASHP System	$500	$3,500
5-Ton Whole-House Solution ASHP System	$500	$4,500
Other than Whole-House Solution ASHP System[4]	$500	$0
Qualifying Control/Thermostat		
Integrated Control Package	$0	$500
Dual Fuel Thermostat	$0	$50

Source: NYSERDA, Air Source Heat Pump Manual, April 2019 Version 4

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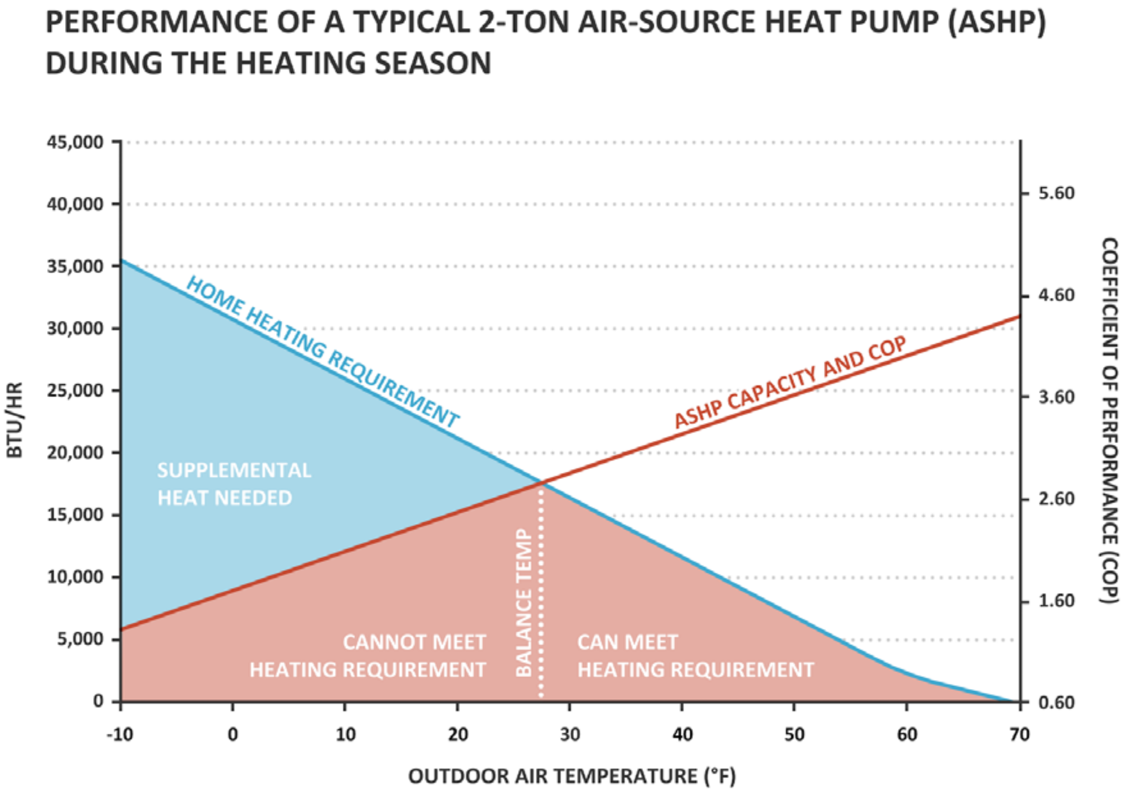
Temperature-Dependent Performance of Air Source Heat Pumps



Source: https://www.doityourself.com/forum/heat-pumps-electric-home-heating/612896-heat-pump-cold-efficiency.html#&gid=1&pid=1

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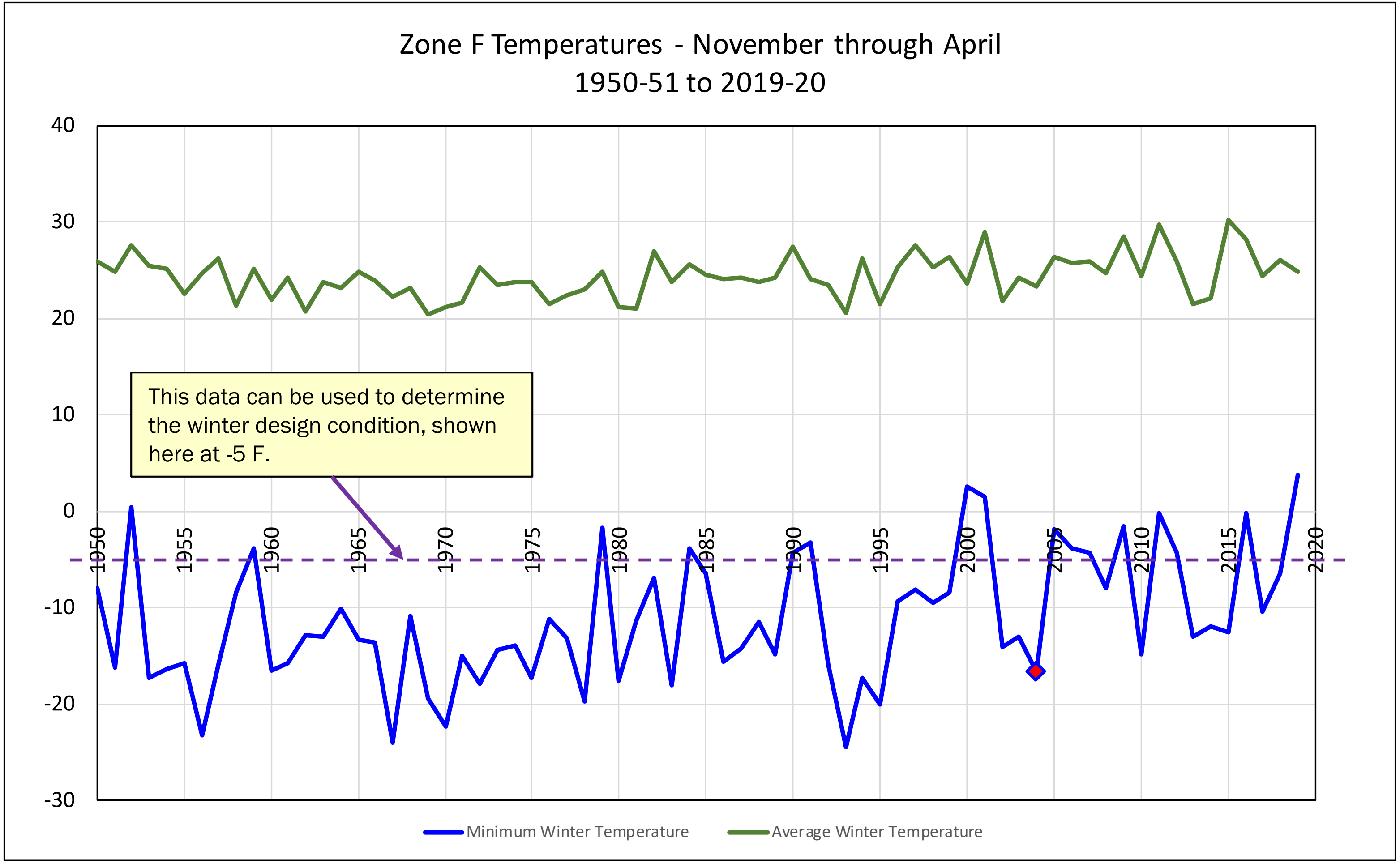

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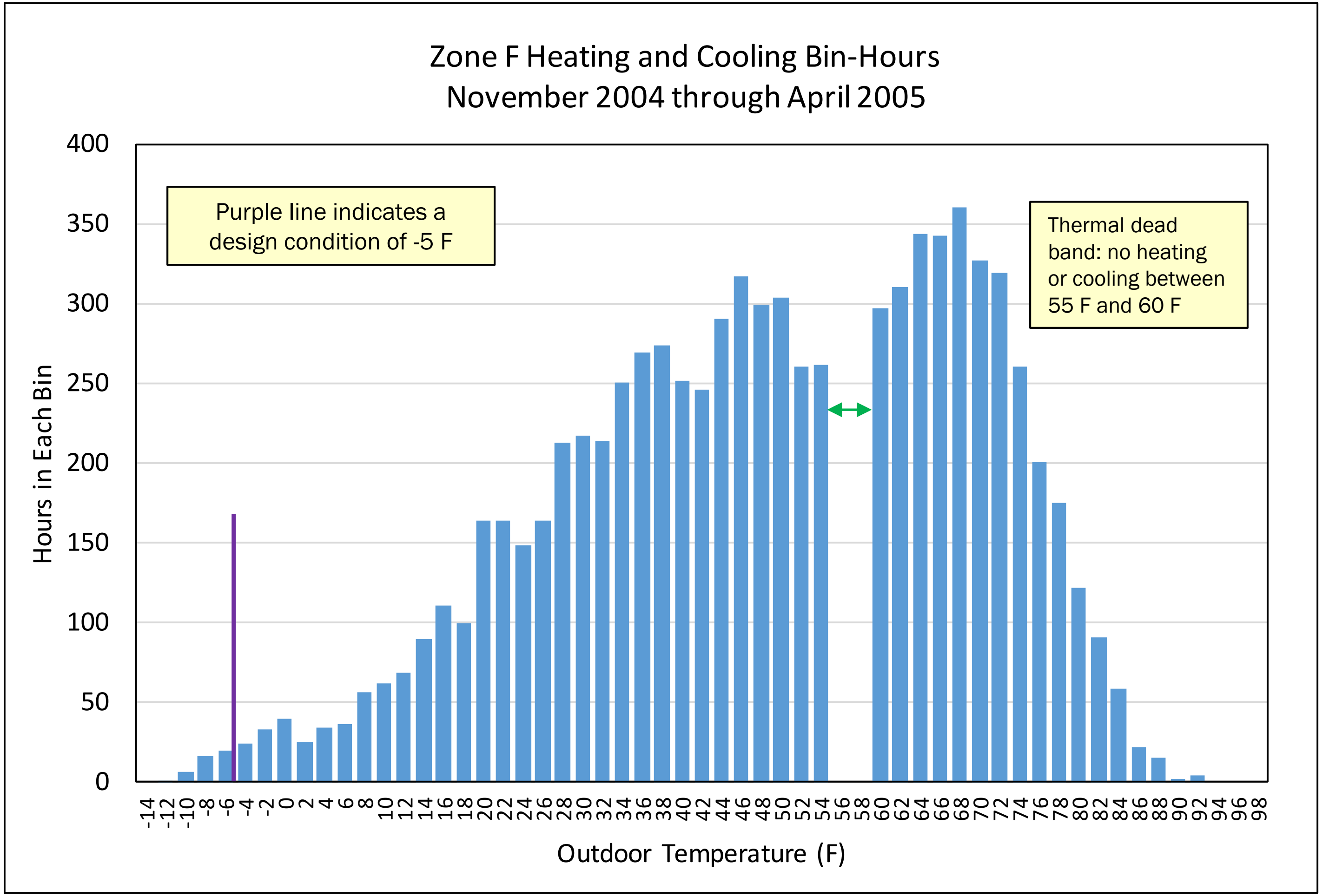

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Histogram of 2004 Hourly Temperatures (Heating Conditions)

Metric	Heating	Cooling
Deg-Hours	97,606	31,118
Deg-Days	4,067	1,297

Degrees	*Hours*	*Heating-Degree Hours (Ref T=55)*
-14	0	0
-12	1	66
-10	7	448
-8	17	1054
-6	20	1200
-4	24	1392
-2	33	1848
0	40	2160
2	25	1300
4	34	1700
6	36	1728
8	57	2622
10	62	2728
12	69	2898
14	90	3600
16	111	4218
18	100	3600
20	164	5576

Degrees	*Hours*	*Heating-Degree Hours (Ref T=55)*
22	164	5248
24	149	4470
26	164	4592
28	213	5538
30	217	5208
32	214	4708
34	251	5020
36	269	4842
38	274	4384
40	252	3528
42	246	2952
44	291	2910
46	317	2536
48	299	1794
50	304	1216
52	261	522
54	262	0
56		0

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Heating Capacity Estimation Tool				
row	Parameter	Value	Units	Formulas
(a)	Annual Usage	70,000,000	BTU	Given
(b)	Degree-Hours	100,000	Hr-F	Given
(c)	k- factor	700.00	BTU/Hr-F	(a)/(b)
(d)	Outdoor Ref Temp	55	F	Given
(e)	Design Temperature	0	F	Given
(f)	Furnace efficiency	80%	percent	Given
(g)	Design Furnace Size	48,125	BTU/Hr-F	(c)*(d-e)/(f)

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Manufacturer’s Data for a 4-Ton Air Source Heat Pump

			Indoor Temperature (F)														
			60			65			70			72			75		
			Heat kBtu/h	Power kW	COP*	Heat kBtu/h	Power kW	COP*	Heat kBtu/h	Power kW	COP*	Heat kBtu/h	Power kW	COP*	Heat kBtu/h	Power kW	COP*
Outdoor Temperature	DB (F)	WB (F)															
	-5	-7	35.10	4.57	2.25	34.25	4.66	2.15	33.43	4.78	2.05	32.58	4.85	1.97	31.78	4.95	1.88
	5	3	37.89	4.57	2.43	36.97	4.66	2.33	36.09	4.76	2.22	35.17	4.85	2.13	34.28	4.95	2.03
	14	12	42.84	4.57	2.75	41.83	4.66	2.63	40.82	4.76	2.51	39.78	4.86	2.40	38.78	4.95	2.30
	17	21	44.68	4.57	2.87	43.63	4.66	2.74	42.58	4.76	2.62	41.50	4.86	2.50	40.44	4.95	2.39
	23	19	48.22	4.57	3.09	47.06	4.66	2.96	45.90	4.76	2.83	44.77	4.85	2.71	43.60	4.95	2.58
	32	28	51.85	4.57	3.33	50.63	4.66	3.18	49.41	4.76	3.04	48.16	4.86	2.90	46.93	4.95	2.78
	41	37	55.98	4.58	3.58	54.63	4.67	3.43	53.29	4.77	3.27	51.98	4.87	3.13	50.63	4.97	2.99
	47	43	57.75	4.58	3.70	56.38	4.66	3.55	56.00	4.77	3.44	53.63	4.87	3.23	52.25	4.97	3.08
	50	47	59.22	4.57	3.80	57.81	4.66	3.64	56.41	4.75	3.48	54.97	4.85	3.32	53.57	4.95	3.17
	59	50	60.62	4.53	3.92	59.16	4.82	3.60	57.72	4.71	3.59	56.28	4.81	3.43	54.85	4.88	3.29

* COP is a result derived by NYISO from heat output and power input

Source: FUJITSU GENERAL LIMITED • Model:ARU48RGLX

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Thermal Output of 48,000 BTU per Hour Gas Furnace

Degrees	Delta T	Hours	K: Btu/Hr-F	BTU/Hr|out	kBTU	BTU/Hr|in	Duty Cycle	Tons|in	~HP Cost
(a)	(b)=55-(a)	(c)	(d)	(e)=(b)*(d)	(f)=(c)*(e)	(g)=(e)/.8	(h)=(g)/Cap.	(i)=(g)/12000	(j)=(i)*$4000
-14	68	0	700	38,500	0	48,125	100%	5.0	$20,000
-12	66	1	700	38,500	39	48,125	100%	4.8	$20,000
-10	64	7	700	38,500	276	48,125	100%	4.7	$20,000
-8	62	17	700	38,500	671	48,125	100%	4.5	$20,000
-6	60	20	700	38,500	789	48,125	100%	4.4	$20,000
-4	58	25	700	38,500	947	48,125	100%	4.2	$20,000
-2	56	34	700	38,500	1302	48,125	100%	4.0	$16,000
0	54	41	700	37,800	1549	47,250	98%	3.9	$16,000
2	52	26	700	36,400	932	45,500	95%	3.8	$16,000
4	50	35	700	35,000	1219	43,750	91%	3.6	$16,000
6	48	37	700	33,600	1239	42,000	87%	3.5	$16,000
8	46	58	700	32,200	1880	40,250	84%	3.4	$16,000
10	44	64	700	30,800	1956	38,500	80%	3.2	$16,000
12	42	71	700	29,400	2078	36,750	76%	3.1	$16,000
14	40	92	700	28,000	2582	35,000	73%	2.9	$12,000
16	38	114	700	26,600	3025	33,250	69%	2.8	$12,000
18	36	102	700	25,200	2582	31,500	65%	2.6	$12,000
20	34	168	700	23,800	3999	29,750	62%	2.5	$12,000

Note: Furnace output is limited to 48,000 BTU per hour

Note: 1 ton of heating or cooling equals 12,000 BTU per hour

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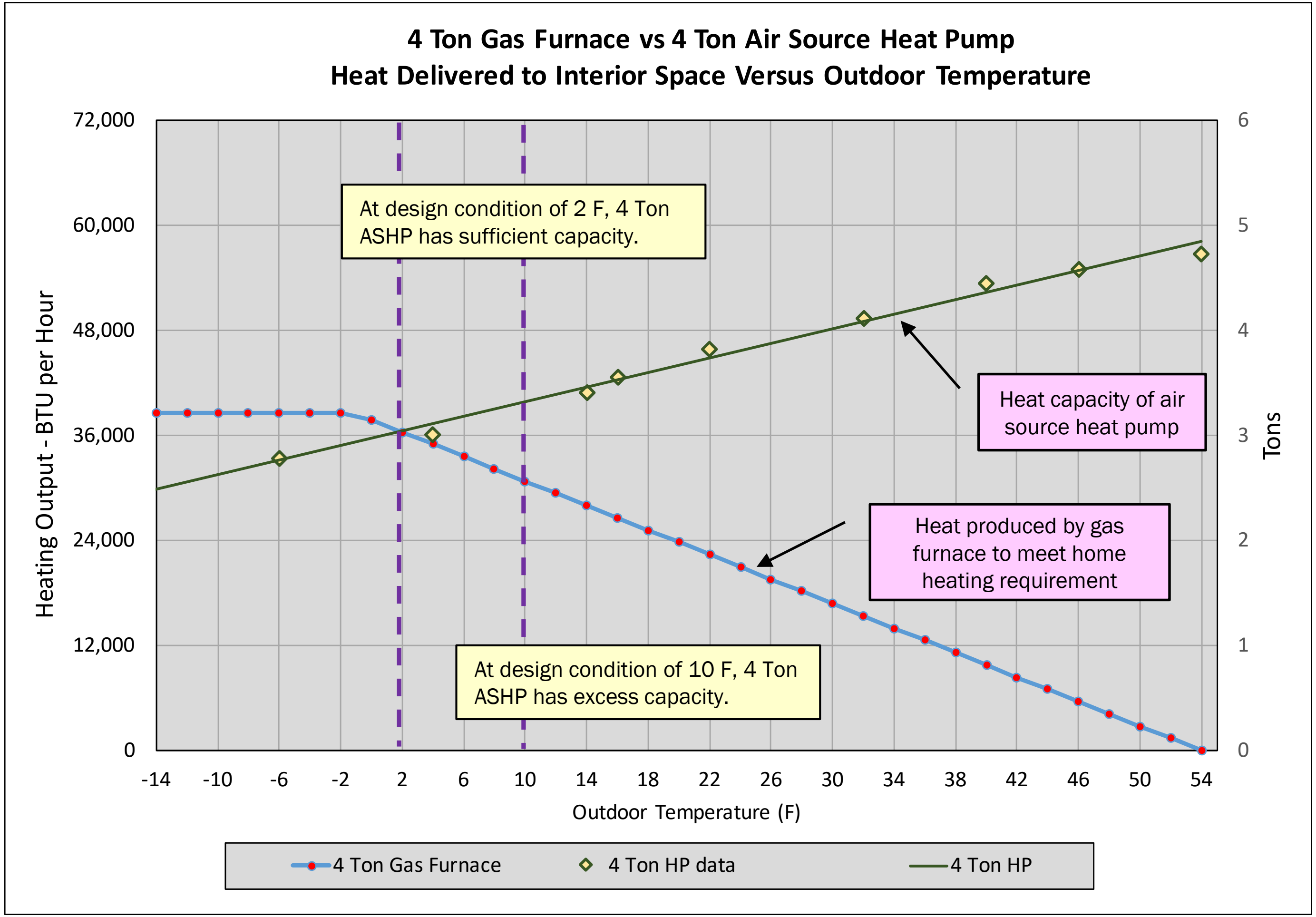

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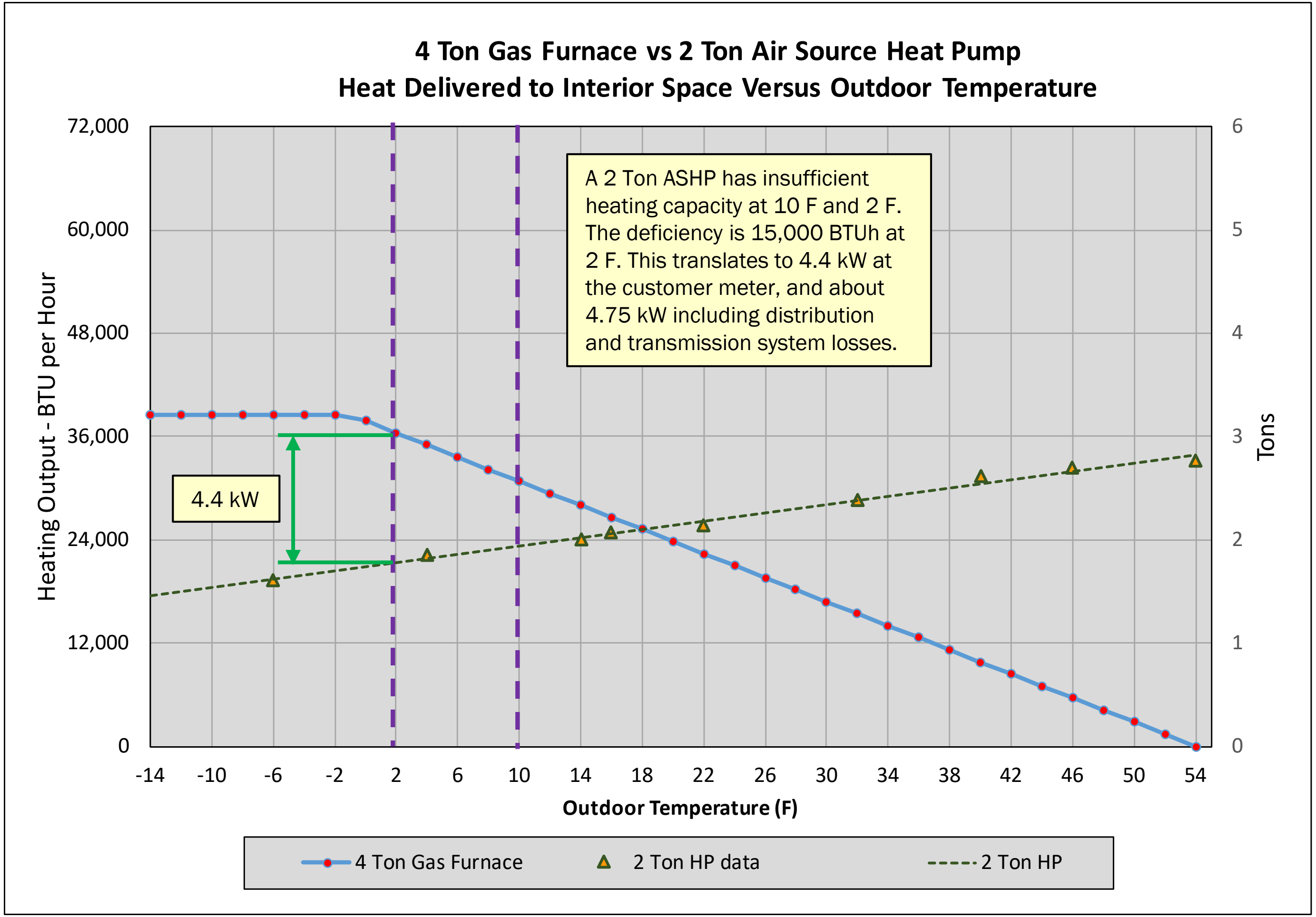

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Our mission, in collaboration with our stakeholders, is to serve the public interest and provide benefit to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policymakers, stakeholders and investors in the power system

New York ISO

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Questions?

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