Commercial Sector Data Development & Residential Heat Pump Performance Assessment

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Load Forecasting Task Force
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Study Objectives

- **Commercial Sector Data Development**
  - Update the 2018 commercial sector electric baseline usage data with new reports and databases
  - Develop results for NYCA and each Transmission District, with data specific to each TD
  - Produce results specific to each commercial sector building type, not just entire sector
  - Update hourly load modeling capabilities & methods for various load modifiers, such as EV, PV, Storage and building electrification
- **Residential Air Source Heat Pump Performance Assessment**
  - Use EnergyPlus, an hourly building simulation tool, to examine performance of three primary heating technologies: gas furnace, electric resistance and air source heat pump.
  - Identify a typical residential building structure for conducting building simulation at a single location and use historical hourly weather for a single year to understand HVAC performance for each technology
  - Size HVAC equipment to meet design winter conditions to minimize the use of supplemental heat.
  - Quantify hourly usage characteristics such as base and supplemental energy usage, delivered air temperature and room temperature, fan air flow energy usage, heat pump energy used in defrost mode
  - Quantify annual and monthly energy usage and peak demand for each heating technology

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(1) Commercial Sector Data Development

Commercial Sector Data Sources

1. Moody's Analytics – Employment & GDP Data by Business Sector
2. County Business Patterns – Employment & Establishment Data
3. EIA & Transmission Owners – Monthly Class Energy & Accounts
4. EIA & Itron – End Use Energy Intensities, Building Square Footage
5. NYSERDA – Commercial Sector Baseline Study
6. NREL ComStock – Commercial Sector End Use Data – Gas & Electric
7. EIA & Itron – Forecasts of End Use Saturations & Intensities

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Simplified Outline of Process

1. Classify NAICS codes into specific commercial sector building types, such as offices, schools, retail, restaurants and others
2. Using data from Moody's Analytics and Census Bureau's County Business Patterns, obtain annual employment for each building type.
3. From EIA and NYSERDA commercial sector databases, obtain the ratio of square feet of building space per employee for each building type
4. Produce square foot estimates of building space for each building type, with results specific to each Transmission District
5. Using EIA and ComStock data, obtain energy intensity - the ratio of electric energy use per square foot – for each end use and building type.
6. Estimate baseline energy usage for all building types in a Transmission District by multiplying the energy intensities for the square footage for each building type.

$$\text{Employment} \; * \; \frac{\text{Square Ft}}{\text{Per Employee}} \; * \; \frac{\text{kWh}}{\text{Per Sq Ft}} \; = \; \text{Energy Usage}$$

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County Business Pattern 2020 Employment Data For Selected Counties & NY State By NACIS Codes

NAICS Code	NAICS Description	Albany	Bronx	Dutchess	Erie	Nassau	New York	Suffolk	Westchester	State
11	Agriculture, Forestry, Fishing and Hunting	5	0	90	41	104	69	197	175	2,730
21	Mining, Quarrying, and Oil and Gas Extraction	496	0	153	141	21	59	152	0	3,062
22	Utilities	753	2,027	875	1,806	2,751	6,836	2,231	2,826	40,425
23	Construction	7,886	12,354	4,984	16,416	31,410	39,977	50,177	28,659	383,683
31	Manufacturing	7,817	5,648	7,413	44,182	14,136	13,663	53,678	9,647	407,386
42	Wholesale Trade	7,500	12,678	1,939	22,129	24,518	75,074	42,093	18,384	340,904
44	Retail Trade	21,725	32,885	14,135	52,587	77,188	146,346	81,976	47,425	917,212
48	Transportation and Warehousing	5,737	13,705	2,683	15,864	22,701	19,602	21,136	11,268	280,851
51	Information	5,607	3,075	1,093	6,029	10,205	210,951	9,171	7,761	314,340
52	Finance and Insurance	11,811	3,962	2,655	32,125	34,055	298,105	23,120	20,486	547,123
53	Real Estate and Rental and Leasing	2,727	9,781	1,440	6,508	10,921	76,977	7,083	8,476	185,729
54	Professional, Scientific, and Technical Services	17,317	4,999	7,358	27,309	41,065	345,037	39,731	24,403	677,347
55	Management of Companies and Enterprises	3,336	787	1,287	10,827	15,488	91,784	11,240	12,957	191,843
56	Administrative and Support	10,304	10,952	3,958	25,475	36,681	149,162	39,262	24,349	732,998
61	Educational Services	8,620	20,859	12,286	13,669	23,922	155,393	8,330	18,937	432,012
62	Health Care and Social Assistance	38,123	117,196	19,869	78,659	136,770	287,870	112,177	84,815	1,789,810
71	Arts, Entertainment, and Recreation	3,766	5,059	1,661	7,596	11,658	73,770	10,328	11,173	184,905
72	Accommodation and Food Services	16,065	18,220	10,422	44,034	51,283	243,379	53,691	31,270	792,022
81	Other Services (except Public Administration)	9,476	10,634	3,697	18,394	30,680	120,894	25,622	20,931	389,669
99	Industries not classified	8	34	13	23	75	329	51	67	1,038
	Total	179,079	284,855	98,011	423,814	575,632	2,355,277	591,446	384,009	8,615,089

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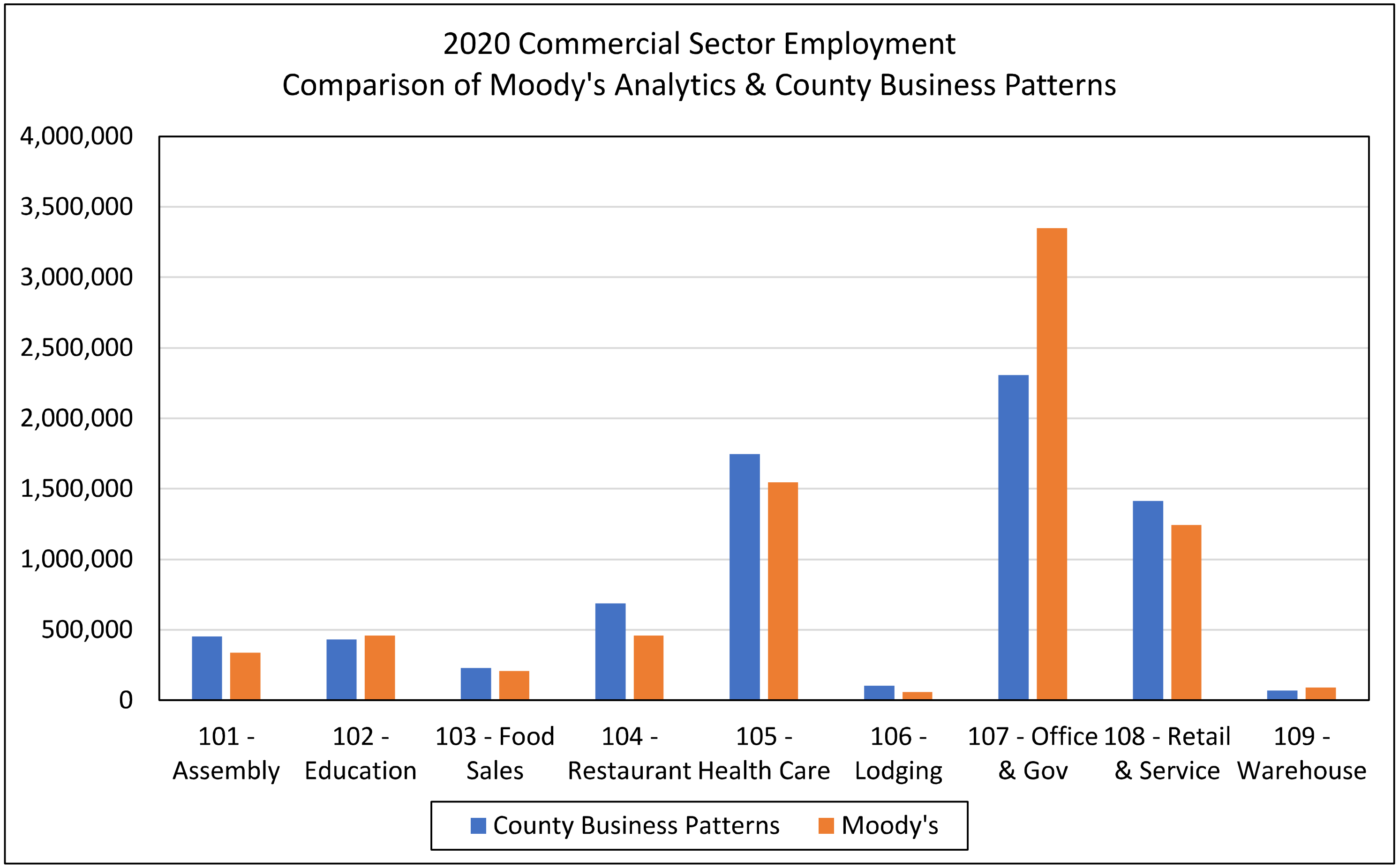
County Business Pattern 2020 Employment Data For Selected Counties & NY State By Commercial Building Types

Building Type	Albany	Bronx	Dutchess	Erie	Nassau	New York	Suffolk	Westchester	State
101 - Assembly	9,322	9,936	3,140	17,167	23,268	215,528	17,312	20,669	451,437
102 - Education	8,620	20,859	12,286	13,669	23,922	155,393	8,330	18,937	432,012
103 - Food Sales	4,510	9,817	4,015	14,505	17,888	28,358	20,241	12,769	229,024
104 - Restaurant	14,066	17,633	9,319	41,147	48,762	196,623	50,925	29,048	688,025
105 - Health Care	38,123	117,196	19,869	78,659	136,770	287,870	112,177	84,815	1,747,244
106 - Lodging	1,999	587	1,103	2,887	2,521	46,756	2,766	2,222	103,997
107 - Office & Gov	45,857	22,323	15,703	98,832	134,383	989,115	115,823	86,116	2,306,791
108 - Retail & Service	32,465	51,463	15,850	78,301	115,239	303,736	132,581	73,687	1,412,659
109 - Warehouse	2,154	3,222	1,512	5,481	7,090	9,812	4,520	2,271	71,121
Commercial Total	157,116	253,036	82,797	350,648	509,843	2,233,191	464,675	330,534	7,442,310

Comparison of Employment Data from County Business Patterns and Moody's Analytics
Some Differences in Classifications Will Be Reconciled



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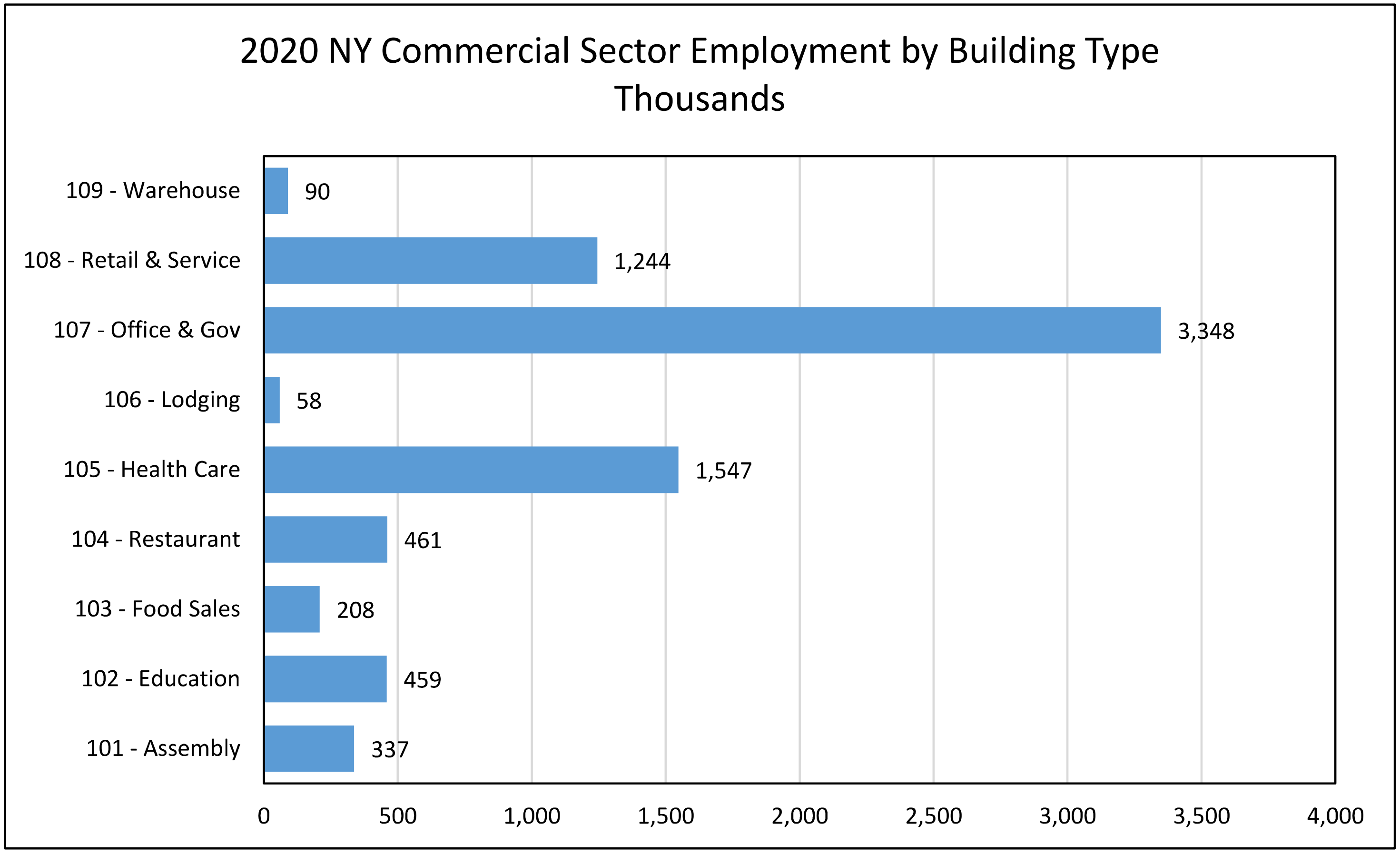
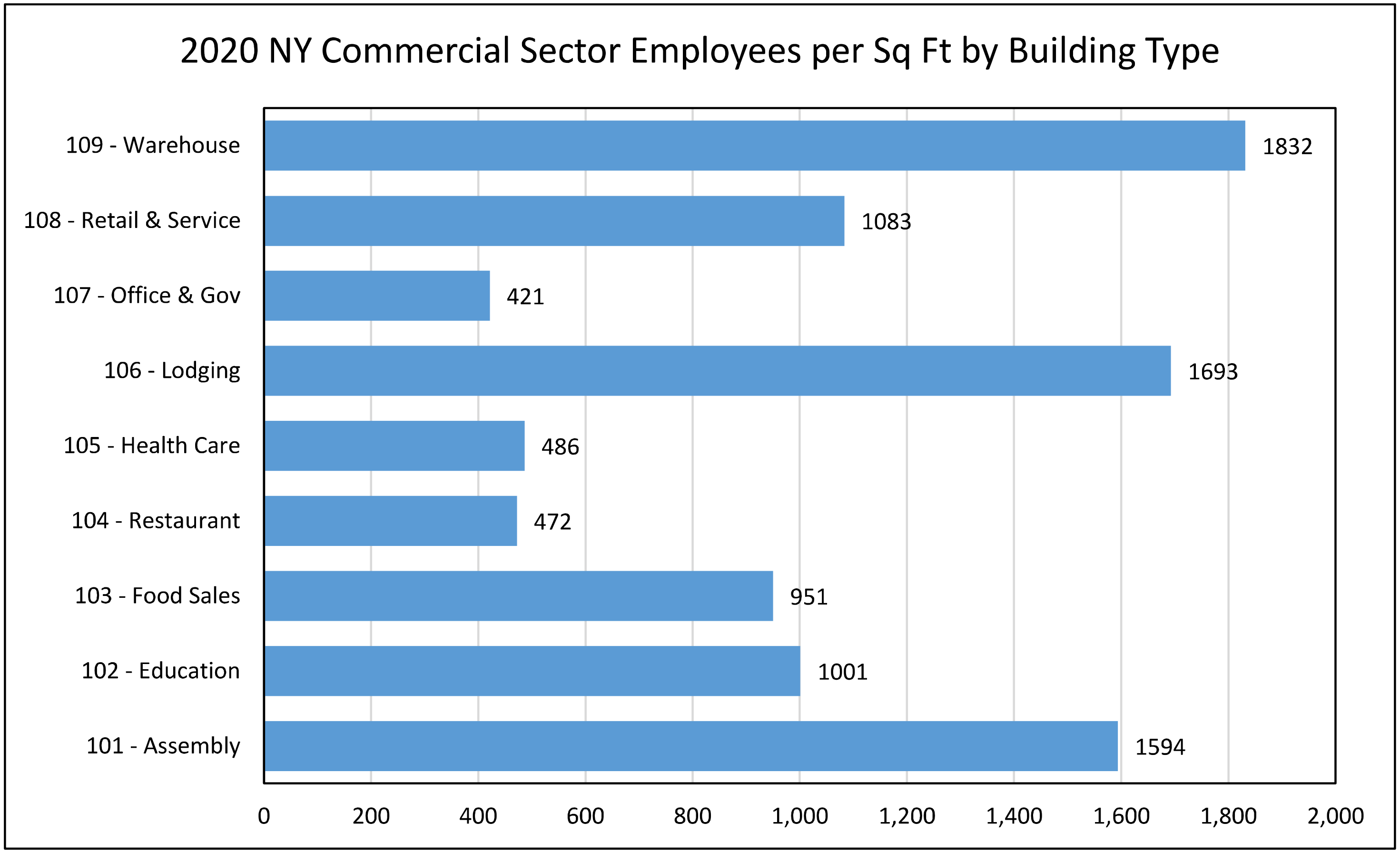
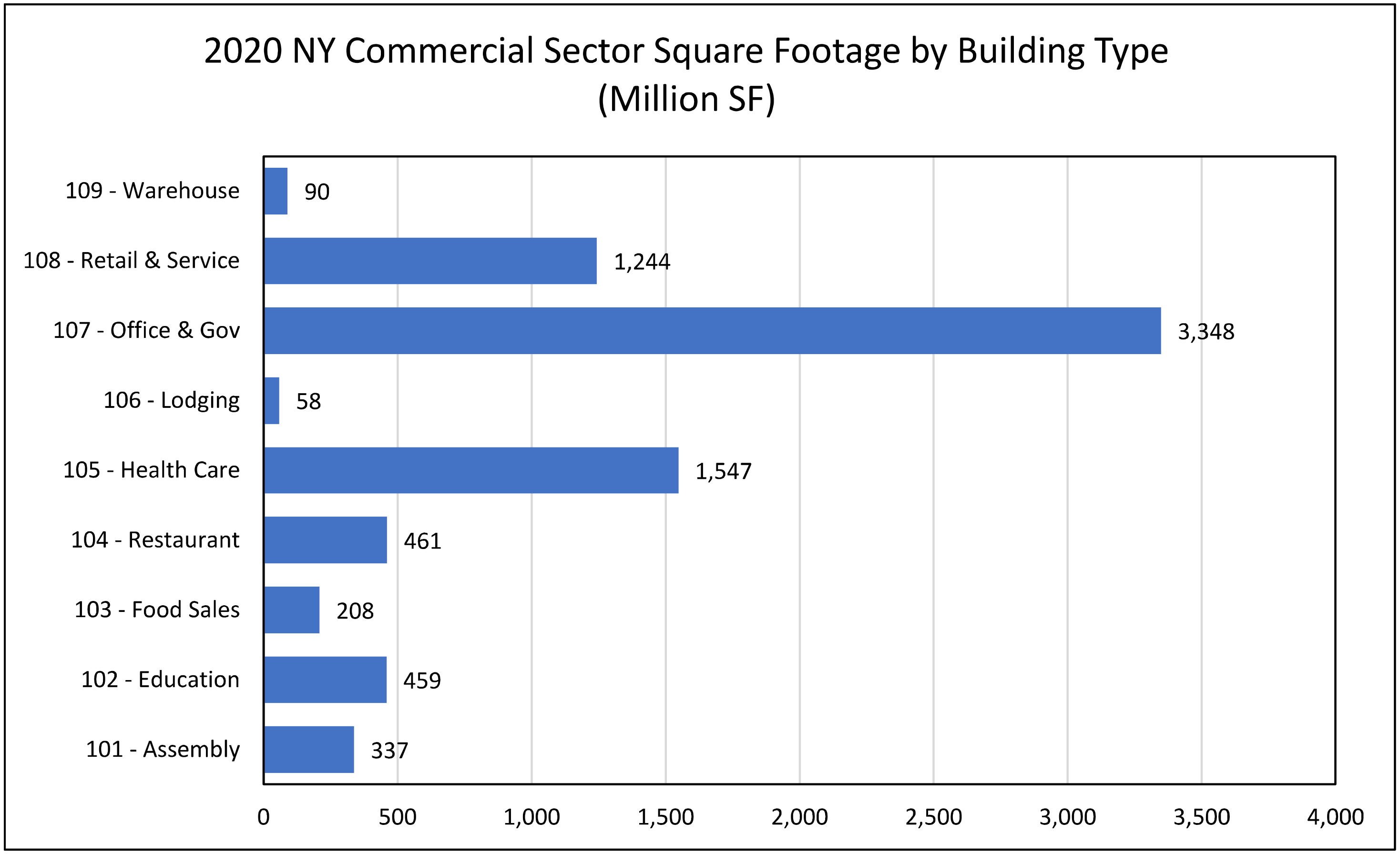


Data from Moody's Analytics



Data from Itron


2020 NY Commercial Sector Square Footage by Building Type
(Million SF)
109 - Warehouse
90
108 - Retail & Service
1,244
107 - Office & Gov
3,348
106 - Lodging
58
105 - Health Care
1,547
104 - Restaurant
461
103 - Food Sales
208
102 - Education
459
101 - Assembly
337
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000

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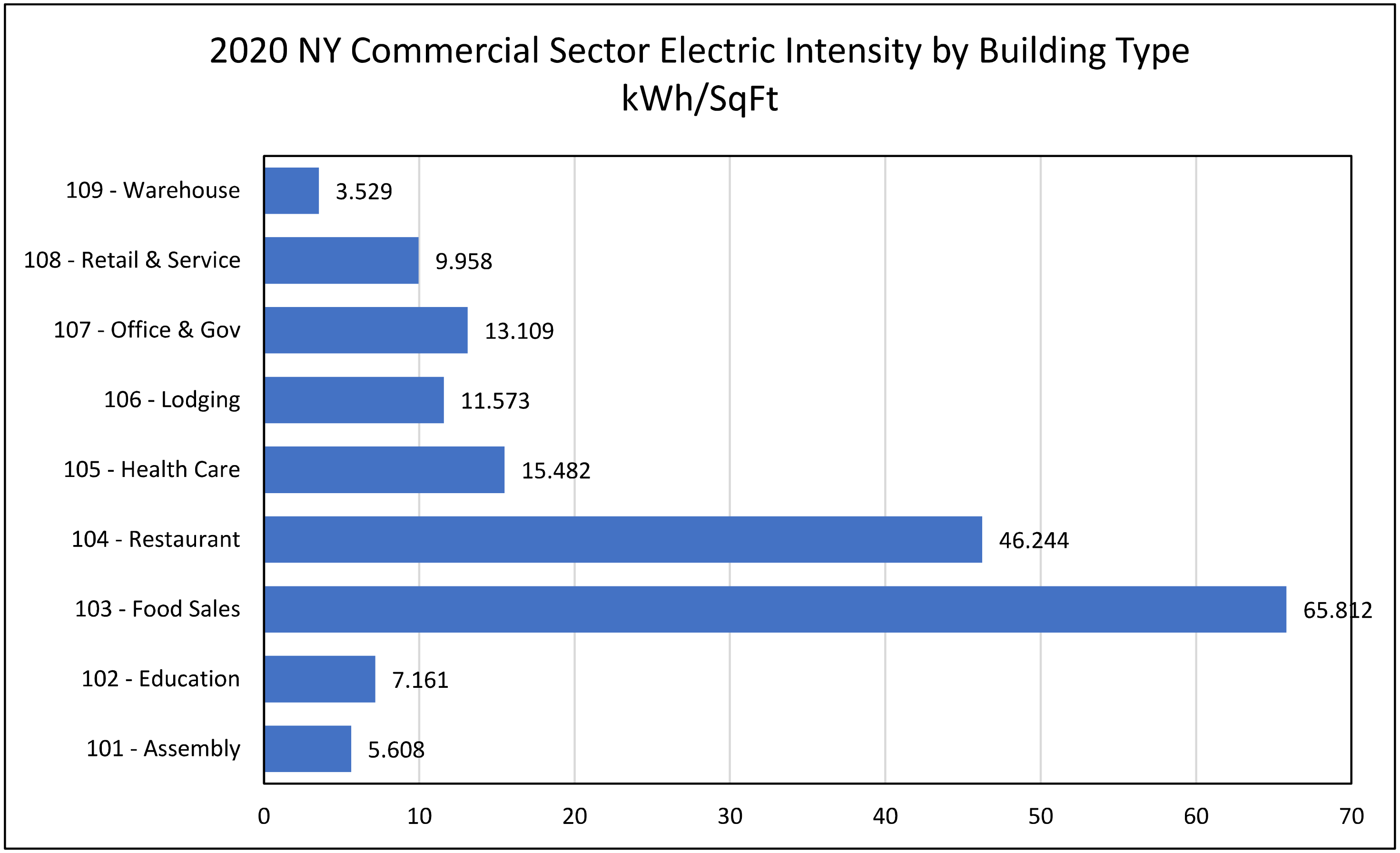

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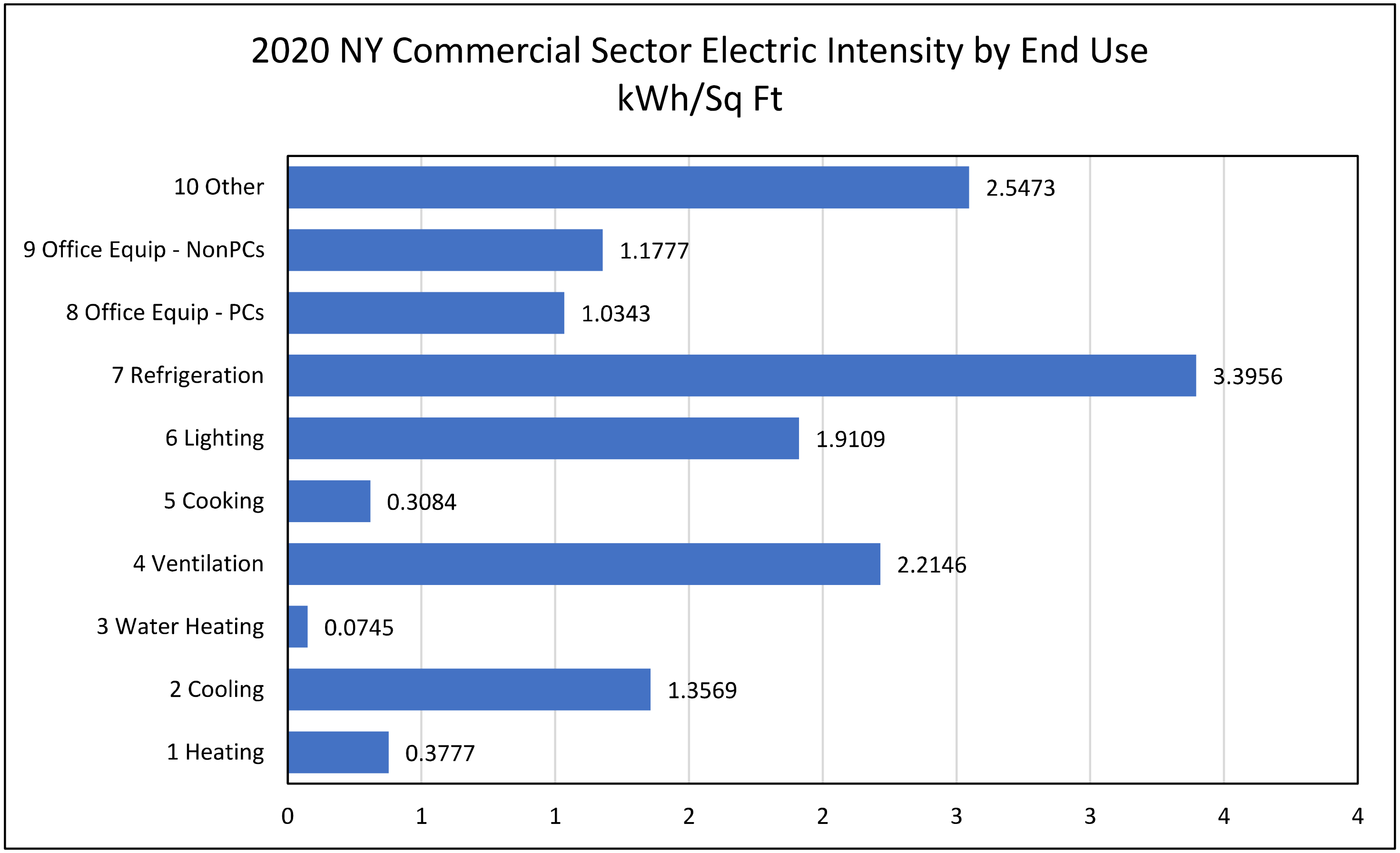
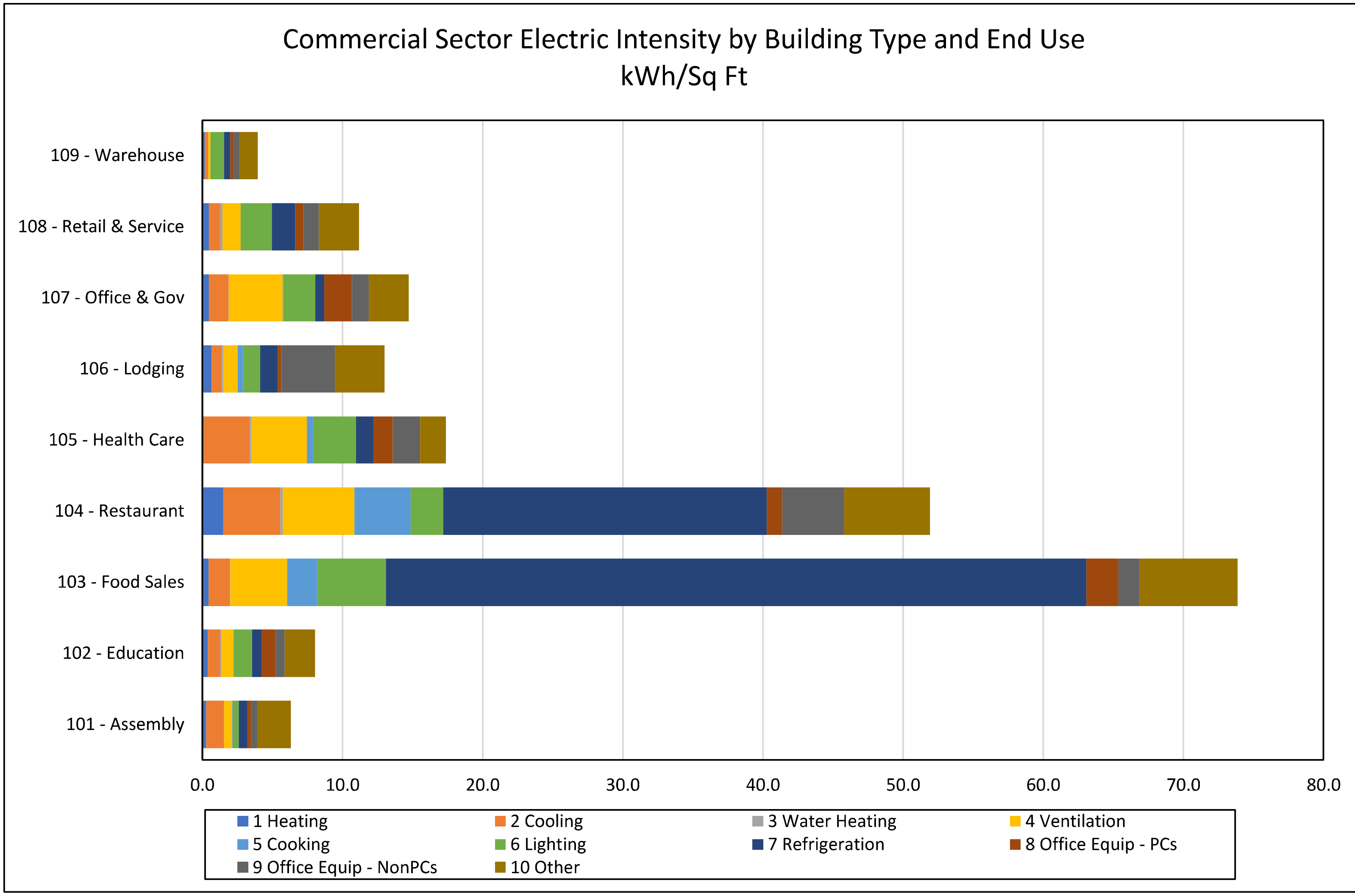
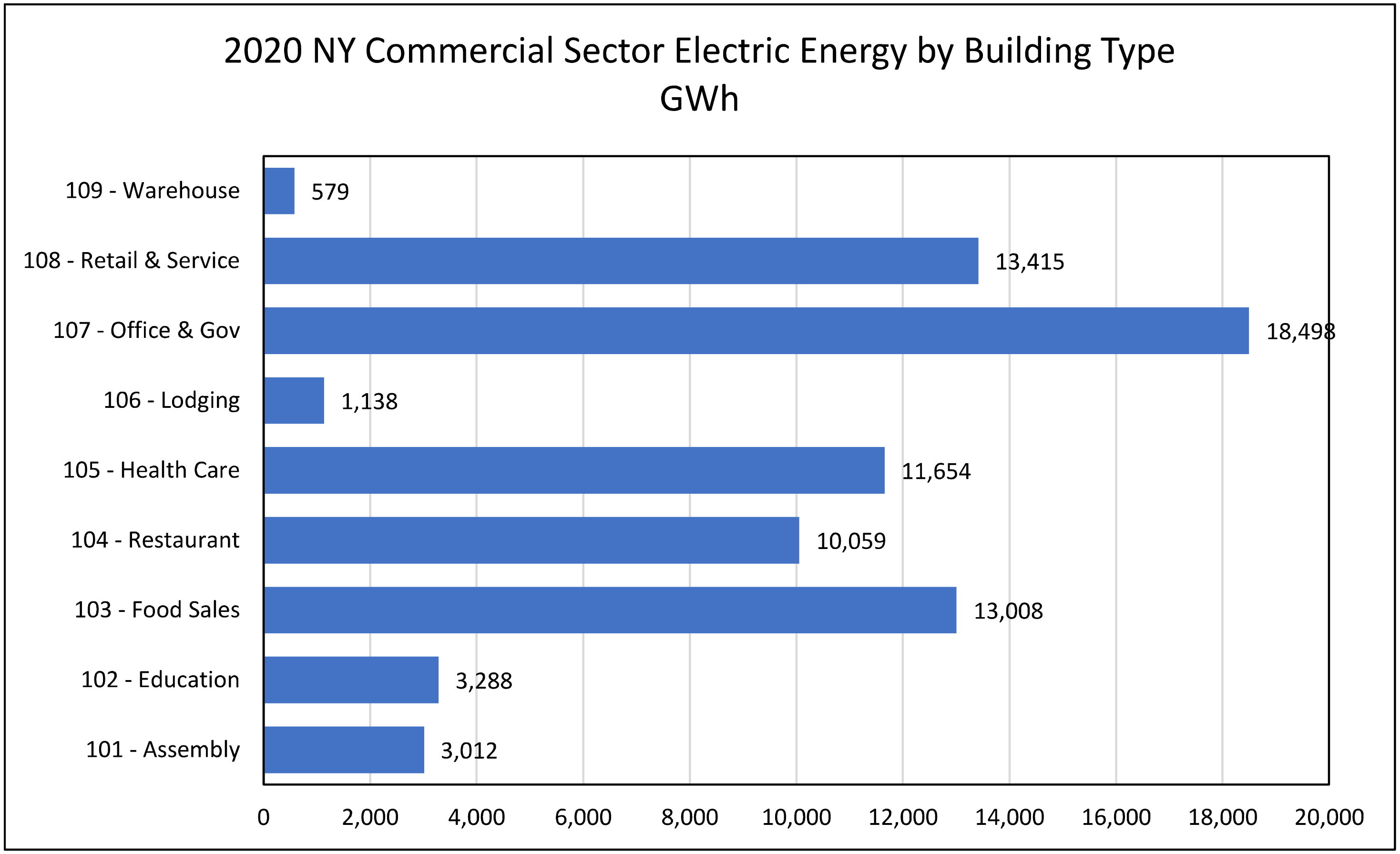


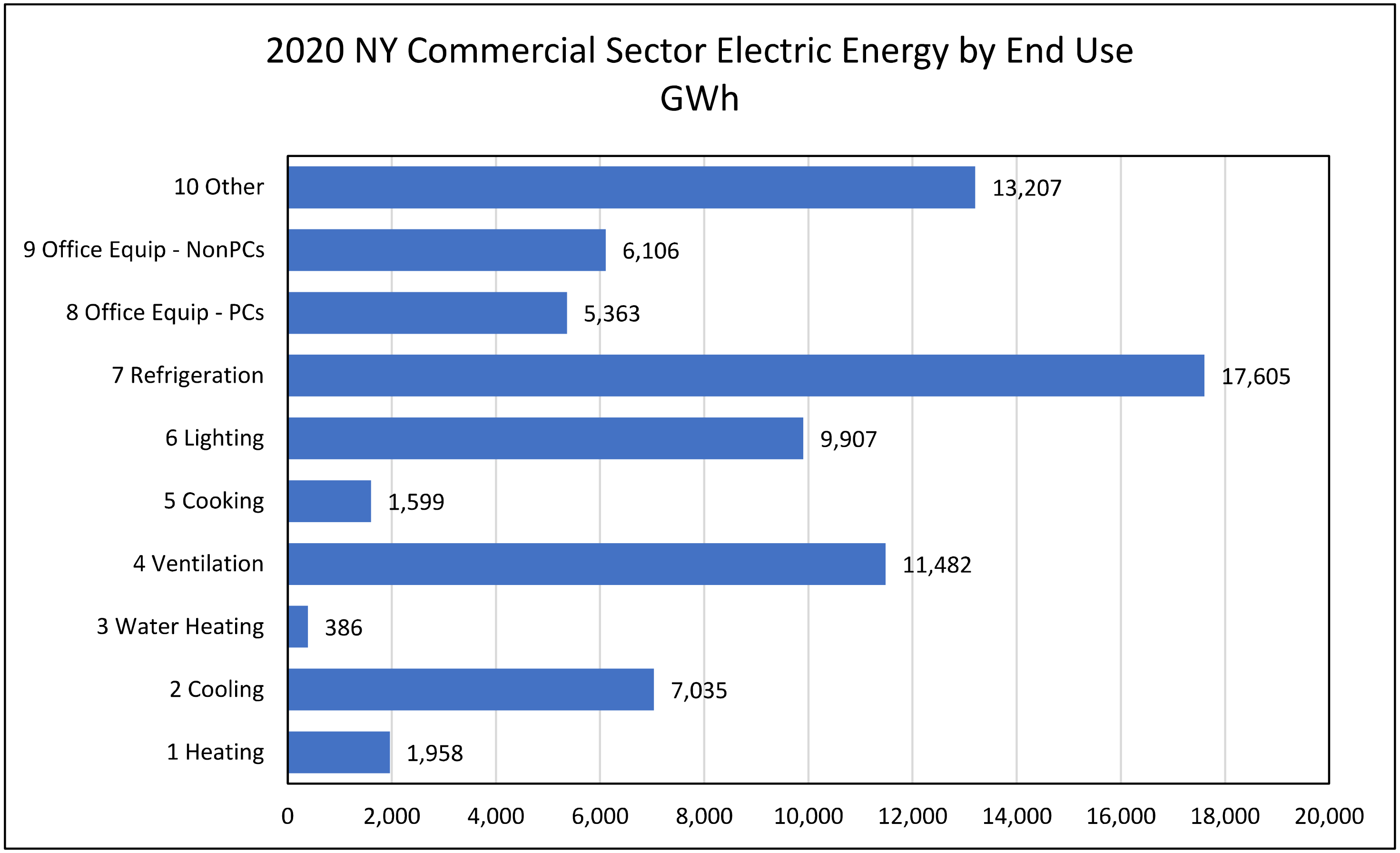
Data from Itron

DRAFT – FOR DISCUSSION PURPOSES ONLY

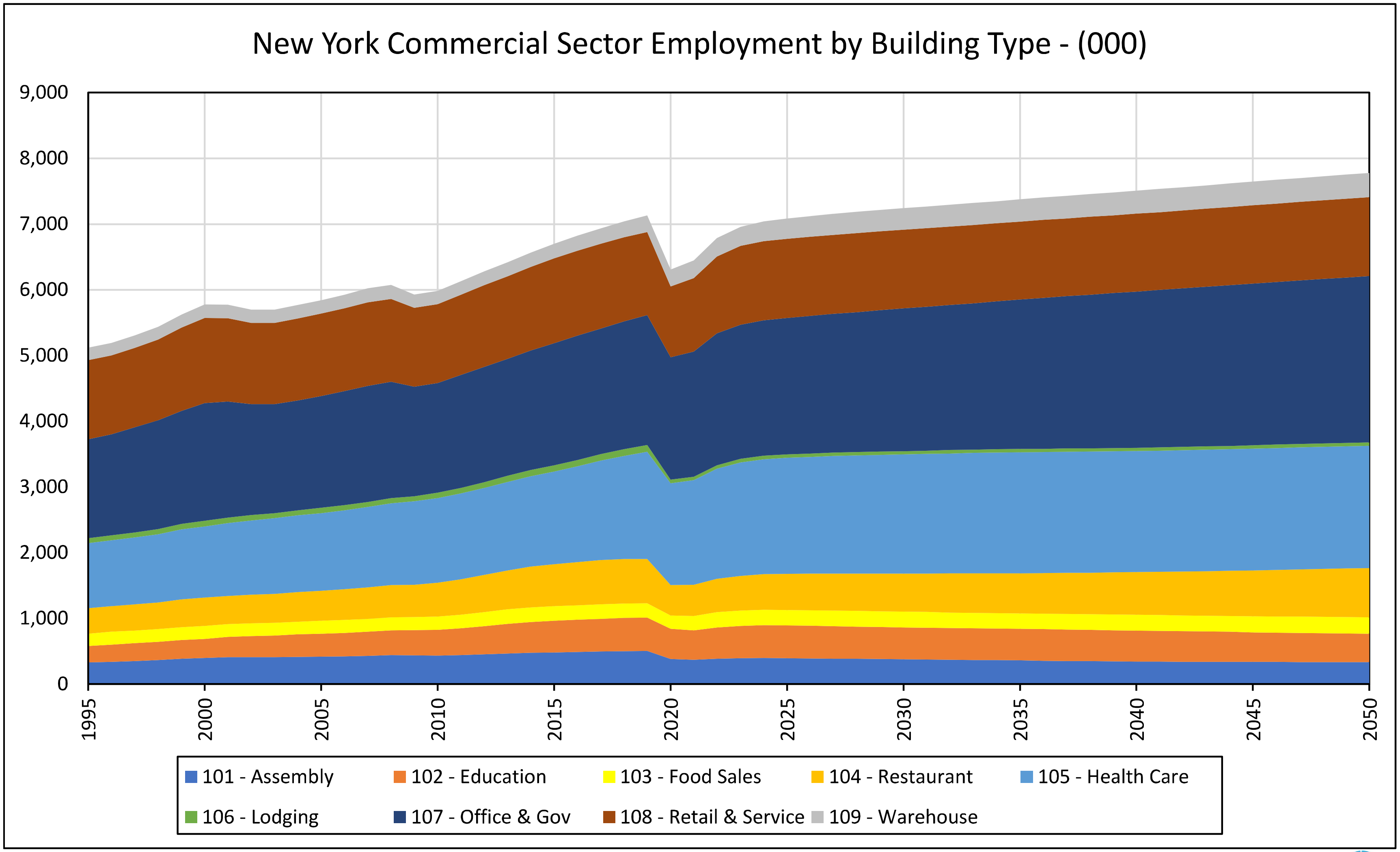


Data from Itron


2020 NY Commercial Sector Electric Energy by Building Type
GWh
109 - Warehouse
108 - Retail & Service
107 - Office & Gov
106 - Lodging
105 - Health Care
104 - Restaurant
103 - Food Sales
102 - Education
101 - Assembly
579
13,415
18,498
1,138
11,654
10,059
13,008
3,288
3,012
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000



2020 NY Commercial Sector Electric Energy by End Use
GWh
10 Other
9 Office Equip - NonPCs
8 Office Equip - PCs
7 Refrigeration
6 Lighting
5 Cooking
4 Ventilation
3 Water Heating
2 Cooling
1 Heating
13,207
6,106
5,363
17,605
9,907
1,599
11,482
386
7,035
1,958
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000



Data from Moody's Analytics

(2) Residential Heat Pump Assessment

Air Source Heat Pump Data Sources

1. Weather Data – NREL & NYISO
2. Winter & Summer Design Weather Data - ASHRAE
3. Air Source Heat Pump (ASHP) Performance Data – From specific manufacturers
4. EnergyPlus Building Simulation Tool – Department of Energy & EPRI
5. Building Envelope & Equipment Specifications – NREL ResStock Data Input files

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Discussion of Electrification Issues to Examine Related to Heat Pumps

1. Building electrification will significantly increase winter peak demands, especially if all fossil heating is converted to electric resistance heat.
2. Depending on the manufacturer, heat pumps in the winter season can deliver 1.5 to 5 times the amount of heating energy for every kWh of electric energy, with the lowest efficiency at design winter conditions. Furthermore, heat pump sizing standards have been focused on summer air conditioning requirements, not winter heating requirements which are much higher.
3. NYISO's electrification plans are based on heat pumps sized to meet winter design conditions and therefore minimize the reliance on supplemental electric resistance heating.
4. NYISO's previous analysis methods, such as temperature bin analysis, are adequate for determining annual heat pump usage but are not reliable for detailed hourly performance.
5. EnergyPlus building simulation tool uses engineering principles to quantify the performance of HVAC equipment in buildings as actually constructed. This enables us to obtain accurate information on all aspects of hourly heat pump performance and building environmental conditions.

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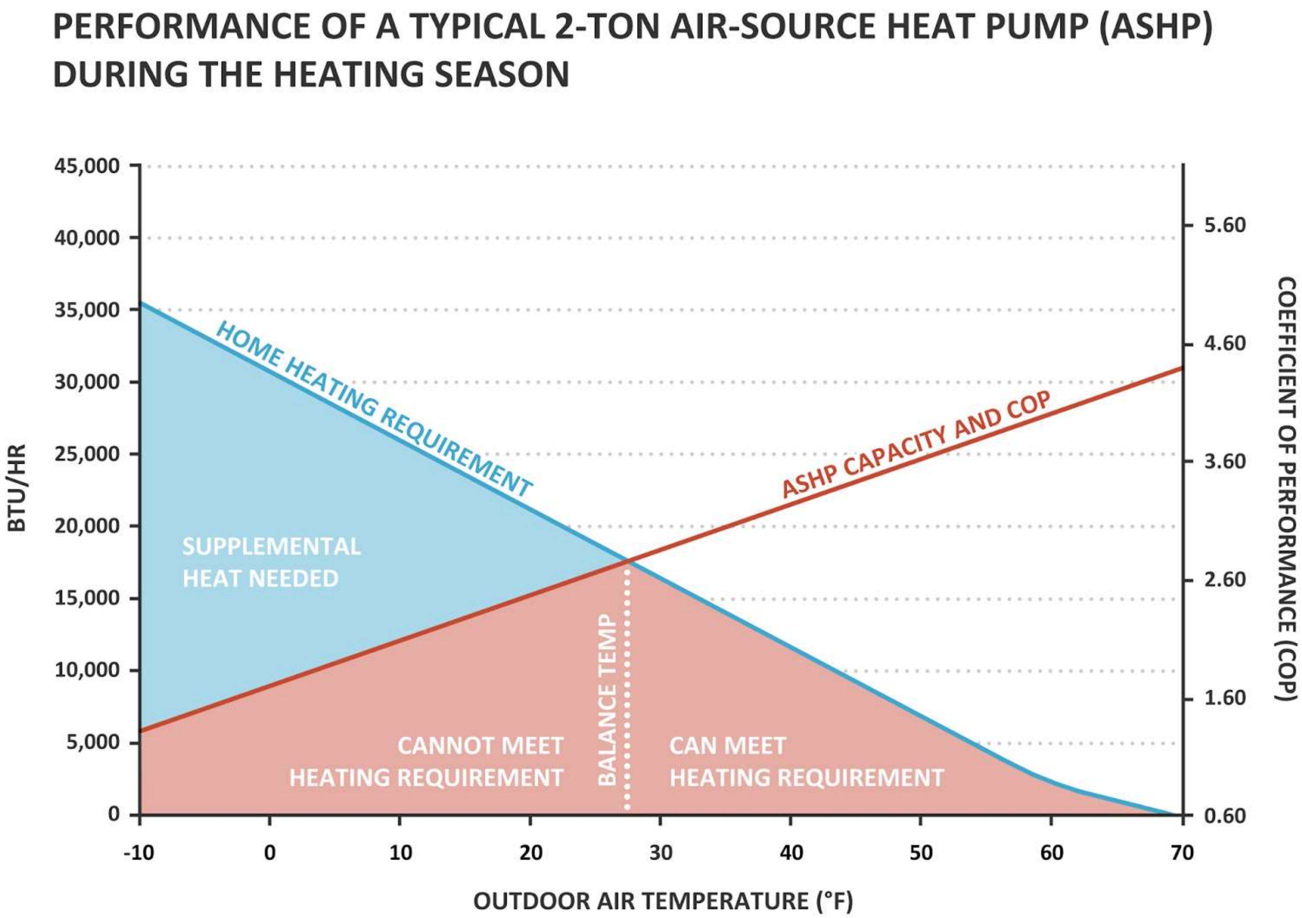

https://www.buildingenclosureonline.com/blogs/14-the-be-blog/post/85012-gauging-the-seasonal-efficiency-of-air-source-heat-pumps

Heat pump efficiency, thermal output and energy input vary continuously with outdoor air temperature. Heat pump output in heating mode decreases as outdoor temperature decreases.

Depending on home and heat pump characteristics, supplemental heat from an alternative fuel may be needed. This supplemental heat may be provided by a fossil fuels furnace or by electric resistance heating.

The crossover from heat pump to supplemental heat depends on the capacity of HVAC equipment, the relative economics of operation, and other factors.

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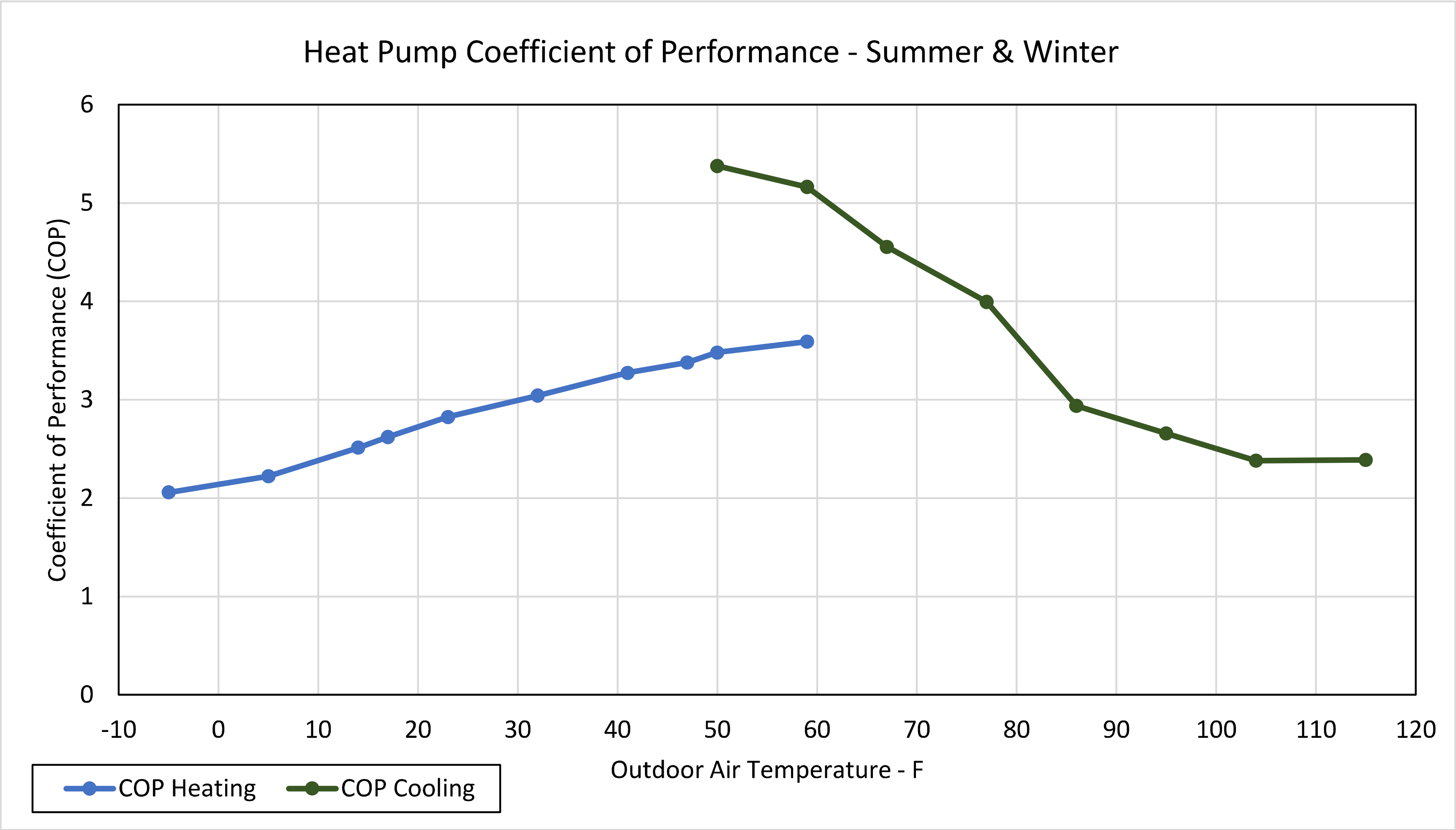
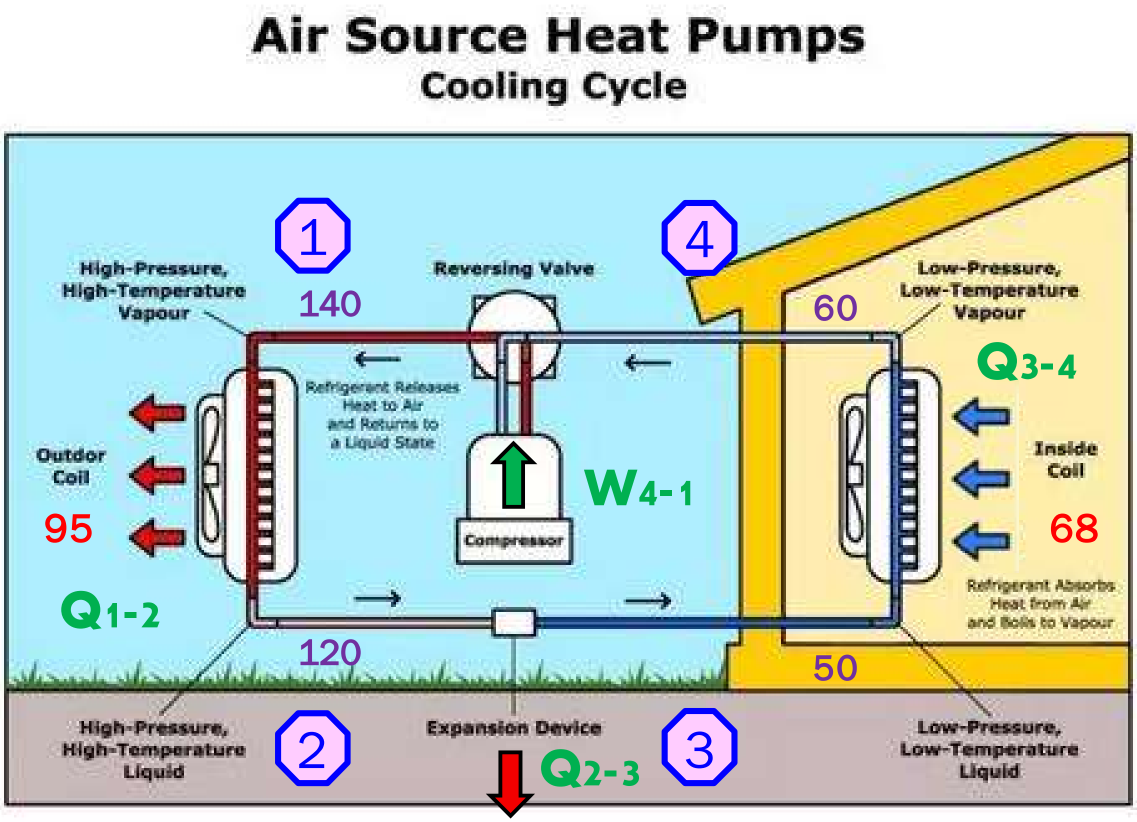


Obtained from Manufacturer's data. Results based on indoor temperature of 70 F.

(3) Appendix – Schematics of Heat Pump Operation in Summer and Winter



Note: Refrigerant circulates counter-clockwise.

https://shortpumpair.com/blog/what-is-a-heat-pump/

Cooling Cycle

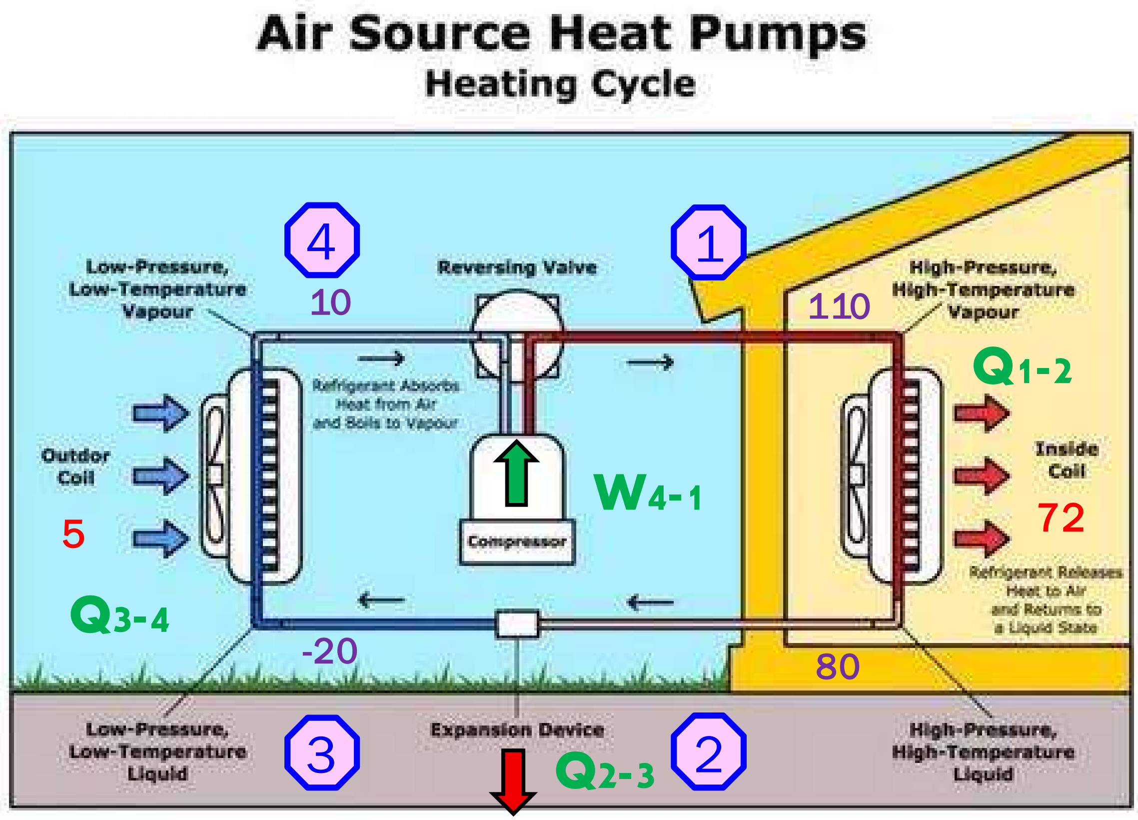
1. Compressor uses electricity W to raise refrigerant temperature *above* outdoor temperature (95 F).
2. Heat exchanger transfers thermal energy from hot refrigerant to outdoor air, reducing temperature from 140 F to 120 F.
3. Expansion valve reduces temperature of refrigerant from 120 F to 50 F, *below* indoor room temperature (68 F).
4. Heat exchanger transfers thermal energy from home interior to the working fluid, which increases in temperature from 50 F to 60 F. This results in *cooling of the home*.

Temperature data (in purple and red) are for discussion only and may not represent actual performance

Cooling Cycle Performance

1. Electric energy $W_{4\text{-}1}$ compresses the refrigerant to a temperature warmer than the outdoor air temperature.
2. Thermal energy $Q_{1\text{-}2}$ is exchanged with the environment, warming the outdoor air and cooling the refrigerant.
3. Energy of expansion $Q_{2\text{-}3}$ changes the phase of the refrigerant from liquid to vapor and cools it below the home's interior temperature. This energy cannot be used to perform any further work.
4. Thermal energy $Q_{3\text{-}4}$ is exchanged with the interior of the home, warming the refrigerant and cooling the home.
5. The source temperature is the working fluid temperature after compression. The sink temperature is the outdoor air temperature.

The *Coefficient of Performance* (COP) is the ratio $Q_{3\text{-}4}/W_{4\text{-}1}$. It varies with outdoor temperature and ranges from about 5-6 in spring and falls to 2-3 at summer design conditions, depending on manufacturers' data.



Note: Refrigerant circulates clockwise.

https://shortpumpair.com/blog/what-is-a-heat-pump/

Heating Cycle

1. Compressor uses electricity W to raise refrigerant temperature from 10 F to 110 F, *above* interior home temperature of 72.
2. Heat exchanger transfers thermal energy from hot refrigerant at 110 F to home interior, *heating the home*. The refrigerant temperature is cooled to 80 F.
3. Expansion valve reduces temperature of refrigerant from 80 F to -20 F, which is *below* outdoor air temperature of 5 F.
4. Heat exchanger transfers thermal energy from outdoor air to working fluid, increasing it from -20 F to 10 F.

Temperature data (in purple and red) are for discussion only and may not represent actual performance

Heating Cycle Performance

1. Electric energy $W_{4\text{-}1}$ compresses the refrigerant to a temperature warmer than the home.
2. Thermal energy $Q_{1\text{-}2}$ is exchanged with the home, warming the home and cooling the refrigerant.
3. Energy of expansion $Q_{2\text{-}3}$ changes the phase of the refrigerant from liquid to vapor and cools it below the outdoor air temperature. This energy cannot be used to perform any other work.
4. Thermal energy $Q_{3\text{-}4}$ is exchanged with the environment, warming the refrigerant and cooling the environment.
5. The source temperature is the outdoor air temperature. The sink temperature is the working fluid temperature after expansion.

The *Coefficient of Performance* (COP) is the ratio $Q_{1\text{-}2}/W_{4\text{-}1}$. It varies with outdoor temperature and ranges from about 1.5 to 2 at winter design conditions, increasing to about 4 to 5 in spring or fall, depending on manufacturers' data.

New York ISO

Our Mission & Vision

Mission

Ensure power system reliability and competitive markets for New York in a clean energy future

Vision

Working together with stakeholders to build the cleanest, most reliable electric system in the nation