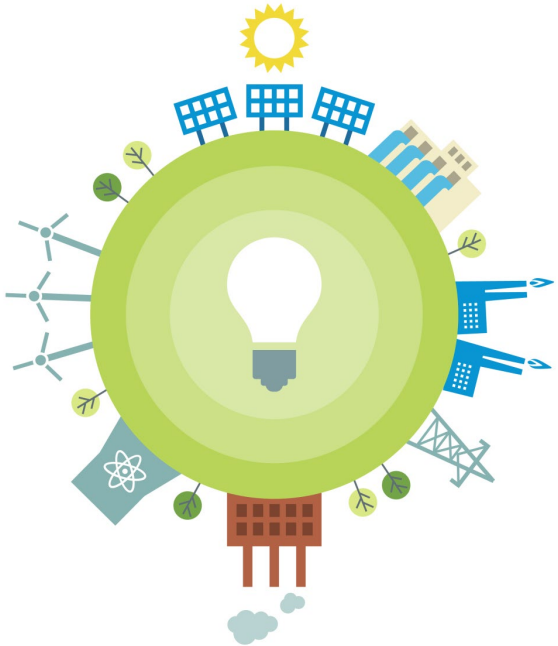
APRIL 28, 2022

2022 Final Transportation Electrification Forecast

Outline

- Introduction & Forecast Methodology
- Electric Vehicle Adoption
- Estimating Impacts of Fleet Vehicles
- Energy Forecast
- Demand Forecast



Acronyms

- **BEV** – Battery Electric Vehicle
- **BTM PV** – Behind-the-meter Photovoltaic
- **CELT** – Capacity, Energy, Loads and Transmission
- **EIA** – Energy Information Agency
- **EV** – Electric Vehicle
- **FCM** – Forward Capacity Market
- **GHG** – Greenhouse Gas
- **HE** – Hour Ending
- **ICR** – Installed Capacity Requirement
- **LDV** – Light-Duty Vehicle
- **LFC-** Load Forecast Committee
- **P75** – 75th Percentile
- **PHEV** – Plug-in Hybrid Electric Vehicle
- **RSP** – Regional System Plan
- **TCI** – Transportation Climate Initiative
- **VMT** – Vehicle Miles Traveled

Introduction

- Transportation electrification is expected to play a pivotal role in the achievement of New England state greenhouse gas (GHG) reduction mandates and goals
- Forecasted impacts of transportation electrification on state and regional electric energy and demand are included as part of the 2022 Capacity, Energy, Loads, and Transmission (CELT) forecast
- ISO discussed methodology, assumptions, and related energy and demand impacts associated with the transportation electrification forecast at the NEPOOL Load Forecast Committee (LFC), including the following presentations:
  - Background, assumptions and methodology at the September 24, 2021 and November 12, 2021 LFC meetings
  - The draft 2022 forecast at the December 10, 2021 LFC meeting
  - The final draft 2022 forecast at the February 18, 2022 LFC meeting

Summary of Methodology

- Transportation electrification forecast framework
  - Forecast the adoption of electrified vehicles or “EVs”, for each state and the region over the next ten years
  - Utilize data-driven assumptions to convert the EV adoption forecast into estimated impacts on monthly energy and demand by state
- Starting with the CELT 2022 forecast, the ISO has expanded the scope of EVs considered to include select categories of fleet vehicles:
  - Light-duty fleet vehicles, medium-duty delivery trucks, school buses, and transit buses
- Light-duty EV adoption forecast figures used in the CELT 2021 forecast, and updated figures provided by the states for CELT 2022, implicitly reflect both personal and fleet light-duty EVs
  - To avoid double-counting, forecasts for light-duty EVs are discounted by the percentages below to remove fleet vehicles
  - These discount factors are based on state level vehicle stock data as of Q1 2021

	CT	MA	ME	NH	RI	VT
% Fleet	4.6%	6.0%	5.5%	7.2%	5.7%	5.3%

ELECTRIC VEHICLE ADOPTION FORECAST

Personal Light-Duty Vehicles and Select Classes of Fleet Vehicles

2022 Light-Duty Personal EV Adoption Forecast

States - Incremental Increases in Vehicle Stock

- Draft 2022 adoption figures shown reflect the removal of light-duty fleet EVs
- ME adoption forecast was developed to align with the state's Climate Action Plan
- VT adoption forecast reflects values submitted by state representatives
- CT adoption forecast values represent a blend of the CELT 2021 forecast and EV targets listed in the state's Electric Vehicle Roadmap
- RI adoption forecast was developed based on discussions with state and utility representatives
- MA and NH adoption forecasts result from carrying forward the CELT 2021 forecast

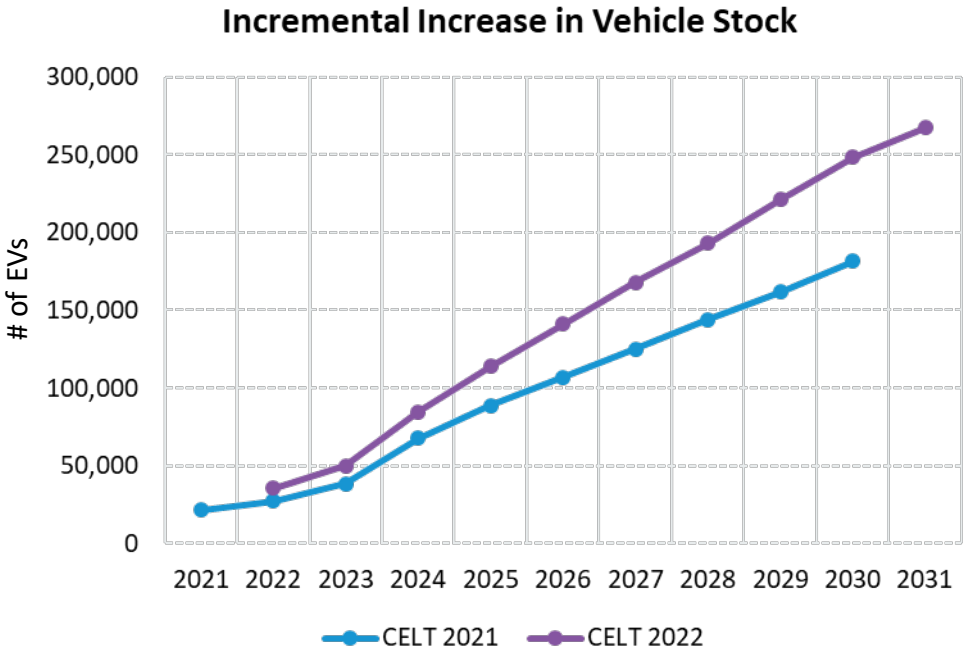
Light-Duty Personal EVs							
Year	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022	17,001	6,201	3,262	3,269	2,332	3,370	35,435
2023	18,843	14,376	4,866	3,461	3,308	4,982	49,837
2024	20,961	38,430	8,259	3,685	4,331	8,776	84,442
2025	22,987	52,242	13,325	3,875	5,549	15,775	113,754
2026	29,365	59,101	18,299	5,165	7,559	21,465	140,954
2027	37,125	64,410	24,611	6,173	9,662	25,886	167,868
2028	44,636	69,735	32,571	7,115	11,895	27,189	193,140
2029	51,281	73,452	41,336	7,796	14,546	32,541	220,953
2030	62,014	75,403	51,368	8,964	17,246	33,285	248,280
2031	65,706	77,405	60,376	9,020	20,223	34,404	267,134
Total	**369,920**	**530,755**	**258,273**	**58,524**	**96,652**	**207,673**	**1,521,796**

Impact of Forecast on Light-Duty Personal Vehicle Stock							
	CT	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2021 Electrified Stock	15,533	36,533	4,822	5,014	3,046	4,332	69,280
Total Electrified (2022-2031)	369,920	530,755	258,273	58,524	96,652	207,673	1,521,796
Total Vehicle Stock	2,856,427	5,082,420	1,247,151	1,222,363	782,764	518,562	11,709,687
% of Stock Electrified by 2031	13%	11%	21%	5%	13%	41%	14%

New England Light-Duty Personal EV Adoption Forecast

Comparison Between CELT 2021 and CELT 2022

Year	CELT 2021*	CELT 2022
2021	21,708	
2022	27,249	35,435
2023	38,594	49,837
2024	67,948	84,442
2025	88,797	113,754
2026	107,095	140,954
2027	124,891	167,868
2028	144,168	193,140
2029	161,861	220,953
2030	181,580	248,280
2031		267,134
10-year Total	**963,891**	**1,521,796**



** CELT 2021 values shown reflect adjustment to remove light-duty fleet vehicles*

Fleet EV Adoption Forecast

- For the 2022 forecast the ISO has expanded the scope of vehicles considered to include 4 classes of fleet vehicles in each of the New England states
  - Light-duty fleet, medium-duty delivery, school buses, and transit buses
- Fleet EV adoption forecast development (for each fleet category, by state)
  - Develop a “sales forecast” of new fleet vehicles to be purchased each year
    - Combines vehicle replacement and fleet growth where possible
    - Assumes no early retirement of vehicles
  - Develop a consensus “EV sales share” forecast
    - Based on various policies, goals, reports, presentations, and/or announcements
  - Apply the “EV sales share” forecast to the “sales forecast” to get the number of additional fleet EVs on the road each year

Current Fleet Vehicle Stock in New England

As of March 31, 2021

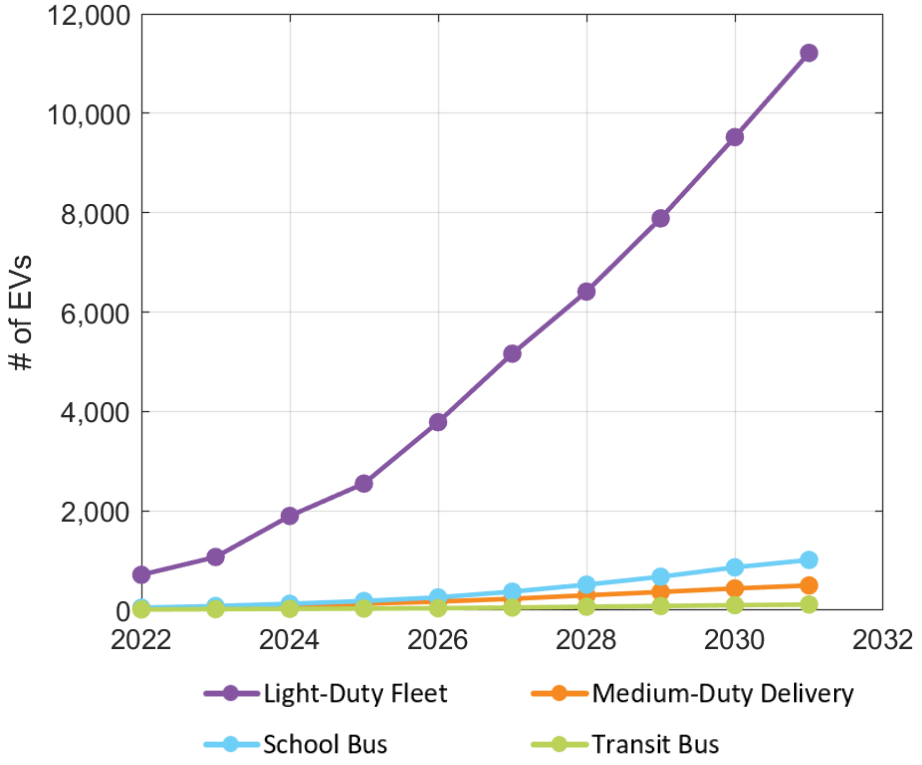
	Light-duty Fleet Vehicles		Medium-duty Delivery Vehicles		School Buses		Transit Buses	
	All	Electric	All	Electric	All	Electric	All	Electric
CT	142,921	623	4,581	0	5,265	2	771	2
MA	337,296	1,915	9,476	8	9,668	7	1,763	25
ME	66,180	210	1,869	0	3,777	1	194	0
NH	98,716	379	2,047	0	3,571	0	143	0
RI	48,552	199	1,389	0	2,404	0	252	3
VT	30,020	219	833	0	1,780	6	118	2
Total	723,685	3,545	20,195	8	26,465	16	3,241	32

Source: DNV Energy Insights USA Inc.

2022 Fleet EV Adoption Forecast

New England - Incremental Increases in Vehicle Stock

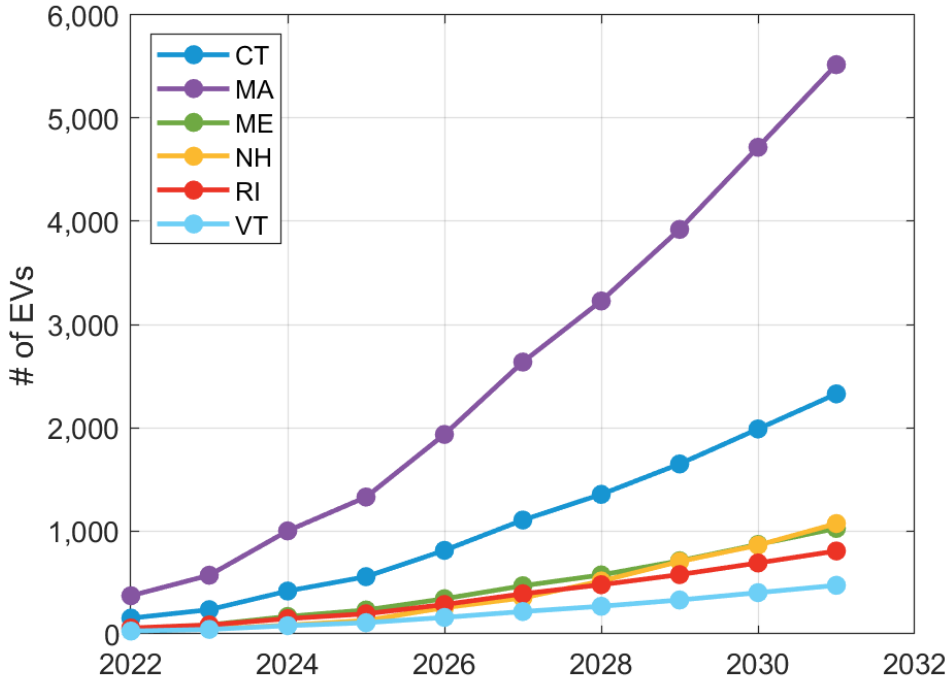
Fleet EV Adoption Forecast					
Year	**LD Fleet**	**MD Delivery**	**School Buses**	**Transit Buses**	**Fleet Total**
2022	713	48	51	15	827
2023	1,071	69	84	22	1,246
2024	1,897	94	130	28	2,149
2025	2,549	133	186	34	2,902
2026	3,784	174	259	41	4,258
2027	5,162	231	374	54	5,821
2028	6,411	301	515	71	7,298
2029	7,885	368	674	85	9,012
2030	9,520	439	864	102	10,925
2031	11,214	499	1,012	115	12,840
Total	**50,206**	**2,356**	**4,149**	**567**	**57,278**



2022 Fleet EV Adoption Forecast

Light-Duty Fleet - Incremental Increases in Vehicle Stock

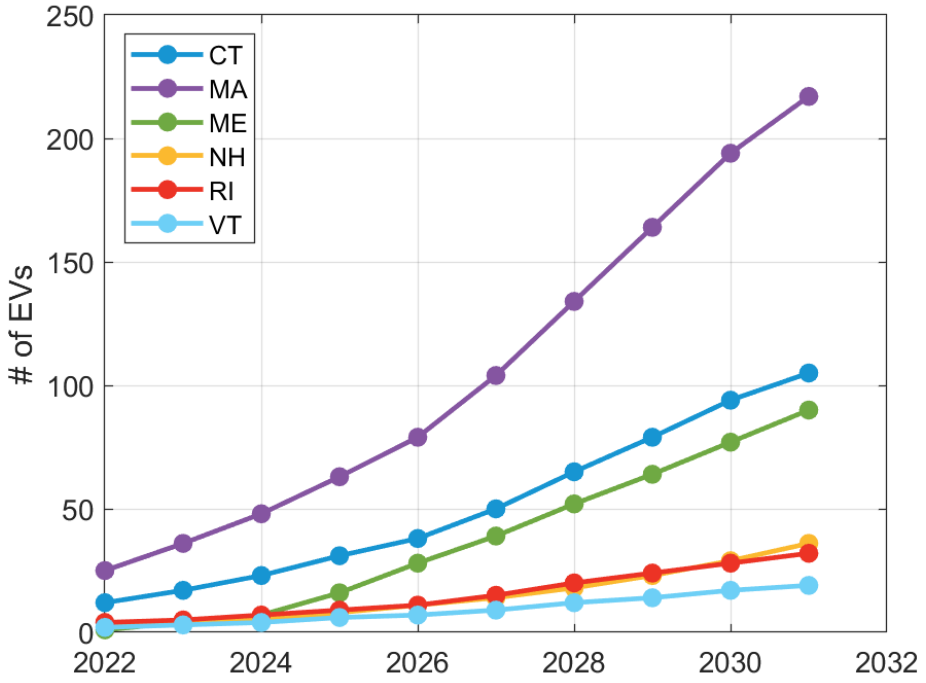
Light-Duty Fleet EVs							
Year	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022	153	370	57	48	57	28	713
2023	235	569	88	48	87	44	1,071
2024	416	999	169	85	148	80	1,897
2025	555	1,327	232	131	195	109	2,549
2026	810	1,934	341	254	285	160	3,784
2027	1,104	2,636	467	349	389	217	5,162
2028	1,353	3,228	572	513	477	268	6,411
2029	1,648	3,922	709	702	575	329	7,885
2030	1,987	4,718	867	860	688	400	9,520
2031	2,327	5,519	1,023	1,070	804	471	11,214
Total	**10,588**	**25,222**	**4,525**	**4,060**	**3,705**	**2,106**	**50,206**



2022 Fleet EV Adoption Forecast

Medium-Duty Delivery - Incremental Increases in Vehicle Stock

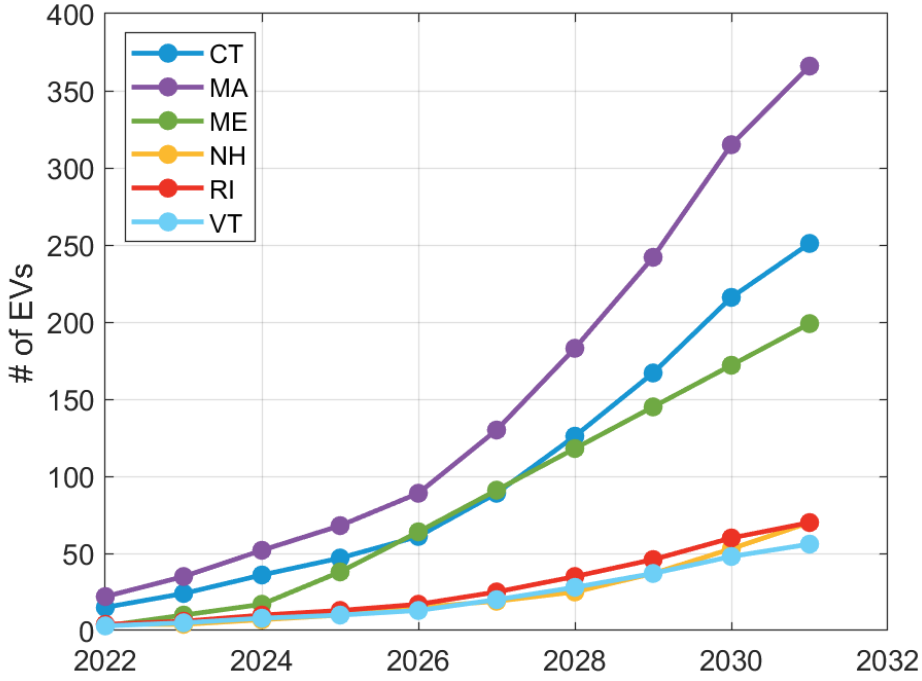
Medium-Duty Delivery EVs							
Year	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022	12	25	1	4	4	2	48
2023	17	36	4	4	5	3	69
2024	23	48	7	5	7	4	94
2025	31	63	16	8	9	6	133
2026	38	79	28	11	11	7	174
2027	50	104	39	14	15	9	231
2028	65	134	52	18	20	12	301
2029	79	164	64	23	24	14	368
2030	94	194	77	29	28	17	439
2031	105	217	90	36	32	19	499
Total	**514**	**1,064**	**378**	**152**	**155**	**93**	**2,356**



2022 Fleet EV Adoption Forecast

School Buses - Incremental Increases in Vehicle Stock

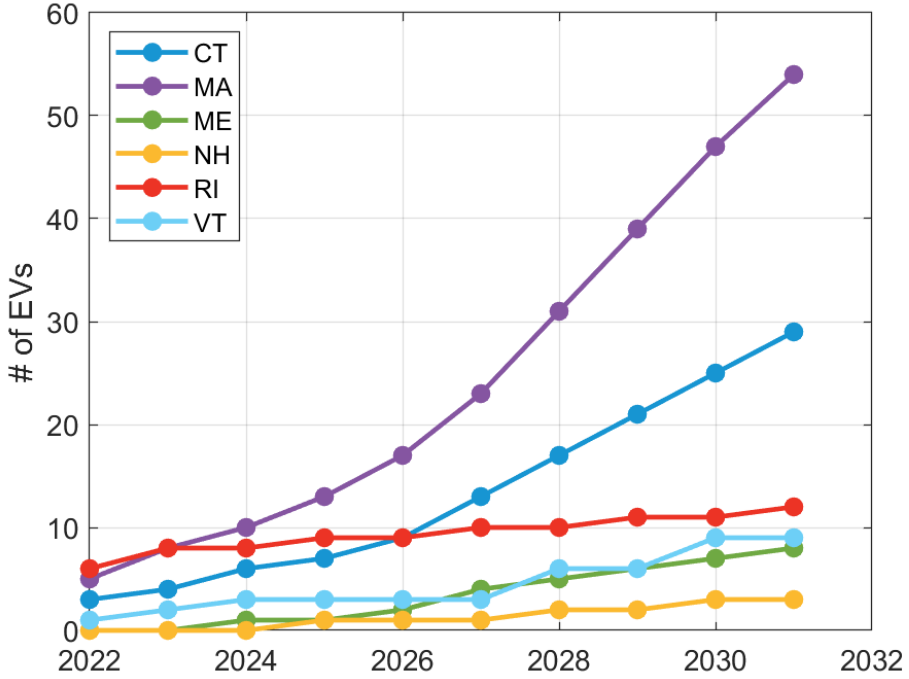
School Bus EVs							
Year	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022	15	22	3	4	4	3	51
2023	24	35	10	4	6	5	84
2024	36	52	17	7	10	8	130
2025	47	68	38	10	13	10	186
2026	61	89	64	15	17	13	259
2027	89	130	91	19	25	20	374
2028	126	183	118	25	35	28	515
2029	167	242	145	37	46	37	674
2030	216	315	172	53	60	48	864
2031	251	366	199	70	70	56	1012
Total	**1,032**	**1,502**	**857**	**244**	**286**	**228**	**4149**



2022 Fleet EV Adoption Forecast

Transit Buses - Incremental Increases in Vehicle Stock

Transit Bus EVs							
Year	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022	3	5	0	0	6	1	15
2023	4	8	0	0	8	2	22
2024	6	10	1	0	8	3	28
2025	7	13	1	1	9	3	34
2026	9	17	2	1	9	3	41
2027	13	23	4	1	10	3	54
2028	17	31	5	2	10	6	71
2029	21	39	6	2	11	6	85
2030	25	47	7	3	11	9	102
2031	29	54	8	3	12	9	115
Total	**134**	**247**	**34**	**13**	**94**	**45**	**567**



ESTIMATING ENERGY AND DEMAND IMPACTS OF ELECTRIFIED FLEET VEHICLES

Methodology

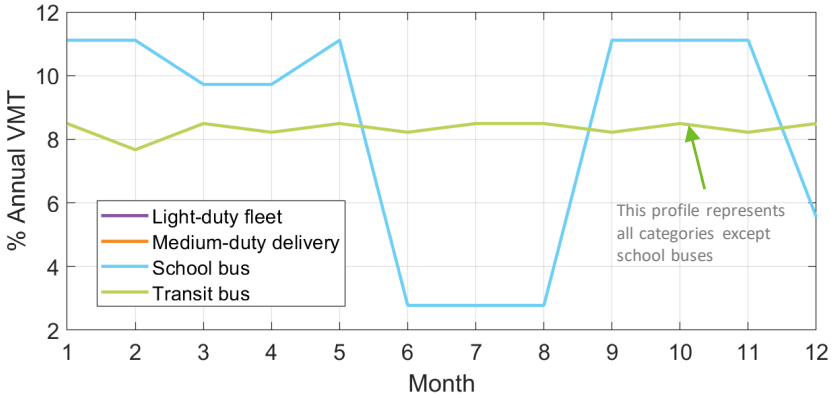
- Energy and demand impacts are based on analysis of fleet vehicle driving patterns and a sample of fleet vehicle charging data
- For each fleet vehicle class the following inputs were developed
  - Annual vehicle miles traveled (VMT)
  - Monthly allocation of VMT
    - Reflects seasonal driving patterns
    - Allocations for monthly VMT to weekdays/weekends
  - Hourly allocation of daily charging, by month
    - Shapes for Weekdays and weekends
  - Relationship between weather (daily average dry-bulb) and EV efficiency (kWh/mile)
- Monthly energy and demand impacts were developed for each fleet vehicle class
  - Develop VMT assumptions for all days within a month
  - Apply temperature sensitive efficiency relationships to get daily energy
  - Apply daily charging shapes to allocate charging to hours
  - Monthly energy impacts stem from the same 30 year normal period used in the load forecast
  - Monthly demand impacts result from applying the weather distribution used in the load forecast and extracting the 95th percentile
  - Scale to adoption forecast

Vehicle Miles Traveled (VMT)

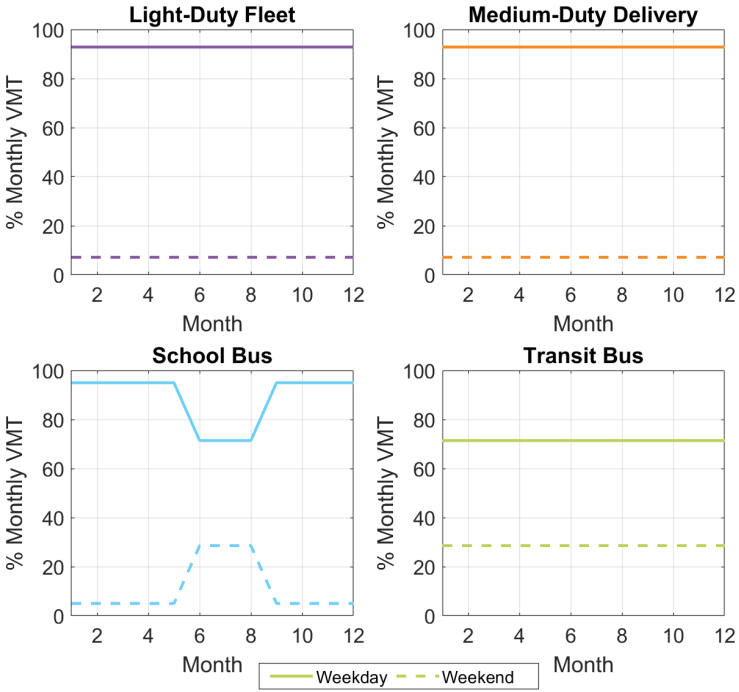
Annual VMT

Vehicle Category	Average Annual VMT
School bus	11,483
Transit bus	38,488
Medium-duty delivery	13,655
Light-duty fleet	21,258

Monthly VMT Allocation

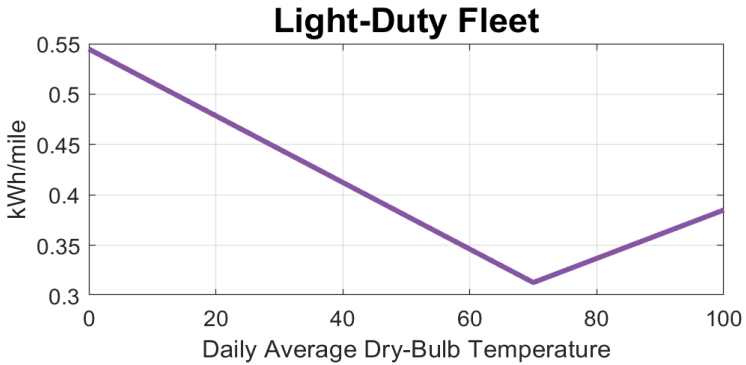


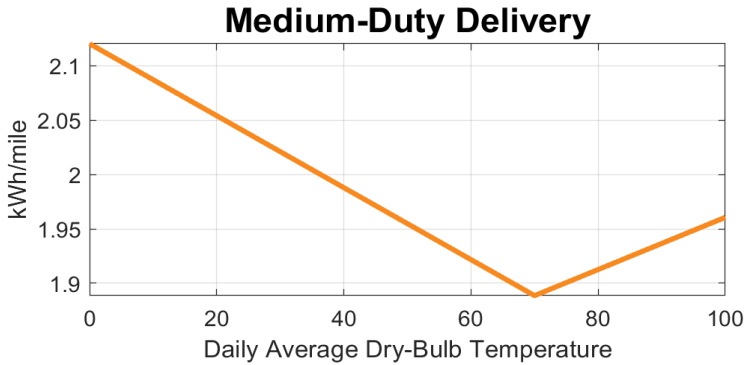
Day-type VMT Allocation

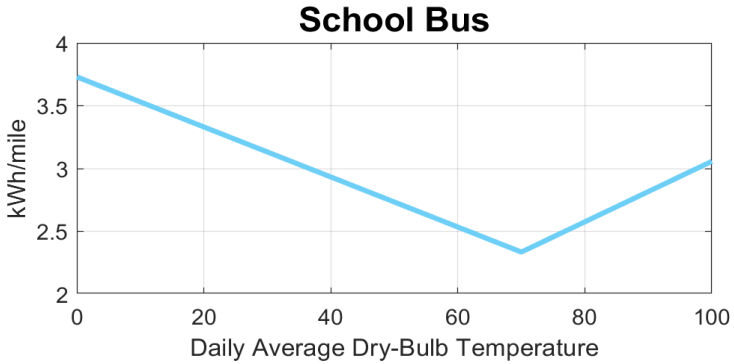


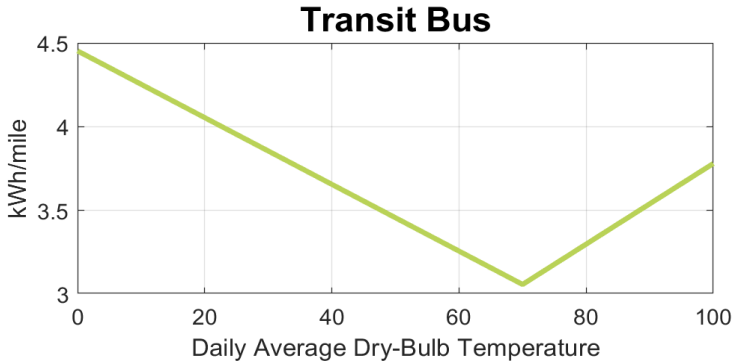
Electric Vehicle Efficiency

Energy Consumption as a Function of Daily Temperature





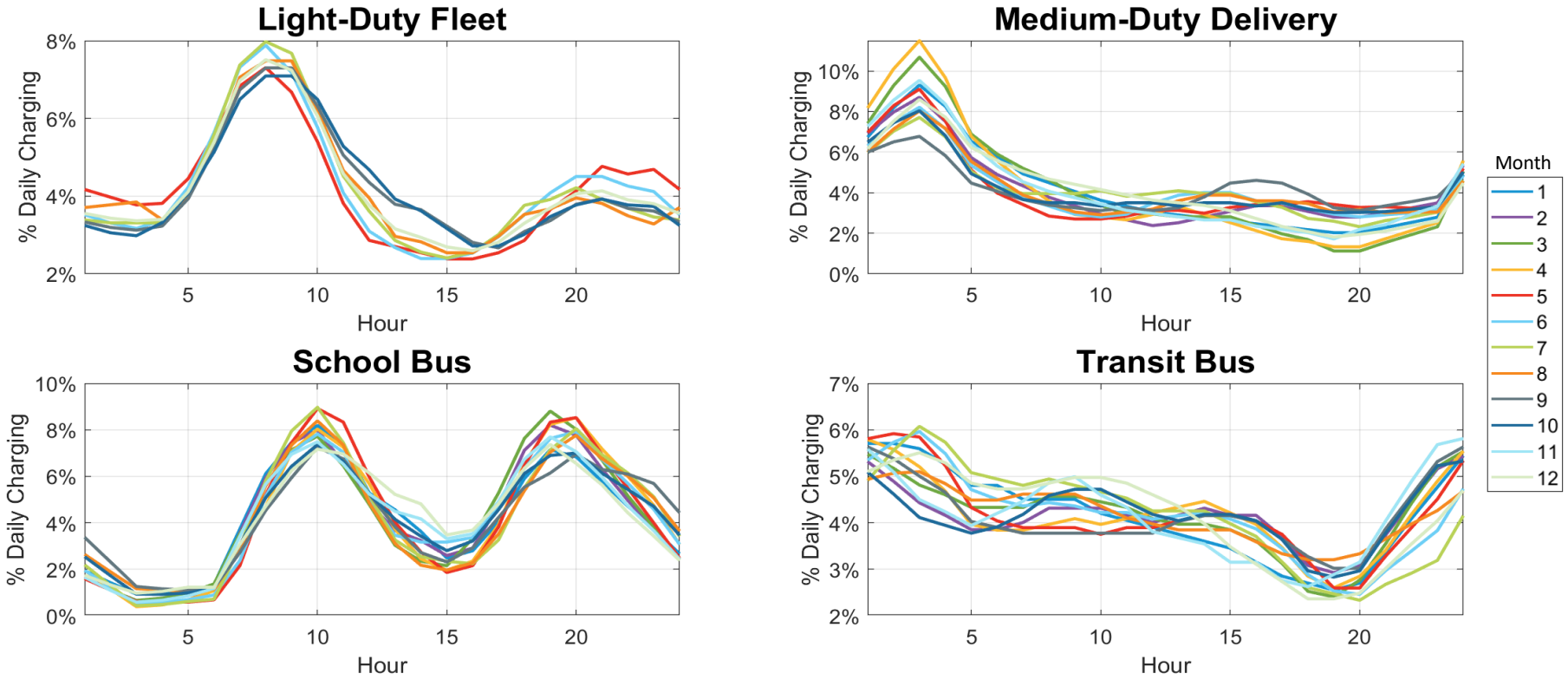




** School bus and transit bus efficiencies reflect an adjustment for the partial use of auxiliary cabin heating systems*

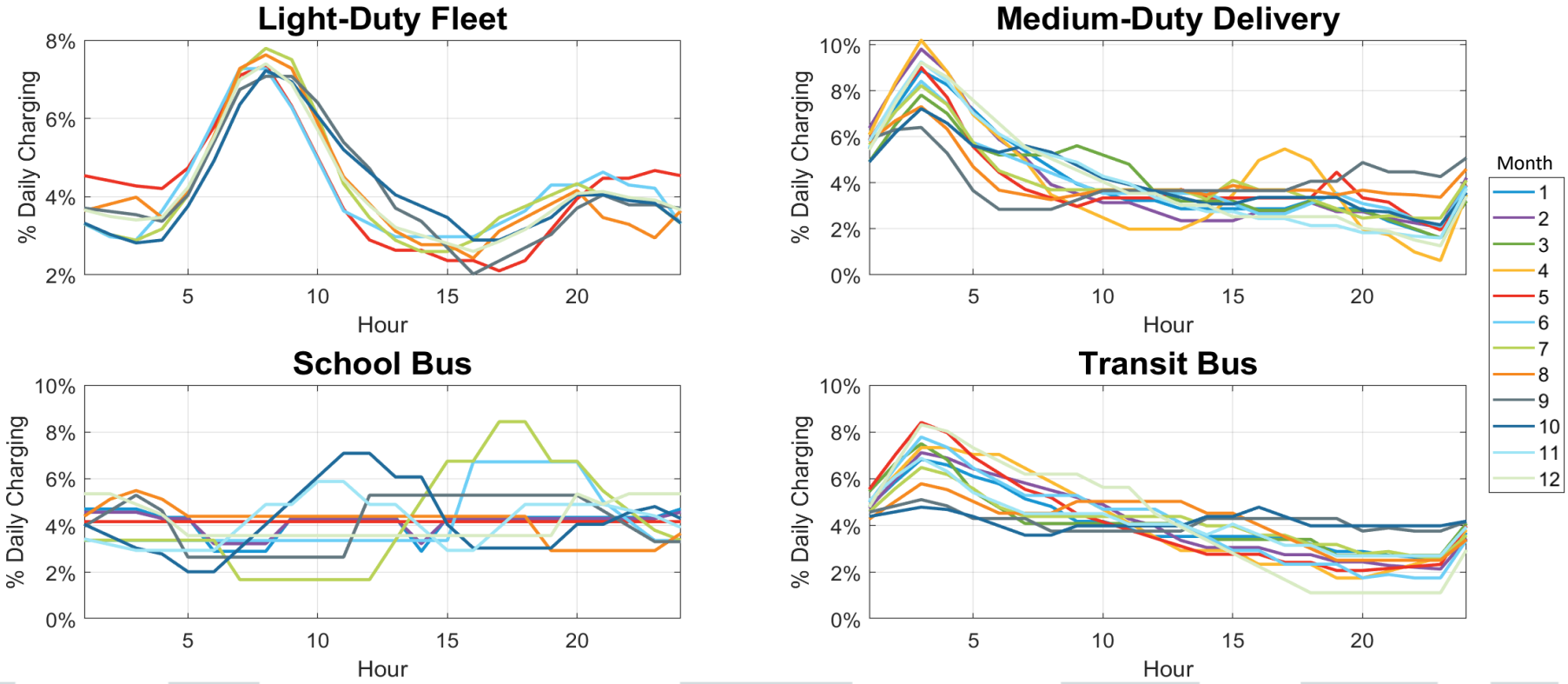
Allocation of Hourly Charging by Month

Non-Holidays & Weekdays



Allocation of Hourly Charging by Month

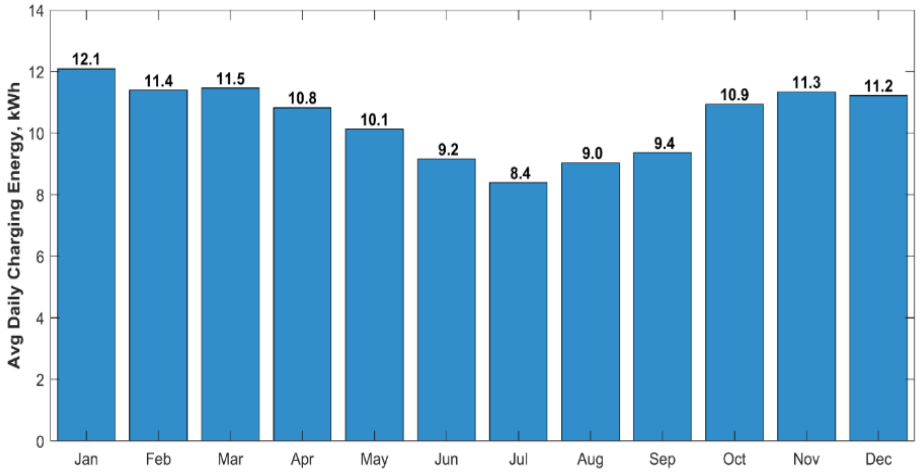
Holidays & Weekends



ENERGY FORECAST

Estimating Energy Impacts of EV Adoption

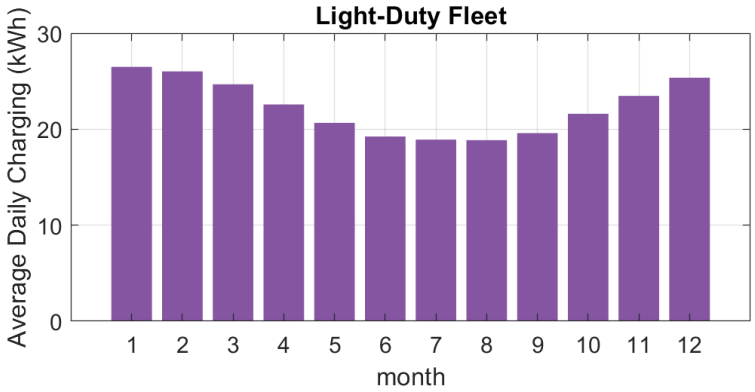
- Personal light-duty vehicles
  - Monthly energy is based on results of the ChargePoint data analysis
  - The adjacent bar chart illustrates monthly kWh/day per EV used to estimate monthly energy

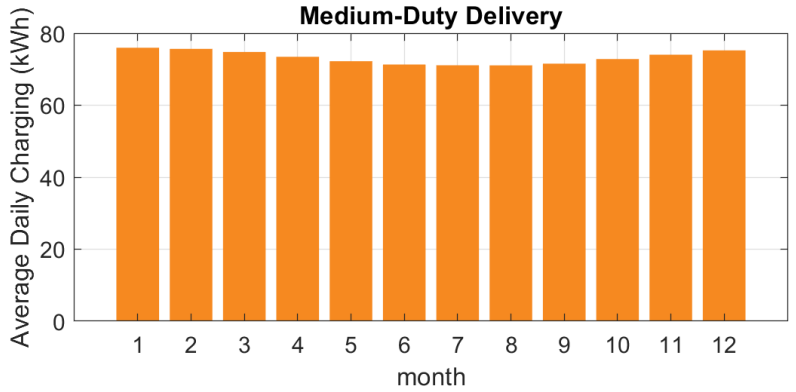


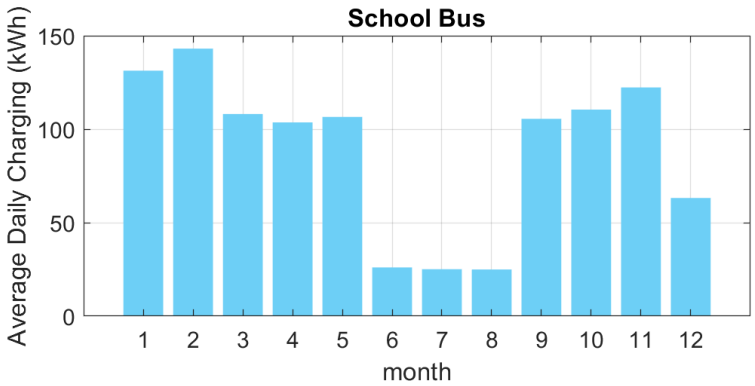
- Fleet vehicles
  - Monthly energy is calculated for each class of fleet vehicles based on state weather and VMT
  - Average monthly kWh/day for New England are shown on the following slide

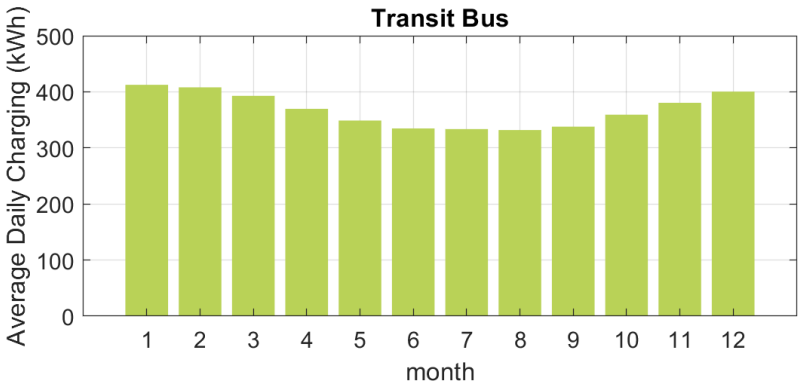
Estimating Energy Impacts of EV Adoption

Fleet EV Average Daily Energy – New England



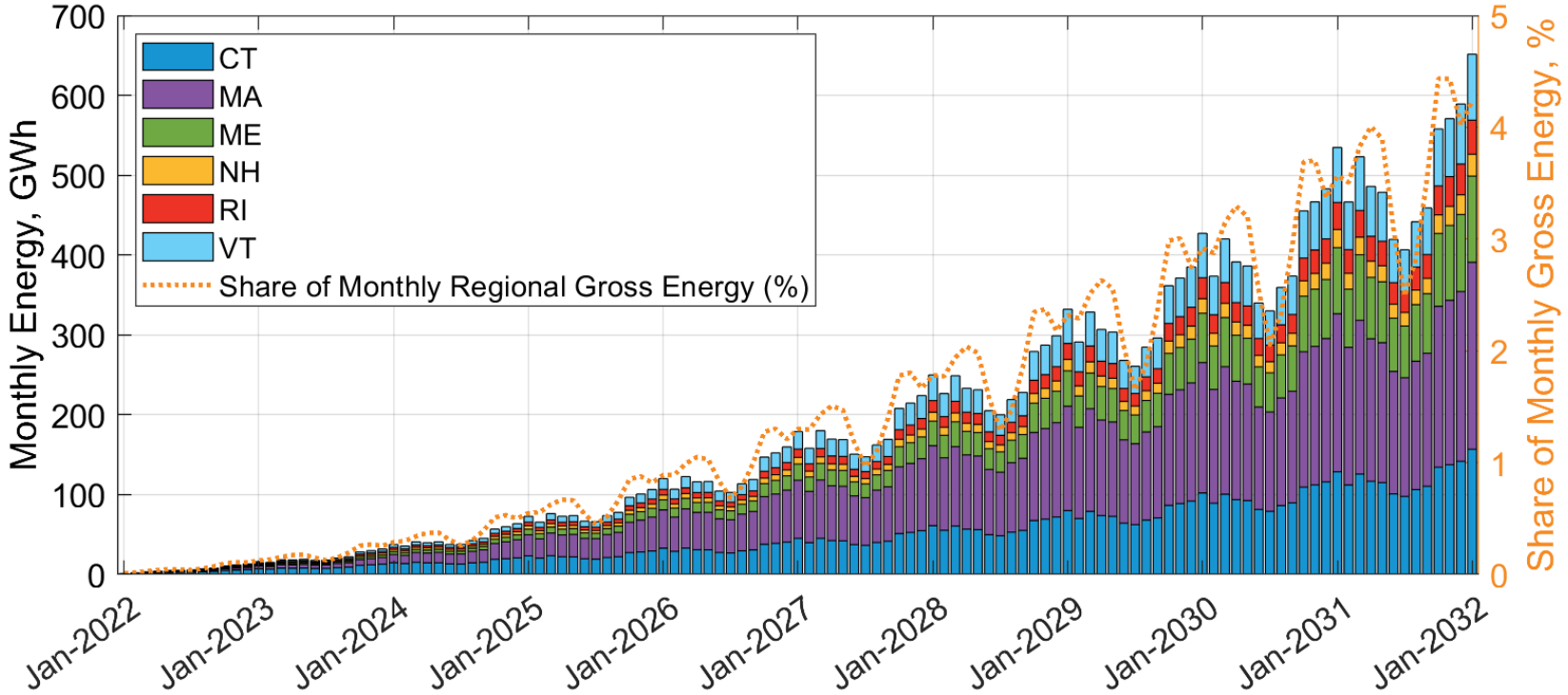






2022 Transportation Electrification Forecast

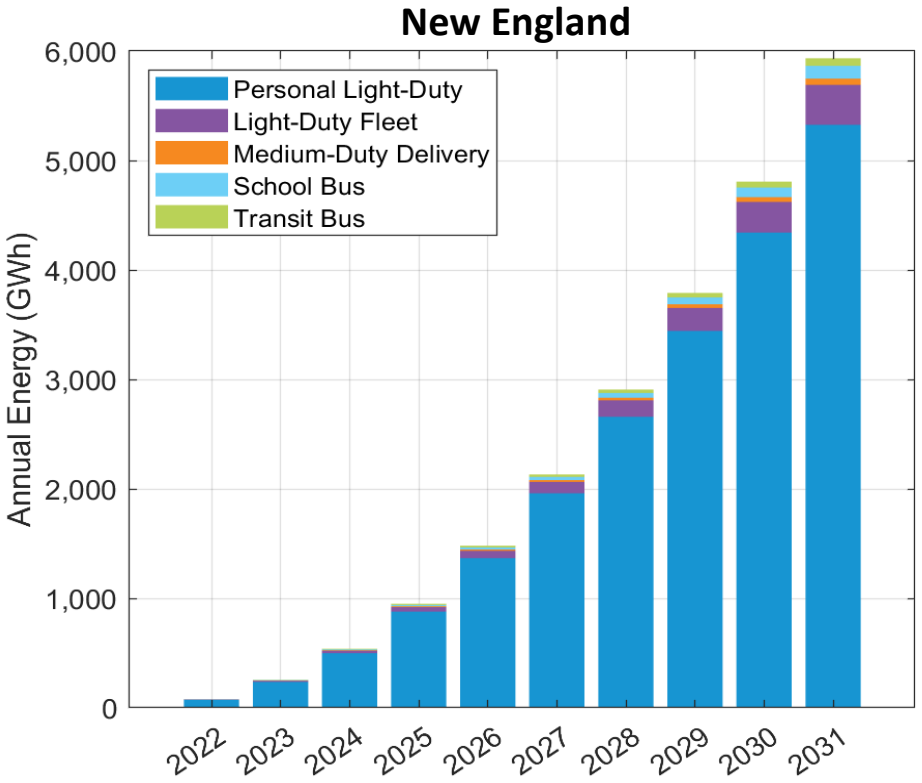
Monthly Energy



2022 Transportation Electrification Forecast

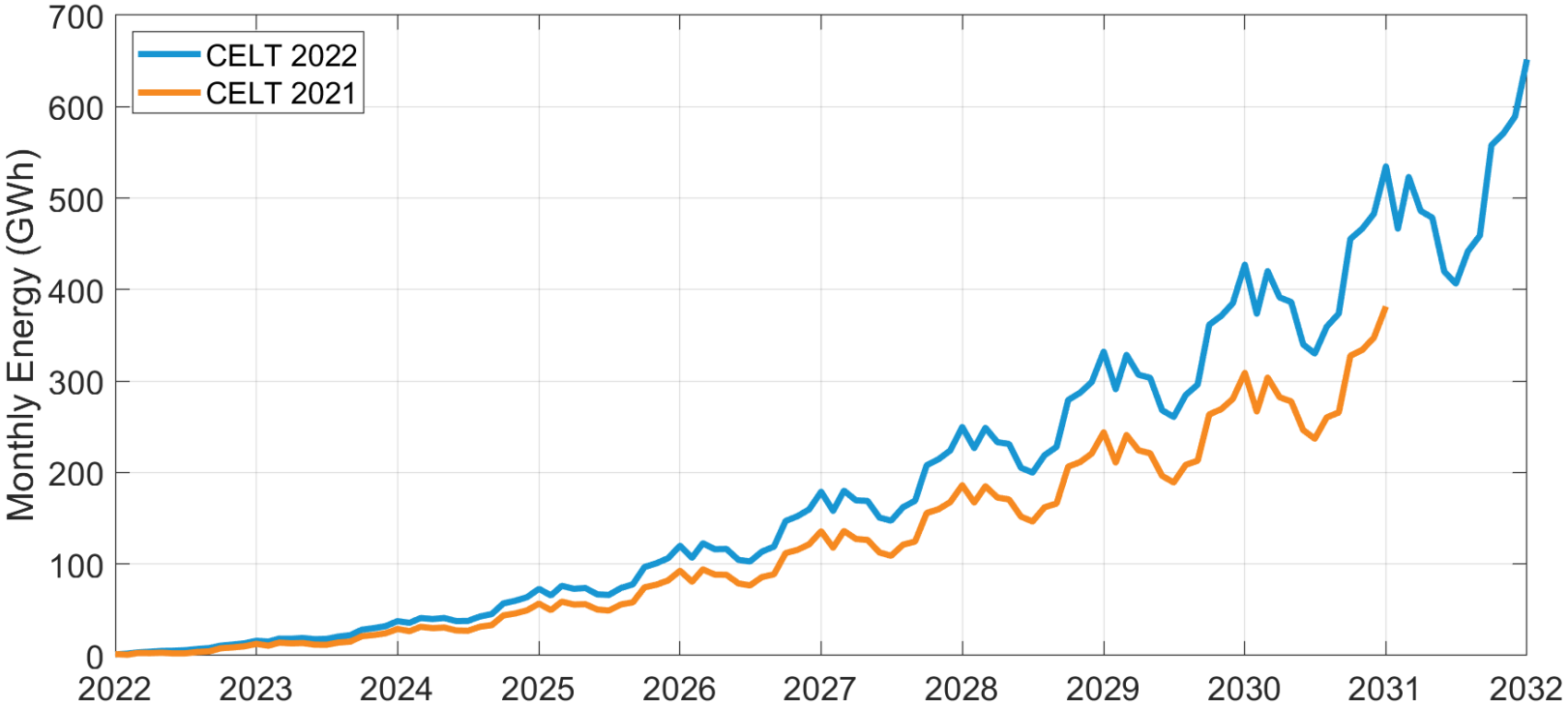
Annual Energy

Annual Energy (GWh)							
Year	CT	MA	ME	NH	RI	VT	NE
2022	36	15	7	7	6	7	78
2023	108	62	24	20	18	24	256
2024	189	176	51	35	35	52	539
2025	279	365	96	51	57	101	950
2026	389	598	161	71	87	175	1,481
2027	530	861	251	96	125	269	2,132
2028	706	1,156	372	127	173	375	2,908
2029	909	1,471	525	162	231	493	3,790
2030	1,152	1,810	718	203	300	624	4,807
2031	1,428	2,166	949	249	383	761	5,934



Transportation Electrification Energy Forecast

Comparison Between CELT 2021 and CELT 2022 for New England

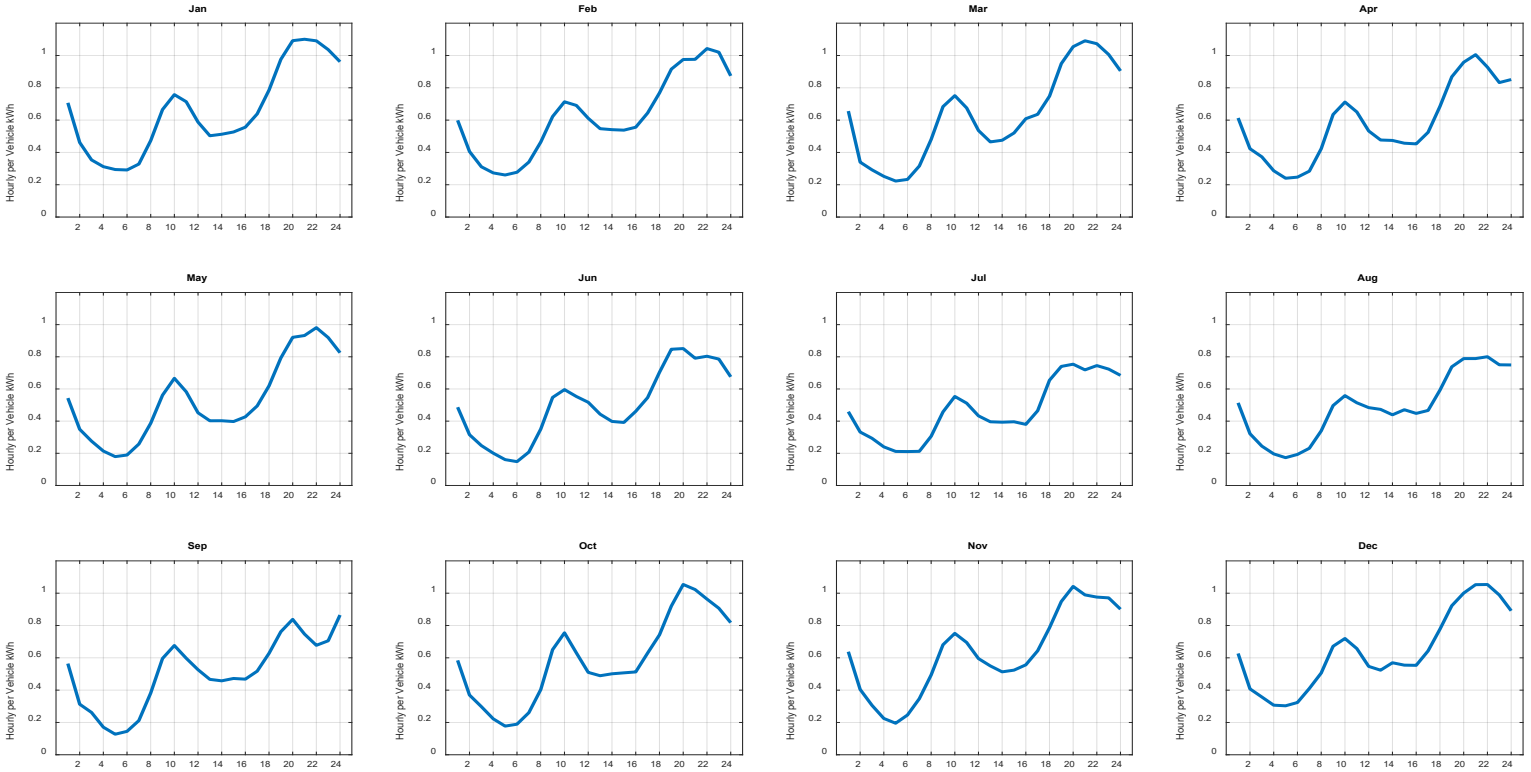


DEMAND FORECAST

Estimating Demand Impacts of EV Adoption

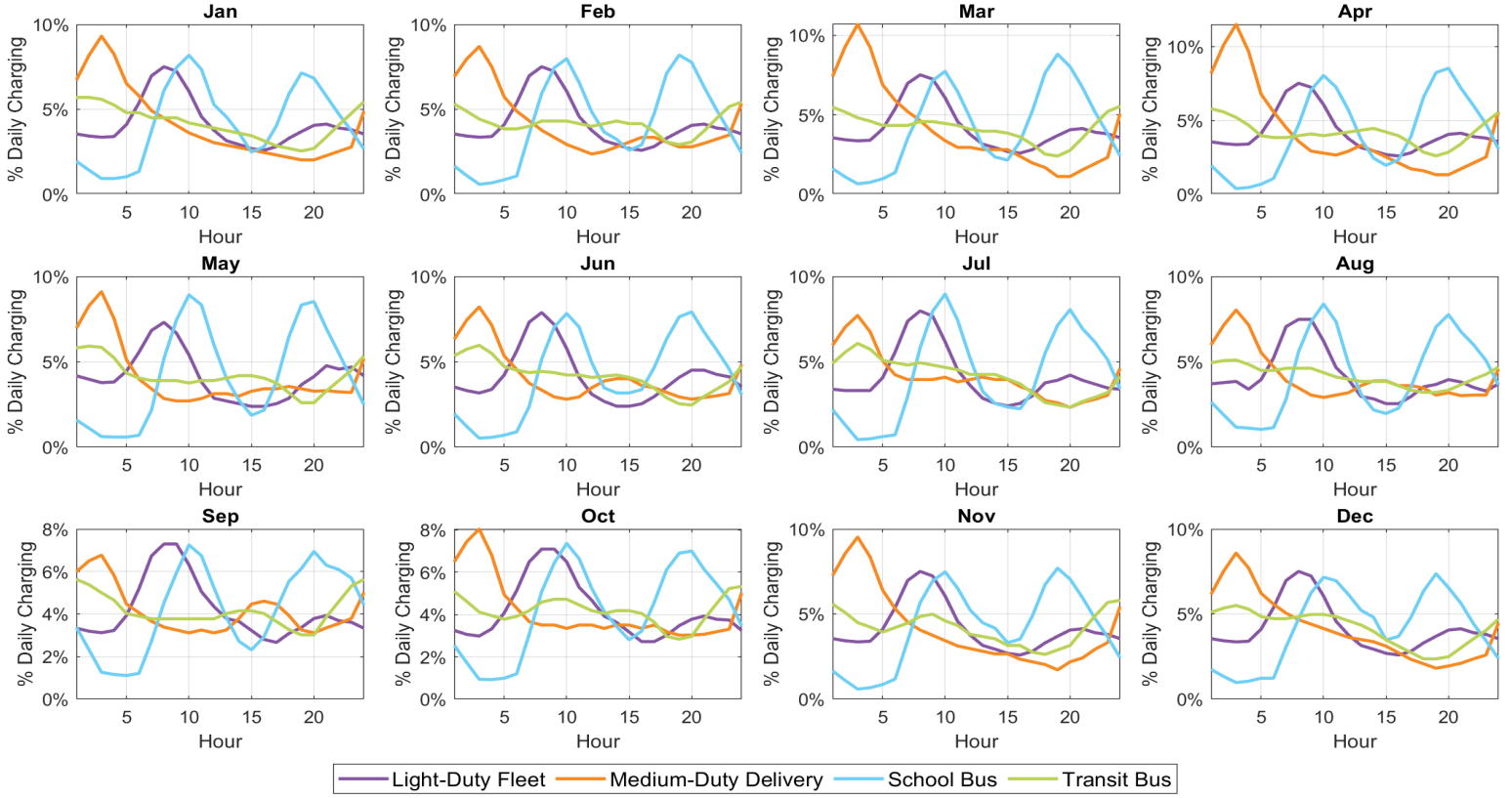
- For applications that include hourly analysis, EV demand will be modeled hourly
  - E.g., probabilistic ICR analysis
- Other forecast applications and reporting require a deterministic peak value (e.g., CELT report), and for which:
  - Winter peak demand:
    - Use the monthly average EV demand from HE 18-19
    - January-April, October-December
  - Summer demand impacts should reflect expectations of peak shifting due to increasing BTM PV penetrations (slides 32 and 33)
- Personal Light-Duty Vehicles
  - Hourly weekday EV demand profiles are used to estimate demand impacts
  - These values reflect the 75th percentile ("P75") of the aggregated hourly EV data discussed as part of the November 18, 2019 LFC (slides 10-25)
    - P75 values serve to capture more extreme values than averages (e.g., due to weather effects), but are not the most extreme data points, which could be more of an artifact of a relatively small EV sample size
- Fleet Vehicles
  - Hourly weekday allocation of daily energy is used to estimate demand impacts
  - Daily energy is derived using VMT and temperature responsiveness of electric vehicle efficiency as outlined on slide 17

Personal Light-Duty EV Hourly Demand



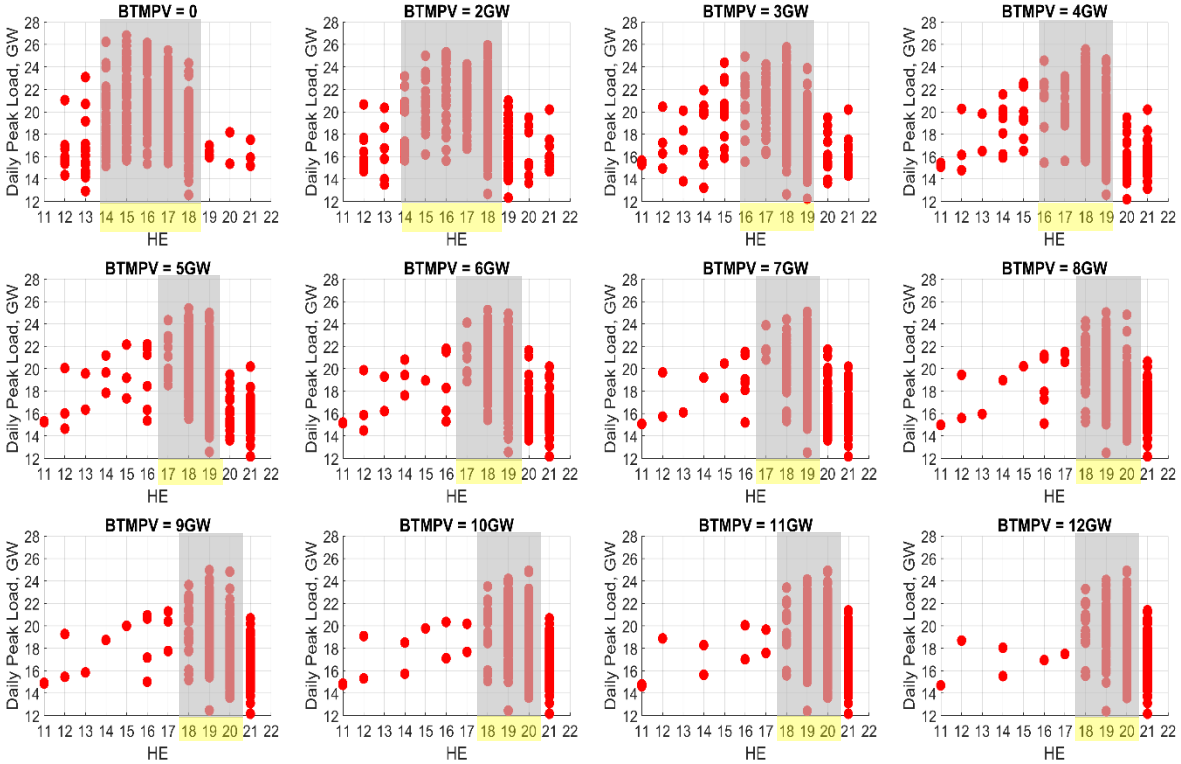
Data source: ChargePoint, Inc.

Fleet EV Hourly Demand



Summer Peak Net Load as BTM PV Increases

- Hourly net load and BTM PV data from the summers (July/August) of 2014-2021 were analyzed to simulate net loads with increasing penetrations of BTM PV
- Scatter plot shows the hour ending (HE) and magnitude (in GW) of net peak load as BTM PV increases
- Gray areas reflect estimated window of hours peak load may occur
  - Yellow areas highlight peak hours



Interaction of EV Summer Demand and BTM PV

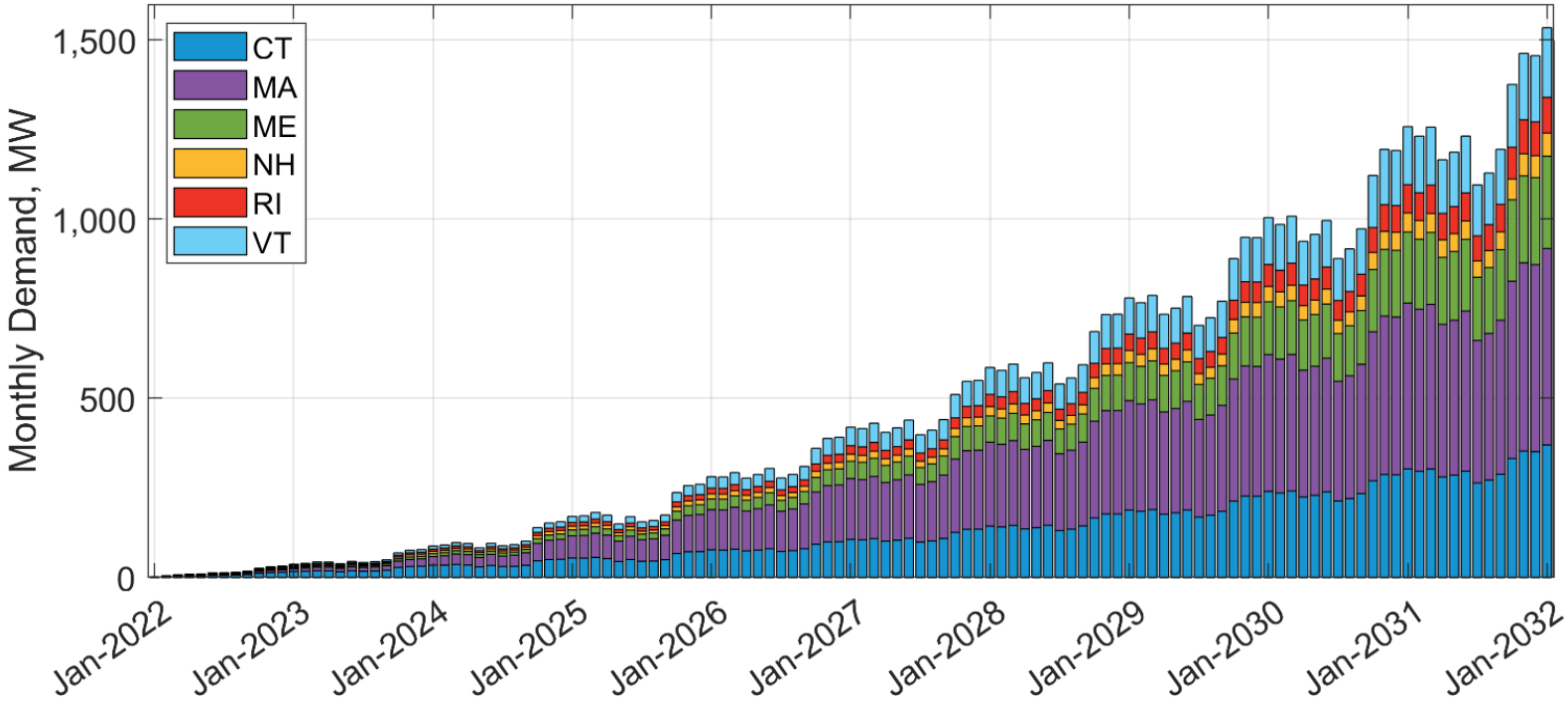
- For forecast applications and reporting that require a deterministic peak value, EV demand during the summer months is estimated as the average monthly EV demand during the summer peak hours tabulated to the right
  - May through September
  - Hours reflect effect of shifting peak demand due to BTM PV
- Used for forecasts of fleet vehicles and personal light-duty personal vehicles

Year	PV Nameplate Bin (GW)*	Summer Peak Hours
2022	5	[17,18,19]
2023	6	[17,18,19]
2024	7	[17,18,19]
2025	7	[17,18,19]
2026	8	[18,19,20]
2027	8	[18,19,20]
2028	9	[18,19,20]
2029	9	[18,19,20]
2030	10	[18,19,20]
2031	10	[18,19,20]

**Based on 2021 PV forecast values*

2022 Transportation Electrification Forecast

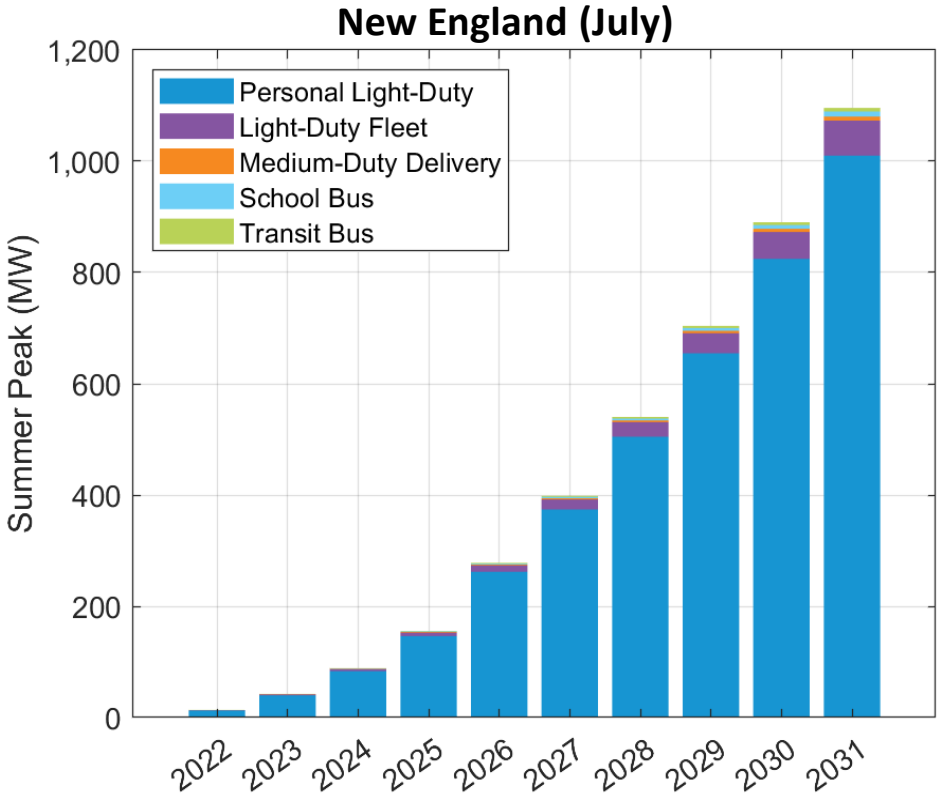
Monthly Demand by State



2022 Transportation Electrification Forecast

Summer Peak Demand

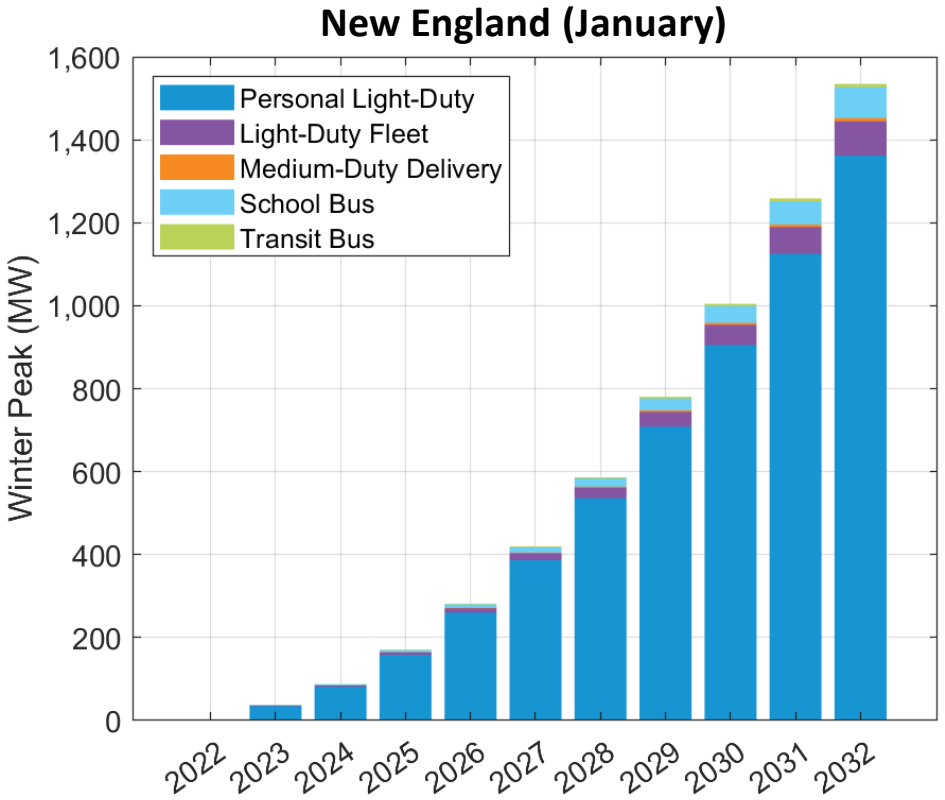
Summer Peak Demand (MW)							
Year	CT	MA	ME	NH	RI	VT	NE
2022	6	3	1	1	1	1	14
2023	18	10	4	3	3	4	43
2024	31	29	8	6	6	9	89
2025	46	60	16	8	9	17	156
2026	73	112	30	13	16	33	278
2027	99	161	47	18	23	51	399
2028	131	215	69	23	32	70	540
2029	169	273	98	30	42	93	704
2030	214	334	133	37	55	117	890
2031	264	398	176	45	70	142	1,096



2022 Transportation Electrification Forecast

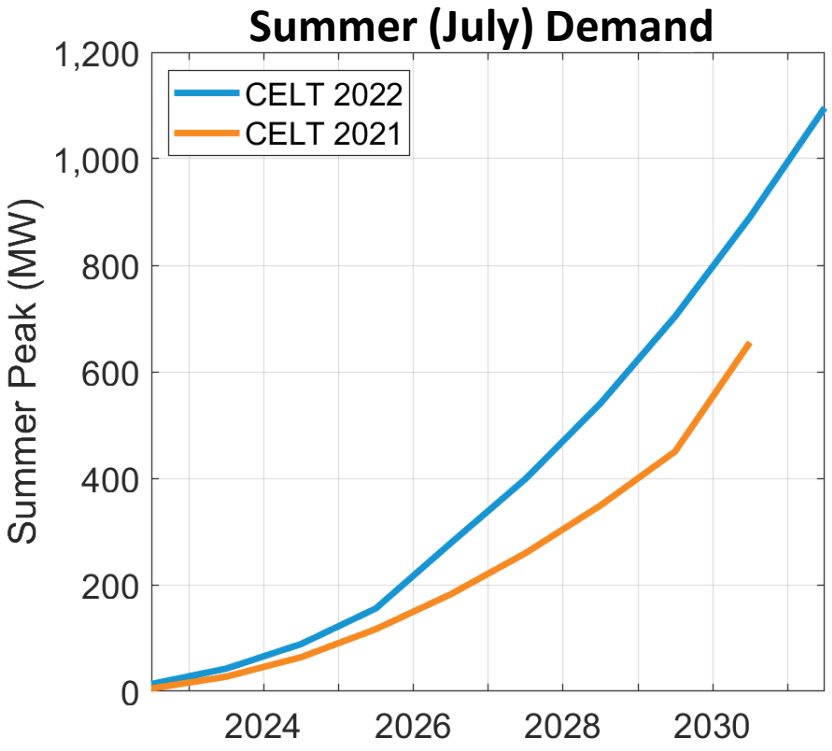
Winter Peak Demand

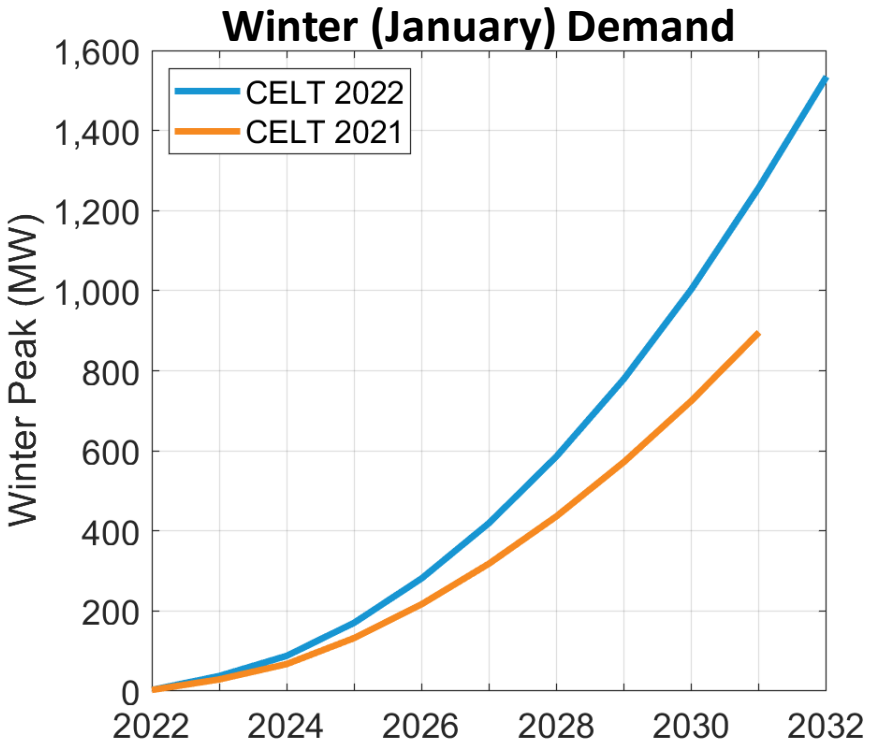
Winter Peak (MW)							
Winter Of	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**	**NE**
2022/23	17	8	3	3	3	3	38
2023/24	35	24	8	7	6	8	88
2024/25	55	62	17	10	10	17	171
2025/26	78	112	30	14	16	32	282
2026/27	107	170	48	19	24	52	420
2027/28	144	234	73	26	34	75	586
2028/29	188	305	106	34	46	101	780
2029/30	241	382	147	43	61	131	1,004
2030/32	303	463	198	53	79	162	1,258
2031/32	370	548	258	64	100	195	1,535



Transportation Electrification Demand Forecast

New England Comparison Between CELT 2021 and CELT 2022*





** CELT 2021 values have been adjusted to begin accumulating 2022*

Transportation Electrification Forecast

New England Comparison Between CELT 2021 and CELT 2022*

Summer Peak (July) MW			
Year	CELT 2021*	CELT 2022	Change
2022	5	14	8
2023	27	43	15
2024	64	89	25
2025	117	156	39
2026	182	278	96
2027	259	399	139
2028	349	540	192
2029	450	704	254
2030	655	890	235
2031		1,096	

Winter Peak (January) MW			
Winter Of	CELT 2021*	CELT 2022	Change
2022/23	29	38	8
2023/24	67	88	21
2024/25	133	171	38
2025/26	217	282	65
2026/27	318	420	101
2027/28	437	586	150
2028/29	573	780	208
2029/30	726	1,004	279
2030/32	896	1,258	362
2031/32		1,535	

Annual Energy GWh			
Year	CELT 2021*	CELT 2022	Change
2022	51	78	27
2023	185	256	71
2024	406	539	133
2025	724	950	226
2026	1,123	1,481	358
2027	1,594	2,132	538
2028	2,147	2,908	761
2029	2,762	3,790	1,029
2030	3,458	4,807	1,349
2031		5,934	

** CELT 2021 values have been adjusted to begin accumulating 2022*

*** All values shown are rounded to the nearest MW or GWh*

Final Transportation Electrification Forecast

Reporting and Publications

- The final 2022 transportation electrification forecast described herein is included in CELT 2022
  - All gross and net, energy and demand forecasts reported in both 2022 CELT* and in the 2022 Forecast Data workbook** are inclusive of transportation electrification
  - Breakout of annual energy and seasonal demand are reported in 2022 CELT Section 1.7, and 2022 Forecast Data worksheet 16

- For probabilistic ICR studies, the transportation forecast is modeled hourly as a load addition
  - Hourly demand based on the demand plots illustrated on slides 30 and 31, scaled up by the monthly forecasted EV adoption in each state

- For the 2022 forecast, the state energy and demand transportation electrification forecasts are allocated to ISO Load Zones and Regional System Plan (RSP) Subareas based on information obtained during the ISO's annual Multiregional Modeling Working Group (MMWG) network model creation process
  - Load shares by substation are submitted by Transmission Owners, as described in Section 2.3 of the Transmission Planning Technical Guide Appendix J: Load Modeling Guide

** Available on the ISO-NE CELT Report webpage: https://www.iso-ne.com/system-planning/system-plans-studies/celt/*

*** Available on the ISO-NE Load Forecast webpage: https://www.iso-ne.com/system-planning/system-forecasting/load-forecast/*