Concord Greenhouse Gas Emissions Reduction Strategy Analysis

Kim Lundgren Associates, Inc.
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Overview of Project

The Town of Concord, MA voted to align its energy goals with the Massachusetts Global Warming Solutions Act of 2008 to achieve an 80% reduction by 2050 from a 2008 baseline. An interim target of a 25% reduction by 2020 was also put in place. In 2018, the Town of Concord updated their 2008 community wide greenhouse gas (GHG) emissions inventory and added another baseline study year of 2016. Kim Lundgren Associates, Inc. (KLA) was hired to standardize and conduct the inventories, analyze results, review the reduction potential of five emissions reduction strategies, and evaluate those potentials vis-à-vis a short-term 2030 GHG reduction target. The Town confirmed five specific strategies to be assessed for their potential to reduce GHG emissions. The reduction potential analysis was based on best available data and potential scenarios. This report is the culmination of that research and analysis.

Greenhouse Gas Emissions Inventory

The 2008 and 2016 GHG emissions inventories were used as a guide to identify appropriate strategies that could best aid the Town in reducing its GHG emissions. Based on the results, Town priorities, and trends that will shape future emissions profiles for Concord, five strategies were selected that pertain to reducing emissions from the Buildings, Transportation, and Electricity Generation sectors. These are the largest sources of emissions in Concord and will therefore have the greatest impact in terms of reducing emissions.

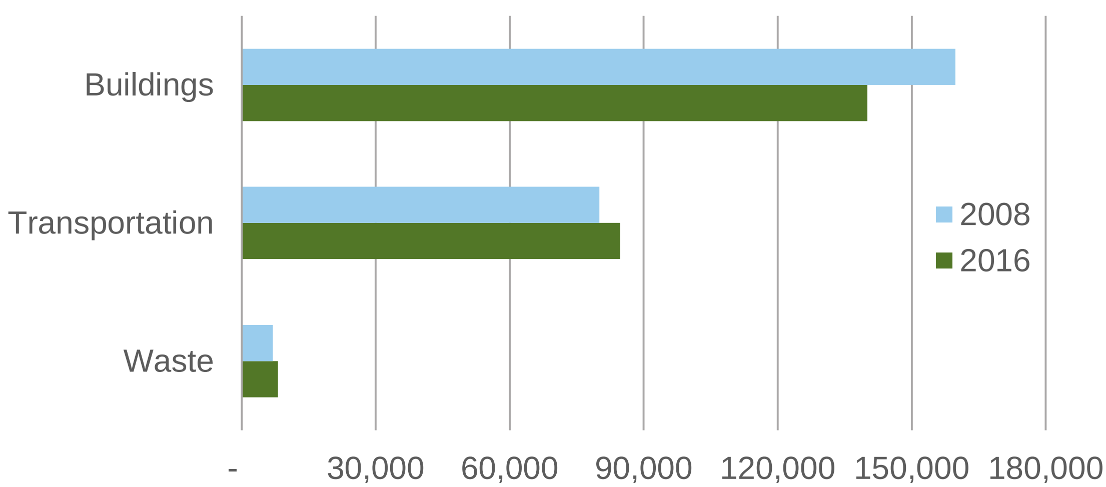


Figure 1. Concord Community GHG Emissions ($MTCO_2e$) by Sector Over Time.

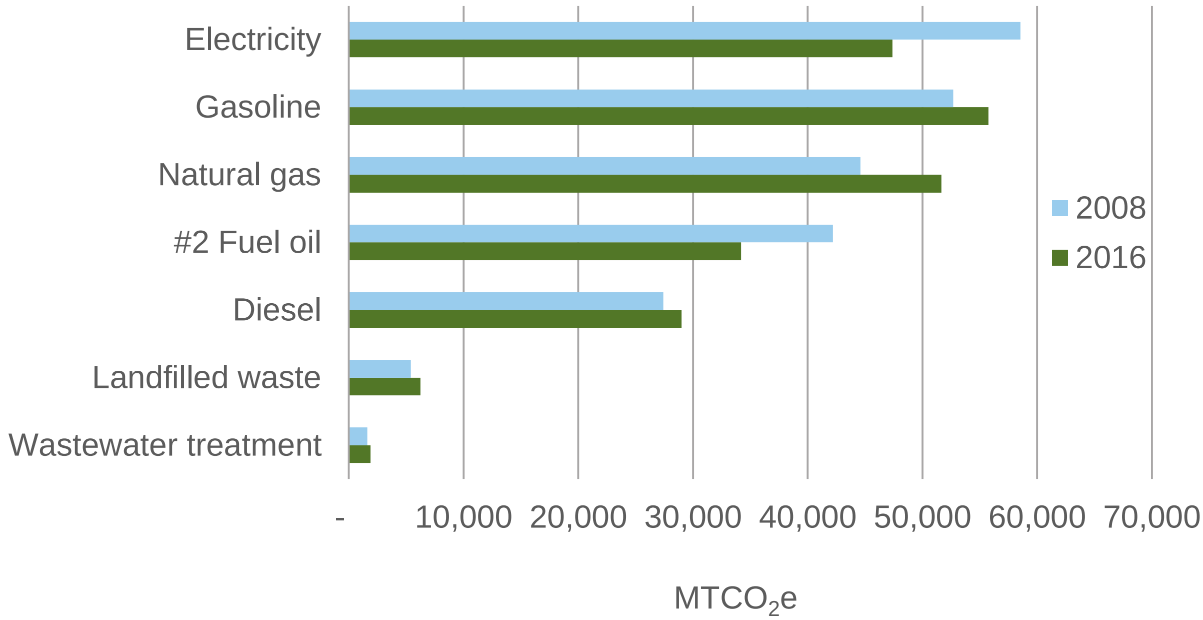


Figure 2. Shows the relative contribution of each source for both 2008 and 2016.

Reduction Targets

In 2008, GHG emissions in Concord totaled 246,890 metric tons of carbon dioxide equivalent (MTCO_2e). An 80% reduction of 2008 emissions by 2050 equates to an emissions target in that year of 49,378 MTCO_2e. The 25% reduction by 2020 target equates to target emissions of 185,167.5 MTCO_2e. This more aggressive short-term target underscores the will to achieve emissions reductions sooner, with a "yearly pace" of reductions needed to meet the 2020 goal calculated at 5,143.5 MTCO_2e reduced per year. From 2020 to 2050, the "pace" of reductions needed to stay on track with the next reduction target slows to 4,526.3 MTCO_2e per year. Along this "pace", and useful for purposes of comparison with the reduction strategies outlined here, a 2030 interim target would be 139,904.3 MTCO_2e, 43.33% below the 2008 baseline and 39.94% below 2016 levels.

Proposed Reduction Strategies

The reduction strategies were identified based on the Town's GHG emissions inventory, conversations with Town staff, and research. A high-level analysis, which incorporated various assumptions and three specific scenarios, was applied to each of the strategies to determine their potential to reduce GHG emissions. The results of this analysis are estimates and are to be used only as guidance. The degree to which each strategy meets these potential reductions will depend on myriad variables associated with how local programs are designed and implemented, regional and national trends supporting or inhibiting related subject areas, and more. Of the three scenarios developed for each strategy, the low case represents a fairly reliable or conservative implementation scenario that is likely to occur in status quo. The mid case scenario was modeled more aggressively than status quo expectations, while remaining reasonably achievable with continued effort, support, and focus on reducing emissions. The high case scenario represents significant market transformation, exemplary achievement, and remarkable progress by the year 2030 in each topic area. The low and high case are therefore outer boundaries of a range of reduction potential that may be observed by the year 2030 in each area.

Finally, it is important to note that GHG emissions are not the only rationale behind implementing sustainability strategies. Each strategy brings with it a host of unique and concurrent benefits to Concord, from financial benefits to improved air quality and more. Sustainability efforts very often convey synergistic impacts with positive externalities such as beautification, increased quality of services, efficiency of use, and more that are real benefits to residents of Concord. A local action, plan, or initiative (strategy) that carries a comparably lower GHG reduction potential than some other strategy should not necessarily be passed over based on that singular consideration.

The low, mid, and high scenarios in the table below show the raw GHG reduction potential, in $MTCO_2e$, of the implementation of five strategies by the year 2030, along with what percentage decrease these amounts represent compared to the 2016 GHG inventory. For example, the low case scenario for the future impact of stronger CAFE & Other Vehicle Standards has the potential to reduce emissions in Concord by 8,253 $MTCO_2e$. 8,253 $MTCO_2e$ represents 3.5% of the 2016 Community Inventory total of 232,951 $MTCO_2e$. The potential of various strategies can be compared in this way, apples to apples, and the total potential of all 5 strategies (low, mid, and high) can be summed.

Strategy	Low	%	Mid	%	High	%
CAFE & Other Vehicle Standards	8,253	3.5	15,279	6.6	25,053	10.8
Electric Vehicle Incentives	3,913	1.7	13,797	5.9	25,934	11.1
Air-Source Heat Pump Incentives	3,865	1.7	9,333	4.0	16,061	6.9
Energy Efficient Buildings (State Goals)	14,376	6.2	10,656	4.6	11,924	5.1
Zero Carbon Electricity	10,672	4.6	34,130	14.7	54,234	23.3
Total	41,079	17.6	83,195	35.7	133,206	57.2

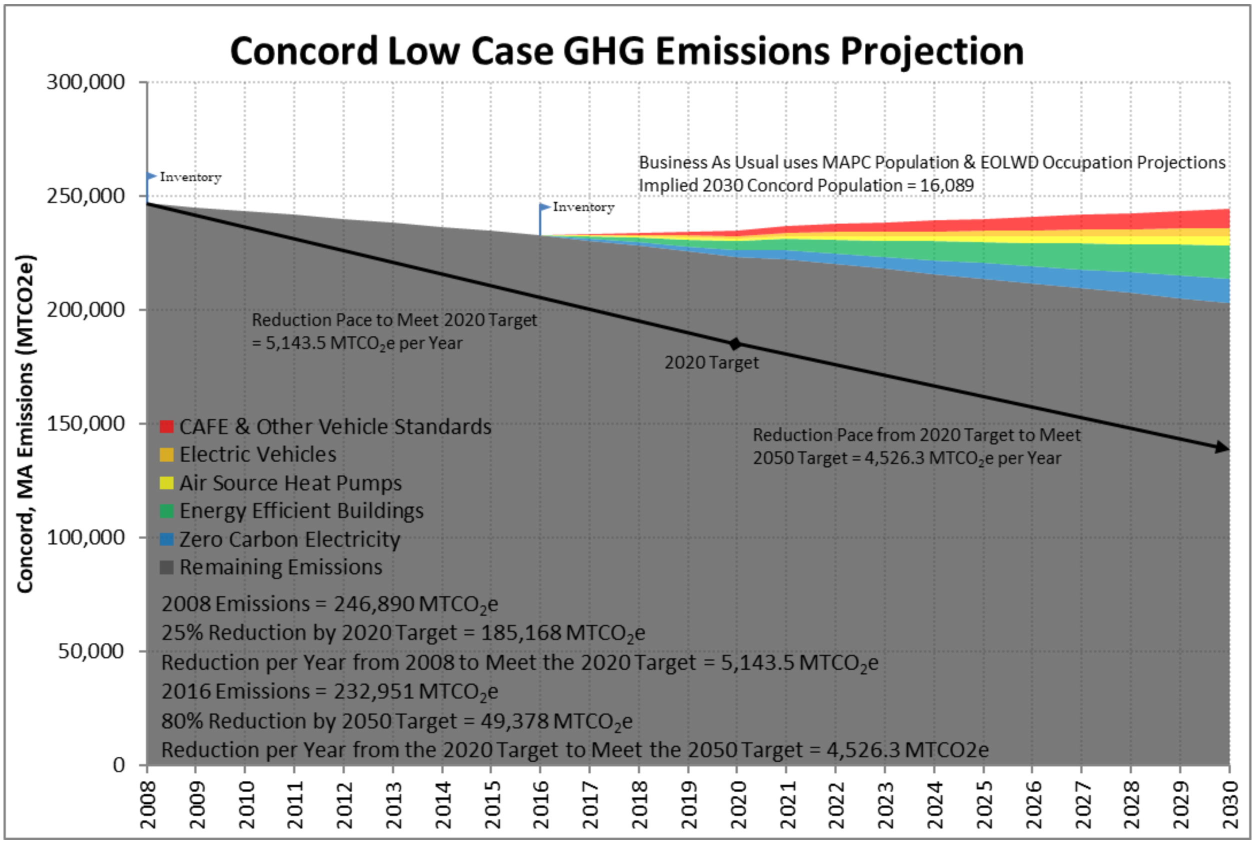
Table 1. GHG reduction potential by strategy.

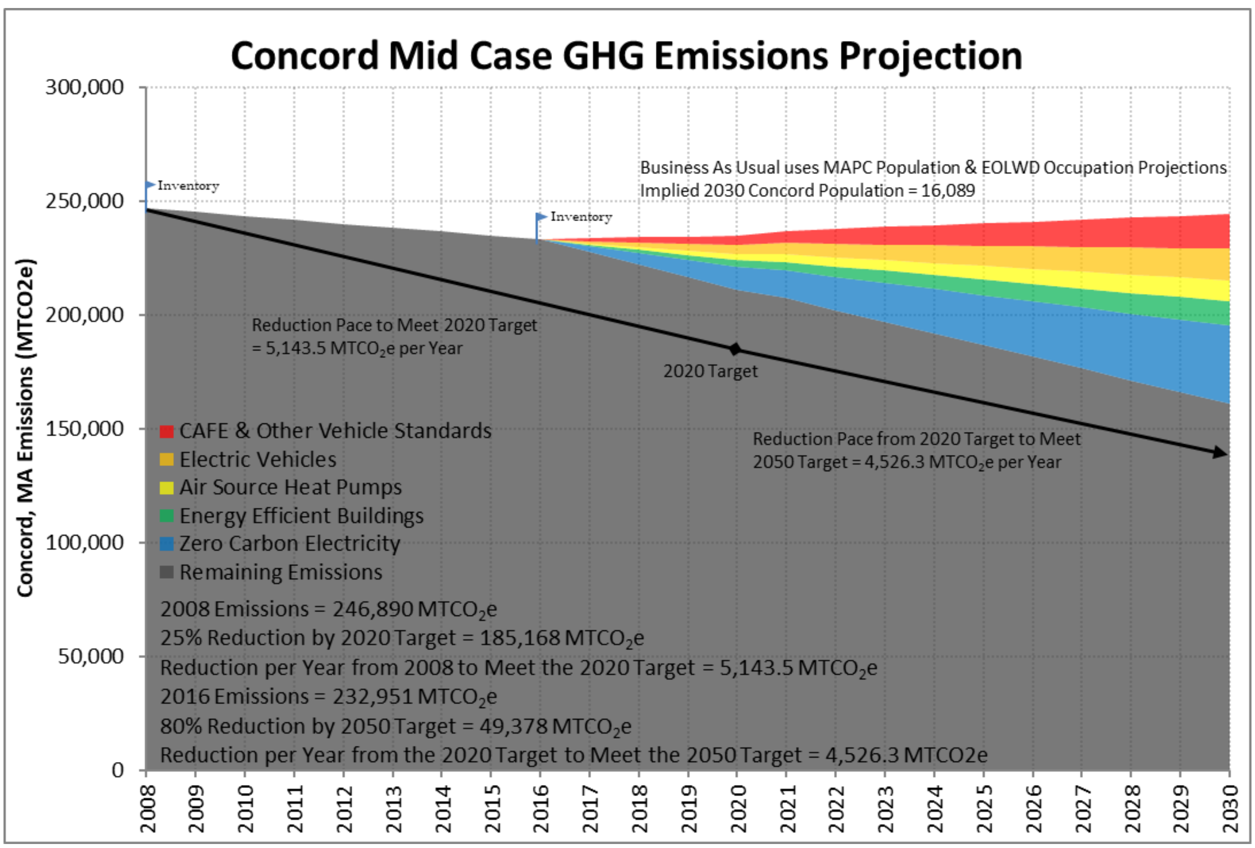
Emissions Projection & the Potential Impact of Reduction Strategies

The emissions projection forecasts a "business as usual" (BAU) growth trend, also described in the 2016 Community Inventory Report that utilizes MAPC population projections and EOLWD regional occupation projections. Additional population and employment result in an increase in energy use or emissions in all sectors. The BAU is an assumption and estimate of the effect of population growth on emissions which must be overcome to achieve the reduction target. Ultimately the BAU forecast results in an addition of 11,300 $MTCO_2e$ to Concord's emissions between 2016 and 2030.

Overcoming population growth is a challenge to meeting GHG reduction targets. However, a comprehensive set of sustainability policies and programs can overcome future growth by reducing its impact and addressing the root causes of emissions.

The following diagrams (low, mid, and high) show the emissions projections for Concord. The black line at the bottom represents the pace to meet stated reduction targets. Each colored wedge represents a reduction strategy and its estimated emissions reduction potential.


Concord Low Case GHG Emissions Projection
Concord, MA Emissions (MTCO2e)
300,000
250,000
200,000
150,000
100,000
50,000
0
Inventory
Inventory
Business As Usual uses MAPC Population & EOLWD Occupation Projections
Implied 2030 Concord Population = 16,089
Reduction Pace to Meet 2020 Target
= 5,143.5 MTCO$_2$e per Year
2020 Target
Reduction Pace from 2020 Target to Meet
2050 Target = 4,526.3 MTCO$_2$e per Year
CAFE & Other Vehicle Standards
Electric Vehicles
Air Source Heat Pumps
Energy Efficient Buildings
Zero Carbon Electricity
Remaining Emissions
2008 Emissions = 246,890 MTCO$_2$e
25% Reduction by 2020 Target = 185,168 MTCO$_2$e
Reduction per Year from 2008 to Meet the 2020 Target = 5,143.5 MTCO$_2$e
2016 Emissions = 232,951 MTCO$_2$e
80% Reduction by 2050 Target = 49,378 MTCO$_2$e
Reduction per Year from the 2020 Target to Meet the 2050 Target = 4,526.3 MTCO2e
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030


Concord Mid Case GHG Emissions Projection
Concord, MA Emissions (MTCO2e)
300,000
250,000
200,000
150,000
100,000
50,000
0
Inventory
Inventory
Business As Usual uses MAPC Population & EOLWD Occupation Projections
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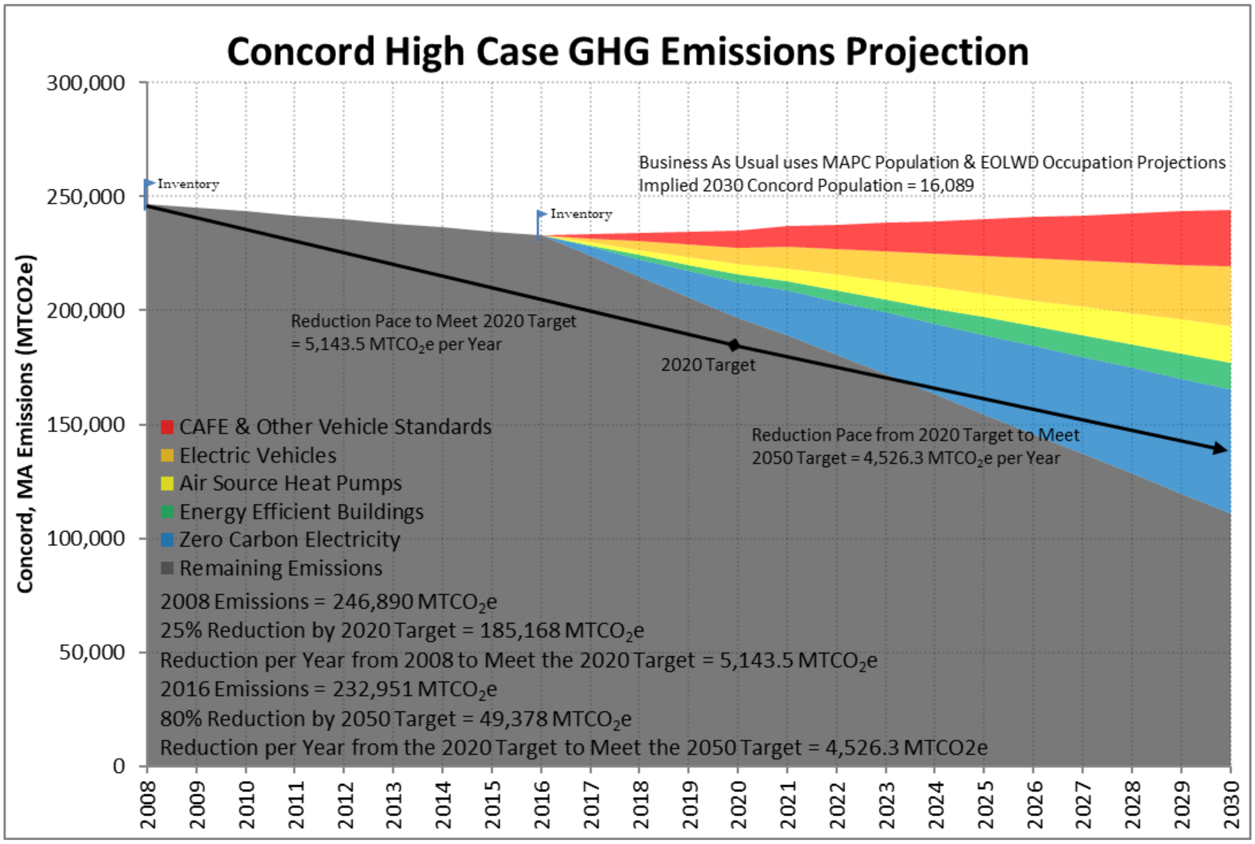

Concord High Case GHG Emissions Projection
Concord, MA Emissions (MTCO2e)
300,000
250,000
200,000
150,000
100,000
50,000
0
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
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Concord GHG Reduction Strategy: CAFE & Other Vehicle Standards

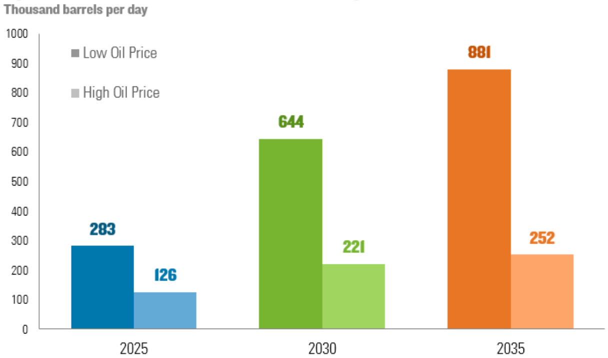
CAFÉ & Other Vehicle Standards Reduction Potential Summary Table			
Scenario	Low	Mid	High
Transportation Sector GHG Emissions Reduction by 2030	8,253 $MTCO_2e$	15,279 $MTCO_2e$	25,053 $MTCO_2e$
% Reduction of 2016 Transport Emissions (84,754 $MTCO_2e$)	9.7%	18.0%	29.6%
% Reduction of 2016 Overall Inventory (232,951 $MTCO_2e$)	3.5%	6.6%	10.8%

Description of Strategy

Corporate Average Fuel Economy (CAFE) standards, first enacted by U.S. Congress in 1975, are regulations intended to improve the average fuel economy for cars and light trucks produced for sale in the U.S. Over time, CAFE standards have contributed to more efficient (higher mpg) passenger vehicles on the road. A major update in 2010 and incremental improvements through 2016 set the timetable for increased CAFE standards through 2025 and added the first fuel economy standards for medium and heavy-duty trucks. Separately, EPA greenhouse gas (GHG) tailpipe emissions regulations also apply to all vehicles, working in coordination with CAFE and medium/heavy-duty truck standards toward more efficient, less polluting vehicles. These standards together are commonly referred to as the "National Program."

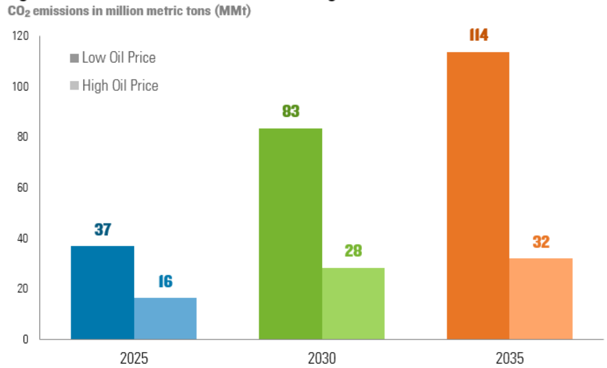
In August 2018, the DOT and EPA proposed the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule which would eliminate pending increases in CAFE and tailpipe emissions standards by freezing model year 2020 standards for both programs through model year 2026. An impact analysis of this rule estimates that freezing standards at 2020 levels will quickly result in lower fleet average miles per

Figure 2: Increase in annual US oil demand from freezing CAFE standards at 2020 levels
Thousand barrels per day



Source: Rhodium US Climate Service

Figure 3: Increase in annual emissions from freezing CAFE standards at 2020 levels
CO_2 emissions in million metric tons (MMt)



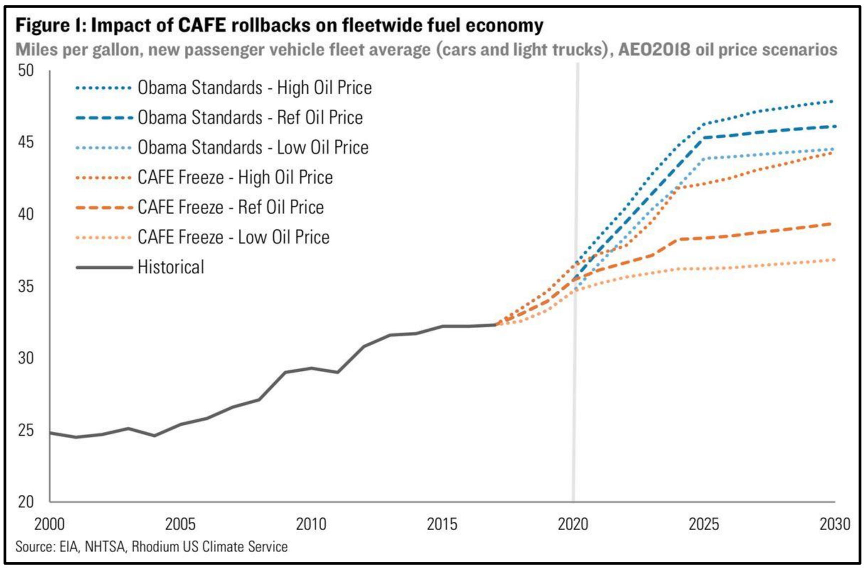
Source: Rhodium US Climate Service

gallon, with a widening performance gap through 2025.[1] The same report forecasts that US 2025 emissions will be 16 to 37 million metric tons higher as a result of the rule, with US annual oil demand increasing by 126,000 to 283,000 barrels of oil per day. A fact sheet produced by the DOT and EPA regarding this rule gives an estimate of 500,000 barrels per day increase in fuel consumption.[2]

The bottom line regarding future transportation GHG emissions in Concord is that fuel efficiency and per vehicle emissions should continue to improve until 2020, however the new rule creates a plateau effect thereafter. Prior to this rule change, emissions could be expected to decline through 2025 and beyond.

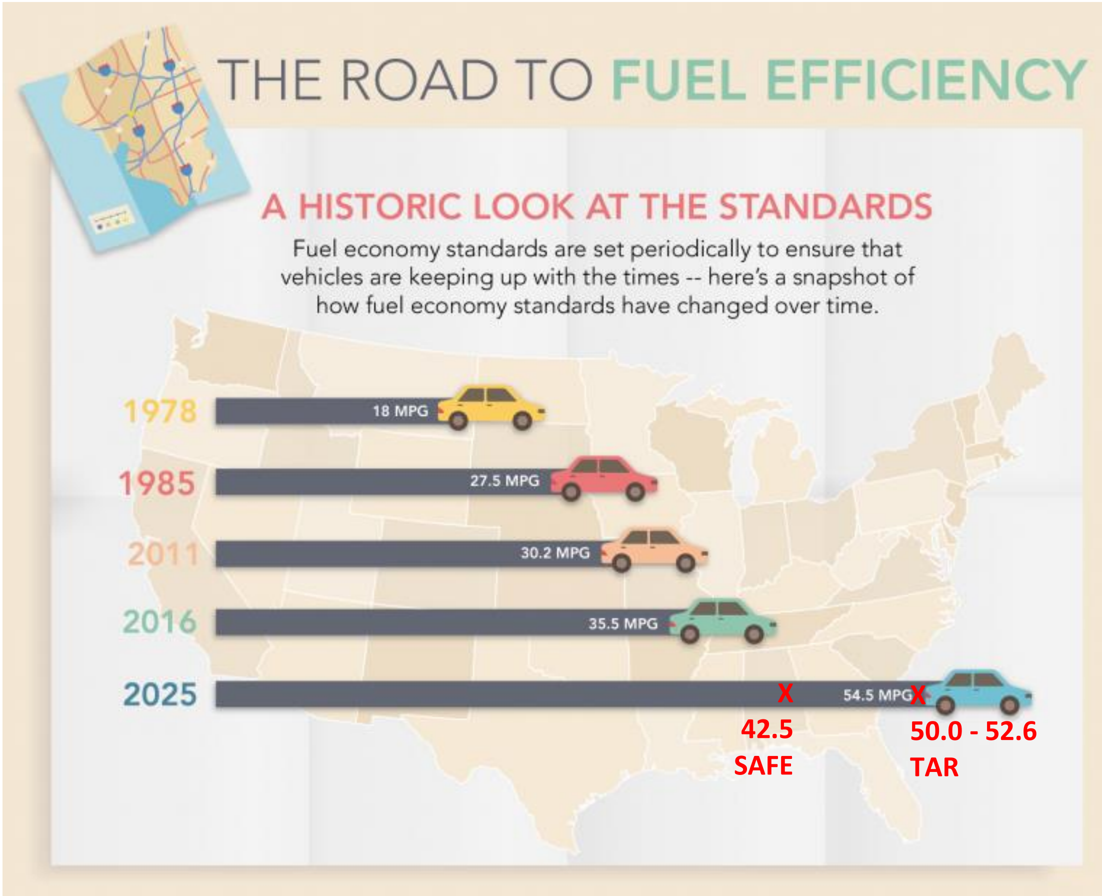
Recognizing that there is a lot of detail associated with CAFE standards[3] and vehicle GHG emissions regulations[4], let's take a look at some of the main ideas and then apply the expected benefits to Concord's community greenhouse gas inventory. Fuel efficiency standards, and the closely associated vehicle GHG regulations, are likely to be the most effective mechanism by which GHG emissions associated with transportation will be reduced in Concord, and across the US, in the coming years.

Understanding CAFE Standards - The Basics



CAFE standards affect only light duty vehicles. The Department of Energy infographic on the following page (figures representing the pre-rule change timetable) highlights the rise of CAFE standards over time for light duty vehicles and looks ahead to 2025.[5] In simplest terms, the average passenger vehicle built in 2025 would be able to go almost 3 times as far on the same amount of fuel as the average passenger vehicle built in 1978. In only 5 years, from 2011 to 2016, average efficiency increased by 17.5%. We've amended the graphic to reflect the July 2016 mid-term evaluation process Technical Assessment Report (also known as the TAR), which revised estimates for 2025 fuel savings targets downward to between 50 and 52.6 miles per gallon (mpg).[6] We've also indicated 2025 CAFE levels as determined by the proposed SAFE Vehicles final rule.

[1] https://rhg.com/research/sizing-up-a-potential-fuel-economy-standards-freeze/
[2] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/rev_fact_sheet_cafe_nprm_by_the_numbers_003-tag.pdf
[3] http://www.nhtsa.gov/fuel-economy
[4] https://www.epa.gov/regulations-emissions-vehicles-and-engines
[5] http://energy.gov/articles/545-mpg-and-beyond-fueling-energy-efficient-vehicles
[6] https://www.nhtsa.gov/corporate-average-fuel-economy/light-duty-cafe-midterm-evaluation



While the overall CAFE mpg standards for passenger cars referenced on the infographic are a decent rule of thumb, there is a lot of detail "under the hood" in CAFE regulations such as the actual formulae for a manufacturer's yearly CAFE number, penalty fees for CAFE shortfall and/or CAFE credits, gross vehicle weight rating limitations, a Gas Guzzler Tax for cars that get less than 22.5 mpg, and more.

EPA United States Environmental Protection Agency

Office of Transportation & Air Quality
EPA-420-B-14-015
March 2014

MPG: Label Values vs. Corporate Average Fuel Economy (CAFE) Values

Label MPG	CAFE MPG
1. Examples (MPG for average new car)	
• Today (MY 2014): 24 • 2025: 40	• Today (MY 2014): 31 • 2025: 50
2. Where you'll find it	
• On the Fuel Economy and Environment Label that is part of the window sticker on new vehicles on auto dealership lots • Websites: Fueleconomy.gov – EPA/DOE comprehensive vehicle website—and other vehicle search sites • Labels provide a single combined value, as well as separate city and highway values; automakers and/or dealers sometimes display only the highest of these three values	• Corporate Average Fuel Economy regulations—The average fuel economy of a manufacturer's annual fleet of vehicle production must be at or above the defined standard ; see "Summary of Fuel Economy Performance" for details • Press articles about these regulations
3. Purpose	
• To provide consumers with a real-world MPG estimate they can use to compare different vehicle models	• To reduce energy consumption by increasing the fuel economy of cars and light trucks • Regulatory tool -- Vehicle manufacturers are required to comply with the CAFE standards, which increase every year, per the Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards

Without going into every detail of these fuel efficiency regulations, it's important to note that the CAFE mpg values are different than the "window sticker" fuel economies consumers see at car dealerships. In a nutshell, the mpg test for CAFE is different than the mpg test for dealer window stickers. The CAFE test uses ideal driving conditions, such as a flat/smooth surface and minimal braking, whereas window sticker tests use real world driving conditions to model fuel efficiency. Dealership sticker mpg values are more reliable and are generally 20-25% lower than CAFE values.[7] Starting with 2008 model year vehicles, the EPA has overseen the protocol for mpg figures presented to consumers which more closely represents today's traffic, road conditions, and air conditioner usage. The same vehicle will have two different mpg ratings for different purposes, and the dealer figures are more useful for our estimates. This means that the 2025 average mpg target for new cars is more realistically in the **31.8-34 mpg range**, not the 42.5 mpg CAFE value proposed by the SAFE Vehicles Rule. A more realistic mpg on the original 54.5 mpg CAFE value for 2025 would have been 40.8 - 43.6 mpg.

[7] https://nepis.epa.gov/Exe/ZyPDF.cgi/P100IENA.PDF?Dockey=P100IENA.PDF

Medium and Heavy-Duty Vehicles

Rules for this category of vehicles are completely different than CAFE standards. Until 2014, there have never been fuel efficiency standards for this category of vehicle in the United States. New regulations involving fuel efficiency and also greenhouse gases have been implemented in two phases: 2014-2018 (phase one) and 2018-2027 (phase two). The phase two regulations also include standards for trailers attached to semi-trucks, requiring trailers to likewise pitch in with the performance of the trucks that haul them.[8] The final outcome of these regulations is as follows:

- **Heavy Duty Pickup Trucks and Vans:** Standards for 2018 represent an average reduction in GHG emissions of 17% for diesel vehicles and 12% for gasoline vehicles from 2010 levels. By 2027, fuel economy will improve by 16% again, compared to the 2018 standards. The final 2027 figures are therefore a 35.72% efficiency gain for diesel and 29.92% for gasoline vehicles since 2010.
- **Combination Tractors** (also known as semi-trucks): 2017 standards will achieve from 9% to 23% reduction in emissions and fuel consumption from affected tractors over 2010 baselines.[9] By 2027, fuel economy will improve by 24% again, compared to the 2017 standards.[10] The final 2027 figures are therefore a 35.16% to 52.52% increase in efficiency for combination tractors since 2010.
- **Vocational Vehicles:** 2017 standards for a wide variety of truck and bus types including delivery, refuse, utility, dump, cement, transit bus, shuttle bus, school bus, emergency vehicles, motor homes, tow trucks, and many more will achieve emission reductions of 6% to 9% from a 2010 baseline. By 2027, fuel economy will improve by 24% again, compared to the 2017 standards. The final 2027 figures are therefore a 31.44% to 35.16% increase in efficiency for vocational vehicles since 2010.
- **Trailers Pulled by Combination Tractors:** Not included under Phase 1 standards, trailers would achieve a 9% reduction in fuel consumption by model year 2027.

Vehicles on the Road

The final piece of information to consider is that although new vehicles are meeting stricter standards, it takes time for new vehicles to thoroughly supplant older models on the roadway. Obviously, vehicles are built to last for many years. The average age of cars and light trucks on the road has been increasing, with consumers hanging onto their cars and trucks for longer. The average age of cars and light trucks, according to registered vehicles, hit a record 11.6 years in 2016.[11]

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[8] http://www.nhtsa.gov.edgesuite-staging.net/About+NHTSA/Press+Releases/ci.md-hd-cafe-final-rule-08162016.print
[9] https://www3.epa.gov/otaq/climate/documents/420f11031.pdf
[10] http://www.c2es.org/federal/executive/vehicle-standards#hdv_2014_to_2018
[11] https://www.energy.gov/eere/vehicles/articles/fact-997-october-2-2017-average-age-cars-and-light-trucks-was-almost-12-years

Heavy duty vehicles exhibit mixed trends in average age by vehicle type and class, with some gross vehicle weight categories becoming "newer" and some "older" on average. Overall, the average age of commercial heavy-duty vehicles is 14.8 years as of 2015.[12]

Contribution to GHG Emissions Target

Federal fuel efficiency and GHG standards for vehicles are likely to be the largest contributing factor to reducing emissions from the transportation sector in Concord by 2030.

Given the multiple considerations of efficiency ranges for future dates, increasing average age of vehicles on the road, possible shifts in models produced by manufacturers in the future, and additional considerations such as changes in the mix of vehicles that Americans buy in the coming years, exact figures of emissions reductions are impossible to pinpoint. Thus, presenting a few scenarios (low, mid, and high) for the kinds of reductions that Concord can expect to see by 2030 is the most appropriate.

According to the 2016 GHG inventory, transportation emissions represented 36% of Town-wide emissions at **84,754 metric tons** of CO_2 equivalent emissions ($MTCO_2e$) out of a total 232,951 $MTCO_2e$ for all sectors.

The following table (condensed here) was pulled from the 2016 inventory showing a breakdown of VMT by vehicle type, mpg, and other figures used to derive the overall transportation emissions figure. Three scenarios follow regarding possible transportation emissions figures that could be observed by conducting a GHG inventory in 2030. It is helpful to see them all on one page - an explanation follows:

2016 GHG Inventory

Vehicle Type	Fuel Type	% of Vehicle Mix	VMT	MPG	Fuel Use (gallons)	MTCO2e
Passenger Vehicles	Gasoline	60.6%	85,645,523	23.4	3,660,065	32,275
Light Duty Trucks	Gasoline	32.4%	45,790,676	17.2	2,662,249	23,483
Passenger Vehicles	Diesel	0.3%	423,988	25.9	16,370	167
Light Duty Trucks	Diesel	1.3%	1,837,280	19.0	96,699	988
Heavy Duty Trucks	Diesel	5.4%	7,631,779	2.8	2,725,635	27,841
TOTAL		100.0%	**141,329,246**			**84,754**

2030 Low Scenario

Vehicle Type	Fuel Type	% of Vehicle Mix	VMT	MPG	Fuel Use (gallons)	MTCO2e
Passenger Vehicles	Gasoline	53.0%	80,817,568	28.1	2,878,119	25,379
Light Duty Trucks	Gasoline	40.0%	60,994,391	20.6	2,955,155	26,053
Passenger Vehicles	Diesel	0.3%	457,458	31.1	14,719	150
Light Duty Trucks	Diesel	1.3%	1,982,318	22.8	86,944	888
Heavy Duty Trucks	Diesel	5.4%	8,234,243	3.5	2,352,641	24,030
TOTAL		100.0%	**152,485,978**			**76,501**

[12] http://press.ihs.com/press-release/automotive/class-8-commercial-vehicles-continue-drive-overall-us-commercial-vehicle-de

2030 Mid Scenario						
Vehicle Type	Fuel Type	% of Vehicle Mix	VMT	MPG	Fuel Use (gallons)	MTCO2e
Passenger Vehicles	Gasoline	60.6%	92,406,503	30.4	3,037,689	26,786
Light Duty Trucks	Gasoline	32.4%	49,405,457	22.4	2,209,546	19,480
Passenger Vehicles	Diesel	0.3%	457,458	33.7	13,587	139
Light Duty Trucks	Diesel	1.3%	1,982,318	24.7	80,256	820
Heavy Duty Trucks	Diesel	5.4%	8,234,243	3.8	2,178,371	22,250
TOTAL		100.0%	**152,485,978**			**69,474**

2030 High Scenario						
Vehicle Type	Fuel Type	% of Vehicle Mix	VMT	MPG	Fuel Use (gallons)	MTCO2e
Passenger Vehicles	Gasoline	60.6%	92,406,503	35.1	2,632,664	23,215
Light Duty Trucks	Gasoline	32.4%	49,405,457	25.8	1,914,940	16,882
Passenger Vehicles	Diesel	0.3%	457,458	38.9	11,775	120
Light Duty Trucks	Diesel	1.3%	1,982,318	28.5	69,555	711
Heavy Duty Trucks	Diesel	5.4%	8,234,243	4.5	1,838,001	18,773
TOTAL		100.0%	**152,485,978**			**59,701**

Assumptions and Calculations

For all of the 2030 scenarios, 2030 VMT figures for Concord were modeled based on a linear growth rate of 0.64% per year applied to 2008 VMT. The 0.64% linear growth rate is an average of 0.56%, the yearly average population growth rate observed for the Town from 2008 to 2016, and 0.73%, the yearly average VMT growth rate from 2008 to 2016 (noting that proxy year data was used for VMT totals).[13] In other words, 2030 VMT is modeled to be 14.16% higher than 2008 VMT and 7.89% higher than the 2016 VMT figures. The growth in VMT are distributed across vehicle categories according to their % of vehicle mix.

In the low, or most conservative estimate, the % of vehicle mix was revised downward for passenger vehicles and that difference shifted into the light duty truck category, which increases emissions. It is important to keep in mind that the vehicle mix can change in coming years depending on consumer purchasing preferences. Automotive purchasing trends suggest that with cheaper fuel costs, American vehicle purchases shift toward larger vehicles. There is no way to predict the extent of fuel pricing trends going forward, but this shift acknowledges the trend. Keeping in mind that the opposite trend can occur at any time, the mid and high scenarios maintain the same vehicle mixes as observed in 2016 data.

Additionally, in the low or most conservative estimate, passenger vehicles and light duty trucks vehicles observe a modest increase of 20% in their fuel efficiency from 2016 to 2030. This estimate heavily weights the concept of ever-increasing age of vehicles continuing to be used as primary transportation rather than being registered but mostly garaged or used as a back-up vehicle. These figures are roughly the realistic average mpg of vehicles produced in 2016, with the CAFE average adjusted downward by

[13] http://www.concordnet.org/DocumentCenter/View/3527/Concord-2011-Energy-Master-Plan-PDF and the Concord, MA 2016 GHG Inventory.

20%. Heavy-duty trucks see a 25% increase in efficiency, less than half of the expected gains and without factoring in efficient trailers.

The mid scenario represents a compromise between the low and high scenarios, with passenger vehicles and light duty trucks seeing an increase of 30% in their fuel efficiency. Heavy-duty trucks are 35% more efficient.

The high scenario represents strong market transformation in fuel efficiency across all categories. Passenger vehicles and light duty trucks are 50% more efficient, slightly above the real-world adjusted (20-25% discount) CAFE numbers for 2025 after the implementation of the SAFE vehicle rule. With many car manufacturers ahead of CAFE regulations, a strong consumer appetite for new vehicles, and penetration of new technologies - it is entirely possible that these figures may be seen in 2030. Heavy-duty trucks are 60% more efficient, factoring in the effect of efficient trailers.

In all cases, despite future growth in overall VMT, transportation emissions are expected to decrease in Concord thanks to federal fuel efficiency and GHG emissions standards for vehicles.

Concord GHG Reduction Strategy: Electric Vehicle Incentives

Electric Vehicle Incentives Reduction Potential Summary Table			
Scenario	Low (1,000 EVs)	Mid (3,000 EVs)	High (5,000 EVs)
Transportation Sector GHG Emissions Reduction by 2030	3,913 $MTCO_2e$	13,797 $MTCO_2e$	25,934 $MTCO_2e$
% Reduction of 2016 Transport Emissions (84,754 $MTCO_2e$)	4.6%	16.3%	30.6%
% Reduction of 2016 Overall Inventory (232,951 $MTCO_2e$)	1.7%	5.9%	11.1%

Description of Strategy

Encouraging the shift toward electric vehicles (EVs) will significantly reduce GHG emissions and improve air quality in Concord. Increased adoption of EVs can be accomplished with a combined approach of:

- Converting more of the Town fleet to electric vehicles.
- Continuously expanding EV charging infrastructure throughout the community.
- Providing incentives and education for local businesses and residents.

According to the ChargeHub database[14], which draws on data from the Department of Energy's alternative Fuels Data Center, there are 149 public charging station ports (Level 2 and Level 3) within 15km of Concord.[15] 100% of the ports are Level 2 charging ports and 15% of them are offered for free. Additionally, local citizens and businesses have installed a good number of private charging stations for their everyday use. An ever-expanding network, a growing user base, and sustained supporting efforts for EV deployment are great signs that this strategy can reap strong benefits for Concord in coming years. Concord has emerged as a leader in Massachusetts and across the US in EV deployment.

[14] https://chargehub.com/en/countries/united-states/massachusetts/concord.html?city_id=3062
[15] http://www.afdc.energy.gov/fuels/electricity_locations.html

Supporting Programs

Concord has a good number of programs in place to encourage Town residents to purchase and use electric vehicles in the most effective way, unlocking the technology's full potential and saving residents money.

- The EV Level 2 Program provides a flexible $250 rebate for setting up charging stations.[16]
- The EV Miles Program provides a monthly bill rebate for residents who schedule their EV to charge off-peak.[17]
- Information about EVs is available online for Town residents including links to more resources.[18]

EV purchasers would be wise to take advantage of federal, state, and other assistance as well.

- A federal tax credit offers up to $7,500 per vehicle[19] and, for qualifying organizations, the Public Transit Innovation Program[20] or the Low or No Emission Vehicle Program[21] can provide more funds.
- Assistance and potentially more funding may be had through the Department of Energy's Clean Cities Coalition, specifically Massachusetts Clean Cities.[22]
- State programs include the MOR-EV rebate of up to $1,500 per vehicle[23] and, for qualifying organizations, the MassEVIP Program Fleets[24] or Workplace Charging[25] initiatives.
- Green Energy Consumers Alliance offers the impressive Drive Green discount program, and many dealers offer significant perks of their own for EV customers.[26]

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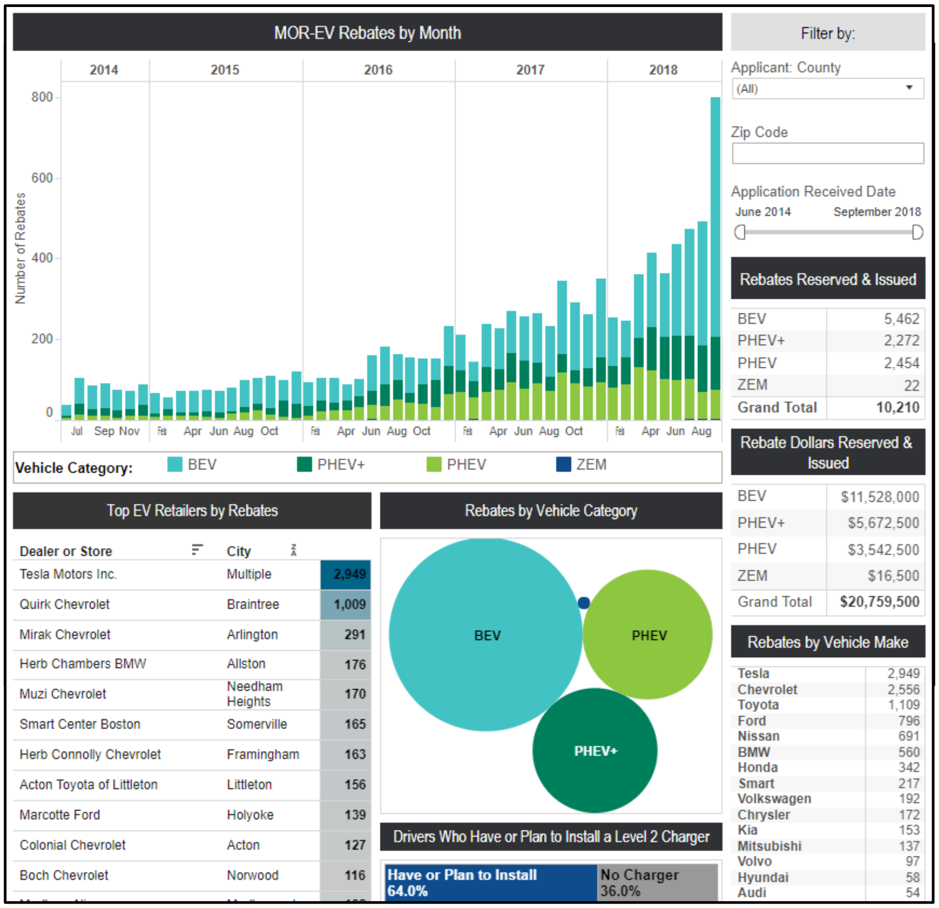
[16] http://www.concordma.gov/2233/EV-Level-2-Program
[17] http://www.concordma.gov/2240/EV-Miles-Program
[18] http://www.concordma.gov/2169/Electric-Vehicles
[19] https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d
[20] https://www.transit.dot.gov/funding/grants/public-transportation-innovation-5312
[21] https://www.transit.dot.gov/funding/grants/lowno
[22] https://www.mass.gov/massachusetts-clean-cities-alternative-transportation
[23] https://mor-ev.org/
[24] https://www.mass.gov/how-to/massevip-fleets
[25] https://www.mass.gov/how-to/massevip-workplace-charging
[26] https://www.greenenergyconsumers.org/drivegreen

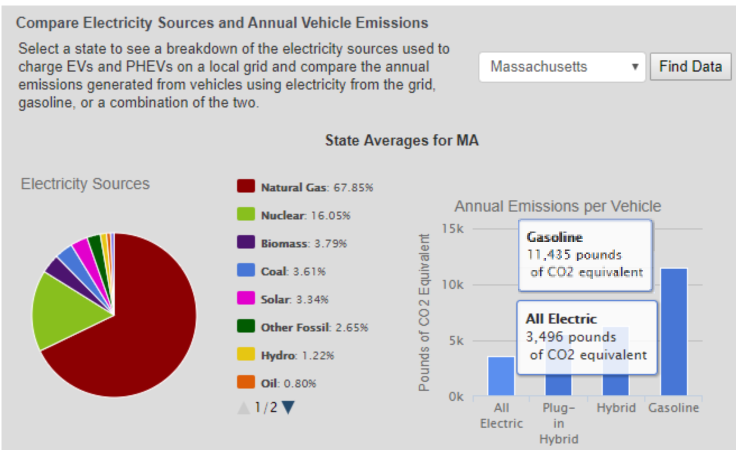


The MOR-EV Program website shows strong demand for EV rebates in Concord and the surrounding area. 158 rebate applications were received between June 2014 and September 2018 from the 01742 postal code, the third highest total among all zip codes, only slightly behind 02478 (Belmont) at 165 rebates and 02421 (Lexington) at 164. Concord had the second most rebates by zip at the end of 2017, but Lexington claimed second place during the course of the year. Middlesex County tallies over 42% of overall participation at 4,295 rebates to date, far in the lead of Norfolk County in second place at 1,419 rebates. 2018 was a strong year for the MOR-EV rebate program with all of the funding issued and reserved as of September. A major reason for the demand spike was opening the program to EV leases, with the requirement that EV leases last at least 3 years. A $2500 rebate on a three-year lease is a compelling offer. Demand for rebates went vertical in September 2018 with over 798 rebates reserved or issued. Demand was so strong in September that the left chart axis has to be resized if that month is included. 509 of those 798 rebates were captured by Middlesex County (64%). This is great news for EVs in Concord, because a strong presence in terms of other EVs and charging stations in the larger region strengthens the overall market. The EV market is moving beyond early adopters in Massachusetts, and the epicenter of the transformation lies in Concord and the surrounding areas.

Estimated GHG Emission Reductions for Concord

Strong evidence that a market shift toward electric vehicles is occurring raises confidence that EV conversion can manifest as a meaningful strategy in reducing Concord's GHG emissions. The potential number of fossil fuel vehicles converted to electric by a given year can be raised with greater confidence of meeting those targets.

The primary barriers to widespread adoption of EV technology are the price of the vehicles, the functionality of the vehicles' range, and the availability of public and private charging infrastructure. In terms of price, the new 2019 Chevy Bolt is a landmark for pushing the price of EVs down to levels that are affordable for a greater share of today's drivers at $37,495 MSRP. The Drive Green discount program lists a dealer that has Bolts available at a price point of $22,495 (40% off MSRP). The Bolt is designed to look and feel more like a traditional compact car, extending the reach of EVs in terms of vehicle types to a wider audience. Tesla and other brands offer luxury models that have intrigued the public with their exceptional performance and style. In short, the number of manufacturers and models is increasing and a great bargain can be had in Massachusetts. There are more EVs to choose from at lower price points, and with better performance, every year. As EV technology continues to march forward in terms of affordability and effectiveness, this barrier to deployment diminishes. In terms of charging infrastructure, Concord's local programs and the strong roll-out of vehicles and charging stations regionally are all positive signs indicating the regional charging network will be able to accommodate a significant conversion to electric vehicles in coming years.



In terms of GHG emissions, according to the Department of Energy's Alternative Fuels Data Center[27], the average conventional vehicle in Massachusetts produces 11,435 pounds of CO_2 equivalent (CO_2e) emissions per year. A fully electric vehicle would also produce emissions as a result of the fuel source of the electricity, however Massachusetts is ahead of the national average here with almost 1,000 lbs. of CO_2e less than the national average per EV (4,455 lbs. CO_2e). Every fully electric vehicle that fully replaces a fossil fuel commuter car in Concord has the average potential to reduce emissions by 7,939 pounds of CO_2e per year (3.6 metric tons). That's nearly 70% less emissions, a figure that matches the estimate provided on Concord's municipal webpage.[28]

How many EVs will replace fossil fuel cars? A bevy of long-term estimates on the EV market are available from investment groups, government agencies, and more. BNEF's Electric Vehicle Outlook 2018 forecasts an encouraging EV adoption trend with 2025, 2030, and 2040 timetables.[29] The International Energy Agency produces a yearly outlook that reported great strides in 2018 and a stronger outlook for EV market transformation by 2030.[30] The latest DOE figure found on electric vehicles by state claims 1.29 plug-in EV registrations for every thousand people in Massachusetts for 2016, up from 0.52 in 2014.[31][32]

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[27] http://www.afdc.energy.gov/vehicles/electric_emissions.php
[28] http://www.concordma.gov/2233/EV-Level-2-Program
[29] https://about.bnef.com/electric-vehicle-outlook/
[30] https://www.iea.org/gevo2018/
[31] https://www.energy.gov/eere/vehicles/articles/fotw-1004-november-20-2017-california-had-highest-concentration-plug-vehicles

Contribution to GHG Emissions Target

Using the GHG estimates provided by the DOE's Alternative Fuels Data Center, some ranges of EV market penetration and associated impacts can be given in relation to Concord's GHG emissions.

- **1,000 new EVs** that replace traditional vehicles would reduce emissions by **3,601 MTCO$_2$e**.
- **3,000 new EVs** that replace traditional vehicles would reduce emissions by roughly **10,803 MTCO$_2$e**.
- **5,000 new EVs** that replace traditional vehicles would reduce emissions by roughly **18,005 MTCO$_2$e**.

The benefits of the Zero Carbon Electricity strategy low (35% renewable by 2030), mid (70% renewable by 2030), and high case scenarios (zero carbon electricity) were added to the DOE calculator figures to model the synergistic effect that a greener electricity supply would have on per vehicle EV replacements in 2030, under those scenarios.

- **35% renewable electricity by 2030** would increase the benefits of each EV replacement from roughly 3.6 MTCO$_2$e to 3.9 MTCO$_2$e.
- **70% renewable electricity by 2030** would increase the benefits of each EV replacement from roughly 3.6 MTCO$_2$e to 4.6 MTCO$_2$e.
- **Zero carbon electricity by 2030** would increase the benefits of each EV replacement from roughly 3.6 MTCO$_2$e to 5.2 MTCO$_2$e.

Assumptions and Calculations

The key assumptions related to these calculations are:

- Use of an average electric vehicle as a full replacement for an average gasoline commuter vehicle.
- The efficiency of electric vehicles and traditional vehicles in terms of emissions produced.
- The electricity generation mix in terms of CO$_2$e resulting from electricity supply in Concord.

Scenario	# EVs	Base Reduction	Electricity Reduction	Total by Case per EV	Total Reduction
Low Case	1,000	3.601	0.312	3.913	3,913
Mid Case	3,000	3.601	0.998	4.599	13,797
High Case	5,000	3.601	1.586	5.187	25,934

[32] http://energy.gov/eere/vehicles/fact-876-june-8-2015-plug-electric-vehicle-penetration-state-2014

Concord GHG Reduction Strategy:
Air-Source Heat Pump Incentives

Air-Source Heat Pump Incentives Reduction Potential Summary Table			
Scenario	Low (1,000 ASHPs)	Mid (2,000 ASHPs)	High (3,000 ASHPs)
Building Sector GHG Emissions Reduction by 2030	3,865 $MTCO_2e$	9,333 $MTCO_2e$	16,061 $MTCO_2e$
% Reduction of 2016 Building Emissions (140,072 $MTCO_2e$)	2.8%	6.7%	11.5%
% Reduction of 2016 Overall Inventory (232,951 $MTCO_2e$)	1.7%	4.0%	6.9%

Description of Strategy

The increased performance and energy efficiency of air-source heat pumps (ASHPs) manufactured for cold weather climates today is a result of technical, manufacturing, and installation advances:

- Variable speed inverter-driven compressor designs.
- Thermostatic expansion valves for more precise control of the refrigerant flow to the indoor coil.
- Internally grooved copper tubing for increased surface area.
- Improved coil design.
- Variable speed blowers.
- Thoughtful placement of outdoor units and improved baffles.
- Growing scale of deployment and level of familiarity within the service industry reducing equipment, installation, and maintenance costs while increasing overall system effectiveness.

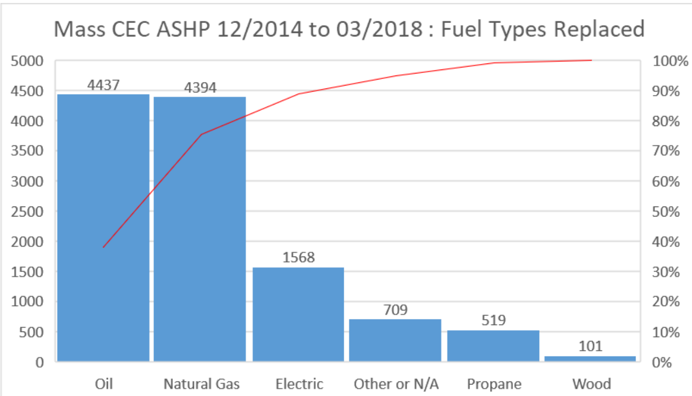
Lessons learned from cold climate ASHP deployment around the world as well as US-based research, deployment, and field testing provide an increasingly reliable fact base for comparative analysis between heating fuel sources and specific equipment or systems. Cold climate heat pumps now consistently show cost savings over electric resistance, oil, and propane fueled heating systems.[33][34][35] Reductions in GHG emissions vary on a project-by-project basis depending on the previously employed system, building size, grade of air sealing and insulation, new ASHP heating system installed, and occupant behavior. Market penetration of ASHPs is increasing thanks to transformation initiatives such as industry training, consumer education, incentive programs and support, improving specs, and more.[36]

[33] https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/inverter-driven-heat-pumps-cold.pdf
[34] https://www.efficiencymaine.com/at-home/home-energy-savings-program/heating-cost-comparison/
[35] https://aceee.org/research-report/a1803
[36] https://neep.org/sites/default/files/NEEP_ASHP_2016MTStrategy_Report_FINAL.pdf

Supporting Programs

CMLP has a rebate program in place for homeowners and renters who install air-source heat pumps in new or existing buildings.[37]

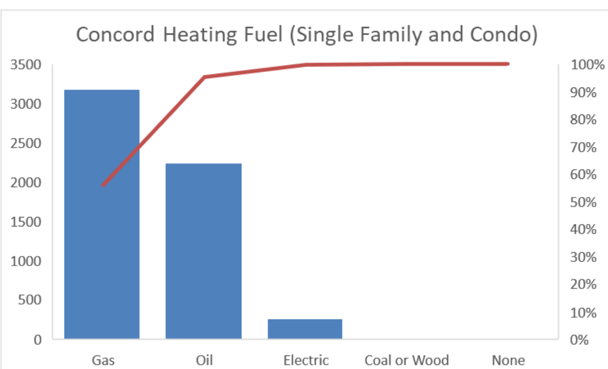
Data from the MassCEC ASHP program was analyzed with the recognition that similar programs employed in neighboring communities provide excellent "peers" for understanding regional trends and market transformation expectations.[38] MassCEC data provides insight on fuel source replacement.

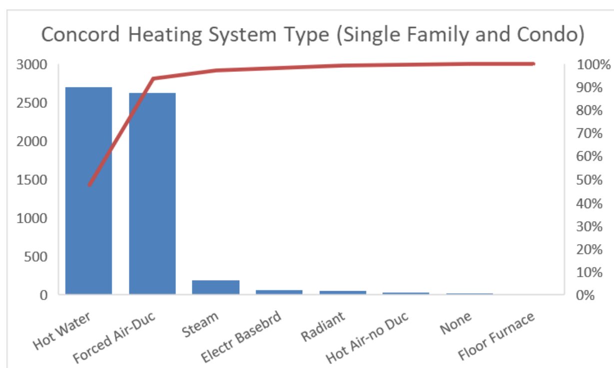


Fuel Source Replaced	Projects	%
Electric	1,568	13.4%
Natural Gas	4,394	37.5%
Oil	4,437	37.8%
Propane	519	4.4%
Wood	101	0.9%
Other or N/A	709	6.0%
Total	11,728	100.0%

37.8% of rebated heat pump projects replaced fuel oil heating systems and 37.5% replaced a natural gas system. Overall, 86.6% of projects replaced a fuel source aside from electricity.

Concord's home heating fuel profile aligns well with Mass CEC ASHP rebate program results, suggesting that an optimistic outlook is warranted for residential ASHP deployment. In particular, aging oil-fueled forced air systems make good candidates for ASHP replacements. There are over 2,200 oil-fueled systems among Concord's single family and condo building stock, including 682 forced air systems.



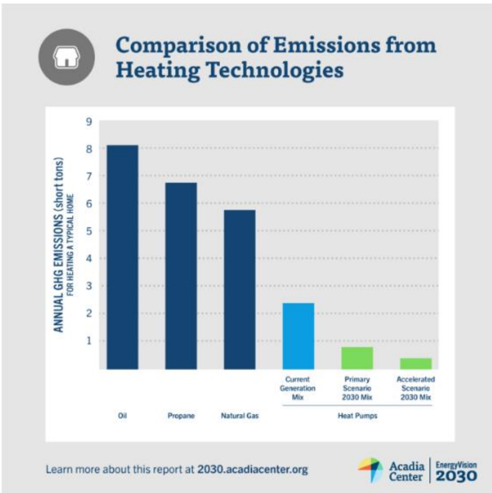


Recognizing that a wide array of projects with varying results in terms of efficiency gains and fuel-switching effects occurs within this type of program, actual project savings in terms of pre- and post-retrofit energy usage is very useful information for evaluating the overall potential of this strategy. Information from the Concord ASHP program indicates that 50 installations were completed to date in

[37] http://www.concordma.gov/1875/Apply-Now-for-an-ASHP-Rebate
[38] http://files.masscec.com/get-clean-energy/residential/air-source-heat-pumps/ResidentialASHPProjectDatabase.xlsx

2018 with 12 more expected, a total of 62 projects in 2018.[39] However, energy savings and/or GHG reductions were unavailable.

Estimated GHG Emission Reductions for Concord



Research on an estimated average reduction potential per project for Concord revealed a wide range of figures. One Northeast-focused study indicates a decrease of 5.7 tons annually (5.17 $MTCO_2e$) for an average fuel oil-heated home converted to ASHPs.[40] The same source indicates a 4.89 $MTCO_2e$ reduction from propane and 3.08 $MTCO_2e$ reduction from natural gas.

ASHP replacement case studies collected as further research offer limited but real-world estimates of energy reduction potential across projects. An EERE case study on the field performance of inverter-driven heat pumps in cold climates revealed difficulty in accurately calculating energy savings from retrofit projects.[41]

Table 9. Cost Data Monitoring Summary

	Site 1	Site 2	Site 4
Total Heat [kBtu]	12,021	5,454	34,924
Total Electricity [kWh]	2,183	974	4,425
Monitoring Start	11/8/2013	1/9/2014	12/3/2013
Monitoring End	5/31/2014	4/30/2014	4/30/2014
# of Days Monitored	204	111	148

Table 11. Operating Cost Increases (Decreases) of Other Heating Systems Compared to ASHPs During the Monitoring Period

Heating Method	Site 1	Site 2	Site 4
Heat Pump	$386	$172	$783
Electric Resistance	61%	64%	131%
Oil (85% efficiency)	10%	12%	58%
Propane (85% efficiency)	53%	56%	120%
Natural Gas (85% efficiency)	(47%)	(46%)	(24%)

Extrapolation of report data indicates heat energy savings potential in a range of zero to 39 MMBtu (or 11,430 kWh) over the course of a year. Resulting emissions reductions are therefore calculated to vary between zero and 3.6 $MTCO_2e$ for these projects using Concord's 2016 electricity emissions factor.

[39] Email correspondence with CMLP
[40] http://2030.acadiacenter.org/buildings/
[41] https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/inverter-driven-heat-pumps-cold.pdf

A NEEP study provides typical annual fuel usage and resulting GHG emissions for a New England home.[42] Yearly GHG emissions per home range from 3.58 $MTCO_2e$ for ASHP systems to 8.96 for electric resistance heat. The study also provides GHG estimates for various types of fuel replacements: 2.02 $MTCO_2e$ per oil burner/furnace conversion and 5.38 for electric resistance heat.

Table 5: Estimated greenhouse gas emissions (in equivalent pounds of CO2) for several fuels and systems.

Fuel	Oil	LP	Natural Gas	ISO-NE Electricity (ASHP)	ISO-NE Electricity (Resist.)
Seasonal Eff/COP	80%	90%	90%	2.5	100%
CO_{2e} [lbm]	26.9 per gallon	16.1 per gallon	14.9 per therm	1.35 per kWh	1.35 per kWh
Fuel and Emissions to meet 50MMBtu thermal load*					
Fuel used	450 gallons	608 gallons	556 therms	5,862 kWh	14,654 kWh
CO_{2e} [lbm]	12,356	10,033	8,555	7,903	19,755

*Fossil fuel system emissions include 750 kWh for fans, pumps, controls, etc. Values do not account for different distribution efficiencies of systems. ASHP and resistance heating values derived from ISO-NE marginal fuel mix and includes line losses. All CO_{2e} figures include pre-combustion emissions.

With the information available, an average estimated GHG reduction per replacement is pegged at 3.5 $MTCO_2e$. As energy usage reduction calculations accumulate for the CMLP ASHP program, or for peer programs in New England, more precise figures may come to light and would represent the best available data. A case study highlighting a "typical" Concord home that received a heating system replacement, either natural gas or oil-fueled via forced air or a boiler, with energy usage quantities by fuel type before and after the project, may also be helpful as an average reduction per project specific to Concord.

Contribution to GHG Emissions Target

Using the per-project GHG reduction estimate at hand and Concord ASHP market penetration rates based on 2018 program participation, associated impacts can be given in relation to Concord's GHG emissions.

- **1,000 cold climate ASHPs** replacing aged heating systems would reduce emissions by **3,500 $MTCO_2e$**.
- **2,000 cold climate ASHPs** replacing aged heating systems would reduce emissions by **7,000 $MTCO_2e$.**
- **3,000 cold climate ASHPs** replacing aged heating systems would reduce emissions by **10,500 $MTCO_2e$**.

The benefits of the Zero Carbon Electricity strategy low (35% renewable by 2030), mid (70% renewable by 2030), and high case scenarios (zero carbon electricity) were added to the estimated figures to model the synergistic effect that a greener electricity supply would have per project under those scenarios. The 5,862 kWh figure from the NEEP assessment, representing yearly ASHP energy consumption in a typical New England home, is multiplied by the 2016 NE-ISO electricity emissions factor from Concord's 2016 GHG inventory to determine what further emissions are possible through decarbonization.

- **35% renewable electricity by 2030** would increase the benefits of each ASHP project from roughly 3.5 $MTCO_2e$ to 3.87 $MTCO_2e$.
- **70% renewable electricity by 2030** would increase the benefits of each ASHP project from roughly 3.5 $MTCO_2e$ to 4.67 $MTCO_2e$.
- **Zero carbon electricity by 2030** would increase the benefits of each ASHP project from roughly 3.5 $MTCO_2e$ to 5.35 $MTCO_2e$.

[42] https://neep.org/sites/default/files/NEEP_ASHP_2016MTStrategy_Report_FINAL.pdf

Assumptions and Calculations

This measure uses a best-known base estimate of 3.5 $MTCO_2e$ per project. A wide variety of projects are possible in terms of building type, size, fuel, and equipment. Compilation of CMLP ASHP Program energy savings estimates by project are recommended. Where possible, heating energy usage prior to the ASHP retrofit along with electrical usage specific to the ASHP system afterward would enable energy and emissions savings estimates. Building performance areas that may be improved in the same scope of work as ASHP installations such as air sealing, insulation, and even occupant behavior represent complicating upside factors that can nevertheless greatly improve results per project.

The emissions reduction potential per project will increase over time as the carbon intensity of electricity decreases.

Scenario	# ASHP Projects	Base Reduction	Electricity Reduction	Total by Case per ASHP	Total Reduction
Low Case	1,000	3.500	0.365	3.865	3,865
Mid Case	2,000	3.500	1.167	4.667	9,333
High Case	3,000	3.500	1.854	5.354	16,061

Concord GHG Reduction Strategy: Energy Efficient Buildings (State Goals)

Energy Efficient Buildings Reduction Potential Summary Table			
Scenario	Low (50%x2050)	Mid (80%x2050)	High (53.3%x2030)
Building Sector GHG Emissions Reduction by 2030	14,376 $MTCO_2e$	10,656 $MTCO_2e$	11,924 $MTCO_2e$
% Reduction of 2016 Building Emissions (140,072 $MTCO_2e$)	10.2%	7.6%	8.5%
% Reduction of 2016 Overall Inventory (232,951 $MTCO_2e$)	6.2%	4.6%	5.1%

Description of Strategy

Commonly recognized as one of the most cost-effective and powerful strategies for GHG emission reductions, improving the energy efficiency of our built environment will continue to be an excellent and worthwhile endeavor. A host of approaches aimed at energy efficient buildings has led to positive results:

- Creation, adoption, and enforcement of more energy efficient building codes
- Better construction practices, industry focus, and professional specialization supporting efficiency
- Continuous improvements in technology and products
- Retrofits/weatherization of existing buildings
- Improved tracking and reporting of energy performance
- Greater awareness of potential savings put into practice through investment and behavioral change

These are just some of the drivers behind improving energy efficiency in buildings. The latest information available on a national scale indicates numerous trends. For example, while commercial building energy use has increased overall, total energy used per square foot has decreased since 2003. [43]

Figure 1. Total electricity usage has increased more than the other energy sources since 2003

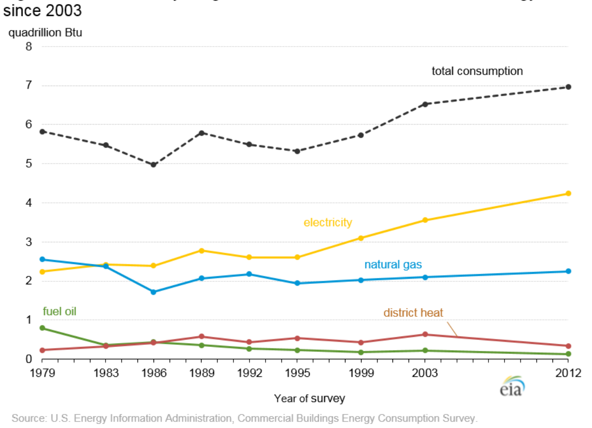
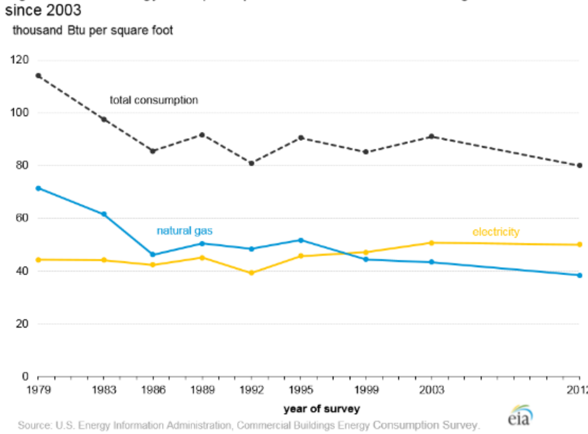
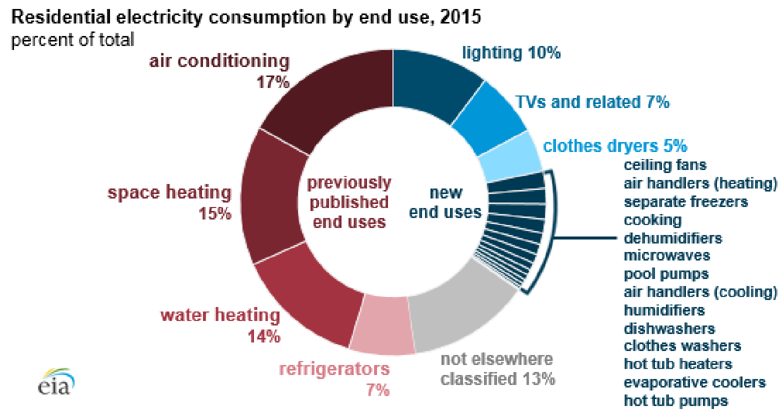


Figure 3. Total energy used per square foot in commercial buildings has decreased since 2003

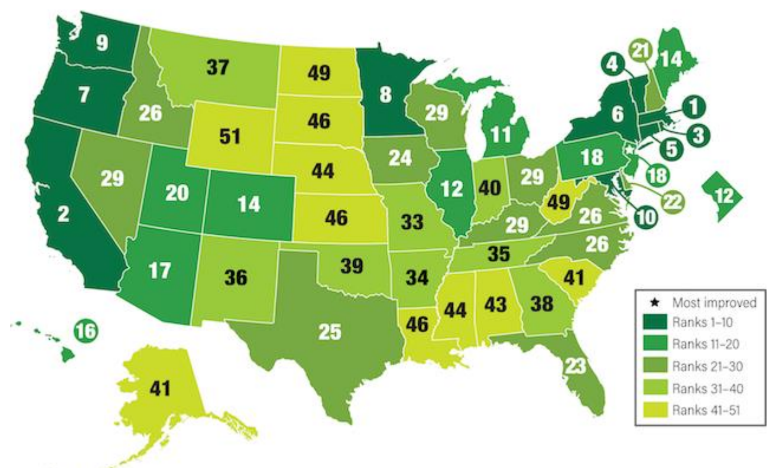


[43] https://www.eia.gov/consumption/commercial/reports/2012/energyusage/index.php

The depth of study in how energy is used in buildings has become increasingly complex. In the residential sector, consumption by end use is tracked in greater detail than ever before on a national, regional, state, local, and individual building level.[44] Energy audits and pre- and post-construction energy modeling enable more effective design through consideration of buildings as an energy system with interdependent parts, each affecting the performance of the entire system and taking the occupants, site, and local climate into consideration. Improving energy use in buildings ultimately comes down to more efficient new construction, updating existing building stock, utilizing the least polluting fuel sources, installing more efficient systems (HVAC, lighting, and appliances), and occupant behavior or awareness.



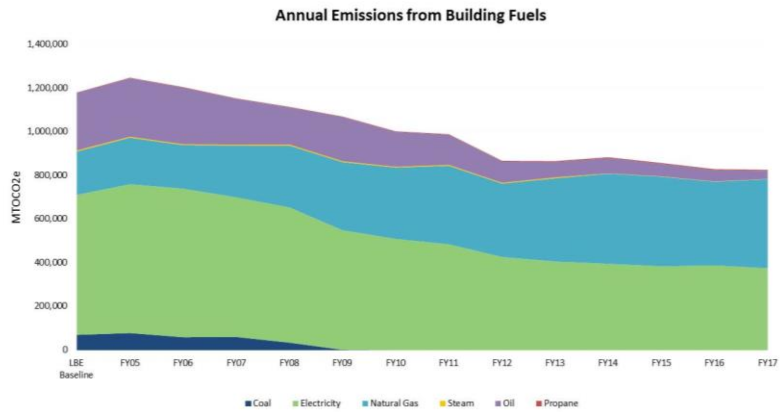
Supporting Programs

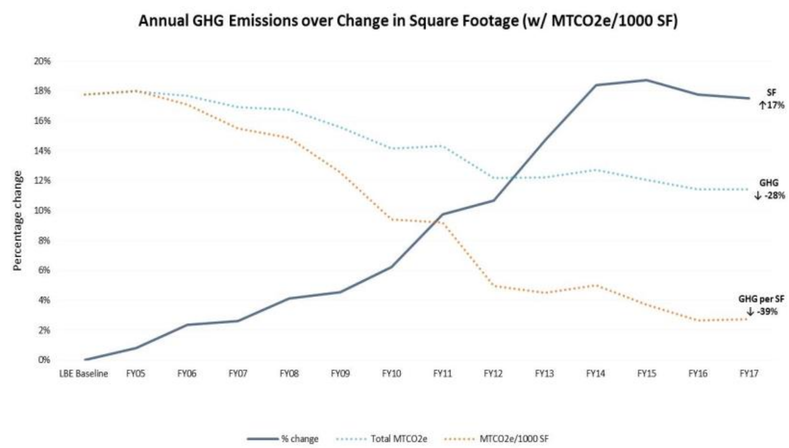


Massachusetts is a national leader in terms of these efforts. The state was ranked #1 for the 8th time in a row on ACEEE's 2018 State Energy Scorecard.[45] Among the reasons for this impressive run are the programs and policies put into action by Executive Order 484[46] which requires a reduction in emissions from state-owned buildings (and leased buildings where the state pays directly for energy) by 25% by fiscal year 2012, 40% by 2020, and 80% by 2050 based on a 2004 baseline. EO484 likewise created targets for energy use reductions and increasing renewable energy use in state buildings. Massachusetts tracks progress toward these goals via the Leading by Example (LBE) Program.[47] The latest available infographics indicate that state building GHG emissions have decreased 28% from the 2004 baseline through FY17, showing an overall emissions reduction of 350,354 metric tons. Fuel source data show the elimination of coal and a dramatic decline in the use of fuel oil for heating, with an increase in natural gas usage. Emissions from electricity decreased dramatically as the carbon intensity of electricity declined over that time period.

[44] https://www.eia.gov/todayinenergy/detail.php?id=36412
[45] https://aceee.org/state-policy/scorecard
[46] https://www.mass.gov/files/documents/2016/07/vs/energy-eo484-final.pdf
[47] https://www.mass.gov/info-details/leading-by-example-progress-greenhouse-gas-emissions

While emissions decreased overall, population growth trends in Massachusetts are mirrored in growth of the total square footage (SF) of state-owned buildings. Even as SF increased 17% between 2004 and FY17 to 80 million SF, LBE and supporting state efforts overcame that growth to achieve lower overall emissions. GHG/SF decreased 39% thanks to continuous implementation of a rigorous retrofit program and new construction projects that were significantly more energy efficient. EO484 states that all new construction and major renovations to state buildings over 20,000 SF must meet the MA LEED Plus green building standard and perform 20% better than the current energy code. Currently, there are 76 LEED certified buildings in the state portfolio, including 3 Platinum and 44 Gold certifications.[48] Several state buildings have now been built or designed to meet the zero net energy standard, and energy use data collected over the next 2-3 years will allow stakeholders to assess the actual performance of these buildings.





Another contributor to the success with state buildings is the Green Communities Act (SB 2768) of 2008, which, among other topics, mandates that new buildings owned or operated by the state must minimize their life-cycle costs by using energy efficiency and renewable energy.[49] It also created the Green Communities Program. Concord has successfully harnessed the Green Community Designation and Grant Program, most recently in July 2018, receiving $686,263 in grant funding for energy efficiency projects since 2013.[50] The Green Community Designation and Grant Program provides a road map along with financial and technical support to municipalities that pledge to cut municipal energy use by 20% over 5 years and meet four other criteria established in the Green Communities Act.[51]

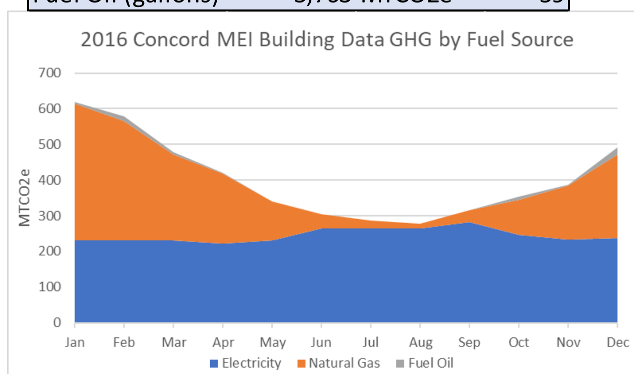
[48] https://database.aceee.org/state/massachusetts
[49] https://www.mjbradley.net/_sis/documents/EPTS/Summary_of_MA_SB_2768.pdf
[50] https://www.mass.gov/files/documents/2018/08/16/map-summary-green-communities-210.pdf
[51] https://www.mass.gov/orgs/green-communities-division

MA Green Communities	Designation Date / Award Date	Designation Grant Award	Grant Project Summary	100% Done	Census 2014 Population
Concord	12/18/13	$147,400	to fund the following energy conservation measures at Peabody School: installation of a high efficiency condensing boiler, hot water heater and additional building controls upgrades, and an LED streetlight conversion.	X	19,512
	July-15	$244,000	to fund the installation of four new efficient condensing boilers to upgrade the heating system at Sanborn Middle School	X	
	July-16	$178,306	to fund the following energy conservation measures: LED lighting upgrade at four schools and four facilities; and individually tuned LEDs implemented by Concord Municipal Light and Power	X	
	July-18	$116,557	to fund energy conservation measures, LED lighting, electric vehicle acquisition, hybrid vehicle conversion, and building management system, in municipal facilities including town vehicle fleet, 55 Church St Building, Public Works, HWCC, Water & Sewer Building, Town House, and Hunt Recreation Center		

Massachusetts also offers the Municipal Energy Technical Assistance (META) Program, which awards META grants to designated Green Communities including municipalities, regional school districts, and water/wastewater districts. META grants help energy projects by funding the services of expert consultants and contractors, aiding in project management or performance studies.

The Green Communities Division has also developed and implemented Mass Energy Insight, a free, web-based tool that helps cities and towns track energy use and make decisions about energy efficiency investments.[52] Concord has utilized the tool, tracking energy usage monthly, by fuel, at the facility and utility account level. Converting electricity, natural gas, and fuel oil usage to the common denominator of GHGs, a 2016 emissions profile for Concord municipal accounts (including streetlights and water/wastewater accounts) shows that electricity use is responsible for 2,939 $MTCO_2e$ (60.5%), natural gas 1,856 $MTCO_2e$ (38.2%), and fuel oil is nearly eliminated at 59 $MTCO_2e$ (1.2%). Between 2008 and 2016, emissions from municipal buildings (excluding streetlights and water/wastewater) decreased by 19% from 5,837 to 4,702 $MTCO_2e$. 2016 Concord municipal buildings represent 3.2% of 2016 community wide building-related emissions.

2016 Concord Mass Energy Insight Data			
Electricity (kWh)	11,489,158	MTCO2e	2,939
Gas (therms)	349,448	MTCO2e	1,856
Fuel Oil (gallons)	5,763	MTCO2e	59



Additional programs supporting efficiency in buildings, state-owned and otherwise, include:

- Pathways to Zero Net Energy Program
- LED Street Lighting Accelerator Program
- Zero Energy Modular Affordable Housing Initiative (ZE-MAHI)
- Capturing Franchise Energy Savings (CaFES) Program
- Community Clean Energy Resiliency Initiative
- Efforts to require disclosure of information regarding the benefits of home energy audits to buyers of single-family homes or small multi-family homes at the time of closing, and to incorporate this information into MLS listings[53]
- Massachusetts' Enterprise Energy Management System (EEMS) project and second-phase Commonwealth Building Energy Intelligence (CBEI) project[54]
- DOE Better Buildings Challenge and Performance Contracting Accelerator Program

[52] https://www.massenergyinsight.net/home
[53] https://neep.org/initiatives/energy-efficient-buildings/green-real-estate-resources/helix
[54] https://www.mass.gov/news/baker-polito-administration-announces-investment-in-commonwealth-building-energy-intelligence

Estimated GHG Emission Reductions for Concord

Community Sector	2008 GHG	2016 GHG	% Change	% 2008 GHG	% 2016 GHG
Buildings	159,779	140,072	-12%	65%	60%
Transportation	80,100	84,754	6%	32%	36%
Waste	7,011	8,126	16%	3%	3%
Total	246,890	232,951	-6%	100%	100%
Local Gov Sector	**2008 GHG**	**2016 GHG**	**% Change**	**% 2008 GHG**	**% 2016 GHG**
Facilities and Infrastructure	6,431	4,525	-30%	46%	36%
Vehicle Fleet	1,263	1,089	-14%	9%	9%
Waste	338	339	0%	2%	3%
Other	6,014	6,782	13%	43%	53%
Total	14,046	12,735	-9%	57%	47%

GHG emissions from Concord buildings represented 60% of community-wide emissions in 2016 (140,072 $MTCO_2e$) and 36% of the municipal profile (4,535 $MTCO_2e$). A 30% reduction in municipal building emissions between 2008 and 2016 is primarily responsible for the overall reduction observed in Concord's local government inventory. Emissions reductions in community-wide building stock is rather strong at 12% particularly in comparison with transportation and waste emissions, indicating efficiency gains in buildings and cleaner electricity. Energy use by source within Concord commercial and residential building stock indicates a strong fuel-switching trend away from #2 fuel oil, particularly in commercial buildings, with growth in electricity usage and natural gas.

Concord Buildings	Fuel	2008 Usage	2016 Usage	Units	% Change	2008 GHG	2016 GHG	% Change
Commercial and Institutional	#2 Fuel oil	1,007,137	482,758	gallons	-52%	10,317	4,945	-52%
	Electricity	109,408,444	98,426,507	kWh	-10%	44,467	31,124	-30%
	Natural gas	4,201,114	5,589,558	therms	33%	22,033	29,315	33%
					Total	76,817	65,384	-15%
Residential	#2 Fuel oil	3,111,934	2,854,169	gallons	-8%	31,879	29,238	-8%
	Electricity	70,188,465	73,082,286	kWh	4%	28,527	23,110	-19%
	Natural gas	4,300,993	4,259,572	therms	-1%	22,557	22,340	-1%
					Total	82,962	74,688	-10%

Concord Buildings	Heating Fuel	2008 MMBTU	2016 MMBTU*	% Change	2008 SQFT	# Bldgs	MBTU/Sqft	2016 SQFT*	# Bldgs	MBTU/Sqft	% Change
Commercial and Institutional	#2 Fuel oil	139,865	67,042	-52%	2,340,170	139	60	1,002,807	77	67	11.9%
	Electricity	373,317	335,845	-10%	309,505	14	1,206	353,044	12	951	-21.1%
	Natural gas	420,111	558,956	33%	2,045,302	75	205	3,710,627	133	151	-26.7%
	Total	933,294	961,843	3%	4,694,977	228	199	5,066,478	222	190	-4.5%
Residential	#2 Fuel oil	432,167	396,370	-8%	12,546,974	2,766	34	11,507,694	2,286	34	0.0%
	Electricity	239,493	249,367	4%	558,744	99	429	819,377	136	304	-29.0%
	Natural gas	430,099	425,957	-1%	10,176,875	1,998	42	13,920,191	2,404	31	-27.6%
	Total	1,101,759	1,071,694	-3%	23,282,593	4,863	47	26,247,262	4,826	41	-13.7%

Trends in primary heating fuel energy use, normalized as BTU, show an increase in average BTU/sqft for #2 fuel oil in commercial buildings, an indicator that the final million square feet of space heated by fuel oil embodies the lower end of the performance spectrum in that building and fuel use category. Other categories of primary heating fuel use show a marked improvement in MBTU/Sqft as higher efficiency new construction and conversion projects lower the overall averages.

Contribution to GHG Emissions Target

The state buildings goal of a 25% GHG reduction by 2012, 40% by 2020, and 80% by 2050 is a useful performance benchmark for building energy and emissions reductions. The 2030 interim goal of a 53.3% GHG reduction can be met in Concord through a combined approach of efficiency gains, fuel switching, and zero carbon electricity supply. Here, the inventory year of 2008 serves as a proxy for the state's 2004 baseline.

With 2008 Buildings Sector baseline emissions totaling 159,779 $MTCO_2e$, interim targets are as follows:

- 25% by 2012: 119,834 $MTCO_2e$
- 40% by 2020: 95,867 $MTCO_2e$
- 53.3% by 2030: 74,564 $MTCO_2e$
- 80% by 2050: 31,956 $MTCO_2e$

The low case scenario mimics the trendline emissions reduction needed to achieve a 50% reduction by 2050. In other words, 2050 emissions from Concord buildings are modeled to equal 79,890 $MTCO_2e$ representing a 38.1% decrease from 2016 levels. The 2050 reduction target of 79,890 $MTCO_2e$ represents a linear reduction in Buildings Sector emissions of 1,789 $MTCO_2e$ per year or 1.27% of Concord 2016 Building Sector emissions. The 2030 reduction needed is therefore 25,049 $MTCO_2e$, or 17.8% of the 140,722 $MTCO_2e$ 2016 Buildings Sector emissions.

The mid case scenario mimics the trendline emissions reduction needed to meet Executive Order 484 by 2050. In other words, 2050 emissions from Concord buildings are modeled to equal 31,956 $MTCO_2e$ representing an 77.3% decrease from 2016 levels. The reduction of 108,766 $MTCO_2e$ represents a linear reduction in Buildings Sector emissions of 3,199 $MTCO_2e$ per year or 2.27% of Concord 2016 Building Sector emissions. The 2030 reduction needed is therefore 44,786 $MTCO_2e$ or 31.8% of the 140,722 $MTCO_2e$ 2016 Buildings Sector emissions.

The high case scenario mimics the trendline emissions reduction needed to meet Executive Order 484 by 2030. This brings Concord as a community "back on track" with the order targeting state owned buildings by 2030. In other words, 2030 emissions from buildings are modeled to equal 74,564 $MTCO_2e$ representing a 47.0% decrease from 2016 levels. The reduction of 66,158 $MTCO_2e$ represents a linear reduction in Buildings Sector emissions of 4,726 $MTCO_2e$ per year. This represents a yearly reduction of 3.36% of Concord 2016 Building Sector emissions. The 2030 reduction needed is therefore 66,158 $MTCO_2e$ or 47% of the 140,722 $MTCO_2e$ 2016 Buildings Sector emissions.

Because the state buildings emissions goal is achievable in large thanks to lower carbon intensity electricity supply, the portion of this reduction pertaining specifically to efficiency gains (and not cleaner electricity) concurs with the low, mid, and high case scenarios within that section of this analysis. Synergistic effects between efficiency, fuel switching, and decarbonized electricity are disaggregated below to assign reduction potentials correctly.

Assumptions and Calculations

The low case scenario assumes a reduction of 10,673 $MTCO_2e$ pertaining to cleaner electricity used in buildings (35% renewable electricity by 2030). Of the 25,049 $MTCO_2e$ reduction needed to meet the low case goal for emissions in buildings, 14,376 $MTCO_2e$ must come purely from efficiency measures.

The mid case scenario assumes a reduction of 34,130 $MTCO_2e$ pertaining to cleaner electricity used in buildings (70% renewable electricity by 2030). Of the 44,786 $MTCO_2e$ reduction needed to meet the mid case goal for emissions in buildings, 10,656 $MTCO_2e$ must come purely from efficiency measures.

The high case scenario assumes a reduction of 54,234 $MTCO_2e$ pertaining to cleaner electricity used in buildings (100% carbon-free electricity by 2030). Of the 66,158 $MTCO_2e$ reduction needed to meet the high case for emissions reductions in buildings, 11,924 $MTCO_2e$ must come purely from efficiency measures.

As the emissions intensity of electricity decreases, the consequences of electricity use from an emissions perspective also decrease. For example, assuming that a supply of zero carbon electricity is available, the reduction potential of an electricity efficiency project is also zero because the energy saved has no associated emissions. Only natural gas and other fossil fuels used in buildings would contribute toward emissions. The corresponding goals used here in each low, mid, and high case scenario influence the importance of efficiency and fuel switching in buildings by the 2030 timeframe. With higher emissions from electricity, electricity-focused energy efficiency projects are more important for achieving reductions. With low-carbon electricity, electricity-focused energy efficiency projects are less important for achieving reductions as compared to fuel-switching projects. In other words, 100% carbon-free electricity would reduce 2016 emissions from buildings (140,722 $MTCO_2e$) by 54,234 $MTCO_2e$ to a total of 86,488 $MTCO_2e$ attributed to natural gas and fuel oil, which is still 11,924 $MTCO_2e$ short of the high case Building Sector emissions target of 74,564 $MTCO_2e$ to meet EO 484 in 2030. The final 11,924 $MTCO_2e$ must come from efficiency measures related to natural gas and fuel oil, or from fuel switching.

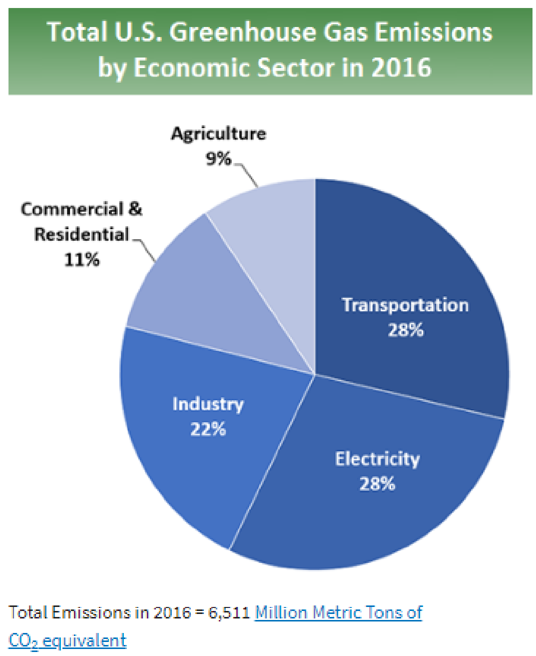
Growth in various portions of energy use by fuel type among Concord buildings was not incorporated into the analysis.

Concord GHG Reduction Strategy: Zero Carbon Electricity

Zero Carbon Electricity Reduction Potential Summary Table			
Scenario	Low (Meet RPS 35%)	Mid (70%)	High (100%)
Electricity Emissions Source GHG Reduction by 2030	10,672 $MTCO_2e$	34,130 $MTCO_2e$	54,234 $MTCO_2e$
% Reduction of 2016 Electricity Emissions (54,234 $MTCO_2e$)	19.7%	62.9%	100%
% Reduction of 2016 Overall Inventory (232,951 $MTCO_2e$)	4.6%	14.7%	23.3%

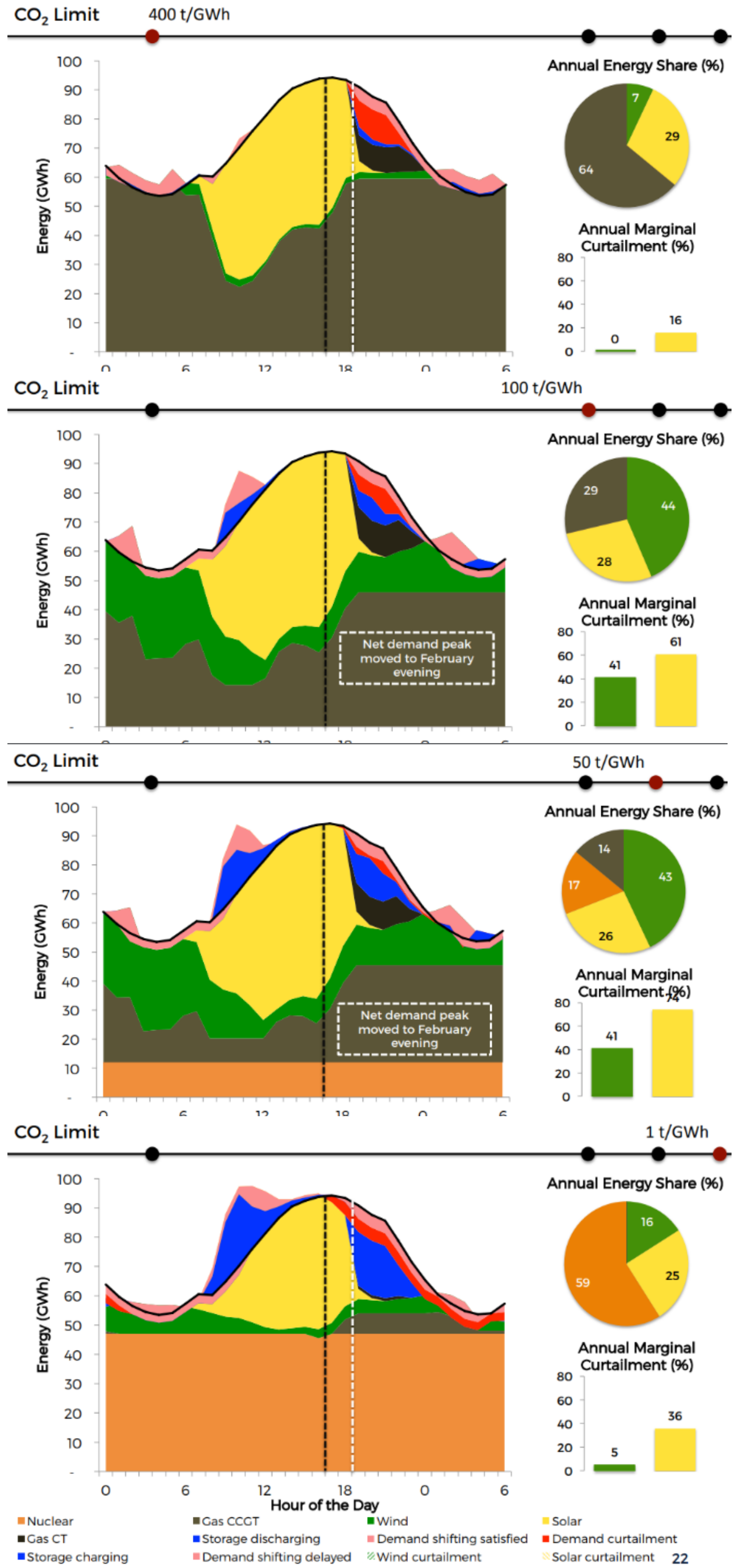
Description of Strategy

Carbon free electricity is, simply put, the most powerful idea for reducing greenhouse gas emissions. In 2016, electricity accounted for 54,234 $MTCO_2e$ (23.3%) of Concord emissions, comparable to 19.6% for Massachusetts[55] and 28.4% of all US emissions[56] according to their respective GHG inventories. Eliminating these emissions would be an incredible step toward protecting Earth's climate. The reduction potential (and scale of the challenge) is yet larger if factoring in the future load growth potential of vehicle and building electrification. **For example, a scenario of also replacing half of the 84,754 $MTCO_2e$ transportation emissions and half of the 85,838 $MTCO_2e$ fossil fuel commercial and residential emissions with carbon free electricity represents an additional 85,296 metric ton reduction for a total of 139,530 $MTCO_2e$, 59.9% of Concord's 2016 emissions. No other strategy holds this kind of potential.** However, deep decarbonization also requires nothing short of an energy revolution in order to achieve its fullest reduction potential.



[55] https://www.mass.gov/lists/massdep-emissions-inventories#greenhouse-gas-baseline,-inventory-&-projection- (see Appendix C updated July 2018)
[56] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

To achieve zero carbon electricity, all fossil fuel generation sources must either be removed, offset, or credited to make up the difference. Setting aside these methods momentarily to consider a pure low carbon supply, Concord's electricity system would need to transform dramatically. It could be a tightly interconnected renewables and energy storage dominated system or one that (while incorporating heavy renewables and storage) replaces the predominantly natural gas base with a functionally similar zero carbon option such as nuclear or next-generation technologies like engineered geothermal or 100% carbon-sequestration.

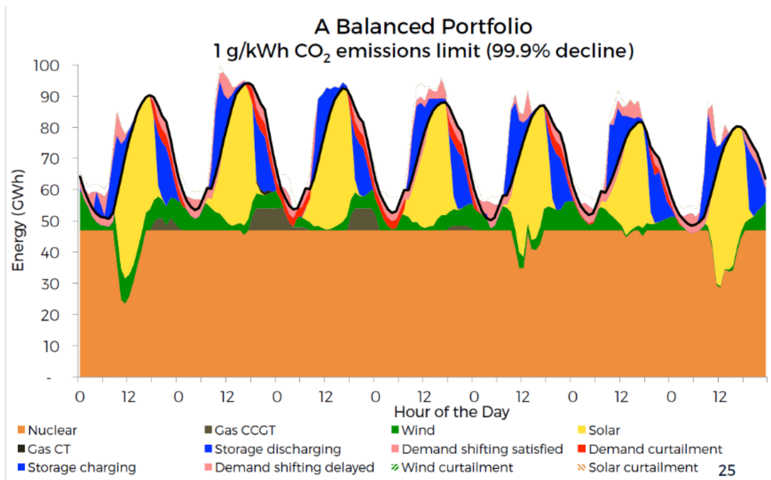


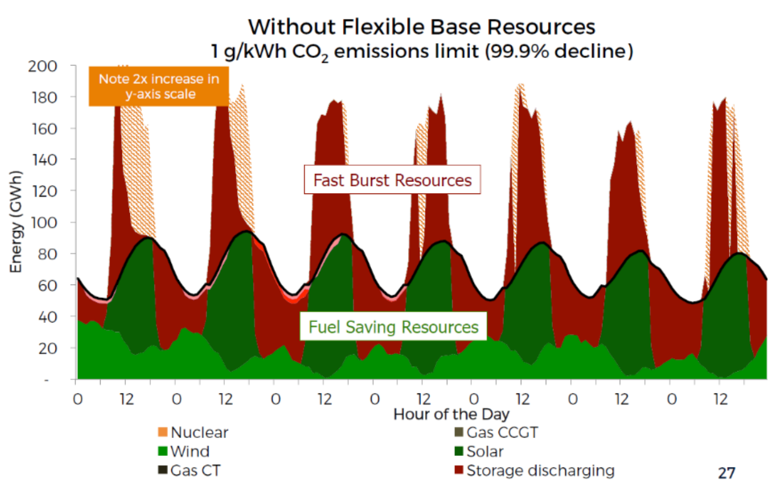
Recognizing cost and reliability as essential factors along a journey toward decarbonization, a recent seminar put forth a model of possible generation mix scenarios for an electricity system under various emissions caps.[57] As CO_2/GWh decrease in this model, the energy share of different technologies shifts. The characteristics of those resources, namely their reliability profiles, cost/scale of deployment, and carbon content have dramatic effects on overall system attributes, one example being a movement of net peak demand by two hours from 5 to 7PM, when solar resources that are vital to achieving supply under the carbon caps diminish. In the 100 and 50 ton/GWh models, where solar and wind play their largest roles, the net peak demand shifts from a summer afternoon to a winter evening when electric heating and lighting loads must be met while solar is unavailable. The flexibility of the natural gas base resource is crucial in these scenarios, as it is able to "move out of the way" and come back online again as renewable supply, overall demand, and seasons fluctuate. In blue, the role of energy storage grows as emissions are reduced ever further. This model reaches a divergence point where cost and scale of additional energy storage capacity and the increasing need for reliable baseload

57 https://kleinmanenergy.upenn.edu/events/getting-zero-pathways-zero-carbon-electricity-systems

ultimately give way to nuclear as a low cost deep decarbonization option, replacing natural gas by necessity under the emissions caps and here providing base load in the 1-ton scenario at 59% of overall energy share. This is but one scenario/model/forecast, with its own assumptions about future demand profiles, cost and effectiveness of technology, and so forth. Yet it is valuable as a possible profile of a truly decarbonized electricity system. A white paper referenced in the presentation claims “strong agreement in [relevant] literature that a diversified mix of low-CO_2 generation resources offers the best chance of affordably achieving deep decarbonization.”[58] In other words, a cost-bound system moving toward decarbonization is most likely to deploy more, rather than less, technologies in varying amounts over time, with each resource contributing uniquely according to its inherent characteristics.

Of course, other zero carbon electricity profiles are possible. Costa Rica’s nearly 100% renewable electricity, as widely reported in recent years, is an example of an existing and successful deeply decarbonized electricity system.[59] Blessed with strong hydro and geothermal resources, Costa Rica does enjoy considerable advantages. With fewer zero carbon options at hand, a system with massive energy storage potential is another possibility. Using the same demand profile seen previously, here at a strict near-zero emissions limit, a “balanced” resource portfolio is modeled comparably to a portfolio without flexible base resources but significant “fast burst resources”, namely storage charging and fast ramping solar. The flexible system utilizes intense deployment of solar, wind and other “fuel saving resources” whose installed capacity necessarily doubles to exceed daytime peak demand while also reliably charging system storage to satisfy overnight demand. Curtailment is necessary when energy storage limits are reached. Reliability is increased primarily through the addition of more and more storage capacity, with demand shifting and reduction playing assisting roles.





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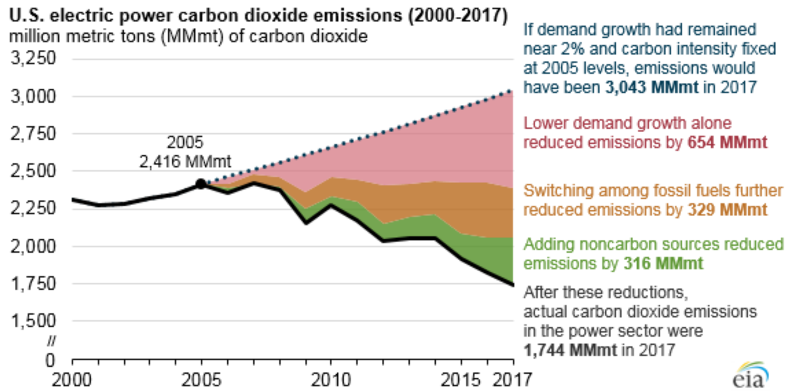
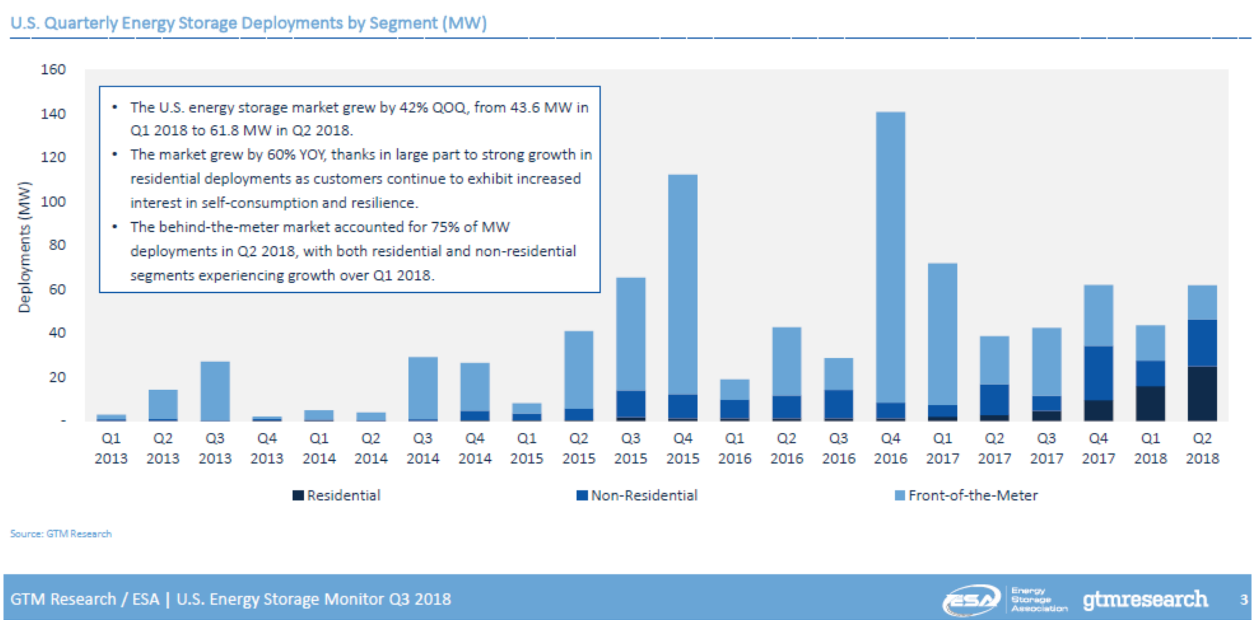
58 https://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf

59 https://www.weforum.org/agenda/2017/11/costa-rica-has-run-on-green-energy-for-300-days

One technology poised to begin its unique contributions to the energy mix, and expected to play a key role particularly with solar, is energy storage which reached 156.5 MW nationwide deployment in Q2 2018. Of note, the latest U.S. Energy Storage Monitor[60] currently ranks Massachusetts #2, behind only Arizona, in terms of front-of-the-meter energy storage capacity markets. Front-of-the-meter deployment is consistently strong year over year nationwide, with major installs seen in California in Q4 2016 and Q1 2017. An encouraging general uptrend in deployments is tracked quarterly by segment, with impressive growth seen recently in the residential segment, behind-the-meter, and overall market. It's reasonable to expect growing deployment in all three segments in Massachusetts.





60 https://www.woodmac.com/our-expertise/focus/Power--Renewables/us-energy-storage-monitor-q3-2018/

Supporting Programs

State efforts including the Renewable Portfolio Standard (RPS), Alternative Energy Portfolio Standard (APS), Clean Energy Standard (CES), new Clean Peak Standard (CPS) and so forth provide a framework for advancing clean energy technologies in Massachusetts.[61] On August 9, 2018 the governor signed H.4857, An Act to Advance Clean Energy, into state law.[62] Among other things, this Act:

- Increases the RPS by 2% instead of 1% yearly for the 10 years of 2020 to 2029. Currently at 13% in 2018, the RPS is therefore pegged at 35% for 2030.
- Reinforces the energy storage deployment target of 200 MWh by 2020 with another target of 1,000 MWh by 2025.
- Creates a first-of-its-kind Clean Peak Standard along with a new RPS attribute called "clean peak certificates" indicating that a resource was not only "clean" but also delivered during a defined "peak" period. Energy storage qualifies as a clean peak resource. In the coming months, the Department of Energy Resources will lay out additional program rules and methodology.
- Authorizes procurement for doubling offshore wind to 3,200 MW by the end of 2035.

The Energy Storage Initiative produced the original 200 MWh by 2020 Massachusetts energy storage target, the "State of Charge" case study examining 10 use cases,[63] and the Advancing Commonwealth Energy Storage (ACES) Program $20 million grant pool which was awarded to 26 projects. Grant recipients were announced in December 2017.[64]

The Solar Massachusetts Renewable Target (SMART) incentive program replaced the Solar Renewable Energy Credit (SREC) Program effective November 26, 2018.[65] Municipal Light Plants were not participants in the initial SMART program, but as of early 2019, Concord residents are eligible for two solar incentives.

Estimated GHG Emission Reductions for Concord

Emissions from electricity accounted for 23.3% of Concord's 2016 GHG inventory at 54,234 $MTCO_2e$. Reductions from this measure are capped at 54,234 $MTCO_2e$, expressed in the high case scenario which represents complete decarbonization of electricity and reduction of all 2016 emissions associated with electricity. The effects of fuel switching, for example bringing on additional load through a market shift toward electric vehicles and electrification of building heating loads via air source heat pumps, are accounted for separately in those measures within this report. Reduction estimates range between a low case of 10,673 $MTCO_2e$ reduced, up to a 100% reduction of electricity emissions at 54,234 $MTCO_2e$. These estimates are tied to RPS and decarbonization milestones.

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61 https://www.mass.gov/service-details/program-summaries
62 https://malegislature.gov/Bills/190/H4857
63 https://www.mass.gov/service-details/energy-storage-study
64 http://files.masscec.com/ACES%20Project%20Details.pdf
65 http://www.concordma.gov/2029/Solar-Panels

Contribution to GHG Emissions Target

The low case scenario represents meeting the updated Massachusetts RPS target of 35% by 2030. A simulated 2030 electricity emissions factor for Concord under the scenario of 35% renewables is modeled at 559.95 lbs CO_2e/MWh, representing a mix of electricity provided by renewable sources (with RECs retired), market purchases, bilateral agreements, and specific supplier contracts. 2016 electricity usage at that factor results in a reduction of electricity related emissions by 2030 of 10,673 $MTCO_2e$, 19.7% of Concord's 2016 electricity emissions and 4.6% of the 2016 community-wide inventory.

The mid case scenario represents achieving a 70% renewable electricity generation mix by 2030 (double the RPS). The 2030 electricity emissions factor for Concord is modeled at 258.42 lbs CO_2e/MWh, representing a mix of electricity provided by renewable sources (with RECs retired), market purchases, bilateral agreements, and specific supplier contracts. 2016 electricity usage at that factor results in a reduction of electricity related emissions by 2030 of 34,130 MTCO2e, 62.9% of Concord's 2016 electricity emissions and 14.7% of the 2016 community-wide inventory.

The high case scenario represents achieving zero carbon electricity by 2030. The 2030 electricity emissions factor for Concord is modeled at zero lbs. CO_2e/MWh. All emissions resulting from Concord 2016 electricity use, 54,234 MTCO2e, are reduced to zero. This represents 23.3% of the 2016 community-wide inventory.

Assumptions and Calculations

KLA reviewed CMLP electricity generating resources while compiling Concord's 2016 greenhouse gas inventory. A custom emissions factor of 697.14 lbs CO_2e/MWh was applied to the electricity activity data, based heavily on ISO New England's Regional 2016 factor of 710 lbs CO_2/MWh. In 2016, almost all sources were assumed to be the same as ISO New England's Regional 2016 factor. RECs from renewable suppliers were not retired by CMLP in 2016. Energy supplied from Constellation, NextEra, and Rise typically include some portion of grid power. The amount of grid power relative to other sources per supplier was not known, thus the ISO New England factor was deemed most appropriate. Kearsage and Solect solar power is connected directly to the CMLP grid, however the RECs generated were sold off. Therefore, power from these sources was also calculated using the ISO New England Regional Factor as basis. NYPA's large hydro resource is considered a zero-emission source. The eGRID 2016 emissions factor was used for the Watson facility. Finally, CH_4 and N_2O factors are not available from ISO New England. eGRID CH_4 and N_2O factors were added to the 710 lbs CO_2/MWh figure, contributing modestly according to their quantity and global warming potential to arrive at a generally used emissions factor of 715.83 CO_2e/MWh.