Town of Harvard Energy Advisory Committee

BRIAN SMITH – CHAIR	ASSOCIATE MEMBERS:	PAUL GREEN
DAVID FAY	STUDENT MEMBER:	OPEN
FORREST HODGKINS	LIAISONS:	KARA MINAR, SELECT BOARD
PETER KELLY-JOSEPH		SUSANMARY REDINGER, SCHOOL COMMITTEE
ELLEN SACHS-LEICHER		SUSANMARY REDINGER, CAPITAL PLANNING
		CHARLES OLIVER, FINANCE COMMITTEE

Meeting Minutes 3/3/22

Attendees: B. Smith, D. Fay, F. Hodgkins, P. Kelly-Joseph, E. Sachs-Leicher
John Snell (Guest PT)

Location: **This Meeting was held virtually in accordance with Chapter 20 of the Acts of 2021, An Act Relative to Extending Certain COVID-19 Measures Adopted During the State of Emergency and signed into law on June 16, 2021**
Zoom Meeting ID: 837 1474 1040

	Meeting Discussion/Status
Admin	1. HEAC approved the minutes of 2/9/22 5-0 without comment.
Schools	1. HES Solar 260 kW DC Behind the Meter project – a. Select Construction – System is operating as of 2/16/22. b. A celebration is planned for March 8..
Energy Initiatives	1. Net Zero Emissions Plan (Decarbonization) – Funded by DOER/MRPC and performed by John Snell. Municipal Buildings/Operations – This is a roadmap for the Town to achieve net-zero emissions by 2050. a. John Snell revised the plan (Rev 3/1) in response to all comments provided at the Feb 9 meeting. John provided responses to specific comments as needed. There were several items discussed to better understand the basis. One example is the benefits of local renewable energy. John emphasized that local generation within town boundaries enables better control, accelerates renewable mix and allows integration of solar PV, batteries and demand management. Another example is electric buses – since Harvard outsources this service, we can try to influence the contractor to convert to electric but it is likely something that will remain outsourced. John will revise the report prior to the next meeting. b. Note that the state climate plan require renewable generation goals earlier than the current RPS utility requirement of 35% by 2030 and 100% by 2100. c. Review with Town stakeholders – on hold; may be combined with HCIC climate plan. d. Community-wide plan – Further discussion is needed to define where to focus John Snell's efforts in conjunction with the Climate Initiative. 2. Climate Plan – Each area (e.g., Buildings, Energy, Transportation) will require one goal and two actions. The municipal and residential goals were reviewed in each category and agreed as shown below. These goals and actions represent HEAC input and will be forwarded to HCIC for proceeding to the next step of reviewing with other primary and stakeholder committees. Next step is to meet with the School Committee.

		Municipal	Residential
Buildings		**Goal: Convert Municipal buildings from carbon-based fuel combustion to high efficiency electric heating.**	**Goal: Replace Residential building fossil fuel consumption with high efficiency electric heating.**
			Residential Electrification (joint HEAC and HCIC Effort)
	Action	Develop Electrification Technical/Financial Analysis and Upgrade Plan	Evaluate/Adopt ways to encourage conversions.

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	Action	Evaluate/Adopt Updated Stretch Code	Engage community on costs, benefits and solutions.
	Action	Communicate with all stakeholders.	Educate community on grants and incentives for conversions.
		Secondary - Non-energy; Energy Reduction Projects - including Building Envelope	
Energy		**Goal: Convert all electricity to 100% renewable energy sources.**	**GOAL: Increase the number of residential solar arrays and battery storage systems**
			Residential includes C&I.
	Action	Create and Implement On-Site Solar PV Strategic Plan (including Battery Storage).	Engage community on costs, benefits and solutions.
	Action	Municipal generation - change to renewable supply contract.	Advocate use of community solar.
	Action	Communicate with all stakeholders.	Educate community on grants and incentives for conversions.
			Secondary - Maximize participation in CCA?
Trans-portation		**Goal: Convert Municipal vehicles from carbon-based fuel combustion to electric.**	**Goal: Increase the number of residential electric vehicles.**
	Action	Capital Plan for replacement of all applicable (light-duty) vehicles.	
	Action	Develop a charging station plan for municipal vehicle charging stations.	Develop a charging station plan for 100% community-wide electric-vehicle market penetration for the town.

Town Energy Project Updates

1. Green Community Program
   a. GC2021 Spring Competitive grant approved award received for the 4 projects below managed through Energy Conservation Inc.
      i. Bromfield Transformers – complete.
      ii. Library Weatherization – Phase 1 insulation in Library attic/roof space. – Project on hold until Air Barrier Solutions can source the spray foam component in 55-gallon drums.- no update.
      iii. Bromfield Weatherization –- Work complete. Need Phase 2 invoice.
      iv. TBS Court Lighting –Brian to submit request to DOER to honor grant even though invoice paid prior to grant. Evaluate re-scope of funds if needed, e.g. TBS interior lighting – Request submitted to DOER 2/6.- request rejected 2/11 and therefore project is removed.
   b. Future Projects – Forrest discussed with Patrick Harrigan and suggested Unit Ventilators in the Bromfield classrooms. The next round is in the Fall and proposals need to be finalized by end of summer.
   c. Quarterly Report- Brian to prepare and submit to DOER. – submitted 2/6.
2. Charging Station – HEAC is working with ECI to evaluate charging stations at multiple locations:

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	a. Library – Input from Library Trustees – prefer location at end of parking lot away from building; may require new service; facilitates standard or fast charger. b. Bromfield – The spots by the courts are closest to the electric panels for connecting the charger conductors. Some prefer to have it be in front and be more visible. c. Town Hall – limited spots but supported by Town. d. General Store – needs separate meter; issue with obstruction and limited space. e. Other areas – Harvard Park (track); commercial district? f. Fire/Police stations – Need fast chargers. The MA state EVIP program should provide 100% of the funds required for the equipment and installation, for publicly available chargers. Brian to request ECI to perform inspection of site locations. – No update 3. Streetlights – The Historical Commission held a hearing on Mar 2. Feedback was generally positive about the replacement of existing lights with LED light fixtures. The Historical Commission requested the next step is to evaluate a sample light installation. David will request from National Grid to install a sample by end of March. 4. Vehicles – Possible vehicles to replace with electric – Fire/Police: Ford Explorers (5), Dodge Chargers (2) F150 (1). Green Community may offer $10-15k toward a replacement vehicle. Focus on police cars in next capital cycle. Chief Babu requested assistance in obtaining the state incentive for the next hybrid police car purchased (currently planned for June). There may be an advantage to paying for the car later if there is another Green Community grant incentive available in Fall 2022. 5. Solar (Photovoltaic) Strategy – Initial focus on Public Safety Building –Define by summer 2022 for the FY24 Capital plan. HEAC to investigate procurement strategy with Marie Sobalvarro. a. Next actions: 1. Investigate PPA/Lease vs Own. 2. Evaluate Interconnect impact with NGRID. 3. Evaluate with the solar readiness of the building with Chief Babu, Jeff Hayes and Tim Bragan. The building was built in 2007; need to determine if the roof needs to be replaced. 6. Earth Day – HEAC will co-sponsor activities to engage with the community on Apr 30. HCIC is planning the activities.
Membership	No update.
	Meeting adjourned 9:30 pm (voted 5-0).
Future Meetings	2022: Mar 23, Apr 13, May 11, Jun 8 HEAC Meeting Location/Time: 8 pm. – Virtual until further notice

Montachusett Regional Planning Commission and John Snell LLC

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85% Decarbonization by 2050 Plan
for
The Town of Harvard's
Municipal Facilities and Operations – 2nd Draft
March 1, 2022

Montachusett Regional Planning Commission and John Snell LLC

Town of Harvard
Municipal Facilities and Operations Decarbonization Plan
2nd Draft - JS
March 1, 2022

Town of Harvard,

Thank you for the opportunity to help develop a path for Harvard to decarbonize its municipal facilities and operations. With financial assistance from the MA Department of Energy Resources (MA DOER), the Montachusett Regional Planning Commission (MRPC) has prepared the following municipal decarbonization plan for the Town of Harvard's facilities and operations.

The plan was developed by MRPC and its consultant John Snell LLC who are solely responsible for the accuracy of this report. We have worked closely with the Energy Advisory CommitteeBrian Smith and town staff to confirm the information in this report and to shape the timing and scale of potential activities designed to meet the state's 2030 and 2050 decarbonization goals.

The process that we followed to produce this report included:

1. Prepared a preliminary carbon emission assessment
2. Developed a preliminary set of recommendations and timeline to meet the State's decarbonization goals
3. Reviewed the draft recommendations and timeline with town staff, management, and committees
4. Prepared a final draft report and providing Harvard with the supporting analysis files for future reference

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Decarbonization Road Map

Harvard's municipal facilities and operations emit about 1,493 mTonsCO2e[1] greenhouse gas emissions ~~of carbon~~ per year. The three primary sources of carbon emissions that we identified for Harvard's municipal facilities and operations were fuel combustion for heating and domestic hot water (DHW), the town's vehicles, and utility provided non-renewable energy electricity generation. Recommendations to reduce carbon emissions from these sources include:

1. Convert heating and domestic hot water (DHW) systems from fuel to high efficiency electricity
2. Convert town vehicles from internal combustion engines to electric motors
3. Convert all electricity generation from fuel to renewable energy

This approach focusses on fossil fuel replacement with electric equipment. However, converting heavy equipment to electric is not realistic in the near term. Unknown technologies like hydrogen or biodiesel might be better solutions longer term for heavy equipment.

The following sections detail our findings and specific recommendations for these three areas.

Appendices A-G include detailed facility-by-facility and vehicle-by-vehicle carbon emissions, potential energy savings, fuel reductions, conversion costs, electricity use increases, local renewable energy, and carbon offset opportunities.

[1] Metric tons of carbon dioxide equivalent
[2] We selected FY2019 utility data for the baseline energy conditions because FY2019 was the last full year pre-COVID19.

Heating and Domestic Hot Water

Harvard has 12 facilities with about 337,648 square feet that burn natural gas, oil, and propane for heat and domestic hot water (DHW). Total energy use for these facilities in fiscal year 2019[2] included:

- Natural Gas – 133,878 therms
- Oil – 3,606 gallons
- Propane – 1,246 gallons

This energy use is equivalent to 14,002 MMBtu[3]. In addition, these facilities consumed about 1,667,351 kWh of electricity which is equivalent to about 5,689 MMBtu[4].

Energy Efficiency Projects

Energy efficiency investments are the most cost-effective solution to reduce total energy use in Harvard's facilities. Energy efficient buildings are often more comfortable, durable, and healthier to work in than less efficient buildings. In addition, energy efficient buildings use smaller heating systems, require less electricity, and are less susceptible to high energy use and cost spikes caused by extreme weather conditions than less efficient buildings.

A reasonable energy performance target for new construction is about 25 kBtu[5] per square foot for all energy use including electricity. This metric is termed energy use intensity (EUI) standard. We used this value to identify potential energy efficiency opportunities for buildings with heating and DHW

[3] Million British Thermal Units
[4] All utility and facility data is from MassEnergyInsight
[5] Thousand British Thermal Units

Commented [JS1]: Forrest Hodgkins comment - Converson 1 kwhr = 3413 btu but not accurate for emissions. Actual emissions would be higher due to lower efficiency of the source. Calc assumes power plant is 100% efficient. Feeds into Co2e.

Commented [JS2R1]: This is just energy not emissions. In addition, it's site energy not source energy. Forrest's observation is correct that electricity emissions need to factor in power plant efficiency. I believe that MEI's emissions calculations factor in powerplant efficiency.

EUIs higher than 25 kBtu/SF. These measures can be implemented as part of scheduled building maintenance and/or major renovation and rehabilitation investments.

Table 1 includes the energy savings assumptions and target implementation dates for the potential energy efficiency opportunities that we identified. Please refer to Appendix C for additional detail.

Facility name	Gross Floor Area (SF)	FY 2019 Heat/DHW (MMBtu)	FY 2019 Heat/DHW (kBtu/SF)	Target Heat/DHW (kBtu/SF)	Heat/DHW Reduction (%)	Target Efficiency Project Date (Year)
bromfield school	180,921	6,631	37	25	32%	2045
hildreth school	68,732	3,942	57	35	39%	2025
new library	22,199	1,394	63	50	20%	2040
highway department	10,180	447	44	25	43%	2030
police/ambulance station	9,345	97	10	10	0%	2035
center fire station	5,712	384	67	35	48%	2035
town hall	11,686	297	25	25	2%	2040
old library	9,881	251	25	25	2%	2045
hildreth house	8,778	204	23	23	1%	2035
bromfield house	6,134	188	31	25	18%	2040
still river fire station	1,792	150	84	40	52%	2035
old ambulance building	2,288	17	7	7	0%	2030
Total	337,648	14,002				

Table 1. Energy efficiency project assumptions and savings

Energy efficiency investments require close coordination with related building renovations and upgrades. Harvard will need to request and review more detailed energy engineering assessments to identify specific energy efficiency recommendations as part of these projects. The incremental cost for high performance building best practices should be about 10% or less of total project costs.

Appendix C includes additional energy efficiency documentation.

Fuel to Electricity Conversions

Converting Harvard's buildings from fuel combustion to high efficiency electric heating and domestic hot water equipment is key to the town's decarbonization efforts. Carbon emission rates will remain high until this equipment is replaced. Table 2 lists very preliminary~~the~~ estimated replacement costs[6] for the existing equipment and the estimated cost to install three alternative types of high efficiency electric heat pump equipment[7]. Please refer to Appendix D for additional detail.

Commented [JS5]: Forrest H – These costs should be in an Appendix and clearly identified as rough estimate (or similar). The footnotes identify assumption and for comparison but certain readers will assume that costs presented are backed up with quotes or that costs that are not rounded off are accurate.

Commented [JS3]: Brian - This will be summarized in a next step section?

Commented [JS4R3]: Next steps added

[6] The replacement cost for existing equipment assumes $100,000 per MMBTU heating output.

[7] Actual equipment costs will vary significantly depending on site specific conditions. The emphasis here is that ductless heat pumps are significantly less expense to install than VRF and ground source heat pumps. Estimated costs per ton are from an oil-fired steam retrofit to high efficiency electric conversion engineering analysis in 2018 for Newburyport City hall.

Facility name	Gross Floor Area (SF)	Estimated Standard Replacement Cost ($)	$5,000 Ductless Cost ($)	$10,000 VRF Cost ($)	$10,000 Ground Cost ($)
bromfield school	180,921	633,224	1,758,954	3,517,908	3,517,908
hildreth school	68,732	240,562	668,228	1,336,456	1,336,456
new library	22,199	77,697	215,824	431,647	431,647
highway department	10,180	35,630	98,972	197,944	197,944
police/ambulance station	9,345	32,708	90,854	181,708	181,708
center fire station	5,712	19,992	55,533	111,067	111,067
town hall	11,686	40,901	113,614	227,228	227,228
old library	9,881	34,584	96,065	192,131	192,131
hildreth house	8,778	30,723	85,342	170,683	170,683
bromfield house	6,134	21,469	59,636	119,272	119,272
still river fire station	1,792	6,272	17,422	34,844	34,844
old ambulance building	2,288	8,008	22,244	44,489	44,489

Facility name	Gross Floor Area (SF)	Estimated Standard Replacement Cost ($)	$10,000 Ductless Cost ($)	$16,000 VRF Cost ($)	$26,000 Ground Cost ($)
bromfield school	180,921	633,224	3,517,908	5,628,653	9,146,562
hildreth school	68,732	240,562	1,336,456	2,138,329	3,474,784
new library	22,199	77,697	431,647	690,636	1,122,283
highway department	10,180	35,630	197,944	316,711	514,656
police/ambulance station	9,345	32,708	181,708	290,733	472,442
center fire station	5,712	19,992	111,067	177,707	288,773
town hall	11,686	40,901	227,228	363,564	590,792
old library	9,881	34,584	192,131	307,409	499,539
hildreth house	8,778	30,723	170,683	273,093	443,777
bromfield house	6,134	21,469	119,272	190,836	310,108
still river fire station	1,792	6,272	34,844	55,751	90,596
old ambulance building	2,288	8,008	44,489	71,182	115,671
Total	337,648	$1,181,768	$6,565,378	$10,504,604	$17,069,982

Table 2. Estimated fuel conversion equipment costs

The first two heat pump technologies are air-source. Ductless heat pumps are used both in residential and commercial applications and are the most cost-effective fuel conversion option. Variable Refrigerant flow (VRF) heat pumps are primarily used in commercial applications.

The third heat pump option is ground-source heat pumps (Ground) sometimes referred to as geothermal. Ground-source heat pumps require a large water source in the form of a pond, stream, or well. Ground source heat pumps are used both in residential and commercial applications.

Ductless heat pumps serve one or two rooms and require multiple systems to serve a large room. VRF and Ground Source heat pumps serve multiple rooms. The cost for these systems is higher because they include the cost to install significant heating and cooling distribution components and advanced control systems.

All three heat pump options provide heating and cooling at very high efficiency. However, they heat water or air at lower temperatures than fossil fuel-fired heating systems. One major consideration for heat pump technology is the air or water temperature that heat pumps deliver. Heat pump technology provides lower air or water temperature than fuel-fired heating systems. Harvard should identify buildings that currently have high-temperature heating distributions and assess additional heating distribution system upgrades that may be required before or as part of a fuel to high efficiency electric conversion installation.

Domestic hot water conversion options include solar, heat pump, and electric resistance water heating systems. Solar and hybrid heat pump domestic hot water systems are better for high-use municipal systems such as school kitchens. Small well insulated electric resistance or heat pump domestic hot water systems are better for low-use municipal settings such as rest rooms.

Commented [JS8]: Brian - There has been recent discussion about a central plant (more than one building) using ground source – is this worth mentioning?

Commented [JS9R8]: Yes, we can add information in the report about Harvard's central plant discussions

Commented [JS6]: Brian - What about the distribution changeover cost for central systems of a large school? Rough estimate. Number should be 2x 3x 5x.Not credible. Need to know end of life.

Commented [JS7R6]: Agreed

Vehicles

Harvard has 48 vehicles and other equipment that have gasoline or diesel-powered internal combustion engines. Please refer to the Aappendix E for a complete list of these vehicles and equipment[8]. Total energy use for these vehicles in fiscal year 2019 was:

- Gasoline – 14,995 gallons
- Diesel – 12,002 gallons

This fuel use is equivalent to about 3,753 MMBtu. Individual vehicle fuel use was unavailable for this report. For the purposes of this report, we estimated the average gasoline and diesel fuel use per vehicle.

Light-Duty Vehicles

Light-duty vehicles are the primary source of gasoline fuel consumption. Affordable electric motor vehicles exist right now that can replace the town's light-duty vehicles that are scheduled for retirement in the next few years. The replacement cost for electric-powered light-duty vehicles has dropped significantly and is close to or on par with internal combustion engine vehicle costs.

Heavy-Duty Vehicles

Heavy-duty vehicles are the primary source of diesel fuel consumption. Few affordable electric-powered vehicles exist to replace the town's heavy-duty vehicles. In addition, heavy-duty vehicles provide services such as around-the-clock snowplowing that may be challenging for electric-powered vehicles to provide.

Heavy-duty vehicle conversions will most likely need to wait until the electric-powered heavy-duty vehicle market develops further. Interim retrofit options exist for heavy-duty vehicles including brake-assist and engine idling management systems.

Harvard outsources school bus services and does not own its school buses. Fuel consumption for the school buses does not have to be and is not included in Harvard's Green Community energy use. Harvard could include school bus fuel consumption as part of the town's municipal facility and operations or the town's community-wide decarbonization efforts.

Future school bus transportation contract negotiations could include discussions with school bus vendors regarding school bus fuel to electric conversions. The negotiations should include a discussion about parking the buses near the schools and purchasing Bi-directional charging stations. The large batteries in school buses may offer Harvard important load management opportunities. Bi-directional charging stations allow vehicle batteries to both charge from and discharge to the electrical distribution system.

Bi-directional charging stations combined with an intelligent charging system will allow Harvard to use school bus and other vehicles to reduce peak electrical load conditions, charge the vehicles during periods of low demand, supplement electrical loads at night, and support emergency electrical power when the electrical system is down. Electric school bus batteries are particularly important because the batteries are very large.

Commented [JS10]: Peter - This is a cool idea but I could never envision Harvard implementing at all or at such a small scale. Harvard's seven buses with 225 kW motors (Thomas school bus website) equals 1.5 MW of demand response opportunity. If we are looking at participating in demand response, we should do it town wide using much larger battery installations.

Commented [JS11R10]: David is skeptical as well. We can discuss what Harvard would like to include (or not) about buses.

[8] Data source: 2019 Town vehicle insurance records

Charging Stations and Load Management

Part and parcel with converting vehicles from fuel to electricity, Harvard needs to anticipate how to pay for, locate, and manage associated electric charging stations. Harvard will need to purchase and place electric charging stations in convenient locations and get approval to connect them to the utility grid. Vehicles that Harvard should consider with its electric charging station deployment include town-owned vehicles, town staff-owned vehicles, and town resident-owned vehicles.

We recommend that Harvard develop a charging station plan for 100% community-wide electric-vehicle market penetration for the town. Harvard can then work backwards to determine the location for Harvard's first wave of electric charging stations. Rapid changes in EV vehicle technology combined with the investment in EV charging stations included in the recently approved Infrastructure bill will undoubtedly create a long-term need for more electric charging stations. On the flip side, most homes might install their own EV chargers and public charging stations may be less important than they are now.

Harvard will need to develop a load management plan with National Grid with this information and coordinate a phased installation plan with the utility company. Charging multiple vehicles rapidly and concurrently will add significant electrical load to the existing utility distribution infrastructure. On a more positive note, connecting multiple electric vehicles with large batteries to the utility distribution system will also offer significant load management opportunities.

Electricity

Harvard uses electricity for its buildings, other structures, streetlights, and other services. Total municipal facility and operations electricity used in fiscal year 2019 was 1,936,032 kWh or about 6,606 MMBtu.

Electricity that Harvard purchased from National Grid in fiscal year 2019 included electricity generated from fossil-fuel and multiple grades of renewable energy electrical generation plants. National Grid's electricity generation sources in 2019 were 86% fossil fuel (mostly natural gas) and 14% renewable energy.

Table 3 summarizes the projected increase in the default electricity supply that utility companies must provide customers. State legislation requires National Grid to increase the percent of renewable energy generation 2% each year until 2029 when the increase is reduced to 1% each year. Other electricity suppliers offer higher levels of renewable energy.

Variables to consider regarding grid-level renewable energy procurement include class, source (local, regional, or national), and renewable energy credit (REC) status. Class I local renewable energy that have not sold the renewable energy credits are the highest quality. Harvard can consider transitioning from "lower quality" to "high quality" renewable energy over time in order to keep grid-level renewable energy procurement more cost-effective.

Commented [JS15]: Brian - I think it is important to provide the RPS plan in MA. My search says it is 35% by 2030 and 1%/year after that, which sounds like a long time – 100% by 2100?

Commented [JS12]: Peter - I support incentives for residential self-performed installs, with a few more chargers we will be at saturation of municipal buildings. Fleet charging is different and we should/are support converting the municipal fleet.

Commented [JS13]: Peter - Do municipalities do these? I would expect commercial/industrial customers to lead this.

Commented [JS14R13]: Maybe the report needs another term here other than load management. I'm suggesting that Harvard communicate directly with National Grid regarding the transition of Harvard's electrical grid as it currently exists to something else. The scale of potential electrification community-wide is significant. In addition, National Grid won't be able to turn on dime to serve this increased demand for electricity. The state will play a major role in how this plays out but individual communities like Harvard should play a role in shaping the transition and the final outcome.

Year	Total	Class I	Class II	Class II Biomass
2019	14.0%	14.0%		
2025	33.1%	26.0%	3.6%	3.5%
2030	42.1%	35.0%	3.6%	3.5%
2035	47.1%	40.0%	3.6%	3.5%
2040	52.1%	45.0%	3.6%	3.5%
2045	57.1%	50.0%	3.6%	3.5%
2050	62.1%	55.0%	3.6%	3.5%

Table 3. Renewable Energy Portfolio Standard[9]

In addition to grid-purchased electricity, Harvard purchased supply electricity through a solar photovoltaic (PV) power purchase agreement from a solar farm in Athol and produced electricity from a small PV installation located on the Hildreth elementary school. Harvard has a renewable energy procurement option for residential and commercial electric customers. However, Harvard does not have a municipal facility renewable energy electricity supply contract.

We project that the total electricity use by Harvard's facilities and operations will increase by about 75% by 2050. This includes additional electricity use for proposed electric heating and DHW fuel to electric conversions and proposed vehicle fuel to electricity conversions. It also takes into consideration proposed energy efficiency projects. Other variables that will affect future electricity use include the economy and the electricity industry's historic 3% per year increase. Recent events and technologies have disrupted and will most likely continue to disrupt small, predictable annual electricity use increases.

Grid Electricity

We project that the source of Harvard's electricity will shift away from grid-provided electric generation sources to about 90% local and regional renewable generation by 2050. Harvard will continue to connect to the local and regional ISO NE[10] electric grid but the source of electricity will increasingly shift to local sources.

Figure 1 summarizes our projected transition for Harvard's electricity use and mix of electricity generation through 2050.

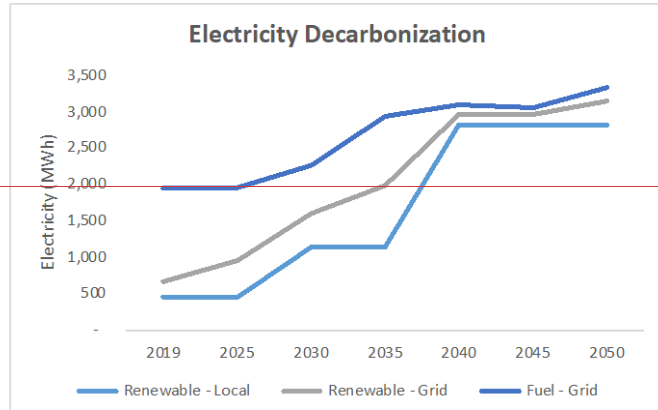

Figure 1. Projected electricity load and fuel mix

[9] Per H3708

[10] **ISO New England Inc.** (ISO-NE) is an independent, non-profit organization that oversees the operation of New England's bulk electric power system and transmission lines.

Commented [JS17]: Peter - This makes no sense recommend removing. Most expect offshore wind and Canadian hydro to be needed to support ISO-NE load. Location of generation is irrelevant to GHG reduction goals.

Commented [JS18R17]: Sounds like we need to discuss prioritizing local renewable energy further. Comments range from "removing" any mention of local solar to why do we need to wait until "2030 or 2040?" to install (I assume local) solar.
My philosophical bent is to emphasize locally integrated efficiency, solar PV, stationary and mobile batteries, and demand management. This may not align with Harvard's priorities, and if not, I should change the report accordingly.

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Commented [JS16]: Brian - This is correct for the Municipality contract but not for residential because we have CCA.

Figure 1 demonstrates a steady decline in fossil fuel grid electricity. State law requires investor-owned utility companies to increase the amount of renewable energy that they provide as part of their standard offer by 2% per year. In addition, we recommend that the town increase the amount of local renewable energy that it produces or procures. The chart highlights the impact of two proposed local renewable energy solar PV initiatives. One suggested initiative would be in 2030 for town facilities and parking lot installations. The second suggested initiative would be in 2040 for a large ground-mounted installation(s).

Local Renewable Electricity

Table 3 identifies current and potential solar PV installation locations on town facilities, town-owned land, and independent power purchase agreements. Please refer to Appendix F for additional detail.

Facility name	Available Roof Area (SF)	Available Land Area (Acres)	Estimated Solar PV Peak Output (kW)	$3,496 < 250 kW Roof ($)	$5,000 < 1 MW Parking ($)	$1,500 <1 MW Ground ($)	$1,200 >1 MW Ground ($)	Solar Electric kWh	Target Installation Date (Year)
bromfield school	36,184		109.3	382,103				139,357	2030
hildreth school	13,746		41.5	145,161				52,942	2030
new library	4,440		13.4	46,884				17,099	2030
highway department	2,036		6.2	21,500				7,841	2030
police/ambulance station	1,869		5.6	19,737				7,198	2030
center fire station	1,142		3.5	12,064				4,400	2030
town hall	2,337		7.1	24,681				9,001	2030
old library	1,976		6.0	20,869				7,611	
hildreth house	1,756		5.3	18,539				6,761	
bromfield house	1,227		3.7	12,955				4,725	
still river fire station	358		1.1	3,785				1,380	2030
old ambulance building	458		1.4	4,832				1,762	
school parking lots		2.0	263.2		1,315,789			335,526	2030
DPW parking lot		0.2	26.3		131,579			33,553	2030
Police parking lot		0.2	26.3		131,579			33,553	2030
Fire parking lot		0.2	26.3		131,579			33,553	2030
Library parking lot		0.2	26.3		131,579			33,553	
Athol PPA		2.2	289.5			434,211		369,079	
Other PPA		10.0	1,315.8				1,578,947	1,677,632	2040
	67,530	15.0	2,007.3	$713,109	$1,842,105	$434,211	$1,578,947	2,776,525	

Table 3. Solar PV costs, output, and target installation dates

We recommend that Harvard prepare or hire a consultant to assess all potential solar PV sites on municipally owned or controlled land for public review. Sites to review include the rooftop, parking lot, and potential open land sites listed in Table 3. The assessment should include aerial surveys of the sites, potential electricity peak output and annual electricity generation, estimated costs, and solar site ratings. ~~Solar Design Associates in Harvard prepared a solar site assessment for Lincoln that Harvard could use as a template.~~

Depending on the solar PV site assessment findings, we envision Harvard signing a power purchase agreement in 2040 to supply about 1.5 MWh of local or regionally located solar PV electricity. This will require about 10 acres of ground-mounted solar PV panels.

Harvard will need to stay attuned to potential grant opportunities, rapidly changing Federal and State incentive programs, and the price of large-scale renewable energy installations. Current municipal sector best practice is to negotiate a solar PV power purchase agreement.

Net Carbon Emissions Reduction

The actions recommended in this decarbonization plan will reduce overall carbon emissions from Harvard's municipal facilities and operations by about 16% in 2030 and about 97% by 2050[11]. This falls short of the State's 50% carbon reduction target by 2030 and exceeds the State's 85% by 2050 carbon

[11] These percent reductions do not include potential carbon offset program benefits discussed later in this report. Harvard could reach 100% decarbonization by 2050 if the town purchased 100% renewable energy supply electricity.

Commented [JS21]: Brian - Hildreth School solar PV is installed. Bromfield roof is a challenge and will face resistance. Ground mounted or canopy are possible.

Commented [JS22]: Peter suggests deleting reference to SDA

Commented [JS23]: Peter -

Commented [JS19]: Peter - "Local" energy is being made out to be better than non-"local" energy. Recommend removing.

Commented [JS24]: Peter - Why local? Recommend removing. Arbitrary cost increase.

Commented [JS20]: Brian - Refer to Appendix F?

reduction target. Adding a carbon sequestration forest management program (described later in this section) would help Harvard meet the State's 2030 carbon reduction target.

Carbon Emissions Reduction

Figure 2 represents the projected transition for Harvard's carbon emissions reduction through 2050.

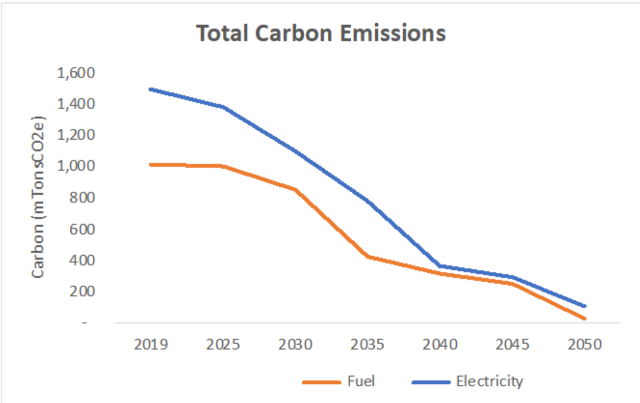


Figure 2. Total carbon emissions reduction

As figure 2 indicates, the primary source of municipal facility and operations carbon emissions is fuel combustion. About 75% of Harvard's carbon emissions are from building and vehicle-related fuel combustion and about 25% of the carbon emissions are from electricity generation fuel consumption.

Fuel-related carbon emissions will drop in close correlation with the speed and scale that Harvard can convert fuel-based combustion equipment to electric-powered equipment. At the same time, Harvard needs to transition to local renewable energy electricity generation.

Commented [JS25]: Peter - Why local- remove.

Carbon Offsets

Table 4 includes preliminary information for potential local carbon offset opportunities with town-owned or town-controlled land.

Type	Owner	Total Land Area (Acres)	Net Carbon Offset Land Area (Acres)	Carbon Offset Land Area (%)	Forest Management (Carbon Credits)	Voluntary Carbon Market ($)	Carbon Project Developer Fee ($)
Forest		3,000	2,400	100%	4,800	24,000	9,600
Forest		2,000		0%			
Forest		500		0%			
Forest		400		0%			
Field		100		0%			
Field		100		0%			
Total		6,100	2,400	49%	4,800	$24,000	$9,600

Note 1: 1 carbon credit = 1 metric ton of CO2 (mTonCO@e)
Note 2: The total project size must be 3,000 acres or more

Table 4. Forest management carbon offset program details

Massachusetts is working on a plan (unreleased) to incorporate carbon sequestration opportunities in forests and fields to offset carbon emissions with the state's decarbonization initiatives. In addition, MA DER and MA Audubon have developed supporting material for municipal carbon offset initiatives.

Based on these efforts, we recommend that Harvard investigate opportunities to enroll town-owned or controlled land into carbon sequestration-focused forest management programs. The minimum recommended size for a formal carbon offset project is about 3,000 acres. A carbon offset project of this scale would allow Harvard to prepare a sequestration forest management and qualify for in-house or voluntary carbon market credits.

Commented [JS26]: Peter - What is a in house carbon credit? Need to note that town land already in conservation would not be eligible as it's already protected.

In-house credits would help offset Harvard municipal or other community carbon emissions. Voluntary carbon market credits would provide a financial return and help Harvard pay for associated sustainable forest management expenses.

Net Carbon Emissions

The proposed fuel conversions, renewable energy generation, energy efficiency, and carbon offset recommendations in this report, offer Harvard the resources necessary to meet Massachusetts 2030 and 2050 decarbonization goals. Figure 3 provides the forecast net carbon emissions glide path through 2050.

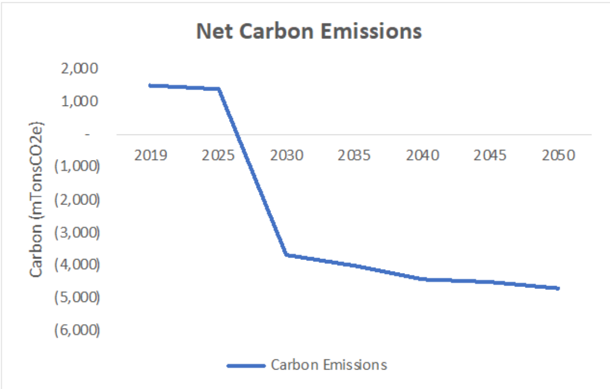


Figure 3. Net carbon emissions with 3,000 acre carbon offset

Next Steps

Share the roadmap with Harvard's technical and financial partners at MA DOER and MRPC

Green Communities/MRPC

The Green Communities program run by MA DOER is the primary conduit between municipalities and the State's decarbonization efforts. Harvard should share this roadmap with its Green Community Regional Coordinator to confirm that the roadmap aligns with the state's 2050 plan.

In addition, Harvard will need additional technical and financial support to plan for and implement the building, vehicle, and renewable energy actions recommended in the roadmap. MRPC and Harvard's regional coordinator can help apprise Harvard of technical and financial planning resources. Specific planning needs for building, vehicle, and renewable energy actions recommended in the roadmap include:

Buildings

Each building should receive a more detailed technical and financial analysis for one of two options. The first option is to replace the existing fossil fuel mechanical equipment with high efficiency electric mechanical equipment. The second option is to replace the existing fossil fuel mechanical equipment replacement as part of a comprehensive upgrade of the building's thermal performance.

The reports should document each buildings current energy performance, utility bill rates and cost, existing equipment, and provide budget level cost estimates for the proposed equipment and building energy performance upgrades. The report should include examples of comparable upgrades to similar buildings in Massachusetts and lessons learned.

On a building portfolio wide basis, the town would benefit from town facility management staff agreement on preferred approaches and associated preferred technology for high efficiency electricity and energy performance upgrades. Managing buildings with different technologies and equipment is very challenging.

In addition, building controls will play an increasingly important role as the primary tool to connect multiple pieces of equipment and every changing electrical loads and manage associated electric costs. Harvard should plan on deploying a portfolio-wide building (and vehicle charging/solar PV/battery) control system. The town's budget should include regular (every 2-3 years) software and hardware updates.

Vehicles

Harvard will need to align the implementation of its vehicle conversions with the state's EV infrastructure upgrades, vehicle procurement, and vehicle incentive programs. The state's EV deployment plan is available at https://www.mass.gov/doc/transportation-sector-technical-report/download

Vehicle procurement will continue through the state's COMMBUYS program. Additional collective procurement opportunities may arise that the Green Communities program and MRPC can alert the town about. EV incentive programs are available for light, medium, and heavy-duty vehicles at https://www.mass.gov/service-details/mor-ev-rebate-program

Renewable Electricity

Harvard should request technical and financial support to develop a solar PV blueprint for the town. The blueprint would identify potential local solar PV sites on rooftops, parking lots, and open space and rank them based on community-developed criteria. Criteria can include but not limited to potential electricity generation, ease of construction, competing land use values, and visual impact.

National Grid/ Mass Save

National Grid and Mass Save are the primary conduits for the State's project implementation support.

National Grid serves two roles in the implementation process. The first role is faciliatory. National Grid can help identify and coordinate technical and financial support that's available through Mass Save and National Grid. The second role is to help coordinate the nuts-and-bolts details of connecting proposed projects to the local electric grid.

The proposed actions in this roadmap will have a significant impact on the local electrical grid. Advanced discussions with National Grid about the proposed scale and timing of these actions will assist National Grid with their local grid upgrade plans. Local and regional electrical grid upgrades often require 2-5 years to implement. The state and National Grid will need to anticipate and plan for similar actions by Harvard's citizens and businesses as well.

Mass Save is the primary source for high efficiency project funding support. The town and all vendors will need to apply for and comply with Mass Save's programs. Harvard should be aware that Mass Save's programs are reviewed and updated every three years. Financial incentives and program requirements may change from one triennial program term to another.

Develop a financial model to implement the roadmap

Financing and procuring the projects and equipment recommended in this roadmap will be a major challenge and test Harvard's financial resiliency. The town will need to weave funding for these projects with ongoing funding requirements and financial limitations imposed on municipal governments.

Harvard should charge a task force with representatives from the Business Manager's office and the Finance and Capital Planning Committees to investigate and report back on financial alternatives to support these projects. Financial alternatives should include but not be limited to municipal ownership, private ownership, and lease-to-own and related power purchase agreement options. The financial framework should be flexible enough to integrate more detailed reports as they are developed for the proposed building, vehicle, and renewable energy projects.

Communicate the findings and recommendations

The scale of the proposed projects in this roadmap are significant. They reflect the scale of effort proposed in this roadmap reflects the urgent call for rapid change in the State's 2050 Decarbonization Roadmap[12]. Effective, transparent communication with the town's citizens, businesses, and industry will be critical to the success of these projects.

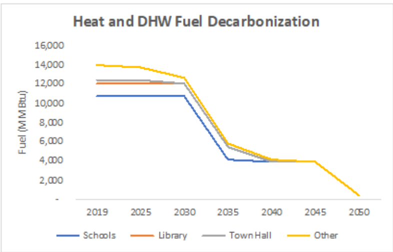
Conclusion

Harvard's municipal facilities and operations emit about 1,493 mTonsCO2e of ~~carbon~~ greenhouse gas emissions per year. Methodical replacement of fuel-powered equipment with electric-powered equipment and fuel-generated electricity with local renewable energy-generated electricity ~~will~~ provides a framework to help the town reduce carbon emissions 16% by 2030 and 97% by 2050. Our report's recommendations and proposed implementation timeline balance the town's need for rapid deployment and prudent fiscal town management.

Commented [JS27]: Brian - May make sense to state that this is a framework of a plan that could result in these results?

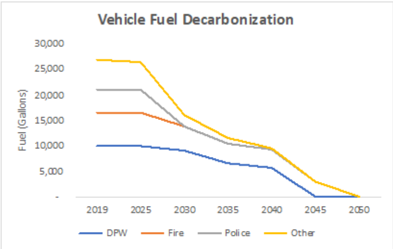
[12] https://www.mass.gov/info-details/ma-decarbonization-roadmap

Appendix A: Decarbonization Summary



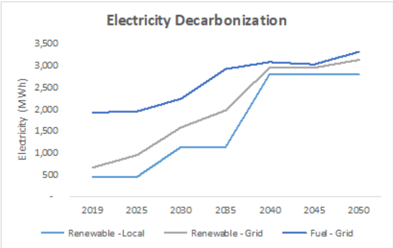
Heating and Domestic Hot Water (DHW) Fuel Decarbonization

Year (Fiscal)	Schools Fuel (MMBtu)	Library Fuel (MMBtu)	Town Hall Fuel (MMBtu)	Other Fuel (MMBtu)	Total Fuel (MMBtu)
2019	10,761	1,394	297	1,550	14,002
2025	10,761	1,394	297	1,383	13,835
2030	**10,761**	**1,394**	-	**552**	**12,707**
2035	4,130	1,394	-	251	5,775
2040	3,942	-	-	251	4,193
2045	3,942	-	-	-	3,942
2050	**461**	-	-	-	**461**



Vehicle Fuel Decarbonization

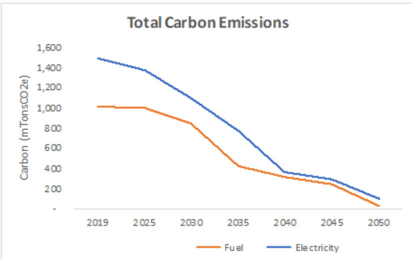
Year (Fiscal)	DPW Fuel (Gallons)	Fire Fuel (Gallons)	Police Fuel (Gallons)	Other Fuel (Gallons)	Total Fuel (Gallons)
2019	10,108	6,519	4,410	5,959	26,997
2025	10,108	6,519	4,410	5,572	26,610
2030	**9,226**	**4,755**	-	**2,044**	**16,025**
2035	6,579	3,873	-	1,162	11,615
2040	5,805	3,486	-	388	9,679
2045	-	3,099	-	-	3,099
2050	-	-	-	-	-



Grid Electricity Decarbonization

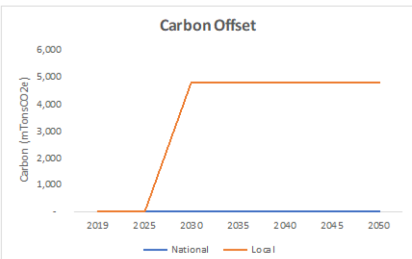
Year (Fiscal)	Fuel - Grid Electricity (MWh)	Renewable - Grid Electricity (MWh)	Total - Grid Electricity (MWh)	Renewable - Local Electricity (MWh)	Total Electricity (MWh)
2019	1,272	207	1,479	456	1,935
2025	1,004	497	1,500	457	1,957
2030	**650**	**473**	**1,123**	**1,132**	**2,255**
2035	951	847	1,797	1,133	2,931
2040	130	141	270	2,811	3,081
2045	104	138	242	2,812	3,054
2050	**195**	**320**	**516**	**2,814**	**3,330**

Appendix B: Carbon Emissions Summary



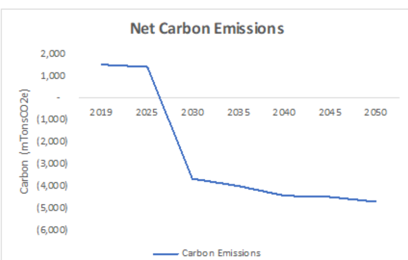
Total Carbon Emissions

Year (Fiscal)	Fuel Carbon (mTonsCO2e)	Electricity Carbon (mTonsCO2e)	Fuel (MMBTU)	Electricity Fuel (MWh)
2019	1,012	482	17,755	1,272
2025	999	381	17,534	1,005
2030	**851**	**247**	**14,935**	**651**
2035	421	361	7,389	953
2040	316	50	5,538	132
2045	249	40	4,373	107
2050	**26**	**76**	**461**	**200**



Carbon Offset

Year (Fiscal)	Total Carbon Offset (mTonsCO2e)	National Carbon Offset (mTonsCO2e)	Local Carbon Offset (mTonsCO2e)
2019	-	-	-
2025	-	-	-
2030	**4,800**	**-**	**4,800**
2035	4,800	-	4,800
2040	4,800	-	4,800
2045	4,800	-	4,800
2050	**4,800**	**-**	**4,800**



Net Carbon Emissions

Year (Fiscal)	Net Carbon Emissions (mTonsCO2e)	Total Carbon Emissions (mTonsCO2e)	Total Carbon Capture (mTonsCO2e)
2019	1,493	1,493	-
2025	1,379	1,379	-
2030	**(3,703)**	**1,097**	**4,800**
2035	(4,018)	782	4,800
2040	(4,435)	365	4,800
2045	(4,510)	290	4,800
2050	**(4,698)**	**102**	**4,800**

Appendix C: Potential Energy Efficiency Impact ~~Project~~s

Building floor area, energy use (MMBtu), current and target energy use (kBtu/SF), proposed project dates, and estimated building heat loss and DHW energy (MMBtu) documentation.

Facility name	Gross Floor Area (SF)	FY 2019 Diesel (MMBtu)	FY 2019 Electric (MMBtu)	FY 2019 Gas (MMBtu)	FY 2019 Gasoline (MMBtu)	FY 2019 Oil (MMBtu)	FY 2019 Propane (MMBtu)	FY 2019 Total (MMBtu)	FY 2019 Heat/DHW (MMBtu)	FY 2019 Heat/DHW (kBtu/SF)	Target Heat/DHW (kBtu/SF)	Heat/DHW Reduction (%)	Target Efficiency Project Date (Year)	Estimated Baseline Fuel Efficiency (%)	Estimated Building Heat/DHW (MMBtu)
bromfield school	180,921		3,106	6,631				9,738	6,631	37	25	32%	2045	75%	4,973
hildreth school	68,732		1,001	3,941				4,942	3,942	57	35	39%	2025	75%	2,957
new library	22,199		698	1,394				2,092	1,394	63	50	20%	2040	75%	1,046
highway department	10,180		107			351	96	555	447	44	25	43%	2030	75%	335
police/ambulance station	9,345		397	97				494	97	10	10	0%	2035	75%	73
center fire station	5,712		64	384				448	384	67	35	48%	2035	75%	288
town hall	11,686		125	297				422	297	25	25	2%	2040	75%	223
old library	9,881		51	251				302	251	25	25	2%	2045	75%	188
hildreth house	8,778		48	204				252	204	23	23	1%	2035	75%	153
bromfield house	6,134		40	188				228	188	31	25	18%	2040	75%	141
still river fire station	1,792		8			150		158	150	84	40	52%	2035	75%	113
old ambulance building	2,288		44				17	61	17	7	7	0%	2030	75%	13
Total	337,648	0	5,689	13,387		501	113	19,692	14,002						10,502

Note: The "Estimated building heat/DHW" MMBtu is the current (FY 2019) fuel consumption in MMBtu times the estimated baseline heating and DHW system fuel efficiency. Shaded areas represent entries and assumptions that can be changed or adjusted.

Estimated efficiency savings potential (MMBtu)

Facility name	Gross Floor Area (SF)	2025 Efficiency Savings (MMBtu)	2030 Efficiency Savings (MMBtu)	2035 Efficiency Savings (MMBtu)	2040 Efficiency Savings (MMBtu)	2045 Efficiency Savings (MMBtu)	2050 Efficiency Savings (MMBtu)	Total Efficiency Savings (MMBtu)
bromfield school	180,921					632		632
hildreth school	68,732	461						461
new library	22,199				85			85
highway department	10,180		58					58
police/ambulance station	9,345							-
center fire station	5,712			55				55
town hall	11,686				1			1
old library	9,881					1		1
hildreth house	8,778			1				1
bromfield house	6,134				10			10
still river fire station	1,792			23				23
old ambulance building	2,288							-
Total	337,648	461	58	79	97	634	-	1,329

Note: The efficiency savings assume a post fuel conversion 250% heat pump efficiency

Commented [JS28]: This is not clear – is the reduction from 14002 to 10502 (25%) just from electrification and installing heat pumps? It may help to explain in this Appendix.

Commented [JS29]: David, the target EUIs in this table are placeholders for discussion and more detailed engineering analysis. The columns I've highlighted in yellow are all variables that need to be discussed, analyzed more closely, and adjusted as needed.

Commented [JS30]: Corrected. Thanks David

Appendix D: Facility Fuel to Electricity Conversions

Estimated standard efficiency and high efficiency costs and post conversion electricity (MMBtu) and (MWh) energy use

Facility name	Gross Floor Area (SF)	Estimated Fuel Equipment Output (MMBtu)	Estimated Replacement Cost ($)	Estimated Electric Equipment Output (Tons)	Estimated Electric Efficiency (%)	10% Estimated Incremental ($)	$5,000 Estimated Ductless ($)	$10,000 Estimated VFR ($)	$10,000 Estimated Ground ($)	Electric MMBtu	3.412 Electric MWh
bromfield school	180,921	6.3	633,224	352	250%	63,322	1,758,954	3,517,908	3,517,908	1,989	583
hildreth school	68,732	2.4	240,562	134	250%	24,056	668,228	1,336,456	1,336,456	1,183	347
new library	22,199	0.8	77,697	43	250%	7,770	215,824	431,647	431,647	418	123
highway department	10,180	0.4	35,630	20	250%	3,563	98,972	197,944	197,944	134	39
police/ambulance station	9,345	0.3	32,708	18	250%	3,271	90,854	181,708	181,708	29	8
center fire station	5,712	0.2	19,992	11	250%	1,999	55,533	111,067	111,067	115	34
town hall	11,686	0.4	40,901	23	250%	4,090	113,614	227,228	227,228	89	26
old library	9,881	0.3	34,584	19	250%	3,458	96,065	192,131	192,131	75	22
hildreth house	8,778	0.3	30,723	17	250%	3,072	85,342	170,683	170,683	61	18
bromfield house	6,134	0.2	21,469	12	250%	2,147	59,636	119,272	119,272	56	16
still river fire station	1,792	0.1	6,272	3	250%	627	17,422	34,844	34,844	45	13
old ambulance building	2,288	0.1	8,008	4	250%	801	22,244	44,489	44,489	5	1
Total	337,648		1,181,768			118,177	3,282,689	6,565,378	6,565,378	4,199	1,230

Facility name	Gross Floor Area (SF)	Estimated Fuel Equipment Output (MMBtu)	Estimated Standard Replacement Cost ($)	Estimated Electric Equipment Output (Tons)	Estimated Electric Efficiency (%)	10% Incremental Cost ($)	$10,000 Ductless Cost ($)	$16,000 VRF Cost ($)	$26,000 Ground Cost ($)	Electric MMBtu	3.412 Electric MWh
bromfield school	180,921	6.3	633,224	352	250%	63,322	3,517,908	5,628,653	9,146,562	1,989	583
hildreth school	68,732	2.4	240,562	134	250%	24,056	1,336,456	2,138,329	3,474,784	1,183	347
new library	22,199	0.8	77,697	43	250%	7,770	431,647	690,636	1,122,283	418	123
highway department	10,180	0.4	35,630	20	250%	3,563	197,944	316,711	514,656	134	39
police/ambulance station	9,345	0.3	32,708	18	250%	3,271	181,708	290,733	472,442	29	8
center fire station	5,712	0.2	19,992	11	250%	1,999	111,067	177,707	288,773	115	34
town hall	11,686	0.4	40,901	23	250%	4,090	227,228	363,564	590,792	89	26
old library	9,881	0.3	34,584	19	250%	3,458	192,131	307,409	499,539	75	22
hildreth house	8,778	0.3	30,723	17	250%	3,072	170,683	273,093	443,777	61	18
bromfield house	6,134	0.2	21,469	12	250%	2,147	119,272	190,836	310,108	56	16
still river fire station	1,792	0.1	6,272	3	250%	627	34,844	55,751	90,596	45	13
old ambulance building	2,288	0.1	8,008	4	250%	801	44,489	71,182	115,671	5	1
Total	337,648		$1,181,768			$118,177	$6,565,378	$10,504,604	$17,069,982	4,199	1,230

Projected fuel use reduction (MMbtu)

Facility name	Gross Floor Area (SF)	Target Conversion Date (Year)	2025 Heat DHW Conversion (MMBtu)	2030 Heat DHW Conversion (MMBtu)	2035 Heat DHW Conversion (MMBtu)	2040 Heat DHW Conversion (MMBtu)	2045 Heat DHW Conversion (MMBtu)	2050 Heat DHW Conversion (MMBtu)	Total Heat DHW Conversion (MMBtu)
bromfield school	180,921	2035			6,631				6,631
hildreth school	68,732	2050						3,481	3,481
new library	22,199	2040				1,394			1,394
highway department	10,180	2030		447					447
police/ambulance station	9,345	2035			97				97
center fire station	5,712	2030		384					384
town hall	11,686	2030		297					297
old library	9,881	2045					251		251
hildreth house	8,778	2035			204				204
bromfield house	6,134	2040				188			188
still river fire station	1,792	2025	150						150
old ambulance building	2,288	2025	17						17
Total	337,648		167	1,128	6,932	1,582	251	3,481	13,541

Note: The Hildreth School conversion savings are adjusted lower to account for the new school construction post 2019.

Appendix E: Vehicle Fuel to Electricity Conversions

Diesel fuel vehicle age, replacement cost, estimated fuel use (gallons), and target electric conversion dates

Department name	Vehicle name	Insurance Year	Insurance Cost New ($)	Estimated Diesel (Gallons)	Target Conversion Date (Year)	2025 Vehicle Conversion (Gallons)	2030 Vehicle Conversion (Gallons)	2035 Vehicle Conversion (Gallons)	2040 Vehicle Conversion (Gallons)	2045 Vehicle Conversion (Gallons)	2050 Vehicle Conversion (Gallons)	Total Vehicle Conversion (Gallons)
department of public works	International dump truck	1990	40,000	387	2045					387		387
department of public works	Elgin pelican sweeper	1999	88,476	387	2045					387		387
department of public works	Caterpillar wheel loader	2000	99,968	387	2045					387		387
department of public works	Mack dump truck	2002	86,568	387	2045					387		387
department of public works	Mack truck	2003	93,885	387	2045					387		387
department of public works	F550 dump truck	2011	50,036	387	2045					387		387
department of public works	F550 dump truck	2012	66,140	387	2045					387		387
department of public works	International dump truck	2012	180,000	387	2045					387		387
department of public works	John Deere loader	2014	162,837	387	2045					387		387
department of public works	F350 pickup	2014	34,250	387	2040				387			387
department of public works	John Deere loader/backhoe	2014	85,400	387	2045					387		387
department of public works	Dump Truck	2015	65,985	387	2045					387		387
department of public works	Mack dump truck	2016	174,990	387	2045					387		387
department of public works	Mack GU712	2018	181,417	387	2045					387		387
department of public works	F550	2019	78,340	387	2045					387		387
department of public works	Mack Granite	2020	194,000	387	2045					387		387
department of public works	F350	2021	63,116	387	2040				387			387
fire department	F450 Ambulance	2018	260,000	387	2040				387			387
fire department	Seagraves Pumper	1930	13,778	387	2050						387	387
fire department	Mack Pumper	1965	28,500	387	2050						387	387
fire department	Mack/Baker Aerialscope	1980	25,000	387	2050						387	387
fire department	International/KME Fire truck	2002	221,068	387	2050						387	387
fire department	Seagrave fire truck	2005	450,000	387	2050						387	387
fire department	F550	2011	140,000	387	2045					387		387
fire department	KME Pumper	2012	525,000	387	2050						387	387
fire department	Seagrave TB40CO	2015	517,002	388	2050						388	388
fire department	KW CONSTR	2018	329,000	388	2050						388	388
school department	F550 super duty	2006	45,000	388	2045					388		388
town administrator	E350 Super Duty	2011	25,705	387	2040				387			387
town administrator	E350 Super Duty	2014	50,000	387	2040				387			387
town administrator	Transit 350	2017	45,000	387	2025	387						387
Total			$4,420,461	12,002		387			1,935	6,580	3,099	12,002

Diesel fuel vehicle projected electric conversion cost ($) and projected electricity use (MWh)

Department name	Vehicle name	2025 Vehicle Conversion ($)	2030 Vehicle Conversion ($)	2035 Vehicle Conversion ($)	2040 Vehicle Conversion ($)	2045 Vehicle Conversion ($)	2050 Vehicle Conversion ($)	Total Vehicle Conversion ($)	2025 Vehicle Conversion (MWh)	2030 Vehicle Conversion (MWh)	2035 Vehicle Conversion (MWh)	2040 Vehicle Conversion (MWh)	2045 Vehicle Conversion (MWh)	2050 Vehicle Conversion (MWh)	Total Vehicle Conversion (MWh)
department of public works	International dump truck					60,000		60,000					8		8
department of public works	Elgin pelican sweeper					132,714		132,714					8		8
department of public works	Caterpillar wheel loader					149,952		149,952					8		16
department of public works	Mack dump truck					129,852		129,852					8		8
department of public works	Mack truck					140,828		140,828					8		8
department of public works	F550 dump truck					75,054		75,054					8		16
department of public works	F550 dump truck					99,210		99,210					8		8
department of public works	International dump truck					270,000		270,000					8		8
department of public works	John Deere loader					244,256		244,256					8		16
department of public works	F350 pickup				59,938			59,938				8			8
department of public works	John Deere loader/backhoe					128,100		128,100					8		8
department of public works	Dump Truck					98,978		98,978					8		16
department of public works	Mack dump truck					262,485		262,485					8		8
department of public works	Mack GU712					272,126		272,126					8		8
department of public works	F550					117,510		117,510					8		16
department of public works	Mack Granite					291,000		291,000					8		8
department of public works	F350				110,453			110,453				8			8
fire department	F450 Ambulance				455,000			455,000				8			16
fire department	Seagraves Pumper						17,223	17,223						8	8
fire department	Mack Pumper						35,625	35,625						8	8
fire department	Mack/Baker Aerialscope						31,250	31,250						8	16
fire department	International/KME Fire truck						276,335	276,335						8	8
fire department	Seagrave fire truck						562,500	562,500						8	8
fire department	F550					210,000		210,000					8		16
fire department	KME Pumper						656,250	656,250						8	8
fire department	Seagrave TB40CO						646,253	646,253						8	8
fire department	KW CONSTR						411,250	411,250						8	16
school department	F550 super duty					67,500		67,500					8		8
town administrator	E350 Super Duty				44,984			44,984				8			8
town administrator	E350 Super Duty				87,500			87,500				8			16
town administrator	Transit 350	90,000						90,000	8						8
Total		$90,000			$757,874	$2,749,563	$2,636,685	$6,234,122	8			40	136	64	240

Gasoline fuel vehicle age, insurance replacement cost, estimated current fuel use (gallons), and target electric conversion dates

Department name	Vehicle name	Insurance Year	Insurance Cost New ($)	Estimated Gasoline (Gallons)	Target Conversion Date (Year)	2025 Vehicle Conversion (Gallons)	2030 Vehicle Conversion (Gallons)	2035 Vehicle Conversion (Gallons)	2040 Vehicle Conversion (Gallons)	2045 Vehicle Conversion (Gallons)	2050 Vehicle Conversion (Gallons)	Total Vehicle Conversion (Gallons)
department of public works	Ford tractor	1994	35,182	882	2035			882				882
department of public works	Ford Explorer	2009	28,000	882	2030		882					882
department of public works	Kubota tractor	2010	96,894	882	2035			882				882
department of public works	F250	2015	38,027	882	2035			882				882
fire department	Tractor	1989	146,500	882	2035			882				882
fire department	Ford Explorer	2014	27,868	882	2030		882					882
fire department	Ford Explorer	2018	35,487	882	2030		882					882
police department	Ford Explorer	2015	29,952	882	2030		882					882
police department	Dodge Charger	2016	41,569	882	2030		882					882
police department	Dodge Charger	2018	34,213	882	2030		882					882
police department	F150	2018	35,086	882	2030		882					882
police department	Ford Explorer	2020	50,353	882	2030		882					882
school department	E350 van	2008	20,260	882	2030		882					882
school department	E150	2008	23,940	882	2030		882					882
school department	F350 pickup	2011	33,454	882	2030		882					882
school department	Econovan	2014	1,000	882	2030		882					882
school department	John Deere tractor	2016	31,000	882	2035			882				882
Total			$708,785	14,995		-	10,585	4,410	-	-	-	14,995

Gasoline fuel vehicle projected electric conversion cost ($) and projected electricity use (MWh)

Department name	Vehicle name	2025 Vehicle Conversion ($)	2030 Vehicle Conversion ($)	2035 Vehicle Conversion ($)	2040 Vehicle Conversion ($)	2045 Vehicle Conversion ($)	2050 Vehicle Conversion ($)	Total Vehicle Conversion ($)	2025 Vehicle Conversion (MWh)	2030 Vehicle Conversion (MWh)	2035 Vehicle Conversion (MWh)	2040 Vehicle Conversion (MWh)	2045 Vehicle Conversion (MWh)	2050 Vehicle Conversion (MWh)	Total Vehicle Conversion (MWh)
department of public works	Ford tractor			38,700				38,700			18				18
department of public works	Ford Explorer		33,600					33,600		18					18
department of public works	Kubota tractor			106,583				106,583			18				18
department of public works	F250			41,830				41,830			18				18
fire department	Tractor			161,150				161,150			18				18
fire department	Ford Explorer		33,442					33,442		18					18
fire department	Ford Explorer		42,584					42,584		18					18
police department	Ford Explorer		35,942					35,942		18					18
police department	Dodge Charger		49,883					49,883		18					18
police department	Dodge Charger		41,056					41,056		18					18
police department	F150		42,103					42,103		18					18
police department	Ford Explorer		60,424					60,424		18					18
school department	E350 van		24,312					24,312		18					18
school department	E150		28,728					28,728		18					18
school department	F350 pickup		40,145					40,145		18					18
school department	Econovan		1,200					1,200		18					18
school department	John Deere tractor			34,100				34,100			18				18
Total		$0	$433,418	$382,363	$0	$0	$0	$815,782	-	216	90	-	-	-	306

Appendix F: Solar Photovoltaic Installations

Potential Solar PV installation area, output, cost, and estimated electricity generation (kWh and MMbtu)

Solar Array Type	Department name	Facility name	Available Roof Area (SF)	Available Land Area (Acres)	Estimated Solar PV Peak Output (kW)	$3,496 < 250 kW Roof ($)	$5,000 < 1 MW Parking ($)	$1,500 <1 MW Ground ($)	$1,200 >1 MW Ground ($)	Total Solar PV ($)	Solar Electric kWh	Solar Electric MMBtu
Building	school department	bromfield school	36,184		109.3	382,103				382,103	139,357	475
Building	school department	hildreth school			-	-				-	-	-
Building	library	new library			-	-				-	-	-
Building	department of public works	highway department	2,036		6.2	21,500				21,500	7,841	27
Building	police department	police/ambulance station	1,869		5.6	19,737				19,737	7,198	25
Building	fire department	center fire station	1,142		3.5	12,064				12,064	4,400	15
Building	town administrator	town hall	2,337		7.1	24,681				24,681	9,001	31
Building	town administrator	old library	1,976		6.0	20,869				20,869	7,611	26
Building	town administrator	hildreth house	1,756		5.3	18,539				18,539	6,761	23
Building	school department	bromfield house	1,227		3.7	12,955				12,955	4,725	16
Building	fire department	still river fire station	358		1.1	3,785				3,785	1,380	5
Building	town administrator	old ambulance building	458		1.4	4,832				4,832	1,762	6
Parking	school department	school parking lots		2.0	263.2		1,315,789			1,315,789	335,526	1,145
Parking	department of public works	DPW parking lot			-		-			-	-	-
Parking	police department	Police parking lot			-		-			-	-	-
Parking	fire department	Fire parking lot			-		-			-	-	-
Parking	library	Library parking lot			-		-			-	-	-
Ground Fixed	town administrator	Athol PPA		2.2	289.5			434,211		434,211	369,079	1,259
Ground Fixed	town administrator	Other PPA		10.0	1,315.8				1,578,947	1,578,947	1,677,632	5,724
			49,343	14.2	1,902.0	$521,064	$1,315,789	$434,211	$1,578,947	$3,850,011	2,572,274	8,777

Solar Array Type	Department name	Facility name	Available Roof Area (SF)	Available Land Area (Acres)	Estimated Solar PV Peak Output (kW)	$3,496 < 250 kW Roof ($)	$5,000 < 1 MW Parking ($)	$1,500 <1 MW Ground ($)	$1,200 >1 MW Ground ($)	Solar Electric kWh	Solar Electric MMBtu
Building	school department	bromfield school	36,184		109.3	382,103				139,357	475
Building	school department	hildreth school	13,746		41.5	145,161				52,942	181
Building	library	new library	4,440		13.4	46,884				17,099	58
Building	department of public works	highway department	2,036		6.2	21,500				7,841	27
Building	police department	police/ambulance station	1,869		5.6	19,737				7,198	25
Building	fire department	center fire station	1,142		3.5	12,064				4,400	15
Building	town administrator	town hall	2,337		7.1	24,681				9,001	31
Building	town administrator	old library	1,976		6.0	20,869				7,611	26
Building	town administrator	hildreth house	1,756		5.3	18,539				6,761	23
Building	school department	bromfield house	1,227		3.7	12,955				4,725	16
Building	fire department	still river fire station	358		1.1	3,785				1,380	5
Building	town administrator	old ambulance building	458		1.4	4,832				1,762	6
Parking	school department	school parking lots		2.0	263.2		1,315,789			335,526	1,145
Parking	department of public works	DPW parking lot		0.2	26.3		131,579			33,553	114
Parking	police department	Police parking lot		0.2	26.3		131,579			33,553	114
Parking	fire department	Fire parking lot		0.2	26.3		131,579			33,553	114
Parking	library	Library parking lot		0.2	26.3		131,579			33,553	114
Ground Fixed	town administrator	Athol PPA		2.2	289.5			434,211		369,079	1,259
Ground Fixed	town administrator	Other PPA		10.0	1,315.8				1,578,947	1,677,632	5,724
			67,530	15.0	2,007.3	$713,109	$1,842,105	$434,211	$1,578,947	2,776,525	9,472

Proposed Solar PV installation or procurement dates and electricity use (kWh)

Commented [JS31]: Peter - Recommend making clear this is potential generation but not a plan for each building. Realistically a building like the new library will never have solar given historic nature of building, visual impact, etc.

Solar Array Type	Department name	Facility name	Target Installation Date (Year)	2025 Solar PV Electricity (kWh)	2030 Solar PV Electricity (kWh)	2035 Solar PV Electricity (kWh)	2040 Solar PV Electricity (kWh)	2045 Solar PV Electricity (kWh)	2050 Solar PV Electricity (kWh)	Total Solar PV Electricity (kWh)
Building	school department	bromfield school	2030		139,357					139,357
Building	school department	hildreth school	2030		-					-
Building	library	new library	2030		-					-
Building	department of public works	highway department	2030		7,841					7,841
Building	police department	police/ambulance station	2030		7,198					7,198
Building	fire department	center fire station	2030		4,400					4,400
Building	town administrator	town hall	2030		9,001					9,001
Building	town administrator	old library								-
Building	town administrator	hildreth house								-
Building	school department	bromfield house								-
Building	fire department	still river fire station	2030		1,380					1,380
Building	town administrator	old ambulance building								-
Parking	school department	school parking lots	2030		335,526					335,526
Parking	department of public works	DPW parking lot	2030		-					-
Parking	police department	Police parking lot	2030		-					-
Parking	fire department	Fire parking lot	2030		-					-
Parking	library	Library parking lot								-
Ground Fixed	town administrator	Athol PPA								-
Ground Fixed	town administrator	Other PPA	2040				1,677,632			1,677,632
					504,704		1,677,632			2,182,335

Solar Array Type	Department name	Facility name	Target Installation Date (Year)	2025 Solar PV Electricity (kWh)	2030 Solar PV Electricity (kWh)	2035 Solar PV Electricity (kWh)	2040 Solar PV Electricity (kWh)	2045 Solar PV Electricity (kWh)	2050 Solar PV Electricity (kWh)	Total Solar PV Electricity (kWh)
Building	school department	bromfield school	2030		139,357					139,357
Building	school department	hildreth school	2030		52,942					52,942
Building	library	new library	2030		17,099					17,099
Building	department of public works	highway department	2030		7,841					7,841
Building	police department	police/ambulance station	2030		7,198					7,198
Building	fire department	center fire station	2030		4,400					4,400
Building	town administrator	town hall	2030		9,001					9,001
Building	town administrator	old library								-
Building	town administrator	hildreth house								-
Building	school department	bromfield house								-
Building	fire department	still river fire station	2030		1,380					1,380
Building	town administrator	old ambulance building								-
Parking	school department	school parking lots	2030		335,526					335,526
Parking	department of public works	DPW parking lot	2030		33,553					33,553
Parking	police department	Police parking lot	2030		33,553					33,553
Parking	fire department	Fire parking lot	2030		33,553					33,553
Parking	library	Library parking lot								-
Ground Fixed	town administrator	Athol PPA								-
Ground Fixed	town administrator	Other PPA	2040				1,677,632			1,677,632
					675,402		1,677,632			2,353,034

Appendix G: Carbon Offsets

Potential Carbon Offset projects and carbon credits

Local Carbon Offset													
									Carbon Credits/Acre	Carbon Credits/Acre	Carbon Credits/Acre		Carbon Credits/Acre
							Low		2	0.4	1		3
							High		7	0.6	1		7
					20%		Selected	2050	2	0.4	1		5
Type	Owner	Parcel	Total Land Area (Acres)	Carbon Offset Land Area (Acres)	Carbon Risk Buffer Land Area (Acres)	Net Carbon Offset Land Area (Acres)	Carbon Offset Land Area (%)	Start Date (Fiscal Year)	Forest Management (Carbon Credits)	No Till/ Low Till (Carbon Credits)	Perenial Grass Planting (Carbon Credits)	Tree Planting (Carbon Credits)	Total (Carbon Credits)
Forest		1	3,000	3,000	600	2,400	100%	2030	4,800				4,800
Forest		2	2,000				0%						
Forest		3	500				0%						
Forest		4	400				0%						
Field		5	100				0%						
Field		6	100				0%						
Total			6,100	3,000	600	2,400	49%		4,800				4,800

Note 1: 1 carbon credit = 1 metric ton of CO2 (mTonCO@e)
Note 2: The total project size must be 3,000 acres or more

Projected carbon credit value, developer fees, and monitoring and verification costs

Local Carbon Offset											
				Carbon Revenue/ Credit	Carbon Revenue/ Credit						
				$13	$3		$30,000	$40,000	10%	8%	8%
				$14	$8		$100,000	$65,000	40%	10%	10%
				$14	$5		$60,000	$50,000	40%	10%	10%
Type	Owner	Parcel	Total Land Area (Acres)	Compliance Carbon Market ($)	Voluntary Carbon Market ($)	Total Carbon Credit Revenue ($)	Small Project Carbon Inventory ($)	Verification of Carbon Stocks ($)	Carbon Project Developer Fee ($)	Measurement & Monitoring ($)	Verification ($)
Forest		1	3,000		24,000	24,000			9,600	2,400	2,400
Forest		2	2,000								
Forest		3	500								
Forest		4	400								
Field		5	100								
Field		6	100								
Total			6,100	$0	$24,000	$24,000			$9,600	$2,400	$2,400

Reviewer comments

David Fay:

- Do you have a way of getting residential auto ownership for Harvard (e.g. through auto insurance records)?

MAPC collects community-wide residential and commercial auto ownership for cities and towns. See: MAPC DataCommon - MA Vehicle Census Summary Statistics

- I disagree that solar thermal is a plausible source of energy for DHW. Does anybody do solar thermal anymore?

I'm assuming that all fossil fuel-fired domestic hot water converts to high efficiency heat pump DHW systems except in high volume commercial settings where solar thermal may make sense. I would like to leave this solar thermal recommendation in as an option for the town to consider if that's OK. When I last looked at this technology closely a few years ago, I felt that the technology is still robust and cost effective.

- What is a "heat pump domestic hot water" system and how does it differ from "hybrid heat pump domestic hot water" system?

I'm using the terms interchangeably and can clean this up. Most heat pump DHW systems have a hybrid feature that allows electric resistance water heating if the heat pump can't keep up with the hot water draw.

- Bi-directional charging from school buses doesn't seem feasible in light of limited parking space for buses near school.

The batteries in electric buses are very large. I recommend that Harvard anticipate the potentially benefits of connecting school buses to the grid wherever they are parked in between student pickup and delivery runs. See: https://cleantechnica.com/2022/02/25/3-design-considerations-for-electric-school-bus-vehicle-to-grid-programs/

- John's suggestion to develop a town EV charging plan is a good one. Maybe HEAC could do that.

- "Figure 1 demonstrates a steady decline in fossil fuel grid electricity. " No, it doesn't. Confusing stacked bar chart and line charts?

I'm happy to change to stacked bar charts

- Why wait until 2030 and 2040 to build solar facilities?

Let's discuss more appropriate dates as part of the discussion about local solar PV emphasis (or not).

- "As figure 2 indicates, the primary source of municipal facility and operations carbon emissions is fuel combustion. " No, it doesn't. Should use stacked bars rather than line graph.

I'm happy to change the graphs to stacked bar charts

- "At the same time, Harvard needs to transition to local renewable energy electricity generation" Not clear why. Isn't the cheapest way to convert to all electric and wait for utilities to convert to clean electricity generation

The current schedule for Massachusetts to convert all grid supplied electric to renewable energy sources does not help Harvard achieve 45% by 2030 and 85% by 2050 carbon emission reductions. Here's my understanding of the current renewable portfolio standard schedule:

Renewable Portfolio Standard (RPS)
Per H3708

Year	Total	Class I	Class II	Class II Biomass
2019	14.0%	14.0%		
2025	33.1%	26.0%	3.6%	3.5%
2030	42.1%	35.0%	3.6%	3.5%
2035	47.1%	40.0%	3.6%	3.5%
2040	52.1%	45.0%	3.6%	3.5%
2045	57.1%	50.0%	3.6%	3.5%
2050	62.1%	55.0%	3.6%	3.5%

Eric Charles:

These are some questions and comments to send to John Snell for potential revision/elaboration in the plan. I laid out a question that could be sent to him with some elaboration as to why I think the question is valid. Instead of trying to line edit the report, I tried to identify areas where I thought some additional detail or clarification might be helpful to implementation.

Question 1 - Can the plan be edited to clarify some proposed metrics for the town to track progress on each of the key strategies?

MassEnergyInsight will continue to be the best tool for the Energy Advisory Committee to use for an annual report to Town committees and the Selectmen for municipal facility and vehicle performance.

Community-based metrics (if that's part of your question) are more challenging. I discuss this issue with towns that I'm writing community wide GHG inventory reports for. Here's the generic information that I include in these reports:

Current energy use is the best marker to track carbon emissions and associated carbon emission reductions. Unfortunately, the most recent town-wide energy use available online is for 2019.

Short of actual energy use, three alternative indicators to monitor annually include:

- Residential and commercial high efficiency heat pump installations
- Electric vehicle purchases (and leases)
- Percent renewable energy that customers purchase

The Building Department may be a good source of information for heat pump-related electrical permits. The Assessor's Office may be a source of information for existing heating and DHW systems from assessor site visits. The tax collector's office or National Grid may be good sources of information for electric vehicles garaged in Harvard. Your Community Aggregation database or National Grid may be potential sources of electricity use and the percent of renewable energy. Fuel oil, gasoline, and diesel fuel will continue to be challenging to monitor.

Elaboration: The plan implicitly uses certain metrics. Town committees have expressed interest in tracking progress to climate goals. The decarbonization plan seems to provide a baseline that could be transferred into performance metrics. Could you elaborate on some simple metrics that could be regularly (annually?) presented to the Select Board to set goals and track progress? These types of metrics seem to be based on what's in the plan.

- Heat and Domestic Hot Water -

  - Fuel to electricity conversions - Percentage of MMBTU from fossil fuels versus percentage from electricity for each building, department, and town wide.
  - Energy efficiency – Total annual energy use in MMBTU for each building, department, and town wide.

- Vehicles –
  - Light duty fleet – Percentage of light duty fleet that use fossil fuel versus percentage of electric vehicles
  - Medium duty fleet – Percentage of medium/heavy duty fleet that use fossil fuels versus zero carbon alternatives.
  - Charging Infrastructure - Number/capacity of publicly available and dedicated municipal chargers

- Electricity
  - Grid electricity – What source do you recommend to track the fuel mix used by National Grid, or preferably the portion of the grid that feeds Harvard?
  - Local Renewable electricity – Capacity measured in kilowatts and energy output measured in kilowatt hours for distributed energy resources

Question 2 – To what extent is it feasible to draft a detailed replacement schedule for building infrastructure or vehicles based on the available data? If this is not feasible, could you identify what additional information the town will need to collect to develop that replacement schedule and use for planning purposes?

Hopefully this report will serve as a useful tool for the EAC and other committees and town staff to review on a regular basis to assess progress compared to what this report recommends for facility and vehicle upgrades.

Elaboration: The plan provides a framework for the town, which will need to be implemented by a long term capital replacement plan. That replacement plan may be out of the scope of this decarbonization plan, but some initial steps to developing the capital replacement plan would give the town direction to move forward into implementation. A list of key information to collect and any considerations would be helpful, as well as any links or resources on leading practices.

Question 3 – Can you add language addressing the fact that technology will be changing and direction on how to navigate changing technology (e.g., identify resources to be aware of that provide useful information, etc)?

Your point's a good one and it's not just technology that will change. Look at how our lifestyles have changed during the COVID pandemic and the effect that it's had on how we do business and interact with each other. In addition, change does not always occur in a smooth curve but often in erratic fits and starts.

That said, 5%-10% market penetration for most technologies will be driven by early adopters and the rest of us will follow. We haven't hit that level of market penetration or are at least at the early stages of the market penetration process for fossil-fuel alternatives. I think the challenge moving forward is more about how we collectively transition to the new technologies that have recently appeared as opposed to adapting to new technologies that we haven't heard about yet. The best resource for this question that comes to mind is the MA decarbonization by 2050 report. It's a good assessment of preferred technologies and a reasonable path with "no regrets" for the state to embrace.

Elaboration: This is a multi-decade plan and the technologies the town can deploy are going to change over that period. The plan has some steps that are obvious now (efficiency, solar deployment, electricity conversion), but the town will need to be flexible to accommodate the maturation of technologies like battery storage, advanced control systems, microgrids, and other technologies that may not exist yet. It seems like this should be stated explicitly (I may have missed it) and any suggestions for how to navigate that be provided.

Question 4 – Can the final data be provided in a format that makes reuse and storage easier?

All the PDFs come from a single Excel file that I will continue to update until the report is finished and provide as part of my deliverables. It's not 100% user friendly but it has all the data.

Elaboration: The plan has jpegs of tables which are hard to work with and require manual data entry. Providing data in a machine readable format (spreadsheets, csv, etc) would be preferable along with any calculations or code used for the analysis.

Question 5 – Can the plan include any discussion on bylaw or process changes beyond the replacement of physical assets that would facilitate climate mitigation?

We can discuss areas of bylaw or process changes that come to mind that should be included in this report. I should have time to do more digging into areas that EAC would like me to investigate and report back on.

Elaboration: Are there any bylaw or policy changes related to new purchases or building construction that are good practices from the other towns that we could adopt? Much of the plan focuses on retrofitting the existing buildings and replacing assets, but adopting good practices for new buildings, vehicles, and other major climate impacting items would help keep the town oriented on a path to carbon neutrality.

Question 6 – To what extent is it feasible to address non-municipal greenhouse gas emissions in this plan?

MA DOER has approved support for me to help Harvard write a municipal facility and vehicle decarbonization plan and to help develop an RFP for a community wide decarbonization plan. Developing the community wide RFP could potential include doing some preliminary assessments of GHG emission reductions and transition priorities for others to flesh out.

Elaboration: This may be too much of a scope expansion for this project, but municipal operations are a portion of the town's total greenhouse gas emissions. Most of the emissions in town are from private property. Any well-known practices on bylaws or processes that can remove barriers to greenhouse gas reduction or incentivize that reduction would be helpful. If it is too much of a scope expansion, any resources you're aware of could be helpful.