Montachusett Regional Planning Commission and John Snell LLC

85% Decarbonization by 2050 Plan
for
The Town of Harvard’s
Municipal Facilities and Operations
November 30, 2021

Town of Harvard
Municipal Facilities and Operations Decarbonization Plan
Working Draft - JS
November 30, 2021

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 Brian 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

Contact information:

John Snell
jsnail56@gmail.com
(617) 510-4198

Karen Chapman
kchapman@mrpc.org
(978) 798-6168

Table of Contents

Decarbonization Road Map

Harvard's municipal facilities and operations emit about 1,493 mTonsCO2e[1] 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

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.

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
- Gasoline – 14,995 gallons
- Diesel – 12,2002 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 EUIs higher than 25 kBtu/SF. These measures can be implemented as part of scheduled building maintenance and/or major renovation and rehabilitation investments.

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

Table 1 includes the energy savings assumptions and target implementation dates for the potential energy efficiency opportunities that we identified.

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 the estimated replacement cost[6] for the existing equipment and the estimated cost to install three alternative types of high efficiency electric heat pump equipment[7].

		Estimated Standard	$5,000	$10,000	$10,000
Facility name	Gross Floor Area (SF)	Replacement Cost ($)	Ductless Cost ($)	VRF Cost ($)	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
Total	337,648	$1,181,768	$3,282,689	$6,565,378	$6,565,378

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.

[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.

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.

Vehicles

Harvard has 48 vehicles and other equipment that have gasoline or diesel-powered internal combustion engines. Please refer to the appendix 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 – 12,2002 gallons

This fuel use is equivalent to about 3,754 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

[8] Data source: 2019 Town vehicle insurance records

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.

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. State legislation requires National Grid to increase the percent of renewable energy generation 2% each year.

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 does not have a 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[9] 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.

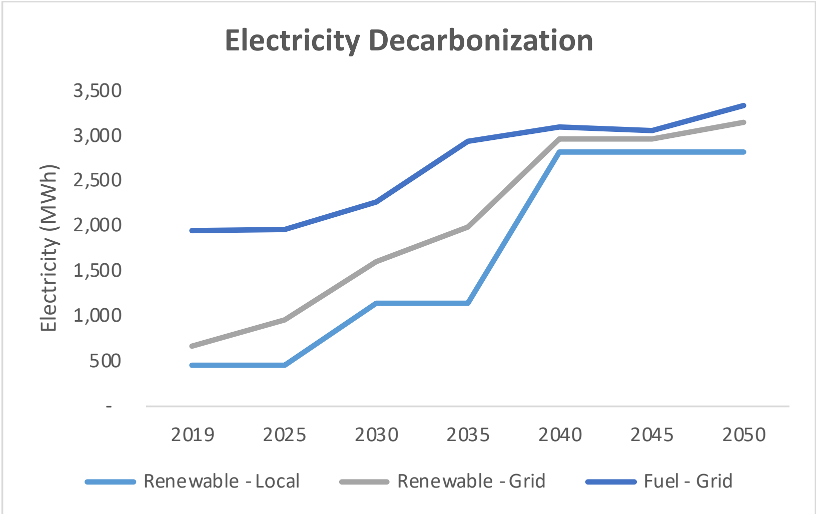


Figure 1. Projected electricity load and fuel mix

[9] **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.

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.

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[10]. This falls short of the State's 50% carbon reduction target by 2030 and exceeds the State's 85% by 2050 carbon reduction target. Adding a carbon sequestration forest

[10] 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.

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.

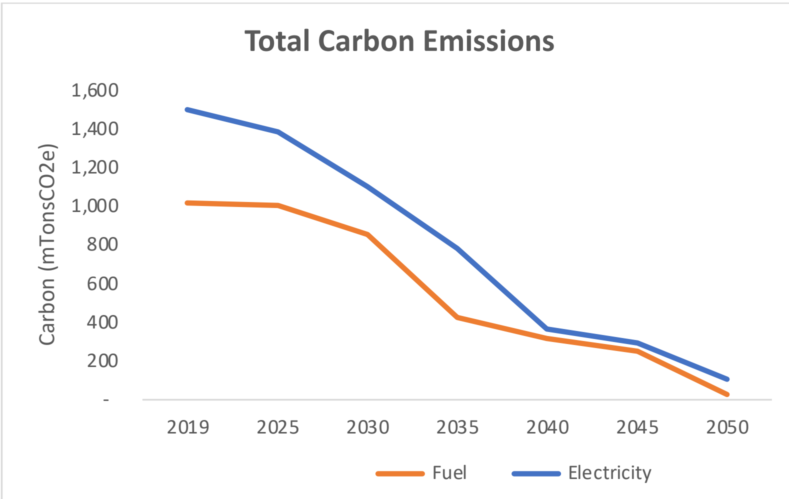


Figure 2. Total carbon emissions reduction

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.

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.

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.

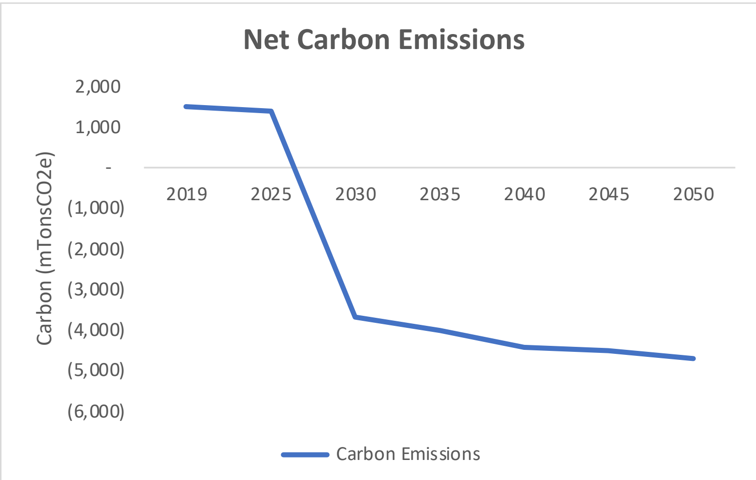
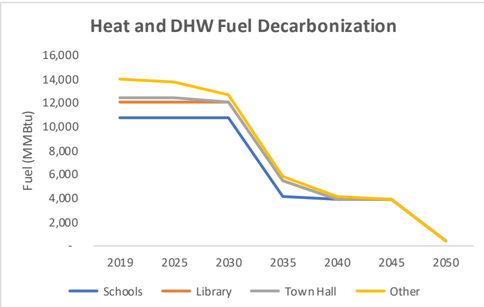


Figure 3. Net carbon emissions with 3,000 acre carbon offset

Conclusion

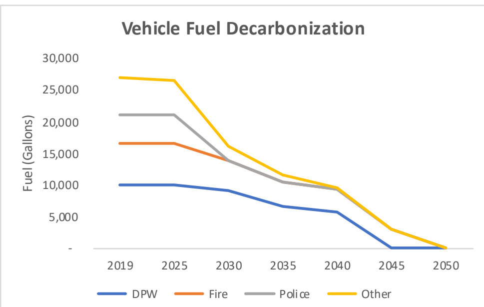
Harvard's municipal facilities and operations emit about 1,493 mTonsCO2e of carbon per year. Methodical replacement of fuel-powered equipment with electric-powered equipment and fuel-generated electricity with local renewable energy-generated electricity will help the town reduce carbon emissions 16% 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.

Appendix A: Decarbonization Summary



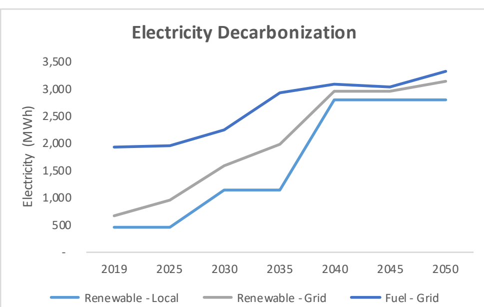
Heating and Domestic Hot Water (DHW) Fuel Decarbonization

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

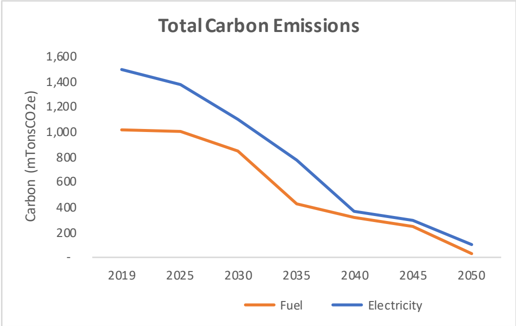
Year (Fiscal)	DPW Fuel (Gallons)	Fire Fuel (Gallons)	Police Fuel (Gallons)	Other Fuel (Gallons)	Total Fuel (Gallons)
2019	10,108	6,519	4,410	5,959	26,997
2025	10,108	6,519	4,410	5,572	26,610
2030	**9,226**	**4,755**	**-**	**2,044**	**16,025**
2035	6,579	3,873	-	1,162	11,615
2040	5,805	3,486	-	388	9,679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



Grid Electricity Decarbonization

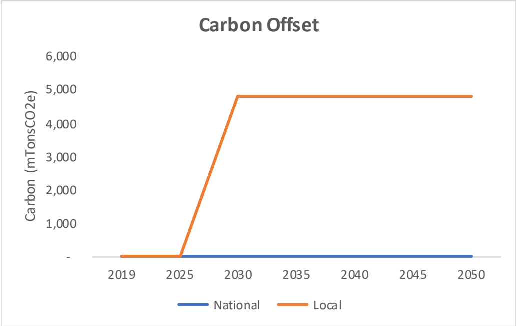
Year (Fiscal)	Fuel - Grid Electricity (MWh)	Renewable - Grid Electricity (MWh)	Total - Grid Electricity (MWh)	Renewable - Local Electricity (MWh)	Total Electricity (MWh)
2019	1,272	207	1,479	456	1,935
2025	1,004	497	1,500	457	1,957
2030	**650**	**473**	**1,123**	**1,132**	**2,255**
2035	951	847	1,797	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



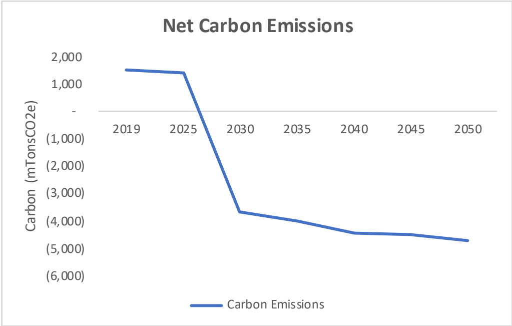
Total Carbon Emissions

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: Energy Efficiency Projects

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).

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 fuel consumption in MMbtu divided by the estimated baseline heating and DHW system fuel efficiency. Shaded areas represent entries and assumptions that can be changed or adjusted.

Estimated efficiency savings (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

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

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)	$3,496 < 250 kW Roof ($)	$5,000 < 1 MW Parking ($)	$1,500 <1 MW Ground ($)	$1,200 >1 MW Ground ($)	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)

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)	Perrenial 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