

Transitioning to Battery Electric Landscaping Equipment

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SUMMARY

The Town of Lexington’s Department of Public Works (DPW) is working with Quiet Communities and the American Green Zone Alliance (AGZA; a state recognized certification agency) to transition its municipal maintenance operations to zero-emission low-noise battery electric equipment as technology allows and certify transitioned properties as AGZA Green Zones[®]. An AGZA Green Zone is a defined area of land on which all routine maintenance is performed with battery electric equipment and/or manual tools. This program will result in substantial reductions toxic pollution, noise, waste and greenhouse gases, improving worker and public health and environmental quality, consistent with the action goals of the Town’s Sustainability Action Plan.

The impacts from non-diesel, gas-powered equipment used to maintain 36 municipal properties (e.g., mowers, blowers, trimmers, saws) were estimated (see table below) and a GIS-based map of the properties reflective of their transition status was created. Together, these can serve as tools for the DPW and the Town to document and communicate the benefits of the transition as it progresses.

Annual Impacts of Gas-Powered Equipment Used to Maintain 36 Municipal Properties*

Category	Impact of Gas Equipment
Toxic and carcinogenic exhaust emissions (non-methane hydrocarbons, nitrogen oxides, carbon monoxide, fine particulate matter)	20,875 pounds (10.4 tons)
Greenhouse gas (carbon dioxide)	67,597pounds (33.8 tons)
Noise (at operator’s ear)	875,742 decibel-hours
Fuel spillage (from re-fueling equipment)	297 gallons (range: 69 - 525)
Gasoline consumption and cost	3,221 gallons
Fuel cost (gas only)	\$8,053
Toxic and solid waste	Ongoing waste related to replacement and disposal of gas parts and gas maintenance

*Does not include diesel powered equipment or turbo blower

Impacts were analyzed by three categories of activity: Routine Maintenance (regular mowings, clean-ups); Spring and Fall clean-ups (heavy leaf, debris); and, Special Tasks (tree/shrub pruning). The analysis showed that Routine Maintenance accounts for 72%-88% of each of the impacts. Properties with the greatest potential for impact reduction were identified.

The DPW's transition to date includes Routine Maintenance of the Town Hall Complex with battery electric equipment only (starting in September 2017) and a partial transition (starting in June 2019) in Routine Maintenance of Cary Library/ Belfry Hill, Buckman Visitors Center and Emery Park. Annual and cumulative reductions in impacts were calculated through the end of 2019.

I. INTRODUCTION

The Town of Lexington's Department of Public Works (DPW) is working with Quiet Communities and the American Green Zone Alliance (AGZA) on a program to transition maintenance of its municipal lands from gas-powered equipment to battery electric equipment, to the fullest extent allowed by advanced battery technology, and to prepare to certify transitioned properties as AGZA Green Zones®. An AGZA Green Zone is a defined area of land on which all routine maintenance is performed with battery electric equipment and/or manual tools. AGZA is recognized by the state of Massachusetts as a certification agency in the area of zero emissions, low noise land care practices. This program is intended to improve health, environmental quality, and quality of life for staff, residents, and visitors, consistent with goals of the Town's Sustainability Action Plan.

Impact metrics are essential for demonstrating the benefits of transitioning to battery electric equipment and for prioritizing properties for further expansion.

This project:

- Quantifies the impacts of maintaining the Town's municipal lands entirely with gas-powered equipment, establishing a baseline against which progress can be measured as the transition to battery electric equipment rolls out.
- Identifies high priority properties and their related impact reductions;
- Estimates progress as of the end of calendar year (CY) 2019.
- Provides a GIS-based map of the municipal properties and identification of transitioned properties eligible for AGZA Green Zone Certification.

II. TECHNOLOGY

Advances in battery technology have enabled the development of zero emissions, low noise battery electric equipment capable of performing at the commercial as well as residential levels. These advances have resulted in equipment that have run times, charge times, and performance that makes it practical and cost-effective when applied to all but the heaviest maintenance work. Currently, lithium battery technology has proven itself to be a comparable alternative to gas powered equipment for 100% of Routine commercial grounds maintenance and Special Tasks, like shrub and tree pruning:

- Mowing
- String/line trimming
- Hedge trimming
- Debris blowing
- Light to medium tree work

Areas in which gas-powered equipment is still needed include blowers for heavier Spring/Fall clean-ups, and heavier equipment capable of dethatching, aeration, heavy tree trimming, rototilling compacted areas, heavy seasonal workloads and contracted enhancement work.

III. PROPERTY AND MAINTENANCE OVERVIEW

- Town of Lexington - 36 properties maintained by Department of Public Works
- TOTAL PROPERTY AREA = 207 acres, of which 189 are maintained
- MAP = http://bit.ly/AGZA_GZ_ToS_Map_Pins

Non-diesel gas-powered maintenance equipment currently used by DPW to service Town lands are listed below:

Routine Maintenance (regular mowing, clean-ups)

- Stand-on mower (e.g., Wright 36")
- String trimmers (e.g., Redmax BCZ2460S)
- Backpack blowers (e.g., Redmax EBZ8500)
- Push mowers (e.g., 21" Columbia)

Spring and Fall Clean-Ups (heavy leaf/debris clean-ups)

- Backpack blowers (e.g., Redmax EBZ8500)
- String trimmers (e.g., Redmax BCZ2460S)
- Stand-on mower (e.g., Wright 36")

Special Tasks (e.g., shrub and tree pruning)

- Shrub pruners (e.g., RedMax CHTZ2460)
- Chain saws (e.g., Husqvarna T540 XP)

IV. METHODOLOGY

An inventory of the DPW's gas-powered equipment used to maintain 36 properties (**see Appendix A**) was conducted to estimate their impacts and the potential benefits of replacing them with battery electric equipment. The inventory involved identifying equipment by brand and model number and documenting their frequency and duration of use on a property to property basis. The analysis included only gas-powered equipment for which commercial grade battery electric equipment are currently available and capable of matching the work productivity of gas equipment. Diesel powered equipment was not included.

Maintenance activities were divided into three categories:

- **Routine Maintenance** (e.g., mowing, blowing, trimming)
- **Spring and Fall Clean-Ups** (major clean-ups of leaves/debris)
- **Special Tasks** (e.g., tree pruning).

Impacts included the following:

A. Toxic and Carcinogenic Exhaust

The exhaust emissions below were quantified in pounds-per-year using validated equations from the US Environmental Protection Agency.

- **Ozone-forming emissions:**
 - **Non-methane hydrocarbons (HC)**, also known as volatile organic compounds, include benzene, 1,3 butadiene, formaldehyde, and acetaldehyde, all of which are potent carcinogens ([Loh, 2007](#)). Additionally, these compounds combine with **Nitrogen Oxides** in warm season months to form ground level ozone, a cause of lung and heart disease.
 - **Nitrogen oxides (NOx)** combine with non-methane HCs in warm season months to form ground level ozone.
- **Carbon monoxide (CO)** is a toxic gas which can harm health when people are in close proximity and which can accumulate in enclosed settings (sheds, trailers) and result in death.

- **Fine particulate matter (PM2.5)** is a cause of cancer, lung disease, heart disease, and premature death ([IARC, 2012](#); [US EPA](#)).

Greenhouse Gases

- **Carbon dioxide** was quantified in pounds per year. CO2 is a major greenhouse gas that contributes to global warming and climate change. Four of the 36 properties account for around half of all CO2 emissions:

Noise

- **Noise** from gas-powered landscape maintenance equipment at the ear of the operator generally exceed the occupational safety standard of 85 decibel (A-weighted) average over an 8 hour day, some up to 1000-times based on the exponential decibel scale ([PLANET, 2012](#)). At 50 feet, most exceed thresholds considered safe for health and hearing ([WHO Guidelines](#); [EPA Levels, 1974](#)). Chronic loud noise may cause irreversible hearing damage, cognitive and psychological problems, sleep disruption, and contribute to heart disease and other stress-related disorders. Loud noise is particularly problematic around playgrounds, schools, homes, and offices in which people are working, studying, or simply trying to enjoy themselves indoors or outdoors. Children with autism and people with hearing and sensory deficit disorders are especially vulnerable. Loud noise is also known to disrupt animal communications and decrease biodiversity.

Noise exposure was quantified as a product of noise level (decibel) at the ear of the operator the number of hours in use (decibel--hours). Sound from all battery electric equipment was assumed to average 85 dB at the ear of the operator vs 95 dB for all gas equipment (a 10.5% reduction). Note: A 10 dB difference translates to a doubling in perceived loudness.

Fuel spillage

- Fuel spillage into ground and drains occurs when equipment is refueled. To account for variation, estimates were measured as a range and averaged. For handheld equipment, a spillage range of 2 to 8 ounces per re-fueling was assumed; for mowers, a range of 2 to 6 ounces per re-fueling was assumed.

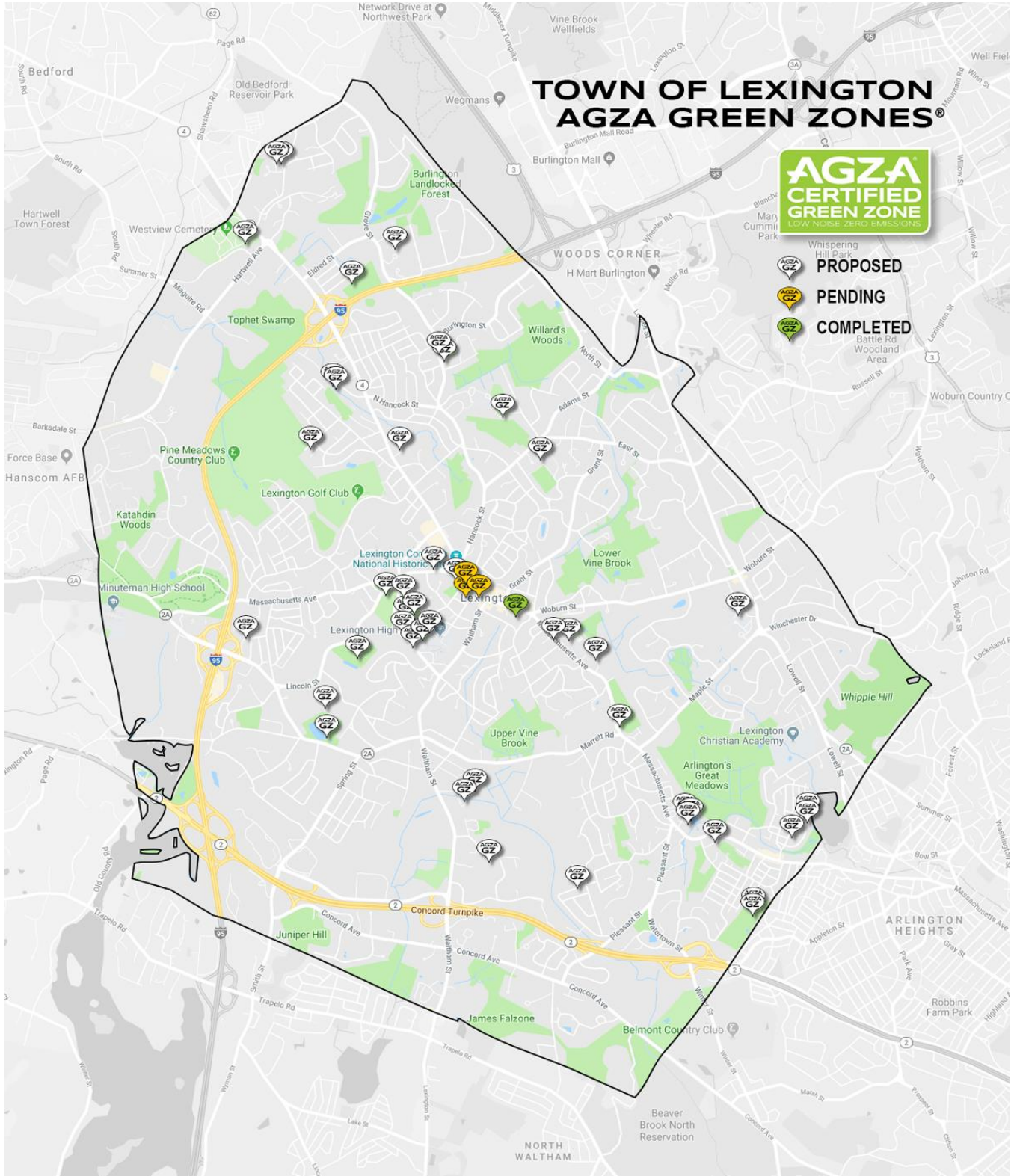
Fuel Consumption and Costs

- Fuel consumption (gallons) and costs of fuel (\$) were based on average fuel capacity and consumption rates for each type of equipment. Cost per gallon of gas was assumed to be \$2.50.

Toxic and Solid Waste

- Toxic and solid waste from maintaining gas equipment (chemicals, solid containers and parts – e.g., spark plugs, air and oil filters, belts, hoses, carburetor cleaner, engine degreasers, etc) create substantial waste streams consisting of solid parts containing toxic chemicals and solid non-recyclable containers with toxic chemical residues. These wind up in landfills and can contribute to soil and water contamination.

An online map of the properties was created to illustrate the properties that account for most of the impacts and to visually track progress.



V. IMPACT RESULTS

A. Annual Toxic and Carcinogenic Exhaust Emissions

Gas-powered maintenance of town properties accounts for 20,875 pounds (10.4 tons) of toxic and carcinogenic exhaust each year.

Note: The amount of each emission type is not indicative of toxicity or carcinogenicity. Rather, the potency or strength of the emission in causing disease must also be considered. As a hypothetical example, small amounts of PM2.5 may be more toxic than large amounts of ozone.

- Ozone-Forming Exhaust:** 1,546 pounds per year of non-methane HC and 76 pounds per year of NOx. **Routine Maintenance** accounts for 72% of HC exhaust and for 87% of NOx. Fourteen properties account for nearly 80% and include the Town Hall Complex which is maintained routinely with battery electric equipment and three properties in the process of transition.

Ozone-Forming Exhaust from Routine Maintenance: Contribution by Property

Westview Cemetery	33.3%	53.4%
Munroe Cemetery	8.7%	
Center Playfield and Courts	7.1%	
Town Hall Complex	4.3%	
Minuteman Bikeway	3.9%	25.5%
Cary Library	3.1%	
Visitor Center-Buckman's Tavern	3.1%	
Adams Playfield and Courts	2.4%	
Ye Olde Cemetery	2.4%	
Battle Green	2.3%	
Clarke School Fields and Courts	2.3%	
Emery Park	2.1%	
Hastings Park	2.0%	
Rindge Park and Courts	1.9%	
Other Properties	21.1%	21.1%
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

- Carbon Monoxide** 18,990 pounds (9.5 tons). **Routine Maintenance** accounts for 86% of CO. Nine properties contribute around 80% of all CO emissions and include the Town Hall Complex which is maintained routinely with battery electric equipment and three properties in the process of transition.

CO Exhaust from Routine Maintenance: Contribution by Property

Munroe Cemetery	18.4%	50.6%
Westview Cemetery	13.0%	
Town Hall Complex	9.9%	
Cary Library	9.4%	
Visitor Center-Buckman's Tavern	8.7%	30.2%
Ye Olde Cemetery	7.1%	
Emery Park	5.3%	
Battle Green	4.6%	
Hastings Park	4.5%	
Other Properties	19.2%	19.2%
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

- **Fine particulate matter:** 264 pounds. **Routine Maintenance** accounts for 79% of PM2.5. Fifteen properties contribute 80% of all PM2 emissions and include the Town Hall Complex which is maintained routinely with battery electric equipment and two properties in the process of transition.

PM2.5 Exhaust from Routine Maintenance: Contribution by Property

Westview Cemetery	39.2%	53.4%
Center Playfields and Courts	7.5%	
Munroe Cemetery	6.7%	
Minuteman Bikeway	4.1%	26.6%
Town Hall Complex	2.9%	
Adams Playfield and Courts	2.5%	
Clarke School Fields and Courts	2.3%	
Ye Olde Cemetery	2.0%	
Visitor Center-Buckman's Tavern	2.0%	
Rindge Park and Courts	1.9%	
Battle Green	1.9%	
Lincoln Park	1.8%	
Tower Park	1.8%	
Cary Library	1.7%	
Public Services Bldg	1.6%	20.0%
Other	20.0%	
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

B. Annual Greenhouse Gases

Gas-powered maintenance of town lands produces 67,597 pounds (33.8 tons) of CO2 each year, 88% of which comes from **Routine Maintenance**. Nine properties contribute over 80% of CO2 emissions - these include the Town Hall Complex which is maintained routinely with battery electric equipment and three properties in the process of transition.

CO2 Exhaust from Routine Maintenance: Contribution by Property

Munroe Cemetery	17.2%	51.8%
Westview Cemetery	16.2%	
Town Hall Complex	9.4%	
Cary Library	9.0%	31.6%
Visitor Center-Buckman's Tavern	8.1%	
Ye Olde Cemetery	7.0%	
Emery Park	5.1%	
Battle Green	4.4%	
Hastings Park	4.2%	
Center Playfields and Courts	2.8%	16.6%
Other Properties	16.6%	
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

C. Annual Noise

Gas-powered maintenance on Town-maintained properties produces approximately 876,000 decibel-hours of noise* of which **Routine Maintenance** accounts for 79%. Three properties account for more than half of the noise exposure.

Noise Exposure from Routine Maintenance: Contribution by Property

Westview Cemetery	38.5%	52.2%
Munroe Cemetery	8.2%	
Center Playfields and Courts	5.5%	
Town Hall Complex	4.0%	28.8%
Ye Olde Cemetery	3.9%	
Cary Library	3.3%	
Minuteman Bikeway	3.2%	
Visitor Center-Buckman's Tavern	3.1%	
Battle Green	2.4%	
Emery Park	2.0%	
Adams Playfield and Courts	1.8%	
Lincoln Park	1.7%	
Tower Park	1.7%	
Hastings Park	1.7%	
Other Properties	19.1%	19.0%
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

*An average 10 decibel reduction (10.5% assuming 95 dB average for gas tools) is 92,000 decibel- hours.

D. Annual Fuel Spillage

Assuming spillage of 2 to 4 ounces for mowers and 2 to 8 ounces for handheld tools per refueling, it is estimated (on average) that an average of 297 gallons of gasoline (range: 69 to 525 gallons) are spilled each year, contaminating soil and water. **Routine maintenance** accounts for approximately 78% of the spillage.

Fuel Spillage from Routine Maintenance: Contribution by Property

Westview Cemetery	38.5%	53.3%
Munroe Cemetery	8.2%	
Center Playfields and Courts	5.5%	
Town Hall Complex	4.0%	27.3%
Ye Olde Cemetery	3.9%	
Cary Library	3.3%	
Minuteman Bikeway	3.2%	
Visitor Center-Buckman's Tavern	3.1%	
Battle Green	2.4%	
Lincoln Park	2.0%	
Adams Playfield and Courts	1.8%	
Tower Park	1.7%	
Emery Park	1.7%	
Hastings Park	1.7%	
Other Properties	19.1%	19.4%
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

E. Annual Fuel Consumption and Costs

Based on the total hours of use and average gallons per hour for the various pieces of equipment, all grounds maintenance activities account for over 3,200 gallons of gasoline at a cost exceeding \$8,000 (assuming \$2.50 per gallon). **Routine Maintenance** accounts for the 81% of fuel consumption and costs.

Fuel Consumption/Cost from Routine Maintenance: Contribution by Property

Westview Cemetery	29.9%	54.0%
Munroe Cemetery	12.0%	
Town Hall Complex	6.4%	
Cary Library	5.7%	
Visitor Center-Buckman's Tavern	5.1%	25.7%
Center Playfields and Courts	4.9%	
Emery Park	3.4%	
Battle Green	3.2%	
Hastings Park	2.8%	
Minuteman Bikeway	2.8%	
Ye Olde Cemetery	1.8%	
Marvin Park and Basketball Courts	1.7%	
Other Properties	20.3%	20.3%
Total	100.0%	

Routine Maintenance

■ Fully transitioned

■ In transition

F. Annual Toxic and Solid Waste

Toxic and solid waste are nearly eliminated when all fully retired gas tools are replaced by electric alternatives.

VI. PROGRESS THROUGH CY 2019

The DPW has purchased battery electric handheld tools for maintaining the Town Hall Complex and other properties. These properties are major impact contributors as shown in the previous sections. Impact reductions on annual and cumulative bases are shown in the table below.

Routine Maintenance of the Town Hall Complex has been performed only with battery electric tools since September, 2017. Cumulative reductions through December 2019 were calculated using a factor of 2.33.

Transition of **Routine Maintenance** to battery electric tools started in June, 2019 for three other properties (Cary Library, Visitor Center-Buckman's Tavern, Emery Park). Approximately 25% of work is currently performed with battery electric tools. Cumulative reductions through December 2019 were calculated using factors of 25% and 0.7 to adjust for the level of transition and fraction of the year, respectively.

Town Hall Complex: Impact Reductions*

Category	Annual Reductions	Cumulative Reductions 9/1/2017 - 12/31/2019
Toxic and carcinogenic exhaust emissions (non-methane hydrocarbons, nitrogen oxides, carbon monoxide, fine particulate matter)	1,647 lbs	3,838 (1.9 tons)
Greenhouse gas (carbon dioxide)	5,458 lbs (2.7 tons)	12,718 (6.4 tons)
Noise**	2,913 decibel-hours	6,788 decibel-hours
Fuel spillage	8.6 gallons	20 gallons
Fuel consumption and cost	168 gallons; \$420	391 gallons; \$979
Toxic and solid waste	100% elimination of waste from replacement/disposal of gas parts and gas maintenance	

*Routine Maintenance only; Cumulative reductions through December 2019 were calculated using a factor of 2.33. ** Assumes an average of 85 db from battery electric vs 95 dB from gas equipment.

Visitor Center/Buckman Tavern, Cary Library, Emery Park: Impact Reductions*

Category	Potential Annual Reductions	Reductions 6/1/2019 - 12/31/2019
Toxic and carcinogenic exhaust emissions (non-methane hydrocarbons, nitrogen oxides, carbon monoxide, fine particulate matter)	3,871 lbs	564 lbs
Greenhouse gas (carbon dioxide)	12,864 lbs (6.4 tons)	1,876 lbs
Noise**	6,043 decibel-hours	881 decibel-hours
Fuel spillage	17 gallons	3 gallons
Fuel consumption and cost	372 gallons; \$930	54 gallons; \$136
Toxic and solid waste	100% elimination of waste from replacement/disposal of gas parts and gas maintenance	

*Routine Maintenance only; Cumulative reductions through December 2019 were calculated using factors of 25% and 0.7 to adjust for the level of transition and fraction of the year, respectively. ** Assumes an average of 85 db from battery electric vs 95 dB from gas equipment.

VII. BENEFITS

The results of the baseline analysis indicate that transitioning to battery electric equipment can substantially reduce harmful exhaust emissions, greenhouse gases, fuel spillage, solid and toxic waste, noise experienced by workers and the surrounding community, and hourly operating costs from avoided fuel and maintenance.

- Battery electric equipment and manual tools produce no toxic and carcinogenic exhaust emissions.
- Battery electric equipment and manual tools produce no carbon dioxide.
- AGZA-approved battery electric equipment has been estimated to substantially reduce perceived loudness levels.
- Because battery electric equipment does not run on liquid fuel, fuel spillage, fuel consumption and costs are eliminated when gas equipment is replaced.
- The crew does not have to carry or mix the gas and oil needed for gas powered handheld equipment.
- The toxic and solid waste stream of gas-related parts and maintenance is completely eliminated for all fully retired gas tools that are replaced by electric alternatives.

In addition to the environmental and health benefits of transitioning away from gas equipment, there are other important benefits.

- Elimination of gas equipment vibration that can cause neurological damage and other harm to worker health.
- A heightened awareness throughout the community about how the Town's DPW is creating a more pleasant and sustainable environment for its citizens.
- Recognition of the Town as a regional and national leader in zero-emissions, low-noise maintenance, helping to strengthen its reputation as an environmental steward.
- Enhanced ability to engage local landscaping businesses in following the Town's example inspiring further impact reductions.
- Long-term benefits from citizens raising expectations about sustainability in all aspects of their lives: zero-emission residential lawn care, electric or other zero-emission cars, rooftop solar, renewable energy infrastructure, etc.

VIII. CLOSING STATEMENT

Lexington's DPW has begun an important transition -- away from fossil fuels to zero emissions, low noise battery electric tools to maintain its municipal properties. As properties transition their Routine Maintenance, they will be eligible for AGZA Green Zone certification, recognized by state agencies. In doing so, Lexington will become the first certified AGZA Green Zone Town in Massachusetts, serving as a leader in sustainable landscape maintenance for the state.

The transition promises substantial benefits for the health of workers, the public and the environment. Further, the Town stands to realize long-term savings accruing from eliminated fuel consumption and reduced maintenance. In addition to healthier working conditions, work crews benefit from recognition and pride in the work they do. Residents benefit from cleaner, quieter neighborhoods, schools, businesses and public spaces. ***Quiet Communities and AGZA applaud the Town of Lexington for its outstanding leadership!***

Appendix A. Property Inventory*

Property #	Property Name	Total Acreage
1	Ye Olde Burying Ground	1.4
2	Munroe Cemetery	6.7
3	Robbins Cemetery	0.2
4	Westview Cemetery	36.0
5	Town Hall Complex	0.4
6	Carey Library	0.3
7	Public Services Building	0.9
8	Visitor's Center/Buckman Tavern	2.2
9	Emery Park	0.4
10	Hastings Park	3.8
11	Justin Park	0.6
12	Marvin Park	1.0
13	Kinneens Park	1.7
14	Rindge Park	1.6
15	Bow Street	0.3
16	Munroe Playground	0.8
17	Battle Green	2.5
18	Garfield Park	1.2
19	Lincoln Park	12.0
20	Franklin Park	2.0
21	Adams Playfields	3.4
22	Valley Park	3.2
23	Sutherland Park	0.7
24	Center Playfields	22.0
25	Clarke School Fields	10.0
26	Diamond School Fields	8.3
27	Fiske School Fields	2.5
28	Estabrook School Fields	3.5
29	Hastings School Playfields	3.4
30	Bridge School Playfields	5.2
31	Bowman School Playfields	3.6
32	Harrington School Playfields	6.2
33	Minuteman Bikeway	45.0
34	Muzzey Field	1.1
35	Old Reservoir Picnic Area	0.3
36	Tower Park	12.4
Total Acreage		206.8

Routine Maintenance ■ Fully transitioned ■ In transition

*189.0 of the 206.8 acres are maintained.