Small Equipment Electrification Program Assessment

MA23R57-E-SEE

Prepared for:

The Electric and Gas Program Administrators of Massachusetts
Part of the Residential Evaluation Program Area

Submitted by:

Guidehouse Inc.
2617 Broadway
Boulder, CO 80304
Telephone (303) 728-2500

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Executive Summary

In 2022, the Massachusetts Electric Program Administrators (PAs) introduced incentives for electric, battery-powered lawn equipment to the Residential Existing Building Program, which is part of the Residential Retail Core Initiative. Through these new incentives, the PAs look to encourage consumers to purchase electric alternatives to historically gasoline-powered equipment and, in doing so, reduce greenhouse gas (GHG) emissions.

Cadeo, as part of a Guidehouse-led evaluation team, led this study to assess the impact of these four residential small equipment electrification measures, which included battery-powered lawn mowers (push and rear engine), string trimmers, leaf blowers, and chainsaws.

This study used three activities to generate updated gross and net savings for each measure:

- **Engineering review**, which focused on assessing the accuracy of the algorithms listed in the current Technical Reference Manual (TRM) for calculating the avoided gasoline usage and additional electric use associated with the battery-powered equipment.
- **Literature review**, which included gathering industry data and details on purchased equipment to populate those gasoline and electric savings algorithms.
- **Participant survey**, which collected information from 155 recent equipment purchasers to assess usage, decision-making, and demographics.

As Table 1 shows, the team found:

1. Evaluated gross **gasoline savings** (i.e., avoided or saved MMBTUs from switching away from gasoline powered equipment) were much lower than existing TRM values for all four measures; realization rates ranged from 0.10 to 0.22.
2. Evaluated gross **electric impacts** (i.e., added load from charging) are much larger than existing TRM-based estimates for everything but lawn mowers, which the TRM previously overestimated.
3. **Net-to-gross (NTG)** ratios, for all four measures, were less than the TRM's default 1.0 assumption.

Table 1. Summary of Gross and Net Savings

Measure	Percentage of 2022 Participation	Gas - Gross Realization Rate	Electric Impact-Realization Rate	Net-to-Gross Ratio
Electric Lawn Mower	44%	0.22	5.68	0.75
Electric String Trimmer	26%	0.11	0.07	0.70
Electric Leaf Blower	23%	0.10	0.07	0.79
Electric Chainsaw	7%	0.20	0.05	0.70

Source: Program tracking data and Cadeo analysis

These evaluation findings—less gasoline savings, more electric consumption associated with charging (for non-lawn mowers), and lower NTG ratios—collectively mean the overall GHG impact of these measures are less than the PAs previously anticipated. Since the PAs apply the results of studies like this prospectively, the findings suggest the PAs will need to revisit the cost-effectiveness of these measures when determining the role of small equipment electrification rebates as part of ongoing planning for the 2025-2027 Three-Year Energy Efficiency Plan.

While this evaluation focused primarily on quantifying the energy and greenhouse gas impacts of switching to electric lawn equipment, there are likely additional user benefits like reduced noise and air pollution that were not measured. Moreover, as programs like this drive increased adoption of electric models, there may be market transformation impacts further up the supply chain as manufacturers shift production away from gasoline-powered equipment.

1. Introduction

The Massachusetts Program Administrators (PAs) recently introduced incentives for electric, battery-powered lawn equipment to the Residential Existing Building Program, which is part of the Residential Retail Core Initiative. Their goal is to encourage consumers to purchase electric alternatives of historically gasoline-powered equipment and, in doing so, reduce greenhouse gas emissions and save customers money over the lifetime of the equipment.

Cadeo, as part of a Guidehouse-led evaluation team, led this study to assess the impact of these four residential[1] small equipment electrification measures, which include battery-powered:

- Lawn mowers (push and rear engine)
- String trimmers
- Leaf blowers
- Chainsaws

First available in 2022, these measures have been offered for just over a year, which was long enough to generate sufficient participation levels for this initial impact assessment. The results of this evaluation will help the PAs understand not only the energy impact of these measures but also the role the measures could play as part of the next three-year program implementation cycle (2025-2027).

1.1 Program Participation Summary

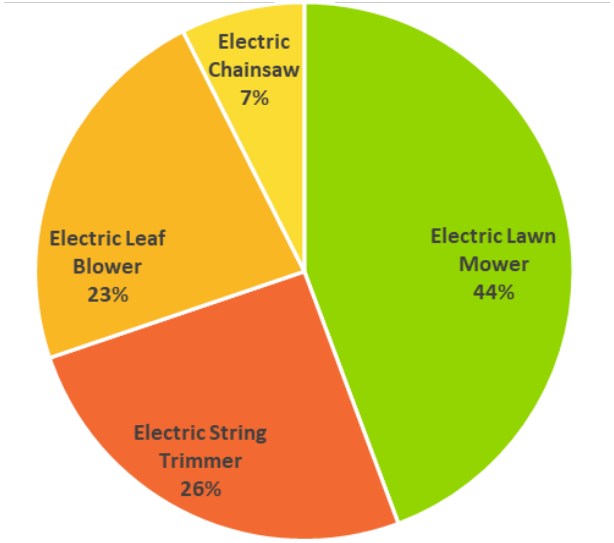
In 2022, a total of 6,352 individuals participated in the program, receiving rebates for 8,658 individual battery-powered pieces of equipment. Figure 1 below shows the number of rebates received by equipment type.

INTERTPRETTING ELECTRIFICATION IMPACTS

Evaluating the impact of electrification measures requires looking at both the **avoided use** of the original non-electric fuel—gasoline for these measures—and **added electric consumption** associated with the new electrified measure. When viewing the results, readers should interpret the avoided usage of the non-electric fuel as savings (like a traditional energy efficiency measure) where a larger value indicates more savings. Conversely, readers should view the electric consumption associated with the transition from gasoline-to-electric powered equipment as added electrical load or negative savings. The overall impact of electrification therefore focuses on the tradeoff of these two competing metrics and the relative importance and values that the PAs associate with each.

[1] The PAs also offer incentives for battery-powered equipment through their commercial offerings.

Figure 1. Participation Summary by Equipment Type



Source: Program Tracking Data

A total of 3,837 electric lawn mowers received a rebate through the program, accounting for 44% of all rebates issued. The other 56% of rebates went to the other three equipment types: electric trimmers, leaf blowers, and chainsaws (referred to throughout this report as handheld products). Electric trimmers and leaf blowers had similar participation levels, accounting for 26% and 23% of the program's rebates, while electric chainsaws accounted for the smallest proportion, with only 645 rebates issued (7%).

1.2 Study Description and Objectives

This study set out to provide a general assessment of the new measures' efficacy and impacts, including:

- **Gross Impacts:** Determine the energy impact of each type of incentivized equipment, including decreases in gasoline consumption and increases in electric consumption due to charging.
- **Net Impacts:** Estimate the net-to-gross (NTG) ratio for each type of incentivized equipment using the Massachusetts's Consistent Methodology for Self-Reported Residential Net-to-Gross Measurement.[2]
- **Process Assessment:** Assess the strengths and weaknesses of the current program design with an eye on identifying opportunities for improvement, which could include but are not limited to mitigating barriers, minimizing free ridership, and expanding the program.

[2] Consistent Methodology for Self-Reported Residential Net-to-Gross Measurement (MA19X03-B-RSRNTG), 2020 https://ma-eeac.org/wp-content/uploads/MA19X03-B-RSRNTG_Residential-SR-NTG-Report_FINAL_2020.5.28.pdf

1.2.1 Research Questions

This study was designed to answer the following questions:

- What is the gross energy impact of incentivized equipment from an electric, gasoline, and total energy perspective?
- What are the net impacts of the measures accounting for both free ridership and spillover?
- How can the PAs and their vendors improve to deliver these measures?

2. Methodology

To answer these questions, the evaluation team performed several tasks: an engineering review of the program's current engineering inputs and savings calculations, a literature review investigating potential sources to improve the current savings inputs and calculations, and a participant survey to assess customer usage and decision-making. Table 2 lays out these activities along with their rationale.

Table 2. Summary of Study Activities

Activity	Rationale
Engineering Review	• Comprehensively reviewed the program's current engineering inputs and savings calculations as documented in the Massachusetts Technical Reference Manual (TRM)[3] • Assessed the appropriateness of current assumed values, the accuracy of algorithms, and looked for opportunities to improve the savings estimate
Literature Review	• Reviewed similar programs/equipment offers throughout the country • Gathered information regarding eligible products, incentives offered, and gross and net savings input assumptions • Identified potential program design improvement opportunities • Reviewed landscaping equipment industry data materials • Examined the latest offerings from major equipment manufacturers and program specifications of incentivized equipment
Participant Survey	• Completed 155 online surveys with 2022 participants in January 2024 • Gathered data to estimate free ridership as well as estimate spillover, and to determine net program impacts • Gather data on any barriers to adoption within the program structure • A copy of the survey is provided in Appendix A

[3] Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2022-2024 Plan Version, 2021. https://www.masssavedata.com/TRL/Technical%20Reference%20Manual%202022-2024%20Final.pdf

3. Results

This section contains three subsections. The first subsection—Savings Summary—succinctly summarizes the evaluation's gross and net findings, while the last two sections—Gross Savings Details and Net Savings Details—provide a more comprehensive explanation of the team's impact analysis.

3.1 Savings Summary

Table 3 and Table 4 summarize the gross gasoline and electric impacts of each measure. As shown, the team's evaluated gasoline impacts (i.e., the MMBTU savings associated with avoided gasoline usage) were meaningfully lower than the PAs' pre-evaluation planning assumptions. This finding is primarily due to the updated primary and secondary data that the team used to calculate the fuel consumption rate.

At the same time, the team found lower electric impacts for lawn mowers but significantly higher electric impacts for the handheld products (leaf blowers, string trimmers, and chainsaws). As participants are transitioning to electric equipment, electric impacts are adding electric load. This finding can be interpreted as negative electric savings or the electric penalty associated with fuel switching. The lower evaluated electric impacts for lawn mowers are caused by the modified fuel consumption rate (as in the gas impacts), as well as the incorporation of electrical efficiencies. The higher evaluated electric impacts for the handheld products are caused by a significant restructuring of the formula used to calculate electric impacts. Whereas the previous formula utilized the time spent charging a given piece of electrical equipment to calculate electrical impacts, the current algorithm instead focuses on the usage of the product itself to find this information.

Collectively, the combination of lower gasoline impacts and higher electric impacts for the handheld products means the total energy impact of customers switching to purchase electric, battery-powered equipment instead of a traditional gas model is significantly less than anticipated.

Table 3. Annual Gas Impacts (MMBtu/year)

Measure	BCR ID	Percentage of 2022 Participation	Originally Estimated (from TRM)	Evaluated (from MA23R57)	Gross Realization Rate
Lawn Mower	EA2c341	44%	2.5	0.5	0.22
Leaf Blower	EA2c349	23%	1.4	0.2	0.11
String Trimmer	EA2c350	26%	1.4	0.1	0.10
Chainsaw	EA2c351	7%	1.4	0.3	0.20

Source: Program tracking data, MA TRM, and Cadeo analysis

Table 4. Annual Electric Impacts (kWh/year)

Measure	BCR ID	Percentage of 2022 Participation	Originally Estimated (from TRM)	Evaluated (from MA23R57)	Gross Realization Rate*
Lawn Mower	EA2c341	44%	218	38	5.68
Leaf Blower	EA2c349	23%	1	12	0.07
String Trimmer	EA2c350	26%	1	10	0.07
Chainsaw	EA2c351	7%	1	19	0.05

*As electric impacts are added load, the evaluation team flipped the gross realization rate here (previous/evaluated). As a result, a higher value indicates a favorable change (less added load).

Source: Program tracking data, MA TRM, and Cadeo analysis

Net savings account for both free ridership and spillover. Free ridership refers to participants who would have purchased the efficient equipment—in this case battery–powered equipment instead of a gasoline-powered model—without the program incentive. Spillover refers to additional energy-related purchases made by program participants who were influenced by the program but did not receive an incentive. In the process of calculating spillover, the evaluation team limited analysis to the electric equipment present in this program (e.g., participant buying a lawn mower while getting the incentive for a chainsaw) and excluded spillover to equipment types that are not present in the analysis. This approach allowed the team to have more accurate spillover and consequently more accurate NTG values because the team had reliable impact values for each equipment type.

It's important to note that while the net savings analysis provides valuable insights into the direct impacts of the program on participants, it does not fully capture all the potential ways the program could be influencing the broader market for lawn care equipment. For example, the increased demand for electric equipment driven by the program could be affecting manufacturer production decisions and the overall market share of electric vs. gas-powered options. Similarly, shifts in retailer stocking practices in response to program-driven demand changes were not analyzed. While outside the scope of this net savings analysis, these types of broader market effects could be contributing to market transformation and the program's overall impact.

As Table 5 shows, the participant survey yielded free ridership rates ranging from 25% to 34% across the four measures.[4] Given the small sample size, the team applied the total observed participant spillover rate (4%) to each measure. These free ridership and spillover rates resulted in NTG ratios ranging from 0.70 (lawn mowers and trimmers) to 0.79 (leaf blowers), which are all lower than the assumed NTG ratio of 1.0 documented in the TRM.

[4] The evaluation did not explicitly account for towns in Massachusetts that have – or plan to institute – bans on gasoline landscape equipment, whether for emissions or noise limits. However, surveyed participants may have taken this into account when responding to the survey. For example, if a surveyed participated lived in such a town, it is possible they answered survey questions in a way that identified as a free-rider (i.e., they would have purchased an electric model anyway) because of their town's rule.

Table 5. Free Ridership, Spillover, and NTG Impacts

Measure Name	BCR ID	Free Ridership	Spillover	NTG
Lawn Mower	EA2c341	**0.34**	0.04	**0.70**
Leaf Blower	EA2c349	**0.25**	0.04	**0.79**
String Trimmer	EA2c350	**0.34**	0.04	**0.70**
Chainsaw	EA2c351	**0.29**	0.04	**0.75**

Source: Cadeo analysis

The 34% free ridership estimate for the lawn mower aligns exactly with national market share estimates for electric lawn mowers in 2021.[5] The fact that the measure's free ridership rate (i.e., the percentage of participants that would have purchased it without an incentive) matches the broader market share for electric lawn mowers validates the self-reported participant survey results.

3.2 Gross Savings Details

This section details the updated algorithms and inputs that the evaluation team used to calculate gross savings for each small equipment electrification measure and includes two subsections:

- **Algorithm Updates**, which outlines the original algorithms listed in the TRM that the PAs used to estimate savings, as well as the revisions the evaluation team made based on the engineering review and literature review findings.
- **Input Updates**, which covers the specific input values that feed into those algorithms to yield savings, including updated values from the team's literature review and survey of recent participants.

3.2.1 Algorithm Updates

The following gasoline and electric impact algorithms are documented in the TRM by measure. Please note that the TRM uses the same algorithm to report the **gasoline** impact for all four measures (Equation 1), whereas the TRM provides separate algorithms for calculating the **electric** impact of lawn mowers (Equation 2) and the other three handheld product measures (i.e., leaf blowers, trimmers, and chainsaws—Equation 3).

[5]Fact.MR, Market Research Company, "Electric Lawn Mower Market Forecast, Trend Analysis – 2032", https://www.factmr.com/report/811/electric-lawn-mower-market

Equation 1. TRM: Gasoline Impact Algorithm

$$\frac{usage\ sessions}{year} * \frac{gallons_{gas}}{usage\ session} * {MMBtu}/{Gal_{gasoline}}$$

Equation 2. TRM: Lawn Mower Electric Impact Algorithm (Annual Δ kWh)

$$\frac{gallons_{gas}}{year} * ({MMBtu}/{Gal_{Gasoline}} * \frac{kWh}{MMBtu}) * Fuel\ Fired_{Efficiency}$$

Equation 3. TRM: Handheld Products Electric Impact Algorithm (Annual Δ kWh)

$$Battery\ kW\ Draw * Charge\ Time * Charges\ per\ Year$$

The evaluation team closely reviewed the existing TRM algorithms as part of the engineering review (Task 1). Through that review, the team identified the need to make four algorithmic updates to capture the gross impacts of these four battery-powered landscaping measures more accurately:

1. **Standardizing across Measures.** Using separate electric impact algorithms for lawn mowers and handheld equipment introduces an inconsistency in how the PAs are currently estimating electric and gasoline usage across equipment types. As evident in Table 6, the ratio of electric and gasoline consumption for lawn mowers is very different (and much higher) than the comparable ratios for handheld equipment. To address this inconsistency and align how the PAs value electricity and gasoline across measures, the team applied the usage-based algorithm (previously just used for lawn mower electric impacts) when calculating electric impacts for all four equipment types.

Table 6. Electric/Gas Use Ratios Using TRM-Based Results

Measure	Annual Electric Usage (kWh)	Annual Gasoline Usage (MMBTUs)	Ratio (BTUs/BTUs)
Lawn Mower	218	2.5	0.298
Leaf Blower	0.78	1.4	0.002
String Trimmer	0.71	1.4	0.002
Chainsaw	1.02	1.4	0.002

Source: MA TRM, Cadeo analysis

2. **Modifying the Fuel Consumption Rate.** The prior fuel consumption rate (gallons per usage session in Equation 1) in the TRM does not account for differences between the various products. In addition, by not incorporating a load factor, this value assumes that products are being put into full throttle throughout the entirety of a usage session rather than being idled for periods of time. The team has added equipment-specific load factors and brake-specific fuel consumption values to generate fuel consumption rates that are unique by product.

3. **Incorporating Electrical Efficiencies.** The TRM assumes an electrical efficiency of 100% not accounting for energy losses during charging or within electric motors. The team has added both charging and electric motor efficiencies to compensate for the energy lost while using electric equipment.

4. **Changing the Calculation of Gas Efficiencies.** In using a usage-based algorithm to calculate electrical impacts rather than one that is based on charging time, it is necessary to find gas efficiencies that are unique to each product. The team has done so by finding brake-specific fuel consumption values that are specific to each piece of equipment.

After making these adjustments, the updated gas impacts algorithm is similar to what is used in the TRM. In addition, outside of the incorporation of electric efficiencies, the updated algorithm to calculate electric impacts is similar to the formula used to calculate electric impacts for lawn mowers in the TRM. Note that the team's standardization resulted in two algorithms—one for gasoline and one for electricity for all four electrification measures. This differs from the previous differentiation between mowers and handheld equipment. Equation 4 and Equation 5 show the updated formulas.

Equation 4. Updated: Gasoline Impact Algorithm (annual ΔMMBtu)

$$\frac{usage\ hours}{year} * \frac{gallons_{gas}}{hour} * MMBtu/Gal_{gasoline}$$

Equation 5. Updated: Electric Impact Algorithm (annual ΔkWh)

$$\frac{gallons_{gas}}{year} * Fuel\ Fired_{Efficiency} \Big/ Elec.\ Motor\ Eff. * Elec.\ Charging\ Eff.$$

Of the updates the team made, the updated approach for calculating fuel consumption rate (gallons/hour) and fuel-fired efficiency were the most significant. As previously mentioned, load factors account for the time in which a product is powered on but not being used to its fullest capacity, such as when it is put in idle. Adding in the latter two variables in Equation 6 allowed the team to generate fuel consumption rates that account for the unique sizes of the engines within each piece of equipment. The fuel-fired efficiency was updated so that the updated electric impacts algorithm would contain equipment-specific gas efficiencies. Equation 6 and Equation 7 show the updated calculations for these two variables.

Equation 6. Updated Fuel Consumption Rate (gallons/hour) Variable

$$Load\ Factor * \frac{gallons_{gas}}{HP * hour} * Horsepower$$

Equation 7. Updated Fuel-Fired Efficiency Variable

$$\frac{\frac{kW}{HP}}{\frac{gallons_{gas}}{HP * hour} * \frac{kWh}{gallons_{gas}}}$$

3.2.2 Input Updates

The evaluation team's literature review (Task 2) and participant survey (Task 3) yielded multiple "better" input values (relative to the existing TRM input value/source) to populate the updated impact algorithms. The team defined "better," which the team acknowledges is a subjective term, as either primary data collected from actual 2023 participants or secondary data gleaned from a more recent, more robust, or more regionally appropriate study. Thus, although the team generated consistent algorithms across all four measures, the team is using unique inputs to calculate gas and electric impacts for each measure.

Table 7 and Table 8 summarize the inputs and sources that the team used to calculate gross gasoline impacts for lawn mowers and handheld products, respectively. As noted above, the change in fuel consumption rate input between the TRM and this study (for both lawn mower and handheld products) had the largest impact on the evaluated gasoline impacts.

Table 7. Lawn Mower Gasoline Impact Inputs

Variable	Previous Value	Current Value	Current Input Values: Sources/Data	Justification for Update
Annual Usage (hrs)	20[6]	18[7]	-	Replaced default assumption with participants' self-reported hours of use.
Fuel Consumption Rate (gal/hr)	1.03[8]	0.25	Load Factor: 36%[9]	Load factors account for the time in which products are powered on but are not being used or operated at full throttle; previously unaccounted for.
			Brake-Specific Fuel Consumption (gal/hp-hr): 0.13[10]	Previous approach utilized general commercial data for annual hours of use and gallons per year, whereas the current approach uses product-specific values that correspond to the unique engine types within different pieces of equipment.
			Horsepower: 5.4[11]	Incorporating horsepower allows for product-specific fuel consumption values related to the size of the engine for each product; previously unaccounted for.

Source: Program tracking data, MA TRM, and Cadeo analysis

[6] Assumption of 1.25 hours mowed per week from June to September
[7] Participant Survey Data
[8] DOE's Clean Cities Guide to Alternative Fuel Commercial Law Equipment, Argonne Labs - GREET program's Fleet Footprint Calculator (2012).
[9] 2020 California Air Resources Board report titled "2020 Emissions Model for Small Off-Road Engines – SORE 2020"
[10] 2010 EPA report, "Exhaust Emission Factors for Nonroad Engine Modeling – Spark Ignition"
[11] Consumer Reports product data

Table 8. Handheld Products Gasoline Impact Inputs

Variable	Previous Value	Current Value	Current Input Values: Sources/Data	Justification for Update
Annual Usage (hrs)	11.5[12]	7.5-10.0[13]	-	Replaced default assumption with participants' self-reported hours of use.
Fuel Consumption Rate (gal/hr)	1.00[14]	0.13-0.29	Load Factor: 70%-94%[15]	Load factors account for the time in which products are powered on but are not being used or operated at full throttle; previously unaccounted for.
			Brake-Specific Fuel Consumption (gal/hp-hr): 0.13-0.14[16]	Previous fuel consumption rate lacked a source, whereas the current approach uses product-specific values that correspond to the unique engine types within different pieces of equipment.
			Horsepower: 1.04-3.10[17]	Incorporating horsepower allows for product-specific fuel consumption values related to the size of the engine for each product; previously unaccounted for.

Source: Program tracking data, MA TRM, and Cadeo analysis

Table 9 and Table 10 highlight the inputs and sources that the team used to calculate gross electrical impacts for lawn mowers and handheld products, respectively.

[12] Assumption of usage every other week during mowing season
[13] Participant Survey
[14] Rough assumption, determined during Technical Advisory Group (TAG) call
[15] 2020 California Air Resources Board report titled "2020 Emissions Model for Small Off-Road Engines – SORE 2020"
[16] 2010 EPA report, "Exhaust Emission Factors for Nonroad Engine Modeling – Spark Ignition"
[17] Consumer Reports product data.

Table 9. Lawn Mower Electric Impact Inputs

Variable	Previous Value	Current Value	Current Input Values: Sources/Data	Justification for Update
Annual Usage (hrs)	20[18]	18[19]	Survey Data	Replaced default assumption with participants' self-reported hours of use.
Fuel Consumption Rate (gal/hr)	1.03[20]	0.25	Same as Fuel Impact Approach	Though approach is unchanged for lawn mowers, the updated values align with the fuel impact calculation.
Fuel-Fired Efficiency	0.3	0.17	Brake-Specific Fuel Consumption (gal/hp-hr): 0.13[21]	Engine-specific efficiency value based on displacement and stoke type; previously was a general assumption about the efficiency of an internal combustion engine.
			Conversion of Gal Gasoline to kWh: 35.3	N/A
			Conversion of hp-hr to kW: 0.745	N/A
Electric Motor Efficiency	N/A	0.84	Standard Efficiency for 2-Pole Enclosed Motors[22]	Reflects actual electric motor efficiency of program equipment; previously unaccounted for.
Charger Efficiency	N/A	0.79	Average Charger Efficiency of Common Program Equipment[23]	Reflects actual charging efficiency of program equipment; previously unaccounted for.

Source: Program tracking data, MA TRM, and Cadeo analysis

[18] Assumption of 1.25 hours mowed per week from June to September
[19] Participant Survey
[20] DOE's Clean Cities Guide to Alternative Fuel Commercial Law Equipment, Argonne Labs - GREET program's Fleet Footprint Calculator (2012)
[21] 2010 EPA report, "Exhaust Emission Factors for Nonroad Engine Modeling – Spark Ignition"
[22] DOE 10 CFR 431, Subpart X
[23] EERE-2020-BT-STD-0013

Table 10. Handheld Products Electric Impact Inputs

Variable	Current Value	Updated Input Values: Sources/Data
Annual Usage (hrs)	7.5-10.0[24]	Survey Data
Fuel Consumption Rate (gal/hr)	0.13-0.29	Same as Fuel Impact Approach
Fuel-Fired Efficiency	0.16-0.17	Brake-Specific Fuel Consumption (gal/hp-hr): 0.13-0.14[25]
		Conversion of Gal Gasoline to kWh: 35.3
		Conversion of hp-hr to kW: 0.745
Electric Motor Efficiency	0.77-0.87	Standard Efficiency for 2-Pole Enclosed Motors[26]
Charger Efficiency	0.79-0.81	Average Charger Efficiency of Common Program Equipment[27]

Source: Program tracking data, MA TRM, and Cadeo analysis

Again, implementing a usage-based algorithm is necessary, as the prior charging-based algorithm generated unrealistic results.

3.3 Net Savings Details

As described in Section 3.1, the evaluation team used Massachusetts's standardized NTG approach and self-reported participant survey data to determine a relatively narrow band of NTG ratios (between 0.70 and 0.79) for all four battery-powered small equipment measures.

In supplement to these population-level and measure-specific results, the team also explored potential differences in free ridership—the primary determinant of NTG for these measures—for various subsets of participants. Specifically, the team assessed variance in free ridership by demographic, as well as how participants used their equipment and the previous equipment they owned (i.e., gasoline or electric-powered). The evaluation team did not find any notable differences in free ridership by any of the following self-reported characteristics:

[24] Participant Survey
[25] 2010 EPA report, "Exhaust Emission Factors for Nonroad Engine Modeling – Spark Ignition"
[26] DOE 10 CFR 431, Subpart X
[27] EERE-2020-BT-STD-0013.

- Age
- Income
- Race
- Usage frequency (hours per week)

3.4 Additional Insights

The participant survey was primarily designed to gather the information the team needed to estimate gross and net savings. However, the team also used the survey as an opportunity to collect additional insights to support future PA planning efforts:

- **High Satisfaction.** 86% (134 out of 154) of responding participants reported being satisfied or very satisfied (27% and 59%, respectively) with their new battery-powered equipment.

- **Concerns About Power and Toughness.** The small number of participants that indicated they were very dissatisfied (4%, or 6 out of 154) mainly cited concerns that the electric equipment was less powerful than their previous gas-powered tools. As one respondent commented, "Not as powerful as my gas and I have to switch batteries to get the job completed." Others echoed similar statements and said that they retained their gas-powered equipment to handle tough jobs that they felt the electric equipment was less suitable for.

- **Most Replaced Gas Equipment Lives On.** Roughly half of the surveyed participants (78 out of 154) indicated they owned an equivalent functional gas-powered piece of equipment (i.e., a gasoline lawn mower) when they purchased their incentivized electric model. We asked these participants what they did with their old equipment. Only 22% (17 out of 78) threw away or recycled their old gas-powered equipment (i.e., took the equipment permanently out of service). The majority of participants (78%) provided a response that suggests the previous gas-powered equipment may still be in use: kept for future use and tough jobs (33%), gave it away (32%), or sold it (13%).

- **Previous Gas-Powered Equipment Ownership.** The evaluation team looked at the distribution of the respondents who reported that they had previously owned the gas-powered version of the same equipment. The highest rate of previous gas-powered equipment ownership was among the electric lawn mower purchasers (63%), followed by trimmers (48%), leaf blowers (34%), and chainsaws (33%).

- **Income Distribution.** In terms of the income distribution, by far the biggest category of respondents were people with an annual household income of $150,000 or more. They comprise the biggest segment for all equipment types:

    - Participants with annual household incomes between $30,000 and $85,000 accounted for slightly more than 10% of respondents.
    - 25% of respondents preferred not to disclose their annual income.

  - 32% of respondents were white, college graduates with annual household income of $150,000 or more.

- **Home Ownership.** 98% of respondents reported that they or a member of their household owned their residence.
- **Personal Use.** All respondents indicated that they intended to use the equipment around their property as opposed to using it for commercial landscaping activities.
- **Why Electric?** The rebate was not the primary motivation for most participants. When asked to select the most important reasons they bought battery-powered equipment over a gas-powered alternative, 73% (113 out of 154) of survey respondents selected convenience as an important motivation for purchasing the new equipment.

  The reasons selected most frequently by survey participants were:

  - The rebate (59% of survey respondents)
  - It's quieter than the gas-powered option (58% of survey respondents)
  - Having a lower carbon footprint (56% of survey respondents)

- **Trade-In Program.** There appears to be interest in a trade-in program for gas-powered equipment, which could better incentivize complete replacement and disposal of old tools. Participants who said they still currently own gas-powered equipment (68 out of 154) were asked how likely they would be to buy a battery-powered alternative if MassSave were to offer a trade-in program. Across all equipment types, participants responded as interested in a trade-in program, with 75% of respondents indicating they were likely or very likely to participate. Providing a trade-in program could increase participation and reduce the amount of gas-powered equipment still in use.

Appendix A. Participant Survey Instrument

MA23R57 - Small Electrification Partici

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