
**DEMONSTRATION OF
THE GREENSTATION
LITHIUM BATTERY POWERED
COMMERCIAL
BACKPACK LEAF BLOWER**

FINAL REPORT

August 31, 2015

**Submitted to:
San Joaquin Valley Air Pollution Control District**



Demonstration of Lithium Battery Powered Commercial Backpack Leaf Blower

Final Report

Submitted to

**Technology Advancement Program
San Joaquin Valley Air Pollution Control District
1990 E. Gettysburg Ave. Fresno, CA 93726
Contract # C-21536-A**

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Section A **Project Background and Objectives**

Background

Gasoline powered landscape maintenance equipment has been the standard in use for keeping residential and commercial properties groomed and beautiful for the last century. However, as technology progresses, electrical equipment has become more desirable due to the environmental and ergonomic benefits afforded to both the workers and the surrounding community. As this technology has improved, the tools have evolved from being powered with extension cords to now running on different types of battery chemistry. Sealed lead acid is now giving way to improved lithium chemistries that provide longer run times with shorter recharge times and with less weight.

Specific tools that directly benefit from this improved technology include lawn mowers and hand tools such as string trimmers, hedge trimmers, chain saws and leaf blowers. The ability to create and maintain beautiful and serene landscapes in our neighborhoods and cities has been harmed by the noisy polluting machinery used to keep them neat and clean. The Greenstation already manufactures battery powered lawn mowers and recognizes that among the gas powered tools being used, the leaf blower stands out as the one most commonly used to keep properties clean regardless of any mowing or trimming activity.

Manufacturers have recognized the benefits in advancing technology and are producing tools primarily focused on the residential market. While this is an important (and obvious) step in the direction of a cleaner quieter environment, The Greenstation is now developing equipment for professionals to use in both residential and commercial applications. Working in conjunction with electrical and mechanical engineers as well as landscape maintenance professionals, The Greenstation has developed a prototype leaf blower ready for testing in commercial use. That means a blower with increased performance in airflow, velocity, run times and recharge times. It also means taking advantage of all the environmental and health benefits provided by zero emission equipment, most notably the complete elimination, at point of operation, of oxides of nitrogen (NO_x), reactive organic gasses (ROG), carbon dioxide equivalent (CO₂e) and particulate matter 2.5 (PM_{2.5}) - unburned gasoline particles so small that they can be breathed in and absorbed into the lungs with no defense capable by the human body.

Objectives

The main objective of this project is to provide a lithium battery powered, commercially rated backpack leaf blower that the property maintenance industry will embrace and put into widespread use.

Section B

Executive Summary

The U.S. Environmental Protection Agency (EPA) is in the process of promulgating tougher ambient air quality standards to provide further protection for health; thus, requiring even more emissions reductions. To attain current and future federal air quality standards, the District will be relying on significant advancements in zero and low-emission technologies for mobile and stationary sources. The District has been successful in developing the Technology Advancement Program, in part because of a funding collaboration with the EPA's Clean Air Technology Initiative.

The Greenstation and its partners are creating and implementing a backpack battery powered leaf blower that can replace two and four stroke gasoline powered leaf blowers for commercial use. Our relationships with the engineers at AeroVironment Inc., Whisper Energy System and Alare Technologies enables us to create the most advanced blower and battery technology available designated for commercial use.

The Greenstation's approach is to collaborate with Alare Technologies and Whisper Energy System to manufacture and assemble ten pre-production prototypes that will be put into use, notably, by the facilities maintenance department of the California State University at Fresno and ABEL Industries in Visalia, as well as a selection of smaller landscape maintenance companies. AeroVironment Inc. has contributed completed design plans and The Greenstation will manage the process and report to the SJVAPCD.

Emission Objective

The primary objective is to eliminate, in the San Joaquin Air Basin, all NO_x emissions, reactive organic gasses, particulate matter 2.5 and greenhouse gasses associated with gas powered leaf blower technology. The Greenstation will achieve this objective through the assembly of a commercially rated, backpack-mounted, battery powered leaf blower that the property maintenance industry will embrace and put into widespread use.

Project Participants

The Greenstation's role is to provide a pre-production, zero emission leaf blower to the TAP Demonstration that can be commercially rated and used in place of gasoline powered leaf blowers in the San Joaquin Air Basin. The Greenstation is responsible for the entire process of manufacturing and assembly of the zero emission leaf blower and lithium ion backpack power supply units. Additionally, the Greenstation implemented demonstration testing and data analysis and submitted the necessary reporting to the SJVAPCD.

AeroVironment Inc. provided the zero emission leaf blower design package and periodic consulting to The Greenstation during the manufacturing and assembly process. AeroVironment also assisted with the demonstration of the technology at the testing locations, working in conjunction with The Greenstation on training and support. They offer a unique set of capabilities in electric motors, energy storage, power electronics, thermal management and fuel cell systems, controls, and systems engineering. These capabilities enable us to increase energy

efficiency, performance, safety and cost effectiveness dramatically, helping customers to meet or exceed design and performance objectives.

Alare Technologies created the plastic injection molds for the blower housing and assisted The Greenstation in manufacturing fan motors and controllers. Final assembly of the completed leaf blower units took place at their facility in Burbank California. Alare Technologies, LLC, is a technical consulting, engineering services, research and development company created in 2012. Alare Tech consists of managing owner members with over 60 years combined experience in the Aerospace Industry. Core capabilities include Computer Aided Design, Aerodynamics, Structural Analysis, Flight Simulation, Electronic Computer Aided Design, Power Supply Simulations, Antenna Simulations, Composites Design and Fabrication, Electronics Fabrication, and Flight Test Data Collection and Analysis.

Whisper Energy System assisted The Greenstation in manufacturing and assembling lithium ion backpack battery power units. Whisper also offered product support during the demonstration phase. Since 2007, Whisper has relied upon customized backpack-mounted Lithium Iron Phosphate battery technology to power “off-the-shelf” cordless equipment (i.e., mowers, blower, string trimmers, hedgers, etc.) because of their following characteristics: 1) unsurpassed safety; 2) exceptional run-time/storage capacity; and 3) superior cycle-life. While other manufacturers offer their own lines of lithium-based batteries, they are expensive, offer limited/insufficient capacity for commercial application (well under 10Ah, which indicates limited run-time), and are rated at a much shorter cycle-life (e.g., 500 cycles) as compared to the cells we use, which are rated at well over 2000 cycles under equivalent conditions. Furthermore, our batteries are backpack-mounted, which is far more suitable for commercial application than the typical appliance-mounted battery systems currently available from manufacturers.

California State University at Fresno facilitated testing and demonstration of the blower units. The entire outdoor portion of the University property is the testing facility for this portion of the process. Michael Frick works in Plant Operations for the University manages the grounds maintenance staff involved in the testing process

ABEL Industries in Visalia is a non-profit organization that offers a variety of services to adults with disabilities. Their Supported Employment program provides employment and training services for motivated people with disabilities. David Horsman is the Community Employment Manager oversees testing in their property maintenance routes that include multiple city parks in the city of Visalia. They specialize in servicing various property sizes from medium to large commercial accounts. ABLE Industries is committed to their reputation for service, quality, and outstanding value.

Century Landscape in Bakersfield participated in the San Joaquin TAP program in 2012 and tested Greenstation Lawn NC Lithium powered mowers with great success. Wayne Cox was anxious to see the new prototypes and to use them in the course of his crew’s daily operations.

Green and Clean Landscaping in Kingsburg participated in the SJVAPCD commercial technology demonstration by purchasing two of The Greenstation Lawn N-C Lithium powered commercial mowers. Michael Lopez and his crew maintain residential and commercial

properties. He has a California contractor's license and is a member of the CLCA – California Landscape Contractor's Association.

Clean Air Lawn Care in Madera also specializes in residential property maintenance. Doug Ambrose is working exclusively with zero-emission equipment and competing successfully with the multitude of gas-powered “mow & blow” services.

King's Canyon Unified School District located in Reedley California facilitated testing and demonstration of the blower units at two of their elementary schools. Director of Maintenance and Operations Joseph Gonzales and Maintenance Supervisor Jesus Mendoza managed the grounds maintenance staff involved in the testing process

All testing facilities retained ownership of the prototype units once the testing phase was concluded.

Conclusions

Throughout the manufacturing and testing phases, the performance of these leaf blower units competes with gas powered equipment in any typical application associated with property maintenance. These prototypes are not the final industrial design required for large scale manufacturing, however, the adjustments required are already being implemented for another set of units being built for further testing.

The most important factors being considered successful are the complete elimination of toxic emissions at the source, the elimination of gasoline and oil consumption during usage, the elimination of solvents and other chemicals associated with the maintenance of a small gas engine, as well as the containers, plastic bottles, metal cans, filters, spark plugs etc. that go to the landfills. All of these factors are further addressed later in this report. Noise reduction has shown to be an important factor in almost all applications and the test of whether or not working crews in real situations can complete the job previously accomplished by gas powered equipment has shown promising results for the future.

Regarding the usability of the units, other factors considered successful include the velocity and airflow delivered. These battery powered units have the power required to complete the tasks associated with wet or dry conditions including leaves and debris matted into a gutter or planter bed or scattered in an open lawn or parking lot. All of the environmental factors mentioned are not only important for the surrounding area but for the operators as well. They are no longer subjected to exhaust emissions, toxic chemicals and elevated noise levels that make the work conditions more hazardous than necessary.

Recommendations

There are improvements on the design being implemented in preparation for manufacturing. One is a longer tube that allows the operator to get closer to the ground for even more power to loosen matted material. Shoulder strap applications are being tested to relieve muscle strain in the operator's hand and arm during extended use periods. Improved trigger assemblies will provide less resistance helping the operator adjust the power more accurately and with less fatigue. The final design for manufacturing will also include the change from creating the plastic

housings using a process known as Urethane Casting to using Plastic Injection Molding. This will include the use of more durable materials commonly used in other lines of maintenance equipment. Lastly, there will be the introduction of a software application that will collect and report usage data that can be submitted for future tax credits for zero emission usage benchmarks. This will be helpful for professionals who are already saving money on gas and oil and on maintenance costs. Immediate operational cost savings are addresses later in this report.

In addition to outdoor property maintenance applications, these battery powered leaf blowers are also being used indoors. During a tour of the testing partner's facilities, it was learned that employees of the King's Canyon Unified School District were using the low noise, zero emission units inside the cafeteria and gym to clear debris from under lunch tables and bleachers. For this purpose of moving trash, rather than particulate matter, the application is successful if done on a regular basis followed by a mopping session. This process can be applied to any large room including, for example, factories, auditoriums, sports arenas and movie theaters.

These zero emission commercial leaf blowers are designed to replace the existing gas powered units in both mobile maintenance companies and in fixed property locations. Mobile maintenance includes major nationwide companies such as ValleyCrest Landscape Companies and LandCare USA that service large scale commercial properties, all the way down to the smallest one or two person "Mow and Blow" residential maintenance companies servicing our neighborhoods on a daily basis. Many commercial properties have their own maintenance staff that can also utilize zero emission equipment and this technology can – and should – be used on all school district properties as well as municipal and other governmental properties.

Section C

Detailed Description of the Scope of Work

AeroVironment Inc. provided the personnel, resources and facilities to produce a document for The Greenstation detailing realistic specifications and requirements for alternative energy solutions for leaf blowers. Proof-of-concept demonstration devices were constructed by The Greenstation and Alare Technologies. These units were tested to aid in the establishment of the specifications to be provided by this document and to be a benchmark of what is practicable with the integration of readily available and near-term technologies.

The Greenstation, in collaboration with Whisper Energy System, assembled pre-production examples of the backpack mounted battery power supply. These lithium ion power packs enable the zero emission blower to compete with gas powered commercial blowers in performance and endurance.

- Source battery enclosure
- Source charging system
- Source cable assemblies and connectors
- Assembly of backpack configuration
- Assembly of final product

December 1, 2013 – August 31, 2015 / Project Management / The Greenstation

Complete oversight of the entire project including manufacturing, testing and reporting phases. Responsible for deliverables and billing at pre-determined milestones

December 1, 2013 – July 15, 2014 / Project Management / Alare Technologies

Alare performed technical and administrative management tasks required to successfully execute the manufacturing portion of the project including management of resources, vendors, subcontractors, schedule procurement and budget. Alare generated battery pack performance specifications for Whisper Energy System. They also coordinated battery pack and charger manufacturing with Whisper to ensure design compliance. They coordinate vendor selection and parts procurement for final demo unit assembly and ensure the quality check of all sub-system components and the final product.

January 1, 2014 – January 31, 2014 / Electric Ducted Fan Evaluation / Alare Technologies

Alare conducted a market survey to identify and procure COTS EDF and Motor combinations as potential drop-in replacements of the AeroVironment- designed fan units. They build test fixtures to simulate blower housing and physically evaluated each EDF's performance for comparison with the existing design. They down selected successful candidates and updated the blower body design as necessary to accommodate the new fan assembly. Alare fabricated an SLA prototype unit to physically validate form, fit, and function.

January 1, 2014 – January 31, 2014 / Finalize Battery Specifications / Alare – Whisper

Based on the final determination of the motor selection, the battery specifications were matched and confirmed.

February 1, 2014 – February 28, 2014 / Packaging Fabrication / Alare Technologies

Alare worked with The Greenstation to fabricate ten (10) transport cases for the leaf blower assemblies that showcased their "green" features. Plastic molding of the blower housing was performed by Scicon and supervised by Alare and The Greenstation.

February 1, 2014 – February 28, 2014 / Source Battery Cells, Enclosures, Cable Assemblies, Interface Connections, Charging Units, Back Pack-Harness / Whisper Energy System

Once the final battery specifications were confirmed Whisper Energy System proceeded to acquire all the raw materials needed to manufacture the backpack battery power pack. The Greenstation worked with Whisper to ensure compatibility with the motor assembly.

March 1, 2014 – June 30, 2014 / Demo Units Assembly / Alare Technologies

Alare worked with The Greenstation to assemble and deliver ten (10) fully functional leaf blowers with no battery packs.

March 1, 2014 – June 30, 2014 / Backpack Battery Assembly / Whisper Energy System

Whisper worked with The Greenstation to assemble and deliver (10) compatible battery backpack power supply units.

July 1, 2014 – June 30, 2015 / Testing Demo Units / The Greenstation

The Greenstation integrated blower units into the daily use of current institutional grounds maintenance schedules and demonstrated the technology to be capable of replacing gasoline powered leaf blowers in commercial applications. Testing facilities logged hours used and evaluated endurance, durability, run time and overall usability in the commercial market.

Emissions testing were unnecessary due to the fact that this is a zero emission unit and simply required data comparison to the baseline emission inventory for gas powered 2-stroke and 4-stroke leaf blowers to calculate the reductions.

July 1, 2015 – August 31, 2015 / Create Final Draft and Final Report / The Greenstation

The final report addresses emission reductions per unit and presents an estimate of the overall reductions made possible by replacing the population of gas blowers with electric blowers. Emission reduction is calculated by comparing the zero emission output to the most current findings of the OFFROAD Model. Observations of usability in the field are detailed and evaluated against the marketability of the design for widespread use.

Chart Illustrating the task list and approximate time frame for completion.

TASK	DESCRIPTION	MONTH 1				MONTH 2				MONTH 3				MONTH 4				Month 5-16				Month 17			
1	Project Management	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
2	Electric Ducted Fan Evaluation	X	X	X	X	X	X																		
3	Motor Selection and Validation					X	X	X	X																
4	Packaging Fabrication							X	X	X	X														
5	Demo Unit Fabrication									X	X	X	X	X	X	X	X								
1	Finalize Battery Specifications	X	X	X	X	X	X	X	X																
2	Source Battery Cells									X	X	X	X	X	X										
3	Source Battery Enclosures									X	X	X	X	X	X										
4	Source Cable Assemblies / Connectors									X	X	X	X	X	X										
5	Source Charging Systems									X	X	X	X	X	X										
6	Source Backpack / Harness System											X	X	X	X										
7	Assembly of Final Product													X	X	X	X								
1	Delivery to Testing Facilities																	X	X						
2	Training																	X	X						
3	Testing Phase																	X	X	X	X				
1	Compile Data and Create Final Report																	X	X	X	X	X	X	X	X

Section D

Findings or Results of Each Task

Task 1—Project Management

- 1.1 General Project Management – Successfully managed project resources, vendors, subcontractors, schedule, parts procurement and budget.
- 1.2 Established binding agreements with project partners, that include equivalent requirements for indemnification and insurance as stated in or required by agreement C-21536-A. Unfortunately, the agreements with the testing partners were not as binding as we had hoped, however we were able to obtain valuable data from the rotating entities. The Greenstation pursued outstanding agreements with the five testing facilities and confirmed Able Industries in Visalia, Century Landscaping in Bakersfield and Healthy Air Lawn Care in Madera.
- 1.3 Coordinate Battery Pack Development – Alare Technology generated battery pack performance specifications and interface control document (ICD). Coordinated battery pack and charger development efforts with Whisper Energy Systems to ensure design compliance.
- 1.4 Coordinate Vendor Selection – successfully worked with Alare Technologies to coordinate vendor selection and parts procurement for final demo unit assembly. Ensured quality check of all sub-system components and final product.
DELIVERABLES: Quarterly reports, battery pack ICD, final project summary and presentation.

Task 2—Fan Evaluation

- 2.1 Candidate Fan Selection & Procurement – Alare Technologies successfully identified and procured a commercially available electric ducted fan (EDF) and motor combination adhering to specifications of the AeroVironment-designed fan units.
- 2.2 Finalized Battery Specifications – Alare Technologies coordinated battery specs with motor selection.
- 2.3 Performance Evaluation Testing - Test fixtures were built to simulate blower housing and physically evaluate each EDF's performance for comparison with the previous design. Selected successful candidates for manufacturing. Discussions were held regarding a software addition to the blower that facilitates data collection via USB port to a computer application that calculates usage per blower and possibly per battery unit. This feature was not initially included in the original proposal, however, the production partners feel that it could be a very useful tool that can be included in final production models available to the public.
- 2.4 Blower Housing Update – Alare Technologies fabricated a 3D printed prototype unit to physically validate form, fit, and function. Alare ensured the quality check of all sub-system components and final product. Test fixtures were built to simulate blower housing and physically evaluate each EDF's performance for comparison with the existing design. Updates to the blower body design were conducted as necessary to accommodate the new fan assembly and fabrication of Stereolithography (SLA) prototype units were completed to physically validate form, fit, and function. (Figure 1.)



Figure 1

(NOTE: Stereolithography (SLA) is an additive manufacturing or 3D printing technology used for producing models, prototypes, patterns, and production parts up one layer at a time by curing a photo-reactive resin with a UV laser or another similar power source. Useful for creating one prototype test unit at a time.)

DELIVERABLES: EDF / Motor Evaluation Summary Presentation

Task 3 was only necessary if Task 2 did not satisfy our requirements. The Deliverables are the same and the completion of Task 3 was not required.

Task 3—Motor Selection & Performance Validation

- 3.1 Candidate Motor Selection & Procurement - Identify and procure motor based on existing motor performance specifications.
- 3.2 Rotor Design Updates - Modify the rotor hub design to have standardized motor mounts to accommodate candidate motors.
- 3.3 Production of Master Rotor - Machine new rotor blades and fabricate new rotor assemblies for motor testing.
- 3.4 Performance Validation Testing - Conduct testing to ensure comparable performance to the baseline.

DELIVERABLES: EDF / Motor Evaluation Summary Presentation

Task 4—Packaging Fabrication

- 4.1 Blower Housing Plastic Fabrication – The Greenstation worked with Alare to fabricate the plastic housing assembly. The Greenstation procured all necessary parts and electronics needed for the final assembly of the leaf blower units. It was decided that the plastic molding of the blower housing will be performed by Scicon Technologies and supervised by Alare and The Greenstation. Additional SLA prototypes were created and tested and production plans were finalized for Scicon to proceed with initial Urethane Casting for the plastic housing pieces. (Figure 2.)



Figure 2

4.2 Transport Packaging Fabrication – The Greenstation worked with Alare to design and fabricate ten transport cases for the leaf blower assemblies that showcase their “green” features. The Greenstation and Alare successfully tested sample transport cases for the leaf blower assemblies. These will help protect the blowers during daily routines of transport and storage. (Figure 3.)



Figure 3

4.3 Based on the final determination of the motor selection, the battery specifications were matched and confirmed. Whisper Energy Systems procured the lithium cells, battery enclosures, cable assemblies and connectors, and sourced the charging system to be used. Through meetings of the production partners, it was decided to utilize the lithium iron phosphate (LiFePo_4) chemistry for the battery cells. This chemistry is undeniably the safest available and is the obvious choice to apply to a backpack unit design. In this application, total run time is sacrificed somewhat for the exceptional level of safety and so it was decided that one additional back up pack and charger would be delivered to

each testing facility. Each facility will receive X number of leaf blowers and X number of batteries and chargers - plus one each. (Figure 4)

DELIVERABLES: Ten leaf blower housing assemblies and transport cases. Lithium cells acquired for backpack units.

Task 5—Lithium Backpack Battery Assembly

- 5.1 Acquire Battery Enclosures.
- 5.2 Acquire Cable Assemblies and connectors.
- 5.3 Acquire Backpack / Harness Enclosure System.
- 5.4 Deliver five extra battery packs at cost.



Figure 4

DELIVERABLES: Material purchase of fifteen lithium backpack power supply units.

Task 6—Leaf Blower Demo Units Assembly

- 6.1 Demo Unit Assembly - Assemble ten fully functional leaf blowers.
- 6.2 Performance Validation - Validate all blower functionality and performance prior to delivery.

Whisper provided a backpack battery unit that Alare was able to connect to a blower and begin testing performance against design specifications. During this time significant testing was done to measure, amperage, operational temperatures, run times, and charging times, as well as comfort, ergonomics and durability. These tests included deliberate overheating and over use in difficult conditions to determine automatic shutoff levels of the internal fuses and to determine if the fuses would protect the battery and blower units from electronic damage.

Specification documentation provided by Whisper Energy Systems:

BATTERY PACK FOR LEAF BLOWER

This 36V battery system is designed to operate cordless gardening appliances – mowers, blowers, string trimmers, etc. – that operate at 36VDC and draw up to 30A continuous current.

Specifications:

1. Lithium iron phosphate technology, 12 cells in series, 9Ah.
2. Nominal voltage 39.6, minimum voltage 33V, maximum voltage (charging) 43.2V.
3. Battery management system balances the cells and protects them from under voltage and over temperature. Protected from short circuit with internal fuses.
4. Two-wire power lead provides connection to Leaf Blower or connection to charger.
5. Charging time is under 90 minutes to bring a completely depleted battery pack to 100% capacity.
6. Pack current expected with Leaf Blower is 15A.
7. Operational temperature from 0⁰F to 120⁰F.
8. Greater than 2000 cycles expected in 100⁰F environment or below.
9. Run time will vary based on daily usage. In commercial settings, on a typical eight-hour workday during the summer months in Los Angeles, California, a two-person gardening crew would require no more than two of these battery back packs to power all of their gardening appliances (i.e.: blowers; string trimmers; and hedge clippers) except for the lawn mowers.

All battery backpack units were delivered by May 5 and in the interest of safety, units were thoroughly retested by The Greenstation and Alare to verify results provided by Whisper and in greater detail.

SAMPLE RESULTS OF GS/ALARE TESTING SESSION:

Ambient Temp: 94.1 F

Battery Start Temp: 119 F

Battery Start Volt: 40 V

Peak Discharge: 764W

Avg. Discharge: 640W

Total Run Time: 32.15 min

Battery End Temp: 124.7 F at the end of motor run 126.1 F peak reached 5.5 minutes after motor shut off

Max Temp Gain: 7.1 F

Battery End Volt: 34.0 V (cut off by blower power control board)

Discharged Capacity: 9.3 Ah

TESTING NOTES PROVIDE BY ALARE ENGINEER GUAN SU:

It took a couple of hours under the sun for the battery core to reach the test temperature. I am putting back out to see if I can get it to reach 140 F before the sun goes down. Snapshot of the test data plot & setup attached.

To achieve an operating temperature of 140 F, the battery unit was wrapped in black plastic and covered with a clear plastic enclosure, simulating a “Solar Oven”. Figures 5 and 6.



Figure 5



Figure 6

Ultimately, the testing temperature of the battery cells rose to 164 F. Previous day’s test showed the temperature continued to climb after the blower was shut off and is evident that the temperature takes a while to equalize. Whisper reports the thermal shutoff at 126 F, however, Alare was not able to verify that number on the sample units they tested. The Whisper manual states not to operate it above 140F and The Greenstation and Alare have determined that it would take a very severe set of circumstances to reach and operate these units in temperature ranges over 140F. Overall, safety levels for the battery operations have been verified at acceptable high temperatures.

The Greenstation assisted Alare in the final assembly of the blower units and initial delivery estimates indicated that The Greenstation would have all pieces of the leaf blower package completed and ready to deliver by the first week in May. The custom chargers that Whisper was assembling took an additional 3 weeks to complete. In addition to charging the batteries, these chargers read the levels of each cell in the pack and balance the voltage equally across the entire unit. This feature allows for more consistent runtimes and extended cycle life for the unit as a whole.

The chargers were completed by the end of May and final testing and quality control was also completed. Once this was completed, The Greenstation team wrote the user manual for the safe operation of the blower, battery packs and charging procedure. Performance was measured against advertised levels of Stihl and Pellenc units as well as the original AeroVironment prototype (DWP). Figure 7.

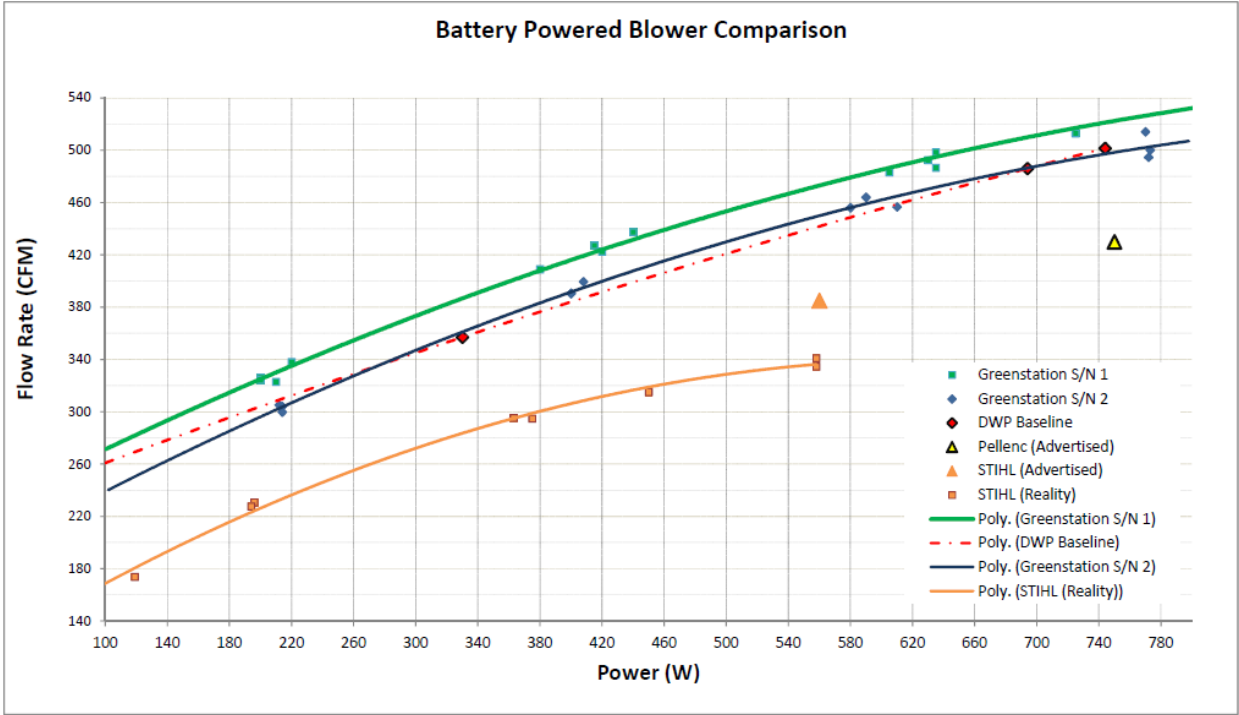


Figure 7

DELIVERABLES: Ten complete leaf blower assemblies. (Figure 8)



Figure 8

Task 7—Leaf Blower Demo Delivery and Testing

7.1 Delivery and Training to Testing Facilities – The Greenstation delivered ten complete leaf blower assemblies and five extra battery packs to testing facilities and trained and educated workers to use the units with efficiently.

Once the charger assembly was complete The Greenstation began delivery and training to the testing partners in the first week of June. Having confirmed the testing partners for participation, representatives from The Greenstation and Alare delivered and trained supervisors and staff on the proper operation, maintenance and storage of the leaf blowers and battery packs.

Testing Facilities

- Cal State Fresno (3 units)
- Able Industries (3 Units)
- Century Landscaping (2 Units)
- Green and Clean Landscaping (1 Unit)
- Clean Air Lawn Care (1 Unit)

Testing partners were issued log sheets to track hours used for each blower and battery unit along with the ability to track charging sessions. A second form was also provided to give participants the ability to comment on usability, comfort and ergonomics.

7.2 Collect usage data and observational information – The testing facilities calculated hours of usage and feedback regarding human factors such as ergonomics, durability, endurance and overall effectiveness and ease of use for a period of 12 months.

DELIVERABLES: Raw data.

Blowers were delivered to the testing partners and usage began in the second week in June 2014. The following chart represents the usage in minutes per unit per testing facility.

	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Cal State University Fresno	1	0	0	0	30	230	100	285	520	60	30	150	115
	2	250	310	195	285	90	145	455	45	90	150	180	365
	3	480	390	255	150	50	205	175	105	320	345	290	105
ABLE Industries	4	960	1260	70	70	110	65	75	70	175	160	198	100
	5	885	930	60	65	65	60	65	60	190	115	165	50
	6	765	1005	70	120	110	70	75	65	60	125	142	155
Century Landscape Inc.	7	Unit 7 retrieved and issued to ABLE Industries with no feedback until issued to Kings Canyon USD											
	8	Unit 8 retrieved and issued to Healthy Air Lawn Care with no feedback until issued to Kings Canyon USD											
Green and Clean Landscaping	9	720	840	24	12	Unit 9 damaged and unusable							
Healthy Air Lawn Care	10	1090	735	470	810	920	690	469	345	233	220	358	338
Kings Canyon USD	7							1140	554	500	565	1080	0
	8							660	305	400	580	1080	0

Task 7 reporting summaries follow

Reporting Time Period

June 2014

Within the first 2 weeks of testing, The Greenstation received an email from a manager at Century Landscaping. The management informed us that, although they signed an agreement to participate in the demonstration and went to the effort to obtain the necessary insurance documents, they would be unable to continue with the project. The Greenstation picked up the equipment and began searching for a new testing partner to participate in the demonstration.

The remaining partners used the blower units in their regular maintenance schedules and their results vary. Usage ranged from 20-90 minutes at a time and is mostly positive. There was an issue regarding static electricity buildup in some circumstances. Not all testers encountered this problem but in very dry conditions static electricity builds up in the unit and discharges through the USB port or the indicator light. Further investigation shows that this is not uncommon among units produced by other manufacturers.

CSUF testers are encountering fatigue when using the blower at full power. These units are very strong and all the participants have been trained to understand that full power is not necessary except in rare circumstances. The Greenstation leaf blower has superior air flow and velocity at half to three quarter speed and can easily clean hardscapes, and most planter beds and lawns without maximizing its capabilities. These “full speed” practices also reduce run time and training will need to be reinforced with the various operators to improve these results. This crew is very seasoned and set in their ways. The supervisor is excited to see these blowers succeed, however, misuse is still somewhat common.

Able Industries testers are improvising a belt hook that allows the operator to have both hands free without having to set the blower on the ground. We encourage users to slightly modify the usability to suit their needs.

Initial indications are that the battery pack is comfortable to wear and the blower unit is very light and easy to use. As a prototype, the plastic materials used in short run Urethane Casting may not be as durable as Injection Molding and there is some feedback indicating a desire for more durability. As long as the units are not being abused during operation, we feel that the current construction is sufficient for this demonstration.

Work planned for July will be to confirm either an additional testing partner to replace Century Landscaping or to reinstate the 2 additional blower packages with existing testing partners. We believe there are several possible participants that would be willing to assist with the program and we are encouraged by the progress with UC Merced.

Alare engineers and The Greenstation are working to recreate the static electricity buildup and discharge that some of the testing partners are experiencing. The solution to this issue is still being developed and we anticipate that we will be able to provide the necessary adjustments to the units in a timely manner.

Continuous training and product support for the testing partners is a high priority as we continue to work with them and communicate on a weekly basis.

Reporting time period

July 1, 2014 – September 30, 2014

This reporting period is the first of a complete testing phase. Manufacturing has been completed, as has the delivery of the units and training of the testing operators.

Testing partners were issued log sheets to track hours used for each blower and battery unit along with the ability to track charging sessions. A second form was also provided to give participants the ability to comment on usability, comfort and ergonomics.

As previously reported, within the first 2 weeks of testing Century Landscaping had opted out of testing program, requiring us to search for a replacement partner. After lengthy communications with UC Merced and an afternoon demonstration at the end of July, their grounds maintenance supervisor ultimately decided not to participate in the program. At that point we re-assigned the 2 extra units to Healthy Air Lawn Care and ABLE Industries, while we worked with another possible testing partner, Kings County Unified School District, whom we ultimately secured but not until October so their testing results will not be included in this report.

Testing Facilities

- Cal State Fresno (3 units)
- Able Industries (4 Units)
- Green and Clean Landscaping (1 Unit)
- Clean Air Lawn Care (2 Units)

The static electricity buildup is still an issue and on August 15 we retrieved all the units and brought them back to our shop in Los Angeles for study and repair. This gave us a good opportunity to observe the physical results of usage on the units.

As previously reported, regarding the plastic parts, we anticipated the fact that the process we used for rapid prototyping (urethane casting) is an interim step between 3D printing – which we would use for one or two units – and the type of injection molding used in full scale manufacturing – does not always yield the most structurally accurate product compared to the engineering drawings submitted to the company. Acceptable tolerances in thickness and size are not always achieved and we do not really know if the parts will fit together until we receive the order. Furthermore, our tolerances are more exact than those of the plastics supplier so we have to have extra pieces to see which yield the best fit and finish. Additionally, the materials used in this process are not of the same density and strength we would have in a manufacturing environment so we are conscious of the possibility that parts may break or warp during the testing usage.

During the testing phase, in the most challenging part of the year regarding high heat conditions, we found that the plastic molding had been damaged in some instances. Although, the operators were provided thorough training and protective cases to use in transport, some of the plastic

housings were somewhat abused and required repair. Since then, the extreme summer temperatures have passed and we expect to complete the remainder of the testing phase with much reduced instances of high heat damage. Additionally, there was a bug in the circuit board that caused a one second delay in the trigger response. That has been addressed as well.

General repair notes are as follows:

Alare Engineering Notes 8-19

We made pretty good progress with the blowers. Nearly all the power control boards have been updated. Russ will conformal coat all the boards tomorrow to better protect them from the environment. All of the fan assemblies were refurbished and checked out.

There are 3 nozzles that were broken from blowers 3, 5, and 9. Number 9 is in pretty bad shape and may not be repairable, but 3 and 5 should be OK. To reduce future breakage, we will re-enforce all the remaining tubes with fiberglass. A few blower housing are deformed, perhaps due to exposure to high temperatures exceeding 125°F. We are going to try to heat them up and form them back into shape.

Individual testing summaries are below.

CSUF testers are still encountering hand fatigue when using the blower at full power and they insist that they require full power to complete their work. They do indicate that the units easily perform 85% of their work. The supervisor suggests a tube extension that would bring the opening closer to the ground for “baked on” debris on the hardscapes. We agree that an extension attachment would be a useful addition in the future. We maintain that these units are very strong and exceed the performance of every other electric leaf blower and many of the gasoline powered leaf blowers. These “full speed” practices reduce run time and training will need to be reinforced with the various operators to improve these results. This crew is very seasoned and set in their ways. The supervisor is excited to see these blowers succeed, however, misuse is still somewhat common.

Able Industries testers agree that an extension piece for the tube would be helpful. They are happy with the weight, noise levels, power levels and the static shock issue has been resolved. They are getting less runtime on the battery units than we predict but that indicates the common thread of full power usage.

Green & Clean Landscaping testers are the most destructive to the equipment. They admit that they do not take much care when using or transporting the units and it shows. The static shock issue seems to be intermittent with them depending on the conditions but they are happy with overall usability and ergonomics. We are working with them to take better care of their tools but high heat and rough treatment during use and transportation may ultimately cause their unit to fail.

Healthy Air Lawn Care on the other hand, is very careful not to abuse the unit and it shows. There was never issue with static shock and for his purposes, full power is only occasionally required – extending the battery life.

The battery pack continues to be comfortable to wear and the blower unit is very light and easy to use. It bears repeating, as a prototype, the plastic materials used in short run Urethane Casting are not be as durable as Injection Molding and there is some feedback indicating a desire for more durability. As long as the units are not being abused during operation, we feel that the current construction is sufficient for this demonstration.

The mid-August “tune up” was helpful in observing the results of varying levels of use and abuse of the units. We are confident that once we get through the complete testing phase we will have all the information we need to move forward with production and distribution to the commercial property maintenance market.

Reporting time period

October 1, 2014 – December 31, 2014

This reporting period is the second of a complete testing phase. Manufacturing has been completed, as has the delivery of the units and training of the testing operators.

The last quarter of 2014 provided cooler temperatures and increased opportunity to test performance with the fall leaves dropping. Overall, increased blower output to move large amounts of debris resulted in reduced battery pack runtimes and more observable hand and arm fatigue. However, favorable results include the fact that the blowers were able to handle the extra debris whether it was wet or dry. During this period, there was also another change in the list of testing partners. As we secured Kings Canyon Unified School District, we lost Green & Clean Landscaping. They concluded that their style of operation did not allow for prototype usage and that the level of damage to the equipment due to rough handling ultimately rendered it unusable. KCUSD provided the necessary paperwork by the middle of October resulting in their first feedback forms being completed for November and December. The two units repossessed from Century Landscaping were issued temporarily to ABLE Industries and Healthy Air Lawn Care but did not receive any more than minimal usage that was not effectively recorded. We are happy that they are back in use with a dedicated testing partner.

Testing Facilities

- Cal State Fresno (3 units)
- Able Industries (4 Units)
- Healthy Air Lawn Care (1 Units)
- Kings County Unified School District (2 Units)

Usage still ranges up to 90 minutes in some instances with the average usage time being about an hour. Alare Technologies has addressed the static shock concern reported last quarter and there has been no current feedback relating to that issue. Additionally, the extreme ambient temperatures experienced during the summer that caused some misshaping of the plastic housing parts have passed and there are no more reports of durability issues. Focus has now shifted to battery performance and ergonomic issues.

There have been three instances of battery failure in this reporting period. Two of the packs were in the possession of ABLE Industries and one came back from Green & Clean

Landscaping. Possible sources of these failures include a combination of user neglect and an engineering flaw from the battery subcontractor, Whisper Energy Systems. Either possibility, if isolated, would probably not have caused a failure, however, together they raise another opportunity to improve the design. Additionally, we are now focusing on human factors both positive and negative, i.e. lower noise levels and zero emissions that benefit the user and the surrounding community as well as observed muscle fatigue.

CSUF 4th Quarter 2014

The crew is submitting quality feedback regarding usability of the blower units. Their insistence on using the unit at full power— almost all the time—creates opportunity for improvements that will assist the user in the future.

They report that the unit and the battery pack are both lightweight and easy to carry. An observable problem stems from such a lightweight unit creating exceptional thrust at maximum power. In addition to the air coming out of the nozzle, thrust also pushes the lightweight unit back in the opposite direction forcing the user's arm to constantly use muscle strength to maintain a constant position. We are designing options for a belt hook or shoulder strap that can utilize the operator's torso to easily keep the blower from forcing in a reverse direction, thereby reducing tension in the arm muscles. Secondly, the variable trigger feature we designed can be improved to have less spring tension and a slightly longer travel length. Stiffer spring tension causes the hand muscles to fatigue more than if the trigger is engaged to the maximum position and a slightly longer "throw" will allow the user more flexibility to comfortably find the level of power needed to do the job satisfactorily without having to clench the fist. Having that flexibility will also extend the battery life and run times.

ABLE Industries 4th Quarter 2014

Overall, the units succeed at the requirements of the job. Previously, they were able to utilize a belt hook that can hold the unit at the waist without putting undue stress on the arm muscles. They suggest a step further that includes a hand strap (rather than a shoulder strap) that helps secure the unit in the grip of the hand.

Regarding battery performance, the ABLE testers have lost the ability to use two of the packs, which we have repossessed and inspected. Their feedback is that they simply no longer charge with any of the charging units issued to them. Upon inspection we have determined that the lithium cells have been depleted below a set point determined by the manufacturer and that the Battery Management System installed in each of the cells prevents them from being recharged from that very low level for safety reasons. To our battery subcontractor's credit, (Whisper Energy System) they used a very reputable manufacturer for these cells (A123) and we are confident that this is not a factory defect. Typically, this issue occurs when the battery is depleted to a very low level and then stored for some length of time without being put back on a charger. Unfortunately, the cost of replacing these cells is prohibitive and battery packs number B-5 and B-7 are now out of use.

Healthy Air Lawn Care 4th Quarter 2014

HALC testers address the increased leaf drop experienced at this time of year. Their unit handles this seasonal event and moves both wet and dry leaves successfully. Healthy Air Lawn Care is well versed in the care, maintenance and operation of the prototype unit and they know that full power is not required most of the time. However, it was required more often during this period and, as is typical, it resulted in shorter run times on the battery and some hand and arm muscle fatigue during usage. Additionally, they report the same hand fatigue from the trigger mechanism. Overall performance is positive.

Kings Canyon Unified School District 4th Quarter 2014

This will be the first testing period for KCUSD and of all the testing partners, they are using the units the most frequently. Their equipment was issued during the month of October and so their feedback forms reflect November and December. They have some of the same observations that other testing partners experience. Negative responses include hand fatigue caused by the trigger and a desire for longer runtimes on the battery. The positive comments include more than adequate power for the daily work activities and reduced noise levels that allow operators to work while students are in class. This is a substantial observation that no other testers have an opportunity to experience. Even at CSUF there is substantial traffic and ambient noise around the classrooms and much of the maintenance schedule in those areas is still completed in early morning hours. However, KCUSD is exploring their flexibility and is successfully using the blower units directly outside classrooms during school hours with no apparent interference with the teachers or students.

Reporting time period

January 1, 2015 – March 31, 2015

The first quarter of 2015 has shown a mix of wet and dry conditions. Overall, increased blower output to move large amounts of debris resulted in reduced battery pack runtimes and continued observable hand and arm fatigue. Except at Cal State Fresno, the blowers were able to handle the extra debris whether it was wet or dry. Our newest testing partner, KCUSD has a thorough weekly schedule of the blowers and are getting the most time used in relation to the other facilities. All other testers have been reiterating previous feedback and we do not anticipate any significant changes in blower, battery or worker performance through the end of the testing phase of this program.

Testing Facilities

- Cal State Fresno (3 units)
- Able Industries (4 Units)
- Healthy Air Lawn Care (1 Units)
- Kings County Unified School District (2 Units)

Usage still ranges up to 90 minutes in some instances with the average usage time being about an hour. Focus has now shifted to battery performance and ergonomic issues.

CSUF 1st Quarter 2015

The CSUF crew reports consistency in the ergonomic feedback. Fatigue and soreness in the upper forearm suggests a need for a brace or belt hook to relieve back pressure on the arm. Additional comments indicate a desire for more power that could possibly be provided by a longer tube or a choke nozzle to increase velocity.

ABLE Industries 1st Quarter 2015

The feedback this quarter reflects the crew's desire for a tube extension (similar to the feedback from CSUF), in addition to their previous comments on the addition of a hand strap and longer battery life. No other new issues are cited.

Healthy Air Lawn Care 1stQuarter 2015

HALC wrote "nothing new" in 3 months of feedback logs.

Kings Canyon Unified School District 1st Quarter 2015

KCUSD reports that they like the reduced noise levels, and that the unit is light and powerful enough to do the required tasks. They feel that the fatigue in the hand is due to the trigger mechanism, which has previously addressed and a desire for longer battery life.

The first quarter is producing some lighter workloads, however, we are continuing to work with the testing partners and help reinforce usage techniques that can extend runtimes and reduce muscle fatigue. Additionally, we continue to emphasize the importance of charging depleted battery units at the end of every work day to eliminate the potential of permanent damage. As we move into the final quarter of the testing phase we expect to see typical spring/summer conditions with reduced moisture levels and warmer temperatures. We do not anticipate any new developments in worker techniques or in perceived unit successes and failures. We are now focusing on the savings of gas and oil consumption and calculation the amount of emissions being eliminated by regular use of The Greenstation leaf blower.

Adjusted reporting time period

April 1, 2015 – June 30, 2015

The second quarter of 2015 is the final reporting period for this phase of the program. The first log reports started in June of 2014 so for the three remaining original testing partners, the final log was May of 2015.

Testing Facilities

- Cal State Fresno (3 units)
- Able Industries (4 Units)
- Healthy Air Lawn Care (1 Units)
- Kings Canyon Unified School District (2 Units)

Kings Canyon began with us in October of 2014 so we requested that they submit a log for June 2015. ABLE Industries submitted a June log as well, but were not required to do so.

As has been consistently reported, increased blower output to move large amounts of debris resulted in reduced battery pack runtimes and continued observable hand and arm fatigue. All other testers have been reiterating previous feedback and we do not anticipate any significant changes in blower, battery or worker performance through the end of the testing phase of this program.

Usage still ranges up to 90 minutes in some instances with the average usage time being about an hour. Focus has now shifted to battery performance and ergonomic issues.

There seems to be some level of “Log Fatigue” in these final feedback documents. They seem to have covered all the attributes and detriments during the course of this testing phase and there is really no new information from them.

CSUF 2nd Quarter 2015

The CSUF crew reports consistency in the ergonomic feedback. Fatigue and soreness in the upper forearm occurs after approximately 45 minutes although they seem to be very happy with the weight and feel of the backpack battery power supply. Additional comments indicate a desire for more power that could possibly be provided by a longer tube or a choke nozzle to increase air flow direction control. They report strong airflow this quarter and a return to issue of static shock buildup in the hand grip.

ABLE Industries 2nd Quarter 2015

The feedback this quarter reflects the crew’s desire for a tube extension, the addition of a hand strap and longer battery life. No other new issues are cited. There does not seem to be any ergonomic issues with their usage and they are happy that it is “smokeless”.

Healthy Air Lawn Care 2nd Quarter 2015

HALC wrote “nothing new” in 2 months of feedback logs.

Kings Canyon Unified School District 2nd Quarter 2015

KCUSD reports they feel that the fatigue in the hand is due to the trigger mechanism, which was previously addressed and a desire for longer battery life. Additionally, they report that they did not use the blowers during the month of May, due to “graduations.” The specific tasks that these units are being used for and the personnel had been reassigned temporarily.

Task 8—Final Report

8.1 Deliver final report to San Joaquin Valley Air Pollution Control District.

Section E
Summary of Emissions Testing and Analysis

Emissions Testing

This cordless electric backpack battery powered leaf blower completely eliminates all oxides of nitrogen, reactive organic gasses and particulate matter (PM 2.5) if used in place of a gasoline powered leaf blower. Emissions testing was unnecessary, as there are zero emissions.

Air Quality Benefit Analysis

Emission reduction calculations focused on oxides of nitrogen (NOx), and particulate matter (PM2.5).

Our calculations are based on the CARB mobile source OFFROAD Model, and the CARB OFFROAD Modeling Change Technical Memo dated June 13, 2003, the 2010 Baseline and Proposed Emissions Inventory for San Joaquin Air Basin, measured in Tons per Day. Table 12 in the Technical Memo illustrates total emissions for residential and commercial lawn and garden units. Table 7 provides the total hours per year for residential use of gasoline powered leaf blowers and vacuums (4,403,866) and Table 8 states the total hours per year for commercial use (28,617,875). Percentages for these categories are as follows:

Residential	13.335
Commercial	86.665

Of the total commercial emission inventory, leaf blowers account for approximately 8.6 percent. Applying these percentages to Table 12 (New Population and Activity Estimates) we get the following estimated reductions measured in Tons per Day, based on the replacement of all commercial gasoline powered leaf blowers in the San Joaquin Air Basin:

	TOTAL	Commercial Total 86%	Commercial Blower = 8.5% of 86%
NOx	0.72	0.62	.053
PM	0.08	0.07	.006

Annual emissions would then be reduced a total of approximately 16.801 tons for NOx and 1.902 tons for PM 2.5.

Using the same calculations of the previous illustrated model, estimated annual reduction of Carbon Monoxide and Hydrocarbons (Exhaust and Evaporative), measured in Tons per Day:

	TOTAL	Commercial Total 86%	Commercial Blower = 8.5% of 86%
CO	50.69	43.93	3.73
HCex	4.69	4.06	.345
HCev	2.70	2.34	.198
HC total	7.39	6.40	.544

Gas Consumption

The chart below (Fig 8) represents the approximate gas and oil consumption for one leaf blower unit calculated by the Stihl Corporation for a sample of popular models.

Reference <http://www.stihlusa.com/products/technology/br600-fuel-savings-calculator/>

Calculations have been converted to gallons in the running time column for comparison purposes. Gasoline oil and prices may vary however, this illustrates a sample of the financial operating costs incurred by one commercial unit used an average of 13 hours per week for 50 weeks in a year. Maintenance and repair costs are not factored. This would be typical of a mobile landscape maintenance vehicle servicing a residential customer base.

Number of Units	1				
Fuel Price (Per gal)	\$3.50				
Oil Price (2.6 oz)	\$1.10				
Run Times (Hours per week)	13				
Operating Weeks per Year	50				
Total hours per Year	650				
	Fuel Consumption (fl. oz. / hr)	Running Time in min / 1 gal of Fuel (min)	Annual Gas Consumed per Year (gal)	Annual Oil Consumed per Year (gal)	Annual Fuel Expenditure
Echo PB 755 S	52.4	146.4	266.39	5.41	\$1,225.41
Echo PB 770 T	51.9	148	263.51	5.35	\$1,212.16
Husqvarna 570 BTS	52.6	146	267.12	5.42	\$1,228.77
Husqvarna 580 BTS	59.4	129.2	301.86	6.13	\$1,388.54
RedMax EBZ 8500	59.8	128.4	303.74	6.17	\$1,397.20
STIHL BR 600 MAGNUM	43.2	178	219.10	4.45	\$1,007.87

Figure 8

The following chart (Fig 9) represents usage information provided by Whisper Landscape Maintenance (<http://whisperlandscapemaintenance.com/>) company reflecting their own measurements as an example of the amount of electrical energy bought and used in one month on average. The annual rate to operate a battery powered leaf blower would be approximately \$26.00 per year.

Whisper Landscape Maintenance, Inc. Energy Usage (2-Person Gardening Crew)

	Blowers	All Appliances (mowers, blowers, string trimmers, hedger, etc.)
Daily Energy Usage (kWh)	~.5kWh	~2.0kWh
Daily Electrical Energy Usage/Fuel Expense (\$.21/kW)	\$.10/day (.5kWh x \$.21/kW)	\$.42/day (2.0kWh x \$.21/kW)
Monthly (daily \$x5 days per weekx4.33 weeks per month)	\$2.165/month	\$9.09/month

Figure 9

Compared to a gasoline powered leaf blower, the operational costs are minimal for the same type of maintenance tasks. Electricity and gasoline rates vary widely among service providers and times of the year. Neither of these charts represents definitive results, however, on average the illustration is clear.

Section F

Costs

The summary of final costs listed by task results in a savings of \$3329.80

Description of Task	Schedule	Budget	Type 1	Dollar
	-10%	Inc. 10%	Billed	Variance
Task 2—Fan Evaluation	44,100.00	49,000.00	48,900.00	100.00
Task 4—Packaging Fabrication	41,176.41	45,751.57	45,275.98	475.59
Task 5—Lithium Backpack Battery Assembly	20,857.50	23,175.00	18,525.00	4,650.00
Task 6—Leaf Blower Demo Unit Assembly	50,733.89	56,370.99	58,266.78	(1,895.79)
Task 7—Demo Delivery and Testing	16,292.20	18,102.44	18,102.44	0.00
Subtotal	173,160.00			
Final Payout of 10% Retention	19,240.00	-		
Total	192,400.00	192,400.00	189,070.20	3,329.80

Section G

Problems and Resolutions

Preliminary testing results provided by Whisper were not as specific as we had requested and Whisper was unable to provide more detailed results. All battery backpack units were delivered by May 5 and each unit was thoroughly tested again by The Greenstation and Alare to verify results provided by Whisper and in greater detail. See page 16 of this report.

The assembly of the leaf blower units concluded in the month of April, in spite of some inconsistencies in the plastic molding. As plastic parts for the housing assembly were delivered, it was clear that some of the tolerances did not adhere to the design drawings provided them by Alare. As the units began to go together some of the seams did not line up correctly and had to be remolded before final assembly of all the units could be completed.

Within the first two weeks of testing, The Greenstation received an email from a manager at Century Landscaping. The management informed us that, although they signed an agreement to participate in the demonstration and went to the effort to obtain the necessary insurance documents, they would be unable to continue with the project. At that point, we re-assigned the two extra units to Healthy Air Lawn Care and ABLE Industries, while we worked with another possible testing partner, Kings County Unified School District, whom we ultimately secured.

There was an issue regarding static electricity buildup in some circumstances. Not all testers have encountered this problem but in very dry conditions static electricity builds up in the unit and discharges through the USB port or the indicator light. Further investigation shows that this

is not uncommon among units produced by other manufacturers. On August 15, 2014 we retrieved them for study and repair. This gave us a good opportunity to observe the physical results of usage on the units. Additional insulation in the handle and trigger mechanism has solved the problem.

During the testing phase, in the most challenging part of the year regarding high heat conditions, we found that the plastic molding had been damaged in some instances. Although, the operators were provided thorough training and protective cases to use in transport, some of the plastic housings were somewhat abused and required repair. Since then, the extreme summer temperatures have passed and we expect to complete the remainder of the testing phase with much reduced instances of high heat damage. The material used in prototype manufacturing is for testing purposes only and is not used in manufacturing for sale. Additionally, there was a bug in the circuit board that caused a one second delay in the trigger response. That has been re-programmed.

Able Industries testers are improvising a belt hook that allows the operator to have both hands free without having to set the blower on the ground. We encourage users to slightly modify the usability to suit their needs. The feedback this quarter reflects the crew's desire for a tube extension (similar to the feedback from CSUF), in addition to their previous comments on the addition of a hand strap and longer battery life. Tube extensions and shoulder straps are being developed for future use.

Green & Clean Landscaping testers are the most destructive to the equipment. They admit that they do not take much care when using or transporting the units. The static shock issue seems to be intermittent with them depending on the conditions but they are happy with overall usability and ergonomics. They concluded that their style of operation did not allow for prototype usage and that the level of damage to the equipment due to rough handling ultimately rendered it unusable. Green & Clean Landscaping ceased participation in the testing program.

Regarding battery performance, the ABLE testers lost the ability to use two of the packs, which we repossessed and inspected. Their feedback is that they simply no longer charge with any of the charging units issued to them. Upon inspection we have determined that the lithium cells have been depleted below a set point determined by the manufacturer and that the Battery Management System installed in each of the cells prevents them from being recharged from that very low level for safety reasons. To our battery subcontractor's credit, (Whisper Energy System) they used a very reputable manufacturer for these cells (A123) and we are confident that this is not a factory defect. Typically, this issue occurs when the battery is depleted to a very low level and then stored for some length of time without being put back on a charger. Future plans for manufacturing include improved design for the battery power system.

The overall result of this process was the successful manufacturing and testing of a lithium battery powered backpack leaf blower prototype that will be the model for an industrial design suitable for professionals working in the property maintenance industry. These zero emission leaf blowers will complement other pieces of equipment taking advantage of rapidly improving technology that will ultimately render gasoline powered property maintenance equipment obsolete.