# Leaf Blower Research

## Executive Summary:

Per direction by the Sustainability Board, staff looked at the following issues as they pertain to leaf blowers: Greenhouse gas emissions, Water Quality, Health, Noise, Florida cases and possible actions. The findings presented in this report were derived mainly from scientific and medical consensus statements, guidelines, and review articles from medical societies, government agencies, and established experts.

**Major Findings Include:**

1) **Greenhouse Gases**: Not all leaf blowers are created equal.
    a. **2-Strokes**: Although they are 75% cleaner and 70% quieter since 1998 regulations, a half hour of yard work with a 2-stroke is the same as driving a Ford F-150 Raptor crew cab from Texas to Anchorage, AK.
    b. **4-Strokes**: Even at idle, a 4-stroke engine emits 94% less greenhouse gasses.
    c. **Electric (Corded and Battery**): Electric motors shift the power generation to the power plant, which has the least greenhouse gas emissions (the Keys uses ~70% natural gas). The best electric engines cannot match the best gas leaf blower, but Consumer Reports found that for most medium duty jobs and ordinary yards, electric blowers were comparable.

2) **Water Quality Issues**: Fuel spillage when filling small engines is common and a large contributor to hydrocarbon emissions. 2-strokes even more so, due to the mixing of oil and gas. 31 local governments have banned gas-powered leaf blowers, either entirely or from residential areas.

3) **Health Issues**: Blowing leaves also stirs up additional small particulates from streets and sidewalks, which can cause or exacerbate lung problems. The max mph of the air blower directly affects how much particulates are resuspended into the air. 200mph is only slightly less than 230mph, but stirred up 50% less fine particulates while still moving large items like leaves. Leaf vacuuming had the same particulates as leaf blowing. Many particulate issues can be helped by better training of operators.

4) **Noise Issues**: The World Health Organization recommends a general outdoor noise level of 55 decibels or less, and 45 or less for sleeping restfully. The City's current noise ordinance sets different limits for the commercial core and for residential/commercial:
    *a)* **Commercial Core**
        - 85 dBA or 94 dBC between the hours of 11am and 2:59am
        - 75 dBA or 84 dBC between the hours of 3am and 10:59am
    **b) Residential and Commercial Areas**
    No decibel level is set for excessive noise at a residential property.

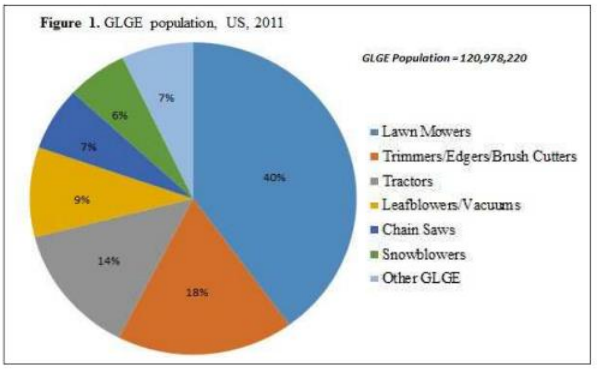
    Domestic power tools for lawn/garden are exempted from these noise rules, as long as they are performing at industry standard, and occurs between 8am and 7pm Mon-Fri and 9am-5pm Saturday and Sunday.

5) **The Free Market**:
    Homeowners tend to buy electric blowers and "virtually all" professionals buy gas blowers. A survey of local hardware stores showed that only 34% of blowers available were gas powered.

**Recommendations:**

1) Phase out gas powered leaf blowers for residential use.
2) Phase out all 2-stroke leaf blowers for commercial use.
3) Require industry stamped "Quiet" leaf blowers (ANSI Standard, B-175.2: ≤70 dBA)
4) Recommend cubic feet per minute thresholds for leaf blower use.
5) Require leaf blower training for all licensed professionals.
6) Modify operational hours for leaf blower use in residential areas.

# 1) Greenhouse Gas Emissions




According to the E.P.A., a commercial leaf blower emits 93 pounds per year of air pollutants[1]. But all leaf blowers are not created equal. In this section we look at 2-stroke engines, 4-stroke engines, and battery powered models.

### A) Gas Powered Engines

Gasoline powered lawn and garden equipment (Figure 1) is a source of high levels of localized emissions that includes hazardous air pollutants, criteria pollutants, and carbon dioxide[2] (Figure 2).

In California, where higher standards have been shaping the nationwide market, ~77% of these small combustion engines are residentially used in lawn and garden, it nearly ties Commercial use for daily HC and NOx emissions (45% vs 36%).[3] Total emissions for SORE consistently comes in 3rd in California only behind total emissions for heavy duty and light duty vehicles.

Lawn mowers and weed eaters constitute a large percentage of GLGE across the nation, but are highly likely more equal to leaf blower ownership/use within the City of Key West.

Figure 2. **Leaf Blowers and Air Pollution**

- Volatile organic compounds (VOC)
  - Benzene
  - 1,3 butadiene
  - Acetaldehyde
  - Formaldehyde
- Nitrogen oxides (NOx)
- Carbon monoxide
- Carbon dioxide
- Hydrocarbons
- Particulate matter

**HAPs***
- Toxic
- Carcinogenic and/or
- Ozone-forming

*Hazardous air pollutants (HAPs) are defined by the US EPA as pollutants that cause or may cause cancer or other serious health effects. See http://www.epa.gov/ttn/atw/pollsour.html; Small particles are formed by a mix of components, eg, acids, organic chemicals, metals, soil, dust.
*Key Sources: American Lung Association; US EPA, etc.*

### I. 2-Stroke Engines

Much of the greenhouse gas issue has to do with the two-stroke engine found in many leaf blowers. The two-stroke engine is ubiquitous because it is lightweight, compact, and cheaper to make. Cost is a common market driver, making the 2-stroke a popular choice for leaf blowers, lawn mowers, chain saws, chippers, scooters and jet skis.

However, for all their cost and size benefits, 2-stroke engines are very inefficient. Approximately 30% of the fuel the 2-stroke uses does not complete combustion, releasing a number of air pollutants. Carbon monoxide, nitrous oxides and hydrocarbons escape from the engine in large quantities. Many people know of the health effects of carbon monoxide, but the other gases are equally problematic. Both nitrous oxides and hydrocarbons contribute to smog formation. Hydrocarbons can be carcinogenic, and nitrous oxides can cause acid rain.

**Table 1. Impact** of regulation on small*, hand-held, gasoline fueled, two stroke engines

| Engine Tech Type | HC (g/hp-hr) | CO (g/hp-hr) | NOx (g/hp-hr) | PM (g/hp-hr) | BSFC (lb/hp-hr) |
|---|---|---|---|---|---|
| Baseline | 261.00 | 718,87 | 0.97 | 7.7 | 1.365 |
| Phase 1 | 219.99 | 480.31 | 0.78 | 7.7 | 1.184 |
| Phase 2 (with catalyst) | 26.87 | 141.69 | 1.49 | 7.7 | 0.822 |

BSFC: Brake-specific fuel consumption; CO: carbon monoxide; HC: hydrocarbon; NOx: nitrogen oxides; PM: particulate matter

* These emission factors are for engines sized from 0 to 1 hp.

The EPA has passed many reforms for 2-stroke engines and they are much cleaner today. Since 1998, manufacturers have reduced emissions by 75 percent and sound by 70 percent. The costs of implementing these environmental measures have made the 4-stroke engine more cost competitive.

Even with these advances, many local governments and states, federal lands[4, 5] and even the countries, have banned two-stroke engines (or at least older model two strokes) in a variety of uses, including personal watercraft, outboard engines and rickshaws. However, in staff's research, no leaf blower ban exists that targets only two stroke leaf blowers.

## II. 4-Stroke Engines

Not only are 4-strokes engines are quieter and more environmentally friendly than 2-strokes, increased consumer interest has brought both the size, weight and price closer to that of a 2-stroke (pg X). The scooter and personal watercraft markets are predominantly 4-stroke because a growing sector of buyers don't want the hassle of mixing oil in with the fuel.

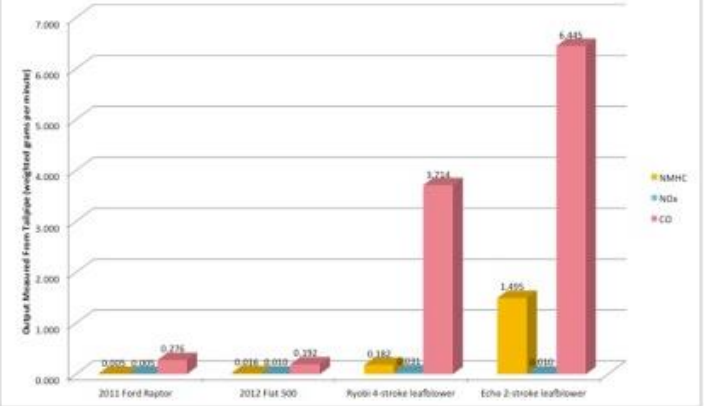
There is not much research comparing 2-stroke versus 4-stroke emissions for leaf blowers. However, testing in 2011 by the vehicle reviewer Edmunds.com compared the emissions of a 2-stroke Echo and 4-stroke Ryobi leaf blower to make a point about vehicle emissions[6]. The company subjected a Ford F-150 SVT Raptor crew cab and Fiat 500 to laboratory emissions tests alongside the leaf blowers. The four-stroke leaf blower performed significantly better than the two-stroke in most of the categories, but surprisingly worse than the car engines.

Comparing just the leaf blowers, the 4-stroke released less non-methane hydrocarbons and carbon monoxide than the 2-stroke. Even at idle, the 2-stroke released 750% more hydrocarbons than the 4-stroke at full power (Table 2).

| **Table 2.** Comparisons | NMHC | CO |
|---|---|---|
| 4-stroke – Idle | 0.077 | 1.822 |
| 4-stroke – Full speed | 0.182 | 3.714 |
| 2-stroke - Idle | 1.367 | 2.043 |
| 2-stroke – Full speed | 1.495 | 6.445 |

At idle and full power, both vehicles released less pollutants than either leaf blower. The two-stroke blower generated 23 times the carbon monoxide and nearly 300 times more non-methane hydrocarbons as the truck (Figure 3). In their words, a half hour of yard work with a two stroke leaf blower is the same as driving the Raptor from Northern Texas to Anchorage, AK (3,887 miles).

Figure 3. Emissions Smackdown - Vehicles vs Leaf Blowers FTP 75 and Quasi-FTP 75




In summary, the 4-stroke is better than the 2-stroke, but both run directly on fossil fuels and therefore both still have sizable emissions.

## III. Electric Powered Engines (Corded &/or Battery)

Electric motors shift fuel combustion from the device to a power plant. Carbon dioxide is still released, but because power plants are equipped with filters and scrubbers and leaf blowers are not, air pollution is still reduced. Also, in the Florida Keys, our energy mix is cleaner than the rest of the nation, because our primary energy fuel is natural gas (approximately 70%[7]), which is the cleanest burning of the three primary fossil fuels[8].

This difference is what prompted the South Coast Air Quality Management District, which covers a large portion of southern California, help support the development of the first backpack electric leaf blowers in the early 1990's. Since then, both the corded and battery models have become more available at prices similar to gas powered models.

While these models don't have the same commercial-grade power, they hold their own for most uses. Popular Mechanics tested 8 electric blowers in four different performance tests, and found that although the machines could not match the most powerful gas engine, they performed well in a wide range of medium duty jobs[9]. Consumer Reports also found that electric blowers perform comparably to gas-powered models for ordinary yards, and recommend that residents use electric for any job within 100 feet of a power outlet[10].

At least 50 local governments have banned gasoline powered leaf blowers, with the bulk of them being from California, which has much stronger emissions regulations. Some bans are for all gasoline leaf blowers, some only banned them from residential areas[11]. Other states with local gasoline powered leaf blower bans include New York, Hawaii and Colorado. The entire Nation of Israel has banned gasoline blowers.

## 2) Water Quality Issues

The activity of leaf blowing has two different phases that affect water quality: Fueling and Operating.

### A) Fueling

The filling of small engines with fuel is very prone to spillage, which is another major cause of hydrocarbon emissions. The U.S. Environmental Protection Agency estimates that 17 million gallons of fuel are spilled each year just in refueling small engines—more than the Exxon Valdez spilled in the Gulf of Alaska accident in 1989. It is estimated that every time a gas leaf blower is filled, approximately 2 ounces of gasoline is spilled. Some states require the use of automatic fuel shut-off containers to reduce fuel spillage.

### B) Operating

If all that was being blown was leaves, there wouldn't be as much concern about the effect to our nearshore waters. The waters around Key West are Florida designated as Outstanding State Waters and are part of the Florida Keys National Marine Sanctuary. To that end, the City has very strong stormwater rules to keep nonpoint pollution to a minimum, including restrictions on how yard waste can be stored on the right of way.

## 3) Health Issues

Using a blower to move leaves also stirs up many other things.

### A) Community Health

Arizona legislature passed a Bill (SB1552) in 2007 directing Maricopa County, AZ to adopt and enforce an ordinance restricting leaf blowers in order to reduce their Particulate Matter.[12, 13]

According to the EPA, Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets.

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects[14]. EPA groups particle pollution into two categories:

- $PM_{2.5}$ or "Fine particles," such as those found in smoke and haze, are $\leq$2.5 micrometers in diameter and are able to travel deeply into the respiratory tract and worsen medical conditions  These particles can come from forest fires, power plants, industries, automobiles and other combustion devices such as gas powered leaf blowers.  According to the EPA, roughly one out of every three people in the United States is at a higher risk of experiencing $PM_{2.5}$ related health effects, especially when being active outdoors[15].

- $PM_{10}$ or "Coarse particles," are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.  They can consist of acids, metals, chemicals, soil particles, and allergens (pollen or mold spores).  They are mostly caused by dust resuspension, and are in higher concentrations near roads as well as construction and demolition activities.  These are the largest particles that can be easily inhaled, causing or exacerbating lower respiratory tract diseases, such as chronic bronchitis, asthma, pneumonia, lung cancer, and emphysema.

- TSP or “Total Suspended Particles” is a now phased-out measurement of PM that includes all particles less than 100 micrometers.  $PM_{10}$ has replaced TSP as a better measurement for particulates that can affect health.

The University of California, Riverside did a study of leaf blower PM and TSP as compared to other yard/road cleaning methods[16] (Table 3).  It found that just about everything except for raking increased both PM2.5 and PM10.  Pushing aside the obvious high numbers associated with of power blowing over packed dirt, it found that power blowing was only slightly higher in PM’s as a push broom.  Also of interest, that vacuuming of debris had roughly the same PM affect as blowing debris.

**Table 3.** UNIVERSITY of CALIFORNIA Riverside

| Cleaning Action and Surface Cleaned | Number of Tests Performed | Type of Emission Factor Obtained from Tests | Emission Factors PM 2.5 (mg/m^2) | PM10 (mg/m^2) | TSP (mg/m^2) |
|---|---|---|---|---|---|
| Power Blowing or Vacuuming over concrete surfaces | 12 | Average emissions from leaf blowing | 30 | 80 | 100 |
| Power Blowing or Vacuuming over asphalt surfaces | 21 | Average emissions from leaf blowing | 20 | 60 | 80 |
| Push Broom on Asphalt Surface | 3 | Average emissions from sweeping | 0 | 20 | 30 |
| Push Broom on Concrete Surface | 3 | Average emissions from sweeping | 20 | 80 | 110 |
| Raking on Asphalt Surface | 1 | Average emissions from raking | 0 | 0 | 0 |
| Raking on Concrete Surface | 3 | Average emissions from raking | 0 | 0 | 10 |
| Raking Lawn | 1 | Average emissions from raking | 0 | 1 | 1 |
| Power Blowing Lawn | 3 | Average emissions from leaf blowing | 1 | 2 | 3 |
| Power Blowing Gutters | 3 | Average emissions from leaf blowing | 9 | 30 | 50 |
| Power Blowing Packed Dirt | 1 | Average emissions from leaf blowing | 80 | 120 | 160 |
| Power Blowing Cut Grass on Walkway | 2 | Average emissions from leaf blowing | 2 | 6 | 9 |
| Breakdown of Emissions by Power Blower Type on Asphalt and Concrete Surfaces | | | | | |
| Elec.Blower | 4 | Asphalt/CECERT | 20 | 60 | 80 |
| Gas Hand Held | 3 | Asphalt/CECERT | 10 | 40 | 50 |
| Gas Backpack | 4 | Asphalt/CECERT | 20 | 60 | 80 |
| Elec.Blower-Vac Mode | 3 | Asphalt/CECERT | 40 | 120 | 150 |
| Elec.Blower-Vac Mode - bag full | 3 | Asphalt/CECERT | 20 | 70 | 90 |
| Elec.Blower | 4 | Asphalt/Kearney | 0 | 20 | 30 |
| Elec.Blower | 3 | Concrete/CECERT | 40 | 130 | 170 |
| Gas Hand Held | 3 | Concrete/CECERT | 10 | 40 | 50 |
| Gas Backpack | 3 | Concrete/CECERT | 30 | 70 | 70 |
| Elec.Blower-Vac Mode | 3 | Concrete/CECERT | 30 | 80 | 90 |

**Right Sizing:** The authors cautioned that some differences may have been based on the particular model used, and when staff looked into this, the electric blower used had 48% more power (measured in maximum air velocity) than the gas backpack model and 15% larger than the gas handheld model. When adjusted for power, the results read a bit differently (Table 4). In light of this, from a health aspect, it may be worth considering limiting the maximum air velocity.

**Table 4.**

| Max Air Velocity | PM2.5 | PM10 | TSP |
|---|---|---|---|
| 155mph blower (gas backpack) | 20 | 60 | 80 |
| 200 mph blower (gas handheld) | 10 | 40 | 50 |
| 230 mph blower (electric handheld) | 20 | 60 | 80 |
| 230 mph vacuum – full bag (electric handheld) | 20 | 70 | 90 |
| 230 mph vacuum – empty bag (electric handheld) | 40 | 120 | 150 |

**Vacuum vs Blower**: One aspect of leaf blower regulation that had been favorably raised is the switch from blower to vacuum. One beneficial aspect of vacuuming is the actual collection of debris rather than pushing the problem around. Another beneficial aspect is the ability to compost the debris if it is all organic.

Unfortunately, based on the study, it shows that the exact same model, when used on vacuum setting creates almost double the PM, at least until the bag is full. This may have to do with the actual material and/or craftsmanship of the vacuum bag. There may have been changes to regulations on vacuum bag standards since this UCR report in 2005.

### B) Worker Health

Commercial operators of leaf blowers are the most at risk to both particulates and noise. Most of these hazards can be mitigated by proper use the equipment and proper wearing of personal protective equipment (PPE).

Commercial grade leaf blowers are favorites for large areas, cited for being very efficient tools that help reduce personnel injuries (mainly repetitive stress from raking and sweeping large areas). Studies have shown that rakes and brooms can take eight to 12 times longer to do the same work as leaf blowers, and still stir up the same amount of particulates as blowers. The City of Key West's Community Services crews use leaf blowers in the Duval commercial core area every morning and in residential area right of ways during working hours on a periodic basis.

Common training for proper leaf blower handling includes[17]

I. Proper PPE
II. Consideration of Bystanders and Adjoining Property
III. Know Your Local Noise Ordinances
IV. Operate at Appropriate RPMs
V. Don't operate more than one blower at a time
VI. Minimize Dust
VII. Never use to move dusty materials

The State of Florida already requires a certification for landscape professionals, called Green Industries Best Management Practices. Research should be done to see if a commercial training in leaf blower use it could be rolled in with the class through the Monroe County Extension Service.


## 4) Noise Issues

Noise is usually the primary complaint against leaf blowers. The U.S. EPA says noise degrades quality of life by impairing communication and social interaction; reducing the accuracy of work, particularly complex tasks; and creating stressful levels of frustration and aggravation that last even when the noise has ceased[18]. Excessive noise has been implicated in higher heart-attack rates, gastrointestinal disturbances, sleep problems, social discord and psychological problems.


The World Health Organization recommends a general outdoor noise level of 55 decibels or less and 45 or less for sleeping restfully. The Occupational Safety and Health Administration (OSHA) has determined that decibel levels above 85 cause permanent hearing loss.

Luckily, noise complaints and localized bans have driven decibel levels down. In 2000, Echo came up with the first "Quiet" leaf blower, that had a 75% reduction in noise, and became the benchmark to measure by*. Over the last decade, a standard has been created, ANSI B175.2, that allows leaf blowers to certify and label themselves as "Quiet", or ≤65 dBA at 50 feet. For worker safety, however, those models still usually measure 85 dBA at the users distance.

In 2010, Consumer Reports tested more than 50 models for noise and performance[10], and found that while all leaf blowers are not created equal, many on the market then did achieve the "quiet" standard. The other major recommendation was that residents should use electric for any job within 100 feet of a power outlet.

Rather than an outright ban, many local governments have enacted ordinances with a 65 dBA maximum for residential areas, and use it to regulate all noise:

- State of New Jersey
- State of Minnesota
- Tampa, FL
- New York City , NY
- Flower Hill, NY
- Chicago, IL
- Provo, UT
- Gloucester, MA
- Montgomery County, MD
- Rockville, MD
- Chevy Chase, MD
- College Park, MD
- Staunton, VA
- Richmond, VA
- Loudoun County, VA
- City of Portland, Oreg
- Cities in California (30+)

**Sound is measured in Micro Pascal's and then converted into decibels. For every 6 dBA change, the sound level measured in Micro Pascal's either increases by a factor of 2 or decreases by half. In other words, 71 dB(A) is twice as loud as 65 and 77 dB(A) is twice as loud as 71. Seventy-seven dB(A) is therefore four times as loud as 65.*

## 5) Free Market

Regulating types of leaf blowers will make some models obsolete. Before creating a reasonable time frame to phase out undesired blowers, an understanding of the availability and cost of the desired alternatives is important.

In a 2000 market report, only 1% of gas engines were 4-stroke. However, 60% of blowers were estimated to be electric. According to the authors, homeowners tend to buy electric and "virtually all" professionals buy gas.

In an unscientific sample, Home Depot's website lists 157 leaf blowers, 27% of which (42) are gas, and 88% of those are compliant with California's stringent CARB regulations already. The gas blowers ranged from 300-600+ max Cubic Feet per Minute (CFM), whereas battery powered ranges from 50-500 CFM. and electric (corded) powered ranges from 100-500 CFM. For the professional market, the only models that can blow 500 CFM or greater are gas models, but do come with one comparable 4-stroke option, which was surprisingly light for its engine type.

A Popular Mechanics article in 2011 pitted gas versus electric blowers at the PGA National Resort in Palm Beach Gardens, FL[19]. They called the noise difference "huge" and agreed that the tools seemed powerful enough to suit many homeowners needs.

Comparaboo, a website that gathers and compiles reviews from multiple sites, listed eight electric blowers at the top of its "10 Best Leaf Blowers of 2017"[20]. Interestingly enough, both gas engines on the list were 2-strokes, and one was a certified "Quiet" model, measuring <65 dBa at 50'.

## 6) References


1. http://www.mv-voice.com/news/2015/08/24/more-than-hot-air
2. https://www.epa.gov/sites/production/files/2015-09/documents/banks.pdf
3. http://www.brooklinema.gov/DocumentCenter/View/7999
4. http://www.nps.gov/lake/learn/management/twostroke.htm
5. http://www.thenational.ae/news/uae-news/environment/concern-over-boat-motor-rules-in-the-uae
6. http://www.edmunds.com/car-reviews/features/emissions-test-car-vs-truck-vs-leaf-blower.phtml
7. https://oaspub.epa.gov/powpro/ept_pack.charts
8. http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2016-Chapter-3-Energy.pdf
9. http://www.popularmechanics.com/home/tools/g2195/best-battery-powered-leaf-blowers/
10. http://www.consumerreports.org/cro/leaf-blowers.htm
11. http://www.consumerreports.org/cro/magazine-archive/2010/september/home-garden/leaf-blower/blower-noise/index.htm
12. https://www.maricopa.gov/aq/divisions/planning_analysis/rules/docs/Final_Staff_Report_for_P-25.pdf
13. https://www.azdeq.gov/environ/air/download/FAQs-Leaf_Blower_Use_Brochure.pdf
14. http://circ.ahajournals.org/content/121/21/2331.full
15. http://www3.epa.gov/pmdesignations/faq.htm
16. https://www3.epa.gov/ttnchie1/conference/ei15/session5/fitz.pdf
17. http://www.leafblowernoise.com/LEAF%20BLOWR%20%20Emanual%2012-13-10.pdf
18. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3988259/
19. http://www.popularmechanics.com/home/tools/reviews/g615/backyard-battle-gas-vs-electric-lawn-tools/?slide=7
20. http://www.comparaboo.com/leaf_blowers