Assessment of Backup Diesel Generators in Massachusetts

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Applied Economics Clinic

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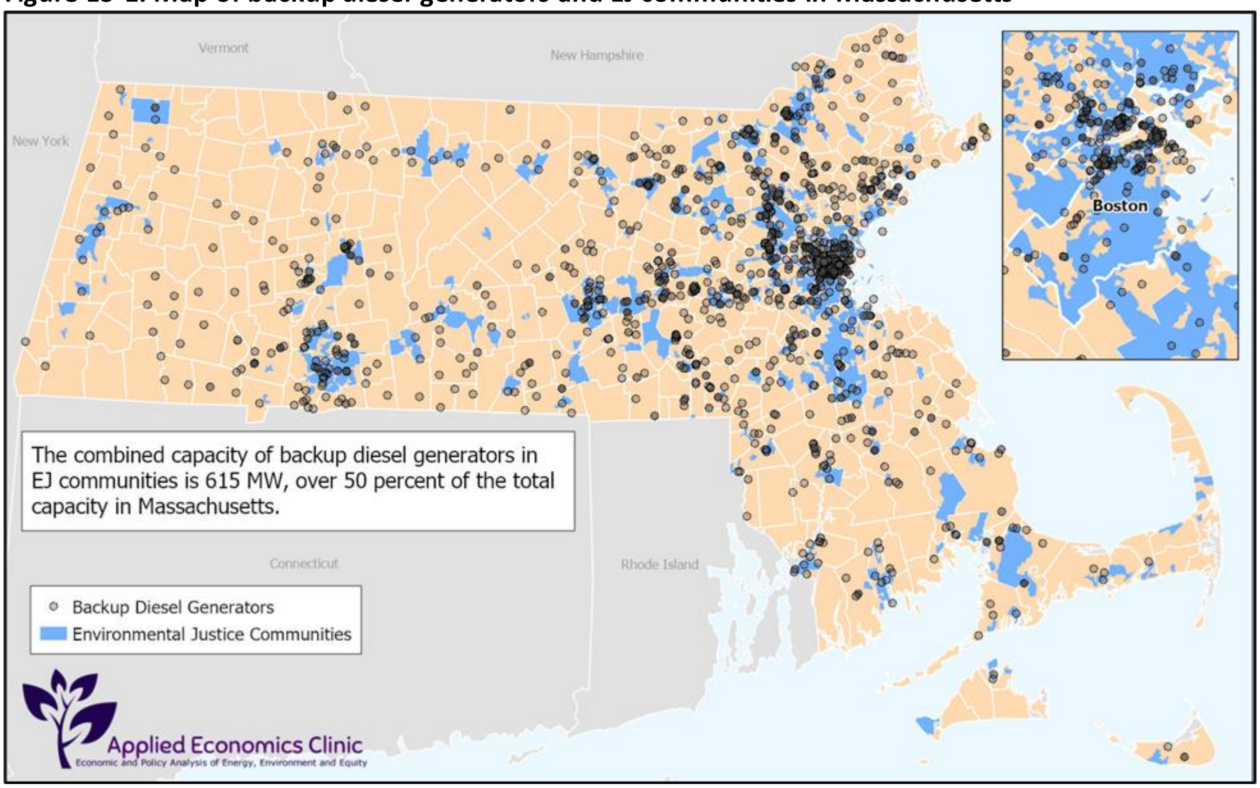
Executive Summary

Largely excluded from emissions inventories and often unreported to state and local authorities, Massachusetts' vast and poorly documented fleet of backup diesel generators makes our air dirty, contributes to climate change, and is disproportionately sited in our most vulnerable communities. Diesel generators, or diesel generating sets, consist of a diesel engine and an electric generator that produce electricity. Emergency, or backup, diesel generators are used to supply electricity when power from the grid is unavailable during a power outage or other service disruption. Reliable backup power is important to electric customers—especially hospitals, fire stations, and other essential buildings/services—and will become more important as climate change increases the frequency of severe weather events that lead to power outages.

While reliable, uninterrupted power is increasingly indispensable for businesses and residents, backup diesel generators are currently the dirtiest remaining electricity generating technology in Massachusetts. Alternative technologies exist, such as clean distributed energy resources that provide the same essential service, without the high costs associated with releasing harmful pollutants into the air.

Figure ES-1. Map of backup diesel generators and EJ communities in Massachusetts



Data sources: Environmental Justice Communities: U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B02001, B19013, C16002]. Backup Diesel Generators: (1) Massachusetts Department of Environmental Protection. 2006. 310 CMR 7.26 (42) Emergency Engines and Emergency Turbines. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download; (2) Massachusetts Department of Environmental Protection. Last Amended March 2021. 310 CMR 7.00: Air Pollution Control. Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

This Applied Economics Clinic (AEC) report—prepared on behalf of Bloom Energy—compiles an inventory of emergency diesel generators based on publicly available data from the Massachusetts Department of Environmental Protection (MassDEP), and assesses the number, capacity, proximity to environmental justice (EJ) communities, and emissions impact of backup diesel generators in the Commonwealth.

Nearly 2,000 of Massachusetts' backup diesel generators are registered with MassDEP, amounting to a combined capacity of roughly 1,150 megawatts (MW); for comparison, this is roughly the same scale as the 1,500 MW Brayton Point coal-fired power plant shuttered in 2017. While backup diesel generators are widespread across the Commonwealth, urban areas house both more generators with larger capacities (see Figure ES-1 above), and most of Massachusetts' EJ communities.

Roughly two-fifths of Massachusetts' residents live in EJ communities. These communities (home to many of Massachusetts minority, low-income, and limited English-speaking households) are disproportionately burdened by higher concentrations of air pollutants due to their proximity to industrial facilities, highways, airports, and other polluting sources. This report finds that 43 percent of Massachusetts' backup diesel generators (nearly 850 generators) are located within an EJ community, while four out of five backup diesel generators are located within a 1-mile radius of EJ communities.

Using conservative assumptions, we estimate that the Massachusetts backup diesel generators that we have been able to identify emit between 44,000 and 54,000 metric tons of CO_2e per year and represent a considerable source of local air pollutants. These emissions result in at least 74 additional workdays lost, 20 additional upper and lower respiratory cases, and a total increase of $5.6 to $12.7 million in healthcare costs for Massachusetts. Furthermore, due to their disproportionate siting in EJ communities, these emissions cause the most harm to Massachusetts' most vulnerable residents.

In Massachusetts and across the country, data on the prevalence, operation and impacts of small-scale and other backup generators is difficult to come by. For this analysis, AEC accessed a partial set of data on backup diesel generators in Massachusetts by filing an information request with MassDEP. Better and more accessible data on emitting generators of all sizes would improve the accuracy of emissions measurement and the targeting of social health investments.

In order to lessen the burden on EJ communities in particular and account for the harmful but overlooked emissions from backup diesel generators across the Commonwealth, recommended state and local policy interventions include:

- **Overcome the false assumption that diesel generators are indispensable.** New zero- and low-emissions alternatives together with public policy can ensure the same level of reliability—or greater—without continuing to rely on the dirtiest remaining electricity generating technology in Massachusetts. The current regulatory landscape appears to perpetuate widespread, and often unknown, deployment of diesel backup generators. Alternatives exist that address reliability concerns without worsening the air quality crisis and its inherent inequities.
- **Improve data availability and access.** Data on backup diesel generators is limited and difficult to access. This has allowed a substantial source of emissions to go relatively unscrutinized even as climate and EJ initiatives have taken center stage.
- **Strengthen reporting standards.** Emissions from small stationary sources, such as backup diesel

generators, need to be included in local air pollution permitting and greenhouse gas inventories. Annual reporting requirements should include: hours for readiness testing and operation, air pollutant and greenhouse gas emissions, energy output, and fuel consumption.

- **Stricter standards for locally polluting energy sources in EJ communities.** With EJ communities already facing disproportionate exposure to local air pollution, more oversight and stricter standards on the siting and operation of backup diesel generators (and other locally polluting energy sources) is essential to protect the health of the most vulnerable. Stricter standards would also highlight the availability of alternative zero- or low-emissions options.

This report demonstrates that there is an abundance of backup diesel generators throughout Massachusetts that are commonly sited near EJ communities and represent a considerable—and largely avoidable—source of air pollution and greenhouse gas emissions that threatens public health and the environment.

Table of Contents

I. Introduction

Diesel generators (also referred to as diesel generating sets) consist of a diesel engine and an electric generator, which are used to produce electricity under either emergency or non-emergency conditions. Emergency diesel generators (also referred to as backup diesel generators) are used as a backup source of electricity when power from the grid is unavailable to customers during a power outage or other service disruption. Non-emergency diesel generators are used to support the grid during times of peak demand and may also be deployed in areas where grid connection is unavailable.

Reliable backup power is important to electric customers—especially hospitals, fire stations, and other essential buildings/services—and will become more important as climate change increases the frequency of severe weather events that lead to power outages.[1] Moreover, the COVID-19 pandemic has redefined essential services to include buildings previously overlooked, such as grocery stores. Between periodic maintenance testing and operation in emergency conditions, Massachusetts' backup diesel generators are assumed for this study to run for 55 hours per year (see the Methodology Appendix below).[2] When running, backup generators release local air pollutants and greenhouse gas emissions into the atmosphere. These public health hazards are of particular concern to Environmental Justice (EJ) communities, which already face disproportionate exposure to local air pollution and the impacts of climate change.[3] EJ communities include minority and low-income populations that face a disproportionate burden from environmental hazards.

Due to their infrequent operation for power generation, backup diesel generators are often overlooked in reporting and registration requirements, and commonly are omitted from energy and emissions inventories gathered by local, state and federal agencies (e.g., U.S. EIA, U.S. EPA, and state energy and environmental agencies). Ignoring these emissions leaves local residents, and EJ communities in particular, vulnerable to the negative health impacts of air pollution, undercounts emissions responsibility, and overestimates progress towards climate goals.

In this report, the Applied Economics Clinic (AEC) reviewed publicly available data from the Massachusetts Department of Environmental Protection (MassDEP) to assess the quantity, location, combined capacity, and emissions impact of backup diesel generators in the Commonwealth. Section II presents an inventory of backup diesel generators in Massachusetts. Section III examines the proximity of these generators to EJ communities. Section IV estimates the quantity (in metric tons) of local air pollutant and greenhouse gas emissions from the backup diesel generators captured in the inventory. Section V offers policy recommendations based on this analysis. The Appendix presents AEC's methodology for this analysis,

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[1] Davis, M. and S. Clemmer. April 2014. "Power Failure: How Climate Change Puts Our Electricity at Risk—and What We Can Do." *Union of Concerned Scientists.* Available at: https://www.ucsusa.org/sites/default/files/2019-10/Power-Failure-How-Climate-Change-Puts-Our-Electricity-at-Risk-and-What-We-Can-Do.pdf

[2] Testing frequency and duration for backup generators varies depending on local, state, or federal mandates. As a general rule, backup generators should be exercised at least once monthly with a load for a minimum of thirty minutes. Source: National Fire Protection Association. 2019 edition. *NFPA 110: Standard for Emergency and Standby Power Systems – Chapter 8: Routine Maintenance and Operational Testing.* Available at: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=110

[3] Mikati, I., Benson, A.F., Luben, T. J. Sacks, J.D, and Richmond-Bryant, J. 2018. "Disparities in Distribution of Particulate Matter Emission Sources by Race and Poverty Status." *American Journal of Public Health*, 108, 480-485. *https://doi.org/10.2105/AJPH.2017.304297*

including data sources, assumptions, and calculations.

II. Inventory of backup diesel generators in Massachusetts

Nearly 2,000 of Massachusetts' backup diesel generators have been confirmed by AEC as registered with MassDEP, amounting to a combined capacity of roughly 1,150 megawatt (MW); for comparison, this is roughly the same scale as the 1,500 MW Brayton Point coal-fired power plant shuttered in 2017.[4] (see Table 1 below). AEC assembled this inventory of backup diesel generators using data on more than 1,000 generators from MassDEP's database of Environmental Results Program (ERP) Compliance Certifications[5] supplemented by data on an additional 900 generators from MassDEP's Source Registration (SR) database.[6]

MassDEP's ERP Compliance Certifications only apply to backup diesel generators with a capacity greater than or equal to 37 kW installed after March 23, 2006; these data are available only by written request to the agency. Since the program relies on self-certification, it is likely that even some larger generators are not captured in the ERP Compliance database due to owners not self-reporting their generators and a lack of enforcement of the ERP Compliance requirements.

MassDEP's SR database provides information on additional backup diesel generators not captured by the ERP Compliance database. In response to an information request filed by AEC, MassDEP provided the manufacturer, model, installation date, location, and capacity of backup diesel generators located throughout the Commonwealth. To supplement the ERP self-certification data, AEC filtered the SR database to capture diesel generators outside of the scope of the ERP Compliance Certifications, including: backup diesel generators installed prior to 2006 and with a capacity outside the bounds captured in the ERP self-certification data (37 ≤ kW ≤ 2,937 kW). These two data sources, however, do not comprise an exhaustive list of backup diesel generators located in Massachusetts.

The inventory compiled in this report does not reflect all backup diesel generators in Massachusetts. AEC retrieved information on a substantial number of backup diesel generators from the ERP and SR databases. However, the information provided was limited by size and year of installation, submitted through self-certification (and therefore incomplete), made available only by written request, and only some data were made available. For example, although the SR database does require owners/operators to provide emissions estimates, this information was not shared with AEC through this information request. Moreover, neither of these databases provide a comprehensive list of backup diesel generators. (For a detailed discussion of the data used in this analysis, refer to the Methodology Appendix below.) Therefore, this report provides only a partial picture of the scale of diesel generator deployments and emissions across the Commonwealth.

Roughly half of the generators included in this analysis are located in Suffolk and Middlesex counties, which

[4] U.S. Energy Information Administration. March 20, 2014. "Planned Coal-Fired Power Plant Retirements Continue to Increase." Available at: https://www.eia.gov/todayinenergy/detail.php?id=15491

[5] Personal Communication with Kevin Tyson, Massachusetts Department of Environmental Protection. Accessed March 22, 2021. *Database of Environmental Results Program (ERP) Compliance Certifications.*

[6] Retrieved through information request to MassDEP. Massachusetts Department of Environmental Protection. Last Amended March 2021. *310 CMR 7.00: Air Pollution Control.* Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

house more than one-third of the Commonwealth's population (see Table 1 below).[7] Moreover, despite being home to only about 9 percent of Massachusetts residents,[8] there are almost 260 generators located in Hampden and Hampshire counties, comprising about 13 percent of all generators.

Table 1. Inventory of backup diesel generators in Massachusetts

County	Number of Generators	Total Capacity (MW)	% of Total Capacity
Barnstable	35	12.9	1.1%
Berkshire	36	7.5	0.7%
Bristol	81	53.7	4.7%
Dukes	2	0.3	0.0%
Essex	133	53.0	4.6%
Franklin	23	3.4	0.3%
Hampden	130	48.7	4.2%
Hampshire	127	29.1	2.5%
Middlesex	642	441.8	38.6%
Nantucket	4	2.6	0.2%
Norfolk	147	136.3	11.9%
Plymouth	82	22.7	2.0%
Suffolk	340	239.9	20.9%
Worcester	191	93.4	8.2%
TOTAL	**1,973**	**1,145**	**100%**

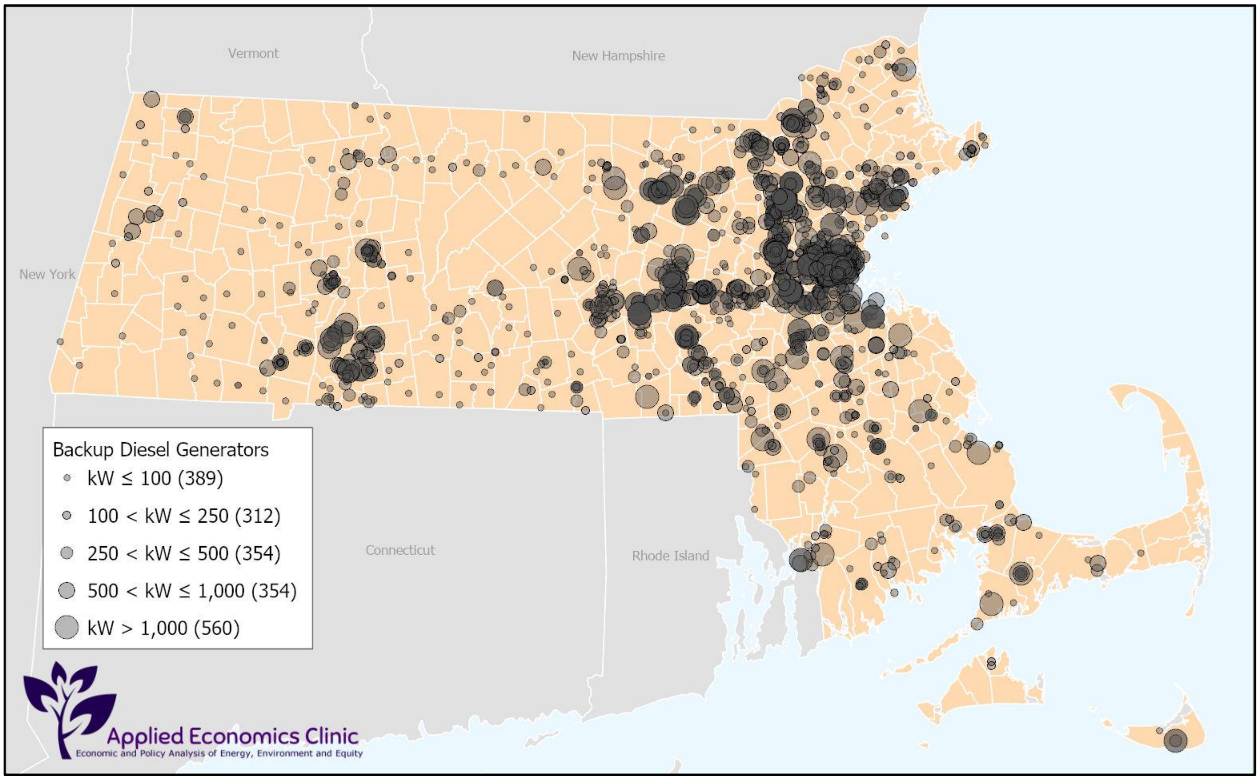
Data sources: (1) Massachusetts Department of Environmental Protection. 2006. 310 CMR 7.26 (42) Emergency Engines and Emergency Turbines. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download; (2) Massachusetts Department of Environmental Protection. Last Amended March 2021. 310 CMR 7.00: Air Pollution Control. Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

Figure 1 shows the location of backup diesel generators in Massachusetts with proportional circle sizes that correspond to each generator's size in kW. While backup diesel generators are widespread across the Commonwealth, they are heavily concentrated in urban areas which house more generators with larger capacities.

[7] U.S. Census. 2019. PEP Population Estimates [Table: PEPANNRES]. Available at: https://data.census.gov/cedsci/table?q=population&g=0400000US25.050000&y=2019&tid=PEPPOP2019.PEPANNRES&hidePreview=true

[8] Ibid.

Figure 1. Inventory of backup diesel generators in Massachusetts



Data sources: (1) Massachusetts Department of Environmental Protection. 2006. 310 CMR 7.26 (42) Emergency Engines and Emergency Turbines. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download; (2) Massachusetts Department of Environmental Protection. Last Amended March 2021. 310 CMR 7.00: Air Pollution Control. Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

III. Proximity of backup diesel generators to EJ communities in Massachusetts

Roughly two-fifths of Massachusetts' residents live in an EJ community.[9] These communities are home to minority, low-income, and limited English-speaking households that the Massachusetts Attorney General's office has determined are disproportionately burdened by higher concentrations of air pollutants due to their close proximity to industrial facilities, highways, airports, and other polluting sources.[10] To assess the potential burden from backup diesel generators on EJ communities in Massachusetts, AEC conducted a co-locational analysis using GIS software. AEC calculated the distance of each generator to the nearest EJ community using (1) an inventory of Massachusetts' backup diesel generators from data provided by

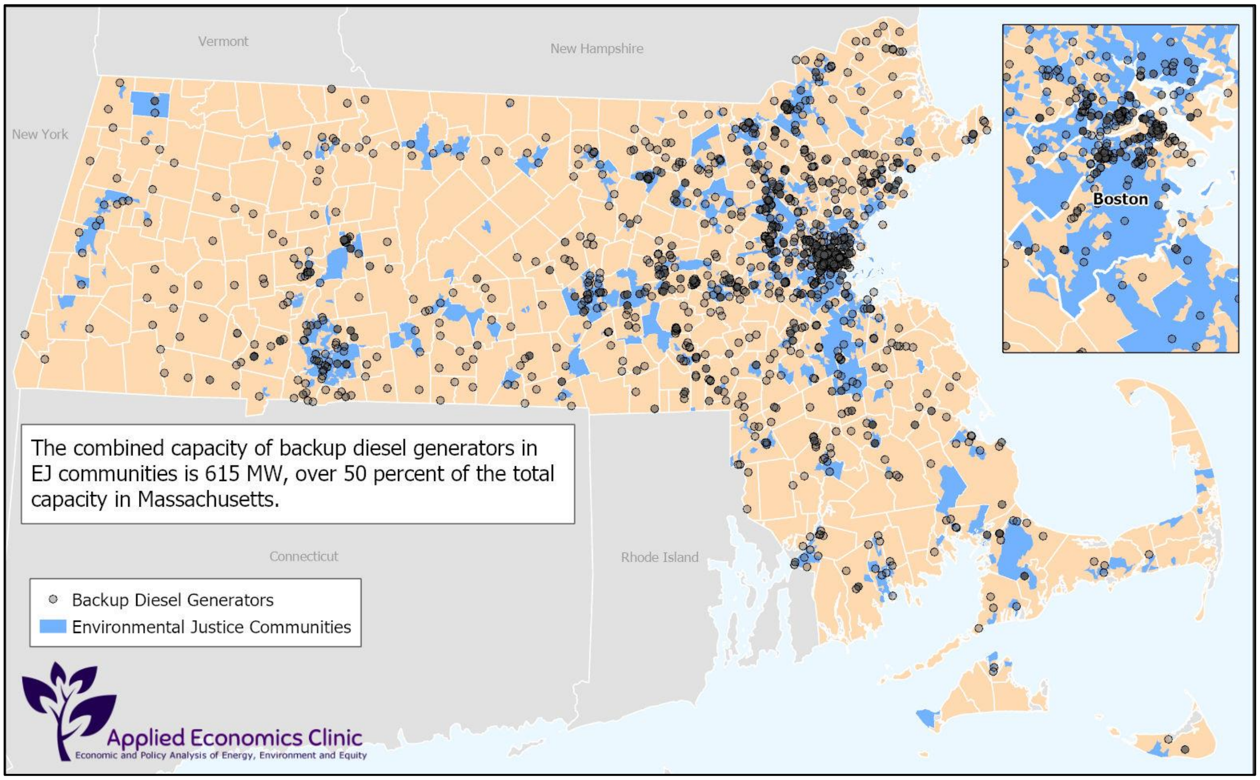
[9] U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B02001, B19013, C16002].

[10] Commonwealth of Massachusetts Office of Massachusetts Attorney General Maura Healey. 2020. *COVID-19's unequal effects in Massachusetts*. Available at: https://www.mass.gov/doc/covid-19s-unequal-effects-in-massachusetts/download

MassDEP and (2) EJ community boundaries as defined by the Commonwealth,[11] updated with 2019 data from the American Community Survey (ACS).[12]

Most backup diesel generators in Massachusetts are located within or near at least one EJ community (see Figure 2). Diesel generators are more concentrated in urban areas, which are home to most of Massachusetts' EJ communities.

Figure 2. Map of backup diesel generators and EJ communities in Massachusetts



Data sources: Environmental Justice Communities: U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B02001, B19013, C16002]. Backup Diesel Generators: (1) Massachusetts Department of Environmental Protection. 2006. 310 CMR 7.26 (42) Emergency Engines and Emergency Turbines. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download; (2) Massachusetts Department of Environmental Protection. Last Amended March 2021. 310 CMR 7.00: Air Pollution Control. Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

Roughly 43 percent of the backup diesel generators (nearly 850 generators) in AEC's Massachusetts inventory are located directly within an EJ community, representing a combined capacity of 615 MW (see Table 2). Backup diesel generators within a 0.5-mile radius of an EJ community account for 70 percent of AEC's inventory (nearly 1,400 generators). When the radius is extended to 1 mile of an EJ community, backup diesel generators account for 78 percent of AEC's inventory with over 1,500 generators. (See the Methodology Appendix below for a more detailed discussion of the development of these estimates.)

[11] Any block group that meets any of the following criteria: an annual mean household income less than or equal to 65.49 percent of the state median of $81,215 in 2019; 25 percent or more residents identify as a race other than white; or 25 percent or more of all households with limited English proficiency. Commonwealth of Massachusetts. 2010. "Environmental Justice Populations in Massachusetts." Available at: https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

[12] U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B02001, B19013, C16002].

Dispersion of air pollutants occurs due to meteorological conditions, terrain, and many other complex parameters. The effects of air pollutants on humans are not only felt locally, but are dispersed around the county, state and even country. Although it is impossible to tell how the air pollutants will disperse in a specific area without completing complex modeling, it is known that the negative effects of air pollutants are experienced beyond the immediate perimeter of the emissions source. Increased air pollution leads to an increased number of respiratory symptoms, infant mortality, heart attacks, and work loss days, and these all results in an increase in healthcare costs for residents living near an emissions source.[13] Backup diesel generators are also unable to effectively disperse air pollutants due to their short exhaust stacks, which leads to larger impacts on the residents and workers in the area.[14]

Table 2. Proximity of backup diesel generators to Massachusetts' EJ communities

Proximity to an EJ Community	Number of Generators	Percentage of Generators	Combined Capacity (MW)
Within community	845	43%	615
Less than a 0.5-mile	1,378	70%	950
Less than 1-mile	1,537	78%	1,031

IV. Estimates of air pollutant and greenhouse gas emissions

Backup diesel generators—while providing an important service—release local air pollutants and greenhouse gas emissions that go largely unaccounted for in public health and climate data. In 2006, the U.S. Environmental Protection Agency (EPA) adopted the *New Source Performance Standards [NSPS] for Stationary Compression Ignition Internal Combustion Engines* to regulate various pollutants from stationary diesel engines, including: carbon monoxide (CO), particulate matter (PM), nitrogen oxide (NO_x), sulfur dioxide (SO_2).[15] These standards did not develop new emission limits for stationary engines, but instead required stationary engines to meet previously established emission standards for mobile nonroad diesel engines.[16] The emission standards for nonroad compression ignition engines (including stationary diesel generators) are determined by both the generator size and an EPA Tier Rating that is based on the generator's year of manufacture.[17]

EPA's Ratings were established for Tiers 1 through 4, with each Tier phased in over time and having stricter

[13] U.S. EPA. (n.d.). "Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)." Available at: https://cobra.app.cloud.gov/

[14] New York State Energy Planning Board. 2015. *New York State Energy Plan*. Volume 2: Impacts & Considerations. Available at: https://energyplan.ny.gov/-/media/nysenergyplan/2014stateenergyplan-documents/2015-nysep-vol2-impacts.pdf

[15] U.S. EPA. November 2019. "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines." 40 CFR Part 60 Subpart IIII. Available at: https://www.govinfo.gov/content/pkg/FR-2019-11-13/pdf/2019-24335.pdf

[16] U.S. EPA. March 2016. Nonroad Compression-Ignition Engines: Exhaust Emission Standards. EPA-420-B-16-022. Office of Transportation and Air Quality. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf

[17] US EPA. March 2016. Nonroad Compression-Ignition Engines: Exhaust Emission Standards. EPA-420-B-16-022. Office of Transportation and Air Quality. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf

emission limits than the previous Tier. The NSPS rule required stationary engines to use ultra-low sulfur (15 ppm) diesel fuel by October 2010. Table 3 shows an example of required emission rate limits for local air pollutants and greenhouse gas emissions—provided in carbon dioxide equivalents (CO_2e)—for a 250 kW, Tier 3 backup diesel generator, on a per megawatt-hour (MWh) basis.[18]

Table 3. Example emission rate limits (kg/MWh) for a 250 kW, Tier 3 backup diesel generator

Power source	Emission Rate Limits (kg/MWh)				
	CO	PM	NO_x	SO_2	CO_2e
Tier 3 Backup Diesel Generator, 250 kW	3.5	0.2	3.8	0.007	786.8

AEC estimated the annual local air pollutant and greenhouse gas emissions from backup diesel generators in Massachusetts. AEC made conservative assumptions for the EPA emission factors used in the emissions calculations, as not all the relevant information to make a correct emission factor determination were available. This results in emission estimates that are mostly likely lower than actual emissions. These emission estimates are provided as a 10 percent sensitivity range above and below an assumed annual operation of 55 hours. (See the Methodology Appendix below for a more detailed discussion of the development of these estimates including data limitations and assumptions.) Our findings show that just the Massachusetts' backup diesel generators that we included in our partial inventory emit between 44,200 and 54,000 metric tons CO_2e per year and represent a considerable source of local air pollutants (see Table 4). Based on AEC's estimated emissions, the U.S. EPA's Co-Benefits Risk Assessment (COBRA) screening tool calculates the following health impacts in Massachusetts: 74 additional work days lost, 20 additional upper and lower respiratory cases, and a total increase of $5.6 to $12.7 million in healthcare costs.[19]

Table 4. Air pollutant and greenhouse gas emissions for backup diesel generators in Massachusetts

Backup Diesel Generators in MA	Annual Emissions (metric tons)				
	SO_2	PM	CO	NO_x	CO_2e
Low-end Estimates	0.4	19	420	370	44,200
High-end Estimates	0.5	23	510	450	54,000

Backup diesel generators, although a source of vital electric reliability, release substantial emissions each year. Alternative backup power options, such as distributed energy resources provide the same essential service, without the high costs associated with releasing harmful pollutants into the air.

[18] The emission factors for CO, PM, and NO_x vary by generator size and EPA Tier rating. However, the emission factors for SO_2 and CO_2e rely solely on the fuel consumption of the generator.

[19] The following inputs were used to generate these results: (1) Location: Massachusetts; (2) Sector/Subsector: Fuel Combustion: Other, Commercial/Institutional Oil; (3) $PM_{2.5}$ emissions increase by 19 tons; (4) SO_2 emissions increase by 0.4 tons; (5) NO_x emissions increase by 370 tons. Source: U.S. EPA. (n.d.). "Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)." Available at: https://cobra.app.cloud.gov/

V. Conclusions and recommendations

Although the thousands of backup diesel generators in Massachusetts, including those not captured in this report, provide electric customers with reliable power in the event of a power outage or other service disruption, they represent an important and largely uncounted source of local air pollutants and greenhouse gas emissions that pose a threat to public health and contribute to climate change. Backup diesel generators provide an important service in ensuring that power continues to flow to essential buildings during service interruptions, but alternative reliable power sources exist that emit less or no pollution into the atmosphere. The infrequent operation of backup diesel generators during service interruptions—about 5 hours, on average, in Massachusetts—leads to these locally polluting energy sources to be overlooked and omitted from energy and emissions inventories gathered by local and state governments. We find, however, that between operation during outages and for generator testing these pollution sources, which are overwhelmingly located in or very near to the Commonwealth's most vulnerable communities, are adding unreported emissions of both local pollutants and greenhouse gases.

Our findings show that four out of five Massachusetts backup diesel generators are located within or in close proximity to EJ communities, which are already disproportionately affected by exposure to local air pollution and the impacts of climate change. Without state and local intervention, these locally polluting energy sources will continue to be overlooked—leaving EJ communities vulnerable to the negative health impacts of air pollution, undercounting emissions responsibility, and overestimating progress towards climate goals.

In order to lessen the burden on EJ communities in particular and account for the harmful but overlooked emissions from backup diesel generators across the Commonwealth, recommended state and local policy interventions include:

- **Overcome the false assumption that diesel generators are indispensable.** New zero- and low-emissions alternatives together with public policy can ensure the same level of reliability—or greater—without continuing to rely on the dirtiest remaining electricity generating technology in Massachusetts. The current regulatory landscape appears to perpetuate widespread, and often unknown, deployment of diesel backup generators. Alternatives exist that address reliability concerns without worsening the air quality crisis and its inherent inequities.
- **Improve data availability and access.** Data on backup diesel generators is limited and difficult to access. This has allowed a substantial source of emissions to go relatively unscrutinized even as climate and EJ initiatives have taken center stage.
- **Strengthen reporting standards.** Emissions from small stationary sources, such as backup diesel generators, need to be included in local air pollution permitting and greenhouse gas inventories. Annual reporting requirements should include: hours for readiness testing and operation, air pollutant and greenhouse gas emissions, energy output, and fuel consumption.
- **Stricter standards for locally polluting energy sources in EJ communities.** With EJ communities already facing disproportionate exposure to local air pollution, more oversight and stricter standards on the siting and operation of backup diesel generators (and other locally polluting energy sources) is essential to protect the health of the most vulnerable. Stricter standards would also highlight the

availability of alternative zero- or low-emissions options.

Our research demonstrates that there is an abundance of backup diesel generators throughout Massachusetts that are commonly sited near EJ communities and represent a considerable—and largely avoidable—source of air pollution and greenhouse gas emissions that threaten public health and the environment.

Methodology Appendix

Inventory of backup diesel generators in Massachusetts

To compile an inventory of backup diesel generators in Massachusetts, AEC used MassDEP's database of Environmental Results Program (ERP) Compliance Certifications[20] and Source Registration (SR) database.[21] The ERP Compliance database is limited to information from operators of new emergency generators through a required self-certification process and only applies to generators installed after March 23, 2006 with a rated power greater than or equal to 37 kW. The ERP Compliance Certification database does not include:

- Backup diesel generators with a capacity less than 37 kW;
- Backup diesel generators installed prior to March 23, 2006 (i.e., older, dirtier generators that may still be in operation are not accounted for); and,
- Backup diesel generators installed in the Commonwealth that are not self-reported by owners.

Of the over 1,400 entries in the ERP Certification database, 1,066 use distillate fuel oil no. 2 (i.e., diesel fuel), the focus of this study, as the primary fuel.[22]

MassDEP's SR database provides additional information on backup diesel generators deployed throughout the Commonwealth. To supplement the ERP Compliance database, AEC filtered the SR database to include backup diesel generators that were installed prior to 2006 or had a capacity outside of the bounds captured in the ERP self-certification data (37 ≤ kW ≤ 2,937 kW). Although this approach results in an addition of 907 diesel generators to the inventory, it does not account for any additional generators have a capacity that falls within the bounds captured by the ERP Compliance database.

With that said, the full extent of backup diesel generator deployment in Massachusetts is unknown, which means that the quantity and capacity reported in the ERP Compliance and SR databases only represent a subset of the actual deployment amount and capacity.

Environmental justice analysis

To identify EJ communities in Massachusetts, AEC utilized the Commonwealth's EJ designation,[23] which is assigned to U.S. Census block groups that meet at least one of the following criteria:

- An annual mean household income less than or equal to 65.49 percent of the state median of $81,215 in 2019;[24]

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[20] Massachusetts Department of Environmental Protection. 2006. 310 CMR 7.26 (42) Emergency Engines and Emergency Turbines. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

[21] Retrieved from MassDEP through information request. Massachusetts Department of Environmental Protection. Last Amended March 2021. 310 CMR 7.00: Air Pollution Control. Sec. 7.12: U Source Registration. Available at: https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

[22] Personal Communication with Kevin Tyson, Massachusetts Department of Environmental Protection. Accessed March 22, 2021. Database of Environmental Results Program (ERP) Compliance Certifications.

[23] Commonwealth of Massachusetts. 2010. "Environmental Justice Populations in Massachusetts." Available at: https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

[24] U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B19013].

- 25 percent or more residents identify as a race other than white; or
- 25 percent or more of all households with limited English proficiency.

Massachusetts makes publicly available its own GIS layer for EJ communities in 2010 using the definition above. AEC created an updated version of this EJ layer by using data on race, income, and language from the U.S. Census' 2019 ACS 5-year estimates[25] to identify EJ communities.

Using GIS software, the locations of the backup diesel generators were mapped based on the addresses listed in the ERP database. Out of the 1,973 backup diesel generators in the inventory compiled from the ERP and SR databases, 4 were not included in the EJ analysis due to incomplete address information. For each diesel generator, the distance to the nearest EJ community was calculated. Using these distances, AEC calculated the number and capacity of generators located inside EJ communities and within particular distance bands.

Estimating emissions from backup diesel generators

To conduct the emissions analysis for backup diesel generators, AEC estimated the annual generation (kWh) by multiplying the capacity (kW) of each generator by the assumed annual operation time range (hours) for outages and testing.[26] AEC also estimated the annual fuel consumption (MMBtu) of each generator by multiplying the calculated annual generation (kWh) by an assumed heat rate of 10,500 Btu per kWh.[27]

We assumed the annual operation time for generator testing to be 50 hours, which is half of MassDEP's maximum allowed operating hours for maintenance checks and readiness testing.[28,29] AEC estimated the annual operation time due to power outages by averaging the U.S. EIA's System Average Interruption Duration Index (SAIDI) across Massachusetts electric utilities over the 7-year period between 2013 and 2019, which resulted in an annual average of 5 hours of outage time per customer served (see Table 5).[30] With these two components, AEC estimated a range of operating hours by taking the average operating time of 55 hours as the midpoint and applying a 10 percent sensitivity above and below this value.

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[25] U.S. Census. 2019. ACS 5-Year Estimated Detailed Tables [Tables: B02001, B19013, C16002].

[26] Generator testing (also referred to as "exercising") is a form of routine maintenance where operators periodically run their generator with and without load to ensure that it is fully operational and ready in the event of a power outage. Source: National Fire Protection Association. 2019 edition. *NFPA 110: Standard for Emergency and Standby Power Systems – Chapter 8: Routine Maintenance and Operational Testing.* Available at: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=110

[27] Based on the average heat rate (9,000 to 12,000 Btu per kWh) for reciprocating engines between 500 and 2,000 kW. Source: U.S. Department of Energy. July 2011. *Hospitals Discover Advantages to Using CHP Systems*. Available at: https://www1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_chp_fs.pdf

[28] General testing requirements call for generators to be tested monthly for a minimum of 30 minutes with load and weekly for a minimum of 30 minutes without load; however, the frequency and duration of testing varies among generator operators based on personal preference and manufacturer guidelines.

[29] Emergency generators in Massachusetts are allowed to operate for up to 100 hours each year. This limit applies to operation during routine maintenance and exercising. Operation during non-emergency conditions is allowed for up to 50 hours of this limit. Source: Massachusetts Department of Environmental Protection. 2018. *Emergency Engine and Emergency Turbine Environmental Certification Workbook*. Available at: https://www.mass.gov/doc/environmental-certification-workbook-emergency-units/download p.5.

[30] U.S. EIA. 2013–2019. *Annual Electric Power Industry Report, Form EIA-861 detailed data files [Reliability]*. Available at: https://www.eia.gov/electricity/data/eia861/

Table 5. Average outage duration per customer served in Massachusetts

Outage Duration per Customer Served (hours)	2013	2014	2015	2016	2017	2018	2019	Annual Average
Massachusetts Average	7.0	2.1	1.5	2.4	4.6	13.6	4.2	**5.0**

Source: U.S. EIA. 2013–2019. Annual Electric Power Industry Report, Form EIA-861 detailed data files [Reliability]. Available at: https://www.eia.gov/electricity/data/eia861/

To estimate the amount of air pollutants (including CO, PM, and NO_x) emitted by these backup diesel generators, AEC multiplied the annual generation (kWh) of each generator by the corresponding emission rate limits (kilograms per kWh)–shown in Table 6 below–established by the U.S. EPA's *New Source Performance Standards for Stationary Compression Ignition Internal Combustion Engines*.[31,32] Some of the emission standards for NO_x are reported as a combined emission standard with non-methane hydrocarbons (NMHC)—referred to as NMHC+NO_x. To separate NO_x from this combined emission standard, AEC assumed that NO_x represents a 75 percent share of the NMHC+NO_x standard based on the Ohio Environmental Protection Agency's assumed NO_x to NMHC ratio.[33]

[31] U.S. EPA. November 2019. "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines." 40 CFR Part 60 Subpart IIII. Available at: https://www.govinfo.gov/content/pkg/FR-2019-11-13/pdf/2019-24335.pdf

[32] These emission standards are defined by EPA Tier Ratings were established for different size generators and phased in over specified time periods that are applicable to a diesel generator's model year. Source: U.S. EPA. March 2016. Nonroad Compression-Ignition Engines: Exhaust Emission Standards. EPA-420-B-16-022. Office of Transportation and Air Quality. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf

[33] Ohio Environmental Protection Agency. *Calculation of NOx Emissions for Compression Ignition (CI), Internal Combustion Engines (ICE)*. Available at: https://www.epa.ohio.gov/portals/27/genpermit/CI.calcs.pdf

Table 6. Nonroad Compression-Ignition Engines: Exhaust Emission Standards

Rated Power (kW)	EPA Tier Rating	Model Year [Start]	Model Year [End]	NMHC (g/kWh)	NMHC+ NOx (g/kWh)	NOx (g/kWh)	PM (g/kWh)	CO (g/kWh)
kW < 8	1	2000	2004		10.5		1.0	8.0
	2	2005	2007		7.5		0.8	8.0
	4	2008			7.5		0.4	8.0
8 ≤ kW < 19	1	2000	2004		9.5		0.8	6.6
	2	2005	2007		7.5		0.8	6.6
	4	2008			7.5		0.4	6.6
19 ≤ kW < 37	1	1999	2003		9.5		0.8	5.5
	2	2004	2007		7.5		0.6	5.5
	4-Initial	2008	2012		7.5		0.3	5.5
	4-Final	2013			4.7		0.03	5.5
37 ≤ kW < 56	1	1998	2003			9.2		
	2	2004	2007		7.5		0.4	5.0
	4-Initial	2008	2012		4.7		0.3	5.0
	4-Final	2013			4.7		0.03	5.0
56 ≤ kW < 75	1	1998	2003			9.2		
	2	2004	2007		7.5		0.4	5.0
	3	2008	2011		4.7		0.4	5.0
	4-Initial	2012	2013		4.7		0.02	5.0
	4-Final	2014		0.19		0.4	0.02	5.0
75 ≤ kW < 130	1	1997	2002			9.2		
	2	2003	2006		6.6		0.3	5.0
	3	2007	2011		4		0.3	5.0
	4-Initial	2012	2013		4		0.02	5.0
	4-Final	2014		0.19		0.4	0.02	5.0
130 ≤ kW < 225	1	1996	2002	1.3		9.2	0.54	11.4
	2	2003	2005		6.6		0.2	3.5
	3	2006	2010		4		0.2	3.5
	4-Initial	2011	2013		4		0.02	3.5
	4-Final	2014		0.19		0.4	0.02	3.5
225 ≤ kW < 450	1	1996	2000	1.3		9.2	0.54	11.4
	2	2001	2005		6.4		0.2	3.5
	3	2006	2010		4		0.2	3.5
	4-Initial	2011	2013		4		0.02	3.5
	4-Final	2014		0.19		0.4	0.02	3.5
450 ≤ kW < 560	1	1996	2001	1.3		9.2	0.54	11.4
	2	2002	2005		6.4		0.2	3.5
	3	2006	2010		4		0.2	3.5
	4-Initial	2011	2013		4		0.02	3.5
	4-Final	2014		0.19		0.4	0.02	3.5
560 ≤ kW < 900	1	2000	2005	1.3		9.2	0.54	11.4
	2	2006	2010		6.4		0.2	3.5
	4-Initial	2011	2014	0.4		3.5	0.1	3.5
	4-Final	2015		0.19		3.5	0.04	3.5
kW > 900	1	2000	2005	1.3		9.2	0.54	11.4
	2	2006	2010		6.4		0.2	3.5
	4-Initial	2011	2014	0.4		3.5	0.1	3.5
	4-Final	2015		0.19		3.5	0.04	3.5

Reproduced from: U.S. EPA. March 2016. Nonroad Compression-Ignition Engines: Exhaust Emission Standards. EPA-420-B-16-022. Office of Transportation and Air Quality. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf

To estimate SO_2 emissions from backup diesel generators, AEC multiplied the annual diesel fuel consumption (MMBtu) of each generator by the U.S. EPA's emission factor for SO_2 of 0.001515 lbs per MMBtu.[34,35]

To estimate the greenhouse gas emissions (CO_2, CH_4, and N_2O) released by these backup diesel generators, AEC multiplied the annual fuel consumption (MMBtu) of each generator by the EPA's emission factors for each greenhouse gas for distillate fuel oil no. 2 (kilograms per MMBtu) as shown in Table 7.[36] The total greenhouse gas emissions in CO_2e were calculated by multiplying the emissions of CO_2, CH_4, and N_2O by their 100-year global warming potentials of 1, 25, and 298, respectively.

Table 7. U.S. EPA greenhouse gas emission factors for distillate fuel oil no. 2

Fuel Type	CO_2 kg per MMBtu	CH_4 g per MMBtu	N_2O g per MMBtu
Distillate Fuel Oil No. 2	73.96	3	0.6

Source: U.S. EPA. Last Modified 1 April 2021. Emission Factors for Greenhouse Gas Inventories. Available at: https://www.epa.gov/sites/production/files/2021-04/documents/emission-factors_apr2021.pdf

Due to the data limitations, several assumptions were made in this analysis to estimate emissions from backup diesel generators. In particular, AEC used the installation year reported in each database as a proxy for the model year of each generator. Since the EPA Tier Ratings for local air pollutants are phased in over time according to model year, diesel generators could have a model year that is older than their installation year. In fact, because diesel generator sets may be purchased used, leased, or rented, model years often differ from the installation year. In addition, AEC assigned Tier 1 to older diesel generators that were installed prior to the phasing in of the EPA Tier Ratings. Collectively, the conservative assumptions made for this study have resulted in calculated emissions that are likely on the lower range of what is occurring, since EPA emission factors are lower for newer models. The real magnitude of the emissions from diesel backup generators is likely higher and the impacts more widespread.

[34] The SO_2 emission factor is equal to 1.01S lbs per MMBtu, where "S" is the sulfur content as a percentage. Since ultra-low sulfur diesel contains 15 ppm of sulfur, "S" in the SO_2 emission factor would be equal to 0.0015 percent. Source: U.S. EPA. October 1996. "3.4 Large Stationary Diesel and All Stationary Dual-fuel Engines." AP 42, Fifth Edition, Volume I Chapter 3: Stationary Internal Combustion Sources. Available at: https://www.epa.gov/sites/production/files/2020-10/documents/c03s04.pdf p.3.4-5

[35] AEC divided the SO_2 emissions by 2.205 to convert from lbs to kilograms.

[36] U.S. EPA. Last Modified 1 April 2021. Emission Factors for Greenhouse Gas Inventories. Available at: https://www.epa.gov/sites/production/files/2021-04/documents/emission-factors_apr2021.pdf