AMERICAN UNIVERSITY OF BEIRUT

# POLICY PROPOSAL FOR STATIONARY ELECTRIC ENGINE COMPRESSORS IN LEBANON

by
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# AN ABSTRACT OF THE THESIS OF

LaVina Ashley Damrell for Master of Science in Environmental Sciences
Major: Environmental Policy Planning

Title: Policy Proposal for Stationary Electric Generating Engine Compressors in Lebanon

Generators within the country of Lebanon have a unique relationship and role within the country. The internal utility infrastructure of the country was severely weakened and degraded after the Civil War, which lasted anywhere from fifteen to twenty years. The lack of available state derived electricity forced consumer to supply their own via private generators. This trend has continued till now as the state has not been able to keep up with the growing population and rising demand. The combination of the quantity of generators and their placement have led to intense debate to curb their impact on air quality and public health. The resulting air toxins and their impacts warrant the application of regulatory oversight and standards to limit their impact. Oversight is further emphasized due to the current proximity of generators to receptors as a result of available space and connections to their intended consumers. Specifically relating to generators, policy involving an emissions template, emission limit values (ELVs) and monitoring requirements remain absent although they have been identified.

The main question addressed in this thesis is: To what extent can policy measures in the United States (US) be applied to the state of Lebanon? Compliance to US requirements involve adherence to standardized methodology for air emission calculations, compliance with emission standards and thresholds, and demonstrated compliance via maintenance, recordkeeping and reporting. These elements lead to two corollary questions that compare current generators in Lebanon to current US operating authorizations. First: could generators meet emission standards? And second: Could they meet the addition requirements for authorization? This thesis is based on generator specific data gathered from currently operating generators (and their owners) in the northern city of Al-Mina, a review of the policy structure of the Texas Commission on Environmental Quality (TCEQ), and research on the historical and sociopolitical implications within Lebanon and the subsequent impact on policy.

This thesis concludes that in theory, it is possible for generators to meet the basic emission standards, which apply to engines' manufacturers and subsequently the emission threshold limit for authorizations. However they will not meet all the requirements of the authorization, either in theory or in practice. This leads to the main question of this thesis and concludes with a proposal of policy framework that combines elements of the TCEQ with the current culture and practices of Lebanon for direct application with current and future generators.

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AEI | Annual Emissions Inventory |
| AFCEC | Air Force Civil Engineer Center |
| AFR | Air to Fuel Ratio |
| AP-42 | AP-42 Compilation of Air Pollutant Emission Factors |
| APIMS | Air Program Information Management System |
| AUB | American University of Beirut |
| BACT | Best Available Control Technology |
| BSFC | Brake-Specific Fuel Consumption |
| Btu/hp-hr | British Thermal Units per Horsepower Hour |
| CARB | California Air Resource Board |
| CEMS | Continuous Emission Monitoring |
| CFR | Code of Federal Regulations |
| CI | Combustion Ignited |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| CTAG | Comprehensive Turbulent Aerosol Dynamics and Gas Chemistry |
| DOC | Diesel Oxidation Catalyst |
| DPF | Diesel Particulate Filter |
| EDL | Electricity of Lebanon (Electricité du Liban) |
| EDZ | Electricité du Zahle |
| EF | Emission Factor |
| EGR | Exhaust Gas Recirculation |
| ELVs | Emission Limit Values |
| EPA | United States Environmental Protection Agency |
| ER | Emission Rate |
| EU | European Union |
| g/hp-hr | Grams Per Horsepower-Hour |
| GHG | Greenhouse Gases |
| GWP | Global Warming Potential |
| $H_2SO_4$ | Sulfuric Acid |
| HC | Hydrocarbons |
| IC | Internal Combustion |
| ICE | Internal Combustion Engines |
| IPCC | Intergovernmental Panel on Climate Change |
| Lb/hr | Pounds per Hour |
| Lb/MMBtu | Pounds Per Million British Thermal Units |
| LES | Large Eddy System |
| MACT | Maximum Allowable Control Technology |
| MoEW | Lebanese Ministry of Energy and Water |
| MOE | Lebanese Ministry of Environment |
| MOI | Lebanese Ministry on Interior |
| MRR | Maintenance, Recordkeeping and Reporting |
| MSS | Maintenance, Shutdown and Startup |
| MW | Megawatt |

| | |
|---|---|
| $N_2$ | Nitrogen |
| NAQMS | National Air Quality Management Strategy, 2015 – 2030 |
| NAAQS | National Ambient Air Quality Standards |
| $NH_3$ | Ammonia |
| $NO_X$ | Nitrogen Oxides |
| NSCR | Non-Selective Catalytic Reduction |
| NSPS | New Source Performing Standards |
| NSR | New Source Review |
| NTPR | Non-Thermal Plasma Reactor |
| OEHHA | California Office of Environmental Health Hazard Assessment |
| OSHA | United States Occupational Health and Safety Administration |
| PAH | Polycyclic Aromatic Hydrocarbons |
| Pb | Lead |
| PEL | Permissible Exposure Level |
| PM | Particulate Matter |
| PSD | Prevention of Significant Deterioration |
| RICE | Reciprocating Internal Combustion Engines |
| RPM | Revolutions per Minute |
| SCR | Selective Catalytic Reduction |
| SI | Spark Ignited |
| $SO_2$ | Sulfur Dioxide |
| $SO_3$ | Sulfur Trioxide |
| $SO_X$ | Sulfur Oxides |
| SOP | Statement of Principles |
| TAC | Texas Administrative Code |
| TCEQ | Texas Commission on Environmental Quality |
| TOC | Total Organic Compounds |
| TPY | Tons per Year |
| TWA | Time Weighted Average |
| UN | United Nations |
| US | United States |
| UNHCR | United Nations High Commission for Refugees |
| VOC | Volatile Organic Compound |

# CHAPTER I

# INTRODUCTION

Lebanon is a small growing nation in the Mediterranean. Although famous for its beauty, its people and heritage, it's also known for its magnetism for strife and its enduring impacts on the country's internal infrastructure. Lebanon endured fifteen years of civil war leaving the infrastructure in a wreck which lead to constant, long shortage hours of electricity and forcing the public to provide their own electricity by installing diesel generators.[1] Private generators (un-surveyed but in the thousands) are found in industries and other establishments, and may be located on balconies, in basements, empty lots, and curbsides.[2] The electricity shortages were threatened further by the 2006 Israeli attacks that left the crippled power supply even more vulnerable. Lebanon's decrepit power generation, transmission and distribution system has failed to keep pace with a huge increase in electricity consumption over the last two decades.[3] The additional demand created by the displaced Syrians has increased the burden and stress further. As of 2018, self-generation represents 33% of total electricity production in the country.[4]

The predominant concern from generators are the exhaust emissions. The main air pollutants are known as criteria air pollutants. These include: include sulfur oxides

1 Nasser, Zeina, Pascale Salameh, Habib Dakik, Elias Elias, Linda Abou Abbas, and Alain Leveque. "Outdoor Air Pollution and Cardiovascular Diseases in Lebanon: A Case-Control Study." Journal of Environmental and Public Health2015. http://dx.doi.org/10.1155/2015/810846.
2 Lebanon. Ministry of Environment. State and Trends of the Lebanese Environment. 2011. http://www.undp.org.lb/communication/publications/downloads/SOER_en.pdf.
3 Bossone, Andrew. "Generators Compounding Public Health Risk in Lebanon." Nature Middle East Emerging Science in the Arab World. March 12, 2013. Accessed April 25, 2019. https://www.natureasia.com/en/nmiddleeast/article/10 .1038/nmiddleeast.2013.34
4 World Bank. Sustainable Development Department Middle East And North Africa Region. Republic of Lebanon: Electricity Sector Public Expenditure Review. World Bank, 2008. https://openknowledge.worldbank.org/bitstream/handle/10986/7990/414210REPLACEM1closed0April01502008.pdf?sequence=1&isAllowed=y.

($SO_X$), particulate matter (PM), carbon monoxide (CO)  volatile organic compounds ($VOCs$) and nitrogen oxides ($NO_X$). Other air toxins, known as hazardous air pollutants, are known to have even more detrimental effects such as being carcinogens.

**Table 1.0.1. Impact of the Main Air Pollutants on Human Health.**

| POLLUTANT | HEALTH EFFECTS |
|---|---|
| **Sulphur oxides ($SO_X$)** | Aggravates asthma and can reduce lung function and inflame the respiratory tract. Can cause head- aches, general discomfort and anxiety. |
| **Particulates (PM)** | Can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. Can cause cancer. May lead to atherosclerosis, adverse birth outcomes and childhood respiratory disease. The outcome can be premature death. |
| **Carbon monoxide (CO)** | May lead to heart disease and damage to the nervous system; can also cause headache and fatigue. |
| **Volatile Organic Compounds (VOCs)** | Irritation to eyes, nose and throat. Headaches, loss of coordination and nausea. Damage to liver, kidney and central nervous system. |
| **Nitrogen Dioxide ($NO_2$)** | Exposure to NO2 is associated with increased all-cause, cardiovascular and respiratory mortality and respiratory morbidity. |

The latest National Air Quality Management Strategy (NAQMS) set by the Lebanese Ministry of Environment in 2017, as part of one of the goals to improve air quality assessment throughout the country, identified the need for three items: updating emission limit values (ELVs) for point sources, establishing a methodology for analysis, and the establishing a monitoring structure. The three items provide the purpose for this study, which include examining possibilities for emission limit values based on the current landscape; provide a methodology for estimating pollutants through traditional methods and field checks, and providing a comprehensive monitoring structure through policy implementation.  Specifically relating to generators, policy involving an emissions template, emission limit values (ELVs) and monitoring requirements remain absent although they have been identified. This study seeks to show that current generators could meet emission standards set by the manufacturer's design, if the correct fuel, maintenance, and operating practices are being done. Although theoretical, it is not only possible but to achieve those limits could only require moderate modifications. However, in going forward more guidance on emission standards, permitting, and compliance requirements are necessary.

In this study, I will study the extent of Lebanon's compliance with international generator standards; TCEQ emission standards, thresholds and operating requirements; as well as National Ambient Air Quality Standards (NAAQS) of both the US and Lebanon. This thesis aims to contribute to the development of air emission regulation and compliance that supports the national framework – its culture and practices – while adhering to specific international standards.

### A. Thesis question

To what extent can policy measures in the United States (US) be applied to the state of Lebanon?

### B. Methodology

As a former TCEQ state investigator and consultant within the US, I have had the opportunity to review and submit permit applications for various facilities – including small paint and body car shops to billion-dollar facilities across the country. I reviewed, prepared and submitted permit applications, testing and monitoring reports, stormwater and facility emergency plans for air, water, and waste in fifteen states. I have also conducted audits over a hundred facilities in four states, acted as a representative and liason between clients, state and federal agencies. Some of my projects were clear and but most involved investigative work – conducting audits and examining operating equipment and practices to determine problem origins and how to work around them by changing administrative or engineering practices. Based on my personal experience within state and industry, I followed a certain method that included field observations, noting processes, conditions, and potential constraints.

To first begin answering the question, generators and their owners had to be located. Although I observed many generators, I only chose to use those which I could visually confirm physical conditions and generator specifications myself. For those chosen, I asked the owners a series of questions regarding maintenance, operation and recordkeeping. I also asked what requirements and generator upgrades would be acceptable, which will be discussed in their respective sections.

The parameters taken were the make, model, year, and fuel type; which establish what emission factors the generator was design and manufactured to conform to. These data and factors were plugged into an excel file to develop emission estimates. The estimates are then applied to TCEQ permit authorizations (henceforth authorizations) requirements and emission thresholds. The results determine which parts of US policy could be applied directly, identify key elements necessary for regulatory oversight to public health, and how to achieve regulatory policy specifically tailored to Lebanon.

### C. Scope and Limitations

The scope of this study focuses on theoretical application of implemented US policies, standards and practices on Lebanese private generators. At the time this study was performed I was not living in Lebanon, and therefore I could not take real-time measurements from generator exhaust stacks or perform air dispersion modelling on current exhaust gas locations. Field research was gathered during a limited timeframe on my returns. The 2017 NAQMS identified three needs previously mentioned: updating emission limit values (ELVs) for point sources, establishing a methodology for analysis, and the establishing a monitoring structure. This study focused on that the approach to do all three, while also providing some policy aspects that would not depend on additional field data or testing.

In addition there are other variables noted such as generators sharing stacks or the combination of different fuels and oil to run generators. Generators are typically considered standalone units that don't share an exhaust stack and it's not known if overall emissions could be determined by multiplying the number of units or if it would be exponential. Within the TCEQ this would most likely be considered a single collective source and would be subject to more stringent permits. Case-by-case reviews would be necessary for these situations. Sulfur oxides are primarily determined by the content of the fuel. $SO_2$ factors are based on standardized fuel in the US and EU so their use will not be as accurate as what it should be as the diesel in Lebanon, like other states in the region, have higher levels of sulfur fuel content.

In addition, there are additional permitting and regulatory programs that are present that can affect generators in terms requirements for specific emission controls to meet a lower limit or the installation of continuous monitoring devices. Typically incorporated for areas of non-attainment for NAAQS or major/area sources of hazardous air pollutants; these were not addressed as this these is a proposal for initial policy.

# CHAPTER II

# LEBANON, GENERATORS AND CULTURE

## A. Lebanon

The Lebanese electric power sector is run by the Electricité du Liban (EDL), an autonomous state- owned power utility, whose mission is to generate, transmit, and distribute electricity to all Lebanese territories. Founded by Decree No. 16878, dated July 10, 1964, the EDL controls over 90% of the Lebanese electricity sector.[5] Total power supply is a cumulation of primary hydroelectric, thermal, gas power plants and substations. Before 1975 a majority of the country's electricity was supplied by eleven major power stations that supplied the country with a surplus. The onset of the Civil War in 1975 set electric utilities on decline. The result of the fifteen-year war was devastation to the entire framework of the country, including power plants and the utility grid. Following the end of the Civil War, a restoration plan was launched in order to improve the transmission and supply networks and to expand the generating capacity. The vision involved the rehabilitation of the transmission a and distribution networks as well as capacity expansion. This plan, and many others, proved to not only be insufficient but deficient as well as growing populations and demand were not accounted for. Technical barriers were also present. A major challenge is dealing with technical damages and losses caused by illegal connections to the grid, which causes a fall in the generation capacity to almost fifty percent. [6]this time, illegal links and

5 Fardoun, Farouk, Oussama Ibrahim, Rafic Younes, and Hasna Louahlia-Gualous. "Electricity of Lebanon: Problems and Recommendations." Energy Procedia 19 (2012): 310-20. doi:10.1016/j.egypro.2012.05.211.
6 Khamis, Reem. "Analysis: Electricity in Lebanon, Understanding the Real Problem." Annahar, August 29, 2018. https://en.annahar.com/article/850746-analysis-electricity-in-lebanon-understanding-the-real-problem.

connections to the electricity network also caused mechanical and technical damages that the additional maintenance and repair costs could not be covered. Despite the end of the war and the resulting stability, significant investment and continued degradation of the network; lack of consistent power brought darkness and inactivity to houses and factories for years to come. The inadequacies of government and planning resulted in reliance on self-supplied electricity and paved way for the electricity mafias that until 2018, charged consumers double or more the cost of state electricity.

The end of the civil war, even if you considered the real end to be in 2000 when Israeli forces finally withdrew from the country, did not mean the end of continual degradation to the utility grid. In July 2006, during renewed conflict between Israel and Lebanon, Israeli bombers targeted the Jiyeh power plant south of Beirut. In the days between July thirteenth through the fifteenth, the plant was left in flames and ten to fifteen thousand tons of fuel oil spilled into the sea. Most of the electricity power plants in Lebanon are between 25 to 45 years old and some are even older. Power plants in the country were already in lack of restoration and maintenance and the Jiyeh attack not only polluted the sea but left the vulnerable utility further exposed.

As of 2019, the Syrian uprising turned civil war entered its ninth year, as did Lebanon's refugee crisis. As of October 31, the United Nations High Commission for Refugees (UNHCR) documented over 950,000 Syrian refugees; while the government continues to estimate the numbers closer to 1.5 million. A study by the United Nations (UN) and the government in 2017 states that at least forty five percent of electrical connections done by Syrian households to the grid are done in an illegal manner.[7] As mentioned before illegal connections only cause more damage. Although

7 Lebanon. Ministry of Energy & Water (MoEW). LEBANON CRISIS RESPONSE PLAN 2017-2020. By Suzy Hoayek and Margunn Indreboe. http://www.un.org.lb/library/assets/Energy.pdf.

the population of refugees has declined, demand has not fallen to meet generated electrical output. Despite the decline of refugees, demand has not fallen enough to meet electrical generated output. In fact, it doesn't seem to have affected demand at all. Lebanon's peak electricity demand last year sat at almost 3,500 megawatts, while production hovers at about 2,050 MW[8], which is consistent with the rates in Figure 2.1.

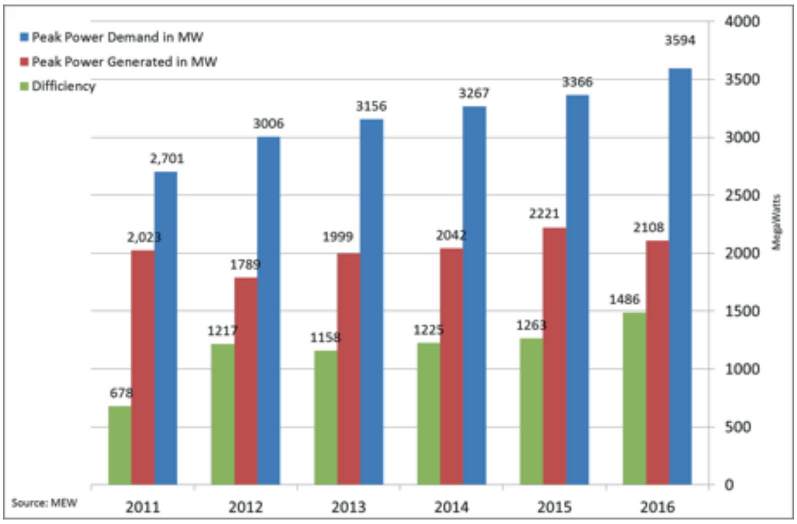


**Figure 2.1. Electricity Generation and Deficiencies**

2010 marked the beginning of several projects targeting electricity production and supply. It was projected that with the passing of six years, the Ministry of Energy and Water (MoEW) and EDL will have provided an additional 715 MW of energy supply capacity once completed.[9] The implementation of the government's reform and investment programs are underway but are being hindered by financial and political obstruction.[10] A new plan adopted this year by the energy ministry involved the

8 Azhari, Timour. "Six New Power Plants in New Electricity Plan." The Daily Star Newspaper - Lebanon. April 4, 2019. Accessed May 14, 2019. http://www.dailystar.com.lb/News/Lebanon-News/2019/Apr-04/480384-six-new-power-plants-in-new-electricity-plan.ashx.
9 Lebanon. Ministry of Energy and Water. Policy Paper for the Electricity Sector. By Gebran Bassil. June 2010. http://www.databank.com.lb/docs/Policy paper for the electricity sector 2010.pdf.
10 Lebanon. Ministry of Energy & Water (MoEW). LEBANON CRISIS RESPONSE PLAN 2017-2020. By Suzy Hoayek and Margunn Indreboe. http://www.un.org.lb/library/assets/Energy.pdf.

building of six new power plants over the next six years[11] and are expected to face the same challenges persisting within government. Despite government obstacles, previous threats to the existing system are still persistent and not addressed specifically. These include poor maintenance, deterioration of facilities, the need for reinforcement of the transmission and distribution network.[12]

### B. Generators

The overall impact of the civil war, subsequent international conflicts and internal conflicts which is dominated by poor government oversight has provided the reliance on generators to continue and will likely still persist. Even in the event that private generators may not be necessary, it is more than likely that they will still exist. The last comprehensive survey was conducted by the Ministry of Industry (MOI) in 2000 according to which there were 22,026 industrial establishments in the country.[13] These industries are mostly located in urban areas where two thirds of Lebanon's population reside.[14] Generators are a standard in industry regardless of their location. Although they are necessary, they come with health risks. What makes them the focus of this study is the lack of policy for generators under 1000MW. No matter the size, the constituency of air emissions remain the same. The particular point that be discussed during this study is not so much the quantity of generators but where they are at. In many cases not only the unit but the exhaust stack is within meters of people,

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11 Azhari, Timour. "Six New Power Plants in New Electricity Plan." The Daily Star - Lebanon (Beirut). Accessed April 4, 2019. http://www.dailystar.com.lb/News/Lebanon-News/2019/Apr-04/480384-six-new-power-plants-in-new-electricity-plan.ashx.

12 "MoEW Energy Sector Strategy LCRP 2017 - 2020." Lecture, Energy National Coordination Meeting, Lebanon, Beirut, February 21, 2017. http://www.cedro-undp.org/content/uploads/event/170301012429364~3-SuzyLCRP-Workshop-21-02-2017.pdf.

13 Lebanon. Ministry of Environment. State and Trends of the Lebanese Environment. 2011. http://www.undp.org.lb/communication/publications/downloads/SOER_en.pdf.

14 Lebanon. Ministry of Interior. Council for Development and Reconstruction. National Land Use Master Plan (2004). 2005.

henceforth referred to as receptors. This threatens traditional ambient air quality standards and exposure limits practiced in the US and elsewhere.

Diesel exhaust forms as a product of internal combustion that occurs when an engine burns diesel fuel. It is a complex mixture of thousands of gases and fine particles that contains more than forty toxic air contaminants. It also contains other harmful pollutants such as nitrogen oxides, which can damage lung tissue, lower the body's resistance to respiratory infection and worsen chronic lung diseases like asthma.

The health effects of diesel exhaust are both acute, from short-term exposure, and chronic, from long-term or repeated exposure. Specific health risks and their severity depend upon the amount of chemical exposed to as well as the duration of the exposure. An acute exposure to diesel exhaust can irritate the eyes, nose, throat and lungs; as wells as causing coughs, headaches, lightheadedness and nausea.[15]

Chronic exposure to diesel exhaust can pose more severe effects on human health, cardinal among them cancer. A lead author of one study, which monitored generators in the Hamra area of Beirut determined that about forty percent of polycyclic aromatic hydrocarbons (PAH) found in the atmosphere were from generators. The lead, Dr. Alan Shihadeh of the American University of Beirut (AUB), warned that the country's continued reliance on diesel generators would lead to higher rates of cancer, respiratory and heart disease.[16] Diesel generators in the country alone are estimated to increase individual exposure to carcinogenic chemicals by forty to fifty percent.[17] The OEHHA estimates that about seventy percent of the cancer risk that the average

15 United States. California Office of Environmental Health Hazard Assessment. Health Effects of Diesel Exhaust. https://oehha.ca.gov/air/health-effects-diesel-exhaust
16 Bossone, Andrew. "Generators Compounding Public Health Risk in Lebanon." Nature Middle East. March 12, 2013. Accessed May 2019. https://www.natureasia.com/en/nmiddleeast/article/10.1038/nmiddleeast.2013.34.
17 Yan, Victoria. "Choking on Toxic Air Pollution." May 4, 2018. PressReader. Accessed May 10, 2019. https://www.pressreader.com.

Californian faces from breathing toxic air pollutants stems from diesel exhaust particles. [18]

The latest National Air Quality Management Strategy (NAQMS, MoE, 2017) highlights air pollution impacts on health and the environment, as well as the resulting ramifications on the economy. A cost-benefit analysis of the Draft Law on Protection of Air Quality in Lebanon determined a benefit to cost ratio of air pollution abatement for the years 2006 – 2025 of 4.6; confirming that the benefits of enhancing air quality monitoring and implementing measures largely exceed the cost of degraded air quality.[19] Similar studies from other countries are also provided in the Strategy, the cost of the European air quality policies was estimated at around €4.5 billion per year in 2030, while the health benefits were estimated to be about €44 billion per year, i.e. ten times the costs. [20] Similar trends are confirmed by the EPA that the benefits of implementing air quality measures under the Clean Air Act (CAA) exceeded the costs by a factor of 30. [21] Albeit the evidence to pursue cleaner air emissions – public health, economics benefits – is strong, implementing regulation or requirements in any aspect does not just cause retaliation but pose significant threats to those issuing them.

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18 United States. California Office of Environmental Health Hazard Assessment. Health Effects of Diesel Exhaust.https://oehha.ca.gov/media/downloads/calenviroscreen/indicators/diesel4-02.pdf.

19 Chabarekh, Capricia, Charbel Afif, Christian Nagl, and George Mitri. "Lebanon's National Strategy for Air Quality Management 2015- 2030." Digital image. Lebanon's National Strategy for Air Quality Management 2015- 2030. January 1, 2018. www.moe.gov.lb/getattachment/83b371ec-8aa0-420f-92fe-7a6a487564b1/.aspx.

20 Chabarekh, Capricia, Charbel Afif, Christian Nagl, and George Mitri. "Lebanon's National Strategy for Air Quality Management 2015- 2030." Digital image. Lebanon's National Strategy for Air Quality Management 2015- 2030. January 1, 2018. www.moe.gov.lb/getattachment/83b371ec-8aa0-420f-92fe-7a6a487564b1/.aspx.

21 Chabarekh, Capricia, Charbel Afif, Christian Nagl, and George Mitri. "Lebanon's National Strategy for Air Quality Management 2015- 2030." Digital image. Lebanon's National Strategy for Air Quality Management 2015- 2030. January 1, 2018. www.moe.gov.lb/getattachment/83b371ec-8aa0-420f-92fe-7a6a487564b1/.aspx.

## C. Culture

The Electricite de Zahle (EDZ), the private local utility, promised subscribers in 2014 that 24/7 electricity would soon be real as early as the beginning of 2015. Local generator owners (or mafias) were not keen on this move. As soon as EDZ made its announcement, local generator owners openly protested the move by blocking roads and burning tires. In 2015 four transformers were assaulted, leaving them out of service and subscribers without electricity for twelve hours a day. Although officially no one was caught in the act, the general view among the citizens is that it was carried out by those who would stand to lose their lucrative business if EDZ's plans were to be implemented.[22] Threats were even made towards the EDZ's chief executive. In the end, EDZ delivered on their promise and remains the only town in Lebanon to have 24-hour electricity that doesn't include private generators. But it didn't come without significant retaliation. Outside Zahle generator mafias still prevail and are still considered the decision makers.

In 2018 the Lebanese state officially declared that generator owners must comply with a new ordinance to install meters by October 1. The decision was a result of the dissatisfaction of consumers who sometimes pay up to six times the amount for generator supplied electricity versus the state. According to the current system, the Energy Ministry-determined rate of one hour of generator production is multiplied by the number of hours with no state-provided electricity to arrive at the generator subscription cost.[23] The meters, which are paid by the generator owners, calculate actual

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22 Baalbaki, Noor. "The Generator Mafia Shatters the Citizens' Dream in Zahle." Heinrich Böll Stiftung Middle East. November 24, 2015. Accessed May 12, 2019. https://lb.boell.org/en/2015/11/24/generator-mafia-shatters-citizens-dream-zahle.

23 "Economy Ministry to Generator Owners: Start Installing Meters." The Daily Star Newspaper - Lebanon. July 12, 2018. Accessed May 12, 2019. http://www.dailystar.com.lb/News/Lebanon-News/2018/Jul-12/456280-economy-ministry-to-generator-owners-start-installing-meters.ashx.

usage. Also, as a result of the heavy practice of tampering, the meters are to be sealed in a transparent, double locked box that reserves a key for the owner and another for the subscriber. The Economy Ministry also advised all subscribers to request a monthly invoice from the generator owner stating the amount paid and the amount in kw/h used during the month.[24] Owners again not only protested against the installation but threatened blackouts across the country. On November 6, some owners moved forward and cut services for people in Tripoli, Baalbeck, Beirut, Sidon and Tyre.

The meters have been installed and emotions have calmed, but the concern remains. Any change that involves generators can lead to protest and retaliation. The development of any policy regarding air emissions must take this into account. Not just the culture must be considered and historical development that led to the rise of generator dependence; but the fact that owners retaliate because of an intended loss of authority and more importantly income. Reduction of air emission will most certainly come a cost, which will be absorbed to some degree by the owners. Acknowledgement of all these factors are crucial.

24 "Economy Ministry to Generator Owners: Start Installing Meters." The Daily Star Newspaper - Lebanon. July 12, 2018. Accessed May 12, 2019. http://www.dailystar.com.lb/News/Lebanon-News/2018/Jul-12/456280-economy-ministry-to-generator-owners-start-installing-meters.ashx.

# CHAPTER III

# EMISSION STANDARDS AND FACTORS

All reciprocating IC engines (RICE) operate similarly. An air-fuel mixture is compressed between the head of a piston and the surrounding cylinder. The mixture is ignited, and the resulting high-pressure products of combustion push the piston down through the cylinder. The downward motion of the piston and connecting rod cause the crankshaft to rotate. The piston returns, pushing out exhaust gases, and the cycle is repeated.

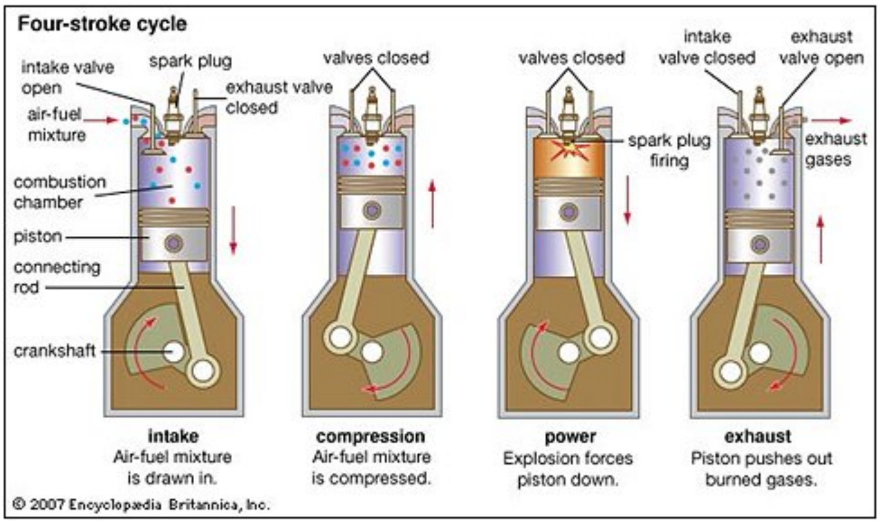


**Figure 3.1. Reciprocating Internal Combustion Engine Cycle.**[25]

There are two methods used for stationary reciprocating IC engines: compression ignition (CI) and spark ignition (SI). All diesel fueled engines are compression ignited,

[25] Dunbar, Brian. "Inside the LEGO Doghouse: Start Me Up!" Inside the LEGO Doghouse: Start Me Up! December 19, 2013. http://dictionary.sensagent.com/J-2 (rocket engine)/en-en/.

and all gasoline-fueled engines are spark ignited. For the purpose of this study, only CI engines are discussed as the engine group examined are electrical-generating diesel-fired engines.

**A. International Engine Tier Standards**

All engines, regardless of the type, are manufactured to adhere to international standards that are formally based on standards adopted in the US and the European Union (EU). The first federal standards – Tier I – for new nonroad (or off-road) diesel engines were adopted in 1994 by the EPA. Tier I applied for all engines over 37 kW (50 hp), which were phased in from 1996 to 2000. These standards are based on the engine power, fuel type and time period of manufacture (i.e, 1996 to 2000 for Tier I). The EU did not adopt standards until 1997, which could been a result of an impending agreement between the EPA and manufacturers. In 1996 a Statement of Principles (SOP) was signed between the EPA, the California Air Resource Board (CARB), and engine makers including Caterpillar, Cummins, Mitsubishi and  Kubota, and others. Finalized in 1998, the SOP and subsequent regulation introduced Tier I standards for engines under 37 kW and increasingly more stringent Tier II and Tier III standards for all equipment with phase in schedules from 2000 – 2008. Tier I – III standards are met through advanced engine design, with no or limited use of exhaust gas aftertreatment technologies. The main difference between the US and EU are the timeframes allowed for phasing in (EU started later, so in order to keep with EPA timeframe phases are shorter and therefore stricter) and the encompassing of standards for engines overs 560 kW. The EU finally adopted standards for engines over 560 kW until Stage V, which was finalized in 2016 and effective as of 2019.

**Table 3.0.1. EPA Tier 1-3 Nonroad Diesel Engine Emission Standards, g/kWh (g/bhp·hr).**[26]

| Engine Power | Tier 1 | Year | CO | HC | NMHC+NOx | NOx | PM |
|---|---|---|---|---|---|---|---|
| kW < 8 (hp < 11) | Tier 1 | 2000 | 8.0 (6.0) | - | 10.5 (7.8) | - | 1.0 (0.75) |
| | Tier 2 | 2005 | 8.0 (6.0) | - | 7.5 (5.6) | - | 0.8 (0.6) |
| 8 ≤ kW < 19 (11 ≤ hp < 25) | Tier 1 | 2000 | 6.6 (4.9) | - | 9.5 (7.1) | - | 0.8 (0.6) |
| | Tier 2 | 2005 | 6.6 (4.9) | - | 7.5 (5.6) | - | 0.8 (0.6) |
| 19≤ kW < 37 (25 ≤ hp < 50) | Tier 1 | 1999 | 5.5 (4.1) | - | 9.5 (7.1) | - | 0.8 (0.6) |
| | Tier 2 | 2004 | 5.5 (4.1) | - | 7.5 (5.6) | - | 0.6 (0.45) |
| 37 ≤ kW < 75 (50 ≤ hp < 100) | Tier 1 | 1998 | - | - | - | 9.2 (6.9) | - |
| | Tier 2 | 2004 | 5.0 (3.7) | - | 7.5 (5.6) | - | 0.4 (0.3) |
| | Tier 3 | 2008 | 5.0 (3.7) | - | 4.7 (3.5) | - | -† |
| 75 ≤ kW < 130 (100 ≤ hp < 175) | Tier 1 | 1997 | - | - | - | 9.2 (6.9) | - |
| | Tier 2 | 2003 | 5.0 (3.7) | - | 6.6 (4.9) | - | 0.3 (0.22) |
| | Tier 3 | 2007 | 5.0 (3.7) | - | 4.0 (3.0) | - | -† |
| 130 ≤ kW < 225 (175 ≤ hp < 300) | Tier 1 | 1996 | 11.4 (8.5) | 1.3 (1.0) | - | 9.2 (6.9) | 0.54 (0.4) |
| | Tier 2 | 2003 | 3.5 (2.6) | - | 6.6 (4.9) | - | 0.2 (0.15) |
| | Tier 3 | 2006 | 3.5 (2.6) | - | 4.0 (3.0) | - | -† |
| 225 ≤ kW < 450 (300 ≤ hp < 600) | Tier 1 | 1996 | 11.4 (8.5) | 1.3 (1.0) | - | 9.2 (6.9) | 0.54 (0.4) |
| | Tier 2 | 2001 | 3.5 (2.6) | - | 6.4 (4.8) | - | 0.2 (0.15) |
| | Tier 3 | 2006 | 3.5 (2.6) | - | 4.0 (3.0) | - | -† |
| 450 ≤ kW < 560 (600 ≤ hp < 750) | Tier 1 | 1996 | 11.4 (8.5) | 1.3 (1.0) | - | 9.2 (6.9) | 0.54 (0.4) |
| | Tier 2 | 2002 | 3.5 (2.6) | - | 6.4 (4.8) | - | 0.2 (0.15) |
| | Tier 3 | 2006 | 3.5 (2.6) | - | 4.0 (3.0) | - | -† |
| kW ≥ 560 (hp ≥ 750) | Tier 1 | 2000 | 11.4 (8.5) | 1.3 (1.0) | - | 0.2 (6.9) | 0.54 (0.4) |

[26] "United States: Nonroad Diesel Engines." Emission Standards: USA: Nonroad Diesel Engines. December 2017. Accessed May 13, 2019. https://www.dieselnet.com/standards/us/nonroad.php.

**Table 3.0.2. EU Emission Standards for Nonroad Diesel Engines.**

| Category | Ignition | Net Power | Date | CO | HC | HC+NOx | NOx | PM | PN |
|---|---|---|---|---|---|---|---|---|---|
| Stage I (1999) | | kW | | g/kWh | | | | | |
| A | - | 130 ≤ P ≤ 560 | 1999.01 | 5 | 1.3 | - | 9.2 | 0.54 | - |
| B | - | 75 ≤ P < 130 | 1999.01 | 5 | 1.3 | - | 9.2 | 0.7 | - |
| C | - | 37 ≤ P < 75 | 1999.04 | 6.5 | 1.3 | - | 9.2 | 0.85 | - |
| Stage II (2001-2004) | | | | | | | | | |
| E | - | 130 ≤ P ≤ 560 | 2002.01 | 3.5 | 1 | - | 6 | 0.2 | - |
| F | - | 75 ≤ P < 130 | 2003.01 | 5 | 1 | - | 6 | 0.3 | - |
| G | - | 37 ≤ P < 75 | 2004.01 | 5 | 1.3 | - | 7 | 0.4 | - |
| D | - | 18 ≤ P < 37 | 2001.01 | 5.5 | 1.5 | - | 8 | 0.8 | - |
| Stage III A (2004) | | | | | | | | | |
| H | - | 130 ≤ P ≤ 560 | 2006.01 | 3.5 | - | 4 | - | 0.2 | - |
| I | - | 75 ≤ P < 130 | 2007.01 | 5 | - | 4 | - | 0.3 | - |
| J | - | 37 ≤ P < 75 | 2008.01 | 5 | - | 4.7 | - | 0.4 | - |
| K | - | 19 ≤ P < 37 | 2007.01 | 5.5 | - | 7.5 | - | 0.6 | - |
| Stage III B (2004) | | | | | | | | | |
| L | - | 130 ≤ P ≤ 560 | 2011.01 | 3.5 | 0.19 | - | 2 | 0.025 | - |
| M | - | 75 ≤ P < 130 | 2012.01 | 5 | 0.19 | - | 3.3 | 0.025 | - |
| N | - | 56 ≤ P < 75 | 2012.01 | 5 | 0.19 | - | 3.3 | 0.025 | - |
| P | - | 37 ≤ P < 56 | 2013.01 | 5 | - | 4.7 | - | 0.025 | - |
| Stage IV (2004) | | | | | | | | | |
| Q | - | 130 ≤ P ≤ 560 | 2014.01 | 3.5 | 0.19 | - | 0.4 | 0.025 | - |
| R | - | 56 ≤ P < 130 | 2014.1 | 5 | 0.19 | - | 0.4 | 0.025 | - |
| Stage V (2016) | | | | | | | | | |
| NRE-v/c-1 | CI | P < 8 | 2019 | 8 | 7.50[a,c] | - | 7.50[a,c] | 0.40[b] | - |
| NRE-v/c-2 | CI | 8 ≤ P < 19 | 2019 | 6.6 | 7.50[a,c] | - | 7.50[a,c] | 0.4 | - |
| NRE-v/c-3 | CI | 19 ≤ P < 37 | 2019 | 5 | 4.70[a,c] | - | 4.70[a,c] | 0.015 | $1\times10^{12}$ |
| NRE-v/c-4 | CI | 37 ≤ P < 56 | 2019 | 5 | 4.70[a,c] | - | 4.70[a,c] | 0.015 | $1\times10^{12}$ |
| NRE-v/c-5 | All | 56 ≤ P < 130 | 2020 | 5 | 0.19[c] | - | 0.4 | 0.015 | $1\times10^{12}$ |
| NRE-v/c-6 | All | 130 ≤ P ≤ 560 | 2019 | 3.5 | 0.19[c] | - | 0.4 | 0.015 | $1\times10^{12}$ |
| NRE-v/c-7 | All | P > 560 | 2019 | 3.5 | 0.19[d] | - | 3.5 | 0.045 | - |
| NRG-v/c-1 | All | P > 560 | 2019 | 3.5 | 0.19[a] | - | 0.67 | 0.035 | - |

## B. US New Source Performance Standards

The new source performance standards (NSPS) for reciprocating internal combustion engines (RICE) establish US federal emission requirements for CI stationary engines. The NSPS rule was initially adopted in 2006 and has been amended several times since. NSPS emission regulations for stationary CI engines are published in the Code of Federal Regulations (CFR), Title 40, Part 60, Subpart IIII.

What separates these emission standards from the previous one is that they only apply to engines whose construction, modification or reconstruction commenced roughly after July 11, 2005.[27] The NSPS rules sets emission standards for NOx, PM, CO and NMHC - depending on the engine size (based on displacement) and application , and set low sulfur fuel requirements for CI stationary engines. Like many rules, federal or state, Subpart IIII also set notification, reporting and recordkeeping requirements which can be found on the Code of Federal Regulations (CFR) online database.

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[27] Standards of Performance for Stationary Compression Ignition Internal Combustion Engines. 40 CFR §60.4200(a). https://www.ecfr.gov/cgi-bin/text-idx?node=sp40.7.60.iiii#sg40.8.60.iiii.sg94

**Table 3.0.3. NSPS Emission Standards for Stationary CI ICEs.**

| Maximum engine power | *All* Pre-2007 model year engines with a displacement <10 liters/cylinder and 2007–2010 model year engines >3,000 HP (>2,237 kW) and with a displacement of <10 liters/cylinder Units: grams/HP-hr (grams/KW-hr) | | | | |
|---|---|---|---|---|---|
| | NMHC + $NO_X$ | HC | $NO_X$ | CO | PM |
| HP<11 (kW<8) | 7.8 (10.5) | - | - | 6.0 (8.0) | 0.75 (1.0) |
| 11≤HP<25 (8≤kW<19) | 7.1 (9.5) | - | - | 4.9 (6.6) | 0.60 (0.80) |
| 25≤HP<50 (19≤kW<37) | 7.1 (9.5) | - | - | 4.1 (5.5) | 0.60 (0.80) |
| 50≤HP<175 (37≤kW<130) | - | - | 6.9 (9.2) | - | - |
| HP≥175 (kW≥130) | - | 1.0 (1.3) | 6.9 (9.2) | 8.5 (11.4) | 0.40 (0.54) |
| **Maximum test speed** | **Pre-2007 model year CI ICEs with displacement ≥10 L/cyl and <30 L/cyl Units: grams/HP-hr (grams/kW-hr)** | | | | |
| <130 rpm | - | - | 12.7 (17.0) | - | - |
| ≥130 and <2000 rpm | - | - | 33.6 x $N^{-0.20}$ (45.0 x $N^{-0.20}$)** | - | - |
| ≥2000 rpm | - | - | 7.3 (9.8) | - | - |

## C. Emission Factors

Emission factors (EFs) are representative values that relate the quantity of a pollutant released with the associated activity.[28] Usually they are simply an average of available data acceptable quality and assumed to be representative of long-term averages.[29] Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply an average of available data of

28 Letcher, Trevor M, and Daniel A Vallero, editors. WASTE: A Handbook for Management. First ed., Academic Press, 2011.
29 United States. Environmental Protection Agency. Office of Air Programs. Compilation of Air Pollutant Emission Factors. 5th ed. Research Triangle Park, NC: US EPA Office of Air Programs, 1995. https://www3.epa.gov/ttn/chief/ap42/toc_kwrd.pdf.

acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category.[30]

### *1. Emission Factor Determinants*

Variations in engine design influence emission factors developed. These include the fuel type, charging method, combustion cycle and method of ignition.

a. Fuel

The three primary fuels for stationary reciprocating IC engines are gasoline, diesel oil, and natural gas. Gasoline is used primarily for mobile and portable engines, natural gas for large stationary IC engines which typically operate pumps or compressors on gas pipelines, and diesel is typically reserved for larger engines.

b. Charging Method

Charging is the method of introducing air or an air and fuel mixture into the cylinder. In a CI engine, fuel is injected into the cylinder near the end of the compression stroke whereas in a SI engine, the fuel is usually added to the air downstream before the mixture enters the cylinder.

c. Combustion Cycle

The combustion process for stationary reciprocating IC engines consists of compressing a combustible mixture with a piston, igniting it, and allowing the high

30 United States. Environmental Protection Agency. Office of Air Programs. Compilation of Air Pollutant Emission Factors – Table 3.3-2. 5th ed. Research Triangle Park, NC: US EPA Office of Air Programs, 1995. https://www3.epa.gov/ttn/chief/ap42/toc_kwrd.pdf.

pressures generated to push the piston back. This process may be accomplished in either four strokes or two strokes of the piston. Two-stroke engines need only two strokes of the piston or one revolution to complete a cycle and four-stroke engines need four.

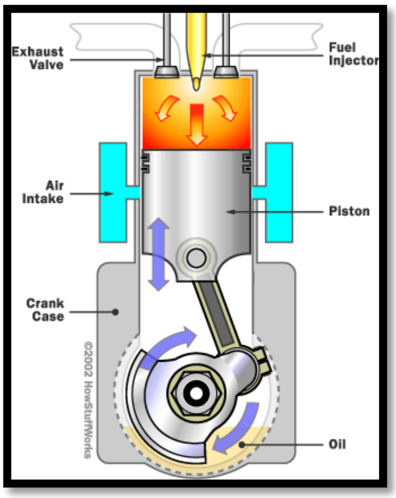


**Figure 3.2. Two Stroke Diesel Engine Cycle.**[31]

d. <u>Method of Ignition</u>

Ignition refers to initiating combustion in the engine cycle. The two methods previously mentioned are SI and CI. In CI engines, combustion air is first compression heated in the cylinder, and diesel fuel oil is then injected into the hot air.[32] At this point, the temperature of the air is high enough to cause the fuel to ignite spontaneously (automatic ignition). SI engines initiate combustion by the spark of an electrical discharge.[33] Figure 1.3 illustrates SI and CI ignitions.

31 Howard, Bill. "Mazda's 2019 Breakthrough: A Diesel Engine That Runs on Gasoline." August 09, 2017. http://www.extremetech.com/extreme/253842-mazdas-2019-efficiency-breakthrough-diesel-engine-runs-gasoline.
32 United States. Environmental Protection Agency. Office of Air Programs. Compilation of Air Pollutant Emission Factors. 5th ed. Research Triangle Park, NC: US EPA Office of Air Programs, 1995. https://www3.epa.gov/ttn/chief/ap42/toc_kwrd.pdf.
33 United States. Environmental Protection Agency. Office of Air Programs. Compilation of Air Pollutant Emission Factors. 5th ed. Research Triangle Park, NC: US EPA Office of Air Programs, 1995. https://www3.epa.gov/ttn/chief/ap42/toc_kwrd.pdf.

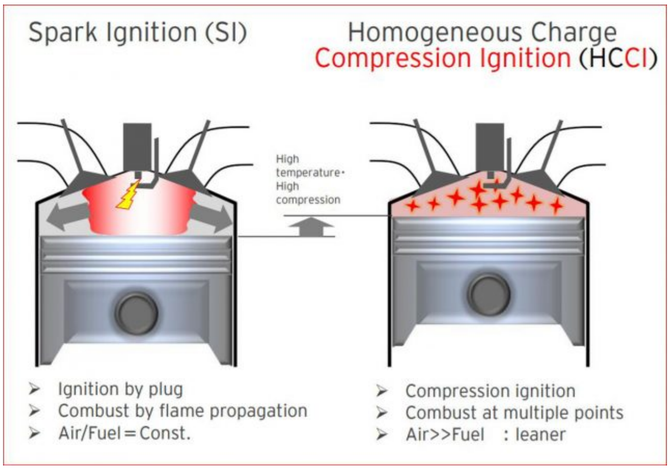


**Figure 3.3. Spark Ignition and Compression Ignition Comparison.**[34]

### 2. *Emission Factor Sources*

The most widely used and trusted source of EFs is *AP-42 Compilation of Air Pollutant Emission Factors* (AP-42) developed by the Office of Air Quality Planning and Standards of the United States Environmental Protection Agency (USEPA). AP-42 provides EFs and recommended methodologies for the most common stationary point and area sources which include external and internal combustion sources, storage tanks, and petroleum and organic chemical process industries. The AP-42 guide was released in 1995 so although it is the most widely accepted source of EFs, it is not the most recent. Increasingly stringent emissions requirements have driven the manufacture of engines that produce far less emissions than those engines that served as a basis for the development of the emission factors found in AP-42.[35] Criteria pollutant and hazardous air pollutant EFs for diesel engines are found in tables 3.4 and 3.5. Tables 3.6 and 3.7 display greenhouse gases and global warming potentials (GWPs).

34 Howard, Bill. "Mazda's 2019 Breakthrough: A Diesel Engine That Runs on Gasoline." August 09, 2017. http://www.extremetech.com/extreme/253842-mazdas-2019-efficiency-breakthrough-diesel-engine-runs-gasoline.
35 "Air Emissions Guide for Air Force Stationary Sources." August 2018. Accessed December 21, 2019. https://aqhelp.com/Documents/2018 StationarySourceGuide.pdf.

## Table 3.0.4. Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines.

| Name | CAS No.[36] | Chemical Formula[37] | Emission Factor[38] |
|---|---|---|---|
| Nitrogen Oxides | NA | NOx | 0.031 |
| Carbon Monoxide | 74-82-8 | CO | 6.68 E-03 |
| Sulfur Oxides | 10024-97-2 | $SO_x$ | 2.05 E-03 |
| Particulate Matter | NA | $PM_{10}$ | 2.20 E-03 |
| Carbon dioxide | 124-38-9 | $CO_2$ | 1.15 |
| Aldehydes | | | 4.63 E-04 |

## Table 3.0.5. Speciated Organic Compound Emission Factors for Uncontrolled Diesel Engines[39]

| Name | CAS No.[40] | Chemical Formula[41] | Emission Factor[42] |
|---|---|---|---|
| Benzene | 71-43-2 | $C_6H_6$ | 9.33 E-04 |
| Toulene | 108-88-3 | $C_7H_8$ | 4.09 E-04 |
| Xylenes | 1330-20-7 | $(CH_3)_2C_6H_4$ | 2.85 E-04 |
| Propylene | 115-07-1 | C3H6 | 2.58 E-03 |
| 1,3 Butadiene | 106-99-0 | $C_4H_6$ | <3.91 E-05 |
| Formaldehyde | 50-00-0 | $CH_2O$ | 1.18 E-03 |
| Acetaldehyde | 75-07-0 | $CH_3CHO$ | 7.76 E-04 |
| Acrolein | 107-02-8 | $CH_2$=CHCHO | <9.25 E-05 |
| PAH[43] | | | |
| *Naphthalene* | 91-20-3 | $C_{10}H_8$ | 8.48 E-05 |
| *Acenaphthylene* | 208-96-8 | $C_{12}H_8$ | <5.06 E-06 |
| *Acenaphthene* | 83-32-9 | $C_{12}H_{10}$ | <1.42 E-06 |
| *Fluorene* | 86-73-7 | $C_{13}H_{10}$ | 2.92 E-05 |
| *Phenanthrene* | 85-01-8 | $C_{14}H_{10}$ | 2.94 E-05 |

36 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
37 Chemical Formulas provided by ChemSpider. http://www.chemspider.com/.
38 EFs expressed in lb/hp-hr
39 United States. Environmental Protection Agency. Office of Air Programs. Compilation of Air Pollutant Emission Factors – Table 3.3-2. 5th ed. Research Triangle Park, NC: US EPA Office of Air Programs, 1995. https://www3.epa.gov/ttn/chief/ap42/toc_kwrd.pdf.
40 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
41 Chemical Formulas provided by ChemSpider. http://www.chemspider.com/.
42 EFs expressed in lb/MMBtu
43 Polycyclic Aromatic Haydrocarbons (PAH)

| Name | CAS No.[40] | Chemical Formula[41] | Emission Factor[42] |
|---|---|---|---|
| *Anthracene* | 120-12-7 | $C_{14}H_{10}$ | 1.87 E-06 |
| *Fluoranthene* | 206-44-0 | $C_{16}H_{10}$ | 7.61 E-06 |
| *Pyrene* | 129-00-0 | $C_{16}H_{10}$ | 4.78 E-06 |
| *Benzo(a)anthracene* | 56-55-3 | $C_{18}H_{12}$ | 1.68 E-06 |
| *Chrysene* | 218-01-9 | $C_{18}H_{12}$ | 3.53 E-07 |
| *Benzo(b)fluoranthene* | 205-99-2 | $C_{20}H_{12}$ | <9.91 E-08 |
| *Benzo(k)fluoranthene* | 207-08-9 | $C_{20}H_{12}$ | <1.55 E-07 |
| *Benzo(a)pyrene* | 50-32-8 | $C_{20}H_{12}$ | <1.88 E-07 |
| *Indio(1,2,3-cd)pyrene* | | | <3.75 E-07 |
| *Dibenz(a,h)anthracene* | 53-70-3 | $C_{22}H_{14}$ | <5.83 E-07 |
| *Benzo(g,h,l)perylene* | 191-24-2 | $C_{22}H_{12}$ | <4.89 E-07 |
| Total PAH | | | 1.68 E-04 |

Global warming potentials are related to GHGs as they were developed to allow comparisons of the global warming impacts from different gases[44]. GWPs are a measure of how much heat a GHG traps in the atmosphere over a given period of time, relative to the $CO_2$.[45] The larger the GWP, the greater potential that gas has to heat the Earth, compared to $CO_2$. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.[46] GWPs listed in Table 4.4 are from the USEPA, compiled from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, published in 2014.

44 "Understanding Global Warming Potentials." EPA. February 14, 2017. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.
45 "Global Warming Potential." Wikipedia. March 29, 2019. https://en.wikipedia.org/wiki/Global_warming_potential.
46 "Understanding Global Warming Potentials." EPA. February 14, 2017. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

**Table 3.0.6. Emission Factors for Greenhouse Gases.**

| Name | CAS No.[47] | Chemical Formula[48] | Emission Factors[49,50] |
|---|---|---|---|
| Carbon dioxide | 124-38-9 | $CO_2$ | 110.00 |
| Methane | 74-82-8 | $CH_4$ | 0.007 |
| Nitrous oxide | 10024-97-2 | $N_2O$ | 0.001 |

**Table 3.0.7. Global Warming Potentials.**

| Name | CAS No.[51] | Chemical Formula[52] | Global Warming Potential[53] |
|---|---|---|---|
| Carbon dioxide | 124-38-9 | $CO_2$ | 1 |
| Methane | 74-82-8 | $CH_4$ | 25 |
| Nitrous oxide | 10024-97-2 | $N_2O$ | 298 |

AP-42 factors may be applicable to older engines (except for GHGs and global warming potentials), and their use in emissions calculations for newer engines may result in the overestimation of pollutant emissions. In lieu of the AP-42 emission factors federal emission standards adopted by the USEPA, known as New Source Performing Standards (NSPS) can be used. The NSPS thresholds were proposed to set standards not only for newly manufactured engines, but also older engines that have been rebuilt or modified.

47 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
48 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
49 Default CO2 Emission Factors and High Heat Values for Various Types of Fuel. Table C-1 to Subpart A, 40 C.F.R. 98 (2014) ECFR.io. https://ecfr.io/Title-40/pt40.23.98#ap40.23.98_138.1
50 Default CH4 and N2O Emission Factors for Various Types of Fuel. Table C-2 to Subpart A, 40 C.F.R. 98 (2014) ECFR.io. https://ecfr.io/Title-40/pt40.23.98#ap40.23.98_138.1
51 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
52 CAS numbers provided by ChemSpider. http://www.chemspider.com/.
53 Global Warming Potentials. Table A-1 to Subpart A, 40 C.F.R. 98 (2014) ECFR.io. https://ecfr.io/Title-40/pt40.23.98#ap40.23.98_19.1

The United States Air Force (USAF) files an Air Emissions Inventory (AEI) each year as required by state and federal agencies. These AEIs are used to determine significant sources of air pollutants, to assist with the development and assess the effectiveness of regulatory and process controls. AEIs are comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors and hazardous air pollutants from air emission sources.[54] The Air Force keeps a tight schedule to remain updated and provide the most current and reliable estimates for their AEI to stay well below the minimum as possible. Therefore, Air Force Civil Engineer Center's (AFCEC) *Air Emissions Guide for Air Force Stationary Sources, Methods for Estimating Emissions of Air Pollutants for Stationary Sources at US Air Force Installations* is regarded as the most current agency accepted source of EFs and recommended methodologies for calculating actual pollutant emissions from these sources. The USAF Emissions Guide combines EFs from AP-42 and the NSPS to provide the best emissions estimates, which means using the best EF to achieve the most accurate or lowest emissions. The USAF factors are represented in Tables 3.8 and 3.9.

54 "National Emissions Inventory (NEI)." EPA. November 29, 2017. Accessed April 25, 2019. http://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei.

**Table 4.5 Criteria Pollutant Emission Factors for Stationary Compression Ignition Internal Combustion Engines**

| Maximum Engine Power | Displacement (L/cylinder) | Model Year | *Emission Factors*[1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NOX[2] | | CO[3] | | SOX[3] | | VOC[4] | | PM10[3] | | PM2.5[3] | |
| | | | (lb/hp-hr) | (lb/MMBtu) | (lb/hp-hr) | (lb/MMBtu) | (lb/hp-hr) | (lb/MMBtu) | (lb/hp-hr) | (lb/MMBtu) | (lb/hp-hr) | (lb/MMBtu) | (lb/hp-hr) | (lb/MMBtu) |
| **All Dual Engines** | | | | | | | | | | | | | | |
| All | | | 1.80 E-02 | 2.70 E+00 | 7.50 E-03 | 1.16 E+00 | 7.31 E-06 | 7.02 E-04 | 1.32 E-03 | 2.00 E-01 | 7.00 E-04 | 1.00 E-01 | 7.00 E-04 | 1.00 E-01 |
| **Diesel Fuel Engines** | | | | | | | | | | | | | | |
| **hp <600** | **<10** | **Pre 2007 and Fire Pumps** | 3.57 E-02 | 4.41 E+00 | 7.68 E-03 | 9.50 E-01 | 2.35 E-03 | 2.90 E-01 | 2.79 E-03 | 3.44 E-01 | 2.51 E-03 | 3.10 E-01 | 2.51 E-03 | 3.10 E-01 |
| | | **2007 - Present** | 1.15 E-02 | 1.42 E+00 | 7.68 E-03 | 9.50 E-01 | 2.35 E-03 | 2.90 E-01 | 8.98 E-04 | 1.11 E-01 | 1.32 E-03 | 1.63 E-01 | 1.32 E-02 | 1.63 E-01 |
| **600 < hp < 3000** | **<10** | **Pre 2007 and Fire Pumps** | 2.59 E-02 | 3.20 E+00 | 6.88 E-03 | 8.50 E-01 | 1.23 E-05 | 1.52 E-03 | 7.16 E-04 | 8.86 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |
| | | **2007 - Present** | 1.03 E-02 | 1.27 E+00 | 5.75 E-03 | 7.11 E-01 | 1.23 E-05 | 1.52 E-03 | 7.04 E-04 | 8.70 E-02 | 3.29 E-04 | 4.06 E-02 | 3.29 E-04 | 4.06 E-02 |
| | **10 < D < 30** | **Pre 2007 and Fire Pumps** | 2.59 E-02 | 3.20 E+00 | 6.88 E-03 | 8.50 E-01 | 1.23 E-05 | 1.52 E-03 | 7.16 E-04 | 8.86 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |
| | | **2007 - Present** | 1.76 E-02 | 2.18 E+00 | 5.75 E-03 | 7.11 E-01 | 1.23 E-05 | 1.52 E-03 | 4.88 E-04 | 6.03 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |
| **hp > 3000** | **<10** | **Pre 2007 and Fire Pumps** | 2.59 E-02 | 3.20 E+00 | 6.88 E-03 | 8.50 E-01 | 1.23 E-05 | 1.52 E-03 | 7.16 E-04 | 8.86 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |
| | | **2007 - Present** | 1.03 E-02 | 1.27 E+00 | 5.75 E-03 | 7.11 E-01 | 1.23 E-05 | 1.52 E-03 | 7.04 E-04 | 8.70 E-02 | 3.29 E-04 | 4.06 E-02 | 3.29 E-04 | 4.06 E-02 |
| | **10 < D < 30** | **Pre 2007 and Fire Pumps** | 2.59 E-02 | 3.20 E+00 | 6.88 E-03 | 8.50 E-01 | 1.23 E-05 | 1.52 E-03 | 7.16 E-04 | 8.86 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |
| | | **2007 - Present** | 1.76 E-02 | 2.18 E+00 | 6.88 E-03 | 8.50 E-01 | 1.23 E-05 | 1.52 E-03 | 4.88 E-04 | 6.03 E-02 | 8.09 E-04 | 1.00 E-01 | 8.09 E-04 | 1.00 E-01 |

1. Values either AP-42 or NSPS worst-case for years specificed.
2. Source (unless otherwise stated): Subpart IIII, "Title 40 - Protection of the Environment, Chapter I - Environmental Protection Agency, Subchapter C- Air Programs, Part 60 - Standards of Performance for New Stationary Sources, Subpart IIII Standards of Performance for Stationary Compression Ignition Internal Combustion Engines," USEPA.
3. Source (unless otherwise stated): USEPA Compilation of Air Pollutant Emission Factors Volume I: Stationary Point and Area Sources. Fifith Edition. 2000. Chapter 3.
4. Source (unless otherwise stated): VOC emission factrs were estimated using the THC or NMHC values as determined in note 2. TOC emissionfactor given in AP-42 assumed to be equal to TOG.

**Table 4.6 HAP Emission Factors for Stationary Compression Ignition Internal Combustion Engines**

| Compound | Emission Factors | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | hp<600 | | | | 600<hp<3000 | | | | | | hp>3000 | | | | | | | | | |
| | Pre-2007 | | Displacement <10L/cylinder 2007-Present | | Pre-2007 | | Displacement <10L/cylinder 2007-Present | | Displacement 10<D<30L/cylinder 2007-Present | | Pre-2007 | | Displacement <10L/cylinder 2007-Present | | Displacement 10<D<30L/cylinder 2007-Present | | | | | |
| | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | (lb/hp-hr) | (lb/MMMBtu) | | | | |
| 1,3-Butadiene | 3.16E-07 | 3.91E-05 | 1.02E-07 | 1.26E-05 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | | | |
| Acenaphthene | 1.15E-08 | 1.42E-06 | 3.70E-09 | 4.57E-07 | 3.79E-08 | 4.68E-06 | 3.72E-08 | 4.60E-06 | 2.58E-08 | 3.19E-06 | 3.79E-08 | 4.68E-06 | 3.72E-08 | 4.60E-06 | 2.58E-08 | 3.19E-06 | | | | |
| Acenaphthylene | 4.09E-08 | 5.06E-06 | 1.32E-08 | 1.63E-06 | 7.47E-08 | 9.23E-06 | 7.33E-08 | 9.07E-06 | 5.08E-08 | 6.28E-06 | 7.47E-08 | 9.23E-06 | 7.33E-08 | 9.07E-06 | 5.08E-08 | 6.28E-06 | | | | |
| Acetaldehyde | 6.20E-06 | 7.67E-04 | 2.00E-06 | 2.47E-04 | 2.04E-07 | 2.52E-05 | 2.00E-07 | 2.48E-05 | 1.39E-07 | 1.72E-05 | 2.04E-07 | 2.52E-05 | 2.00E-07 | 2.48E-05 | 1.39E-07 | 1.72E-05 | | | | |
| Acrolein | 7.48E-07 | 9.25E-05 | 2.41E-07 | 2.98E-05 | 6.37E-08 | 7.88E-06 | 6.26E-08 | 7.74E-06 | 4.34E-08 | 5.36E-06 | 6.37E-08 | 7.88E-06 | 6.26E-08 | 7.74E-06 | 4.34E-08 | 5.36E-06 | | | | |
| Anthracene | 1.51E-08 | 1.87E-06 | 4.87E-09 | 6.02E-07 | 9.95E-09 | 1.23E-06 | 9.77E-09 | 1.21E-06 | 6.77E-09 | 8.37E-07 | 9.95E-09 | 1.23E-06 | 9.77E-09 | 1.21E-06 | 6.77E-09 | 8.37E-07 | | | | |
| Benz(a)anthracene | 1.36E-08 | 1.68E-06 | 4.38E-09 | 5.41E-07 | 5.03E-09 | 6.22E-07 | 4.94E-09 | 6.11E-07 | 3.42E-09 | 4.23E-07 | 5.03E-09 | 6.22E-07 | 4.94E-09 | 6.11E-07 | 3.42E-09 | 4.23E-07 | | | | |
| Benzene | 7.55E-06 | 9.33E-04 | 2.43E-06 | 3.01E-04 | 6.28E-06 | 7.76E-04 | 6.17E-06 | 7.62E-04 | 4.27E-06 | 5.28E-04 | 6.28E-06 | 7.76E-04 | 6.17E-06 | 7.62E-04 | 4.27E-06 | 5.28E-04 | | | | |
| Benzo(a)pyrene | 1.52E-09 | 1.88E-07 | 4.90E-10 | 6.06E-08 | 2.08E-09 | 2.57E-07 | 2.04E-09 | 2.52E-07 | 1.42E-09 | 1.75E-07 | 2.08E-09 | 2.57E-07 | 2.04E-09 | 2.52E-07 | 1.42E-09 | 1.75E-07 | | | | |
| Benzo(b)fluoranthene | 8.02E-10 | 9.91E-08 | 2.58E-10 | 3.19E-08 | 8.98E-09 | 1.11E-06 | 8.82E-09 | 1.09E-06 | 6.11E-09 | 7.56E-07 | 8.98E-09 | 1.11E-06 | 8.82E-09 | 1.09E-06 | 6.11E-09 | 7.56E-07 | | | | |
| Benzo(g,h,i)perylene | 3.96E-09 | 4.89E-07 | 1.27E-09 | 1.58E-07 | 4.50E-09 | 5.56E-07 | 4.42E-09 | 5.46E-07 | 3.06E-09 | 3.78E-07 | 4.50E-09 | 5.56E-07 | 4.42E-09 | 5.46E-07 | 3.06E-09 | 3.78E-07 | | | | |
| Benzo(k)fluoranthene | 1.25E-09 | 1.55E-07 | 4.04E-10 | 4.99E-08 | 1.76E-09 | 2.18E-07 | 1.73E-09 | 2.14E-07 | 1.20E-09 | 1.48E-07 | 1.76E-09 | 2.18E-07 | 1.73E-09 | 2.14E-07 | 1.20E-09 | 1.48E-07 | | | | |
| Chrysene | 2.86E-09 | 3.53E-07 | 9.20E-10 | 1.14E-07 | 1.24E-08 | 1.53E-06 | 1.22E-08 | 1.50E-06 | 8.42E-09 | 1.04E-06 | 1.24E-08 | 1.53E-06 | 1.22E-08 | 1.50E-06 | 8.42E-09 | 1.04E-06 | | | | |
| Dibenz(a,h)anthracene | 4.72E-09 | 5.83E-07 | 1.52E-09 | 1.88E-07 | 2.80E-09 | 3.46E-07 | 2.75E-09 | 3.40E-07 | 1.91E-09 | 2.36E-07 | 2.80E-09 | 3.46E-07 | 2.75E-09 | 3.40E-07 | 1.91E-09 | 2.36E-07 | | | | |
| Fluoranthene | 6.16E-08 | 7.61E-06 | 1.98E-08 | 2.45E-06 | 3.26E-08 | 4.03E-06 | 3.20E-08 | 3.96E-06 | 2.22E-08 | 2.74E-06 | 3.26E-08 | 4.03E-06 | 3.20E-08 | 3.96E-06 | 2.22E-08 | 2.74E-06 | | | | |
| Fluorene | 2.36E-07 | 2.92E-05 | 7.61E-08 | 9.41E-06 | 1.04E-07 | 1.28E-05 | 1.02E-07 | 1.26E-05 | 7.05E-08 | 8.71E-06 | 1.04E-07 | 1.28E-05 | 1.02E-07 | 1.26E-05 | 7.05E-08 | 8.71E-06 | | | | |
| Formaldehyde | 9.55E-06 | 1.18E-03 | 3.07E-06 | 3.80E-04 | 6.38E-07 | 7.89E-05 | 6.27E-07 | 7.75E-05 | 4.34E-07 | 5.37E-05 | 6.38E-07 | 7.89E-05 | 6.27E-07 | 7.75E-05 | 4.34E-07 | 5.37E-05 | | | | |
| Indeno(1,2,3-c,d)pyrene | 3.03E-09 | 3.75E-07 | 9.77E-10 | 1.21E-07 | 3.35E-09 | 4.14E-07 | 3.29E-09 | 4.07E-07 | 2.28E-09 | 2.82E-07 | 3.35E-09 | 4.14E-07 | 3.29E-09 | 4.07E-07 | 2.28E-09 | 2.82E-07 | | | | |
| Naphthalene | 6.86E-07 | 8.48E-05 | 2.21E-07 | 2.73E-05 | 1.05E-06 | 1.30E-04 | 1.03E-06 | 1.28E-04 | 7.16E-07 | 8.85E-05 | 1.05E-06 | 1.30E-04 | 1.03E-06 | 1.28E-04 | 7.16E-07 | 8.85E-05 | | | | |
| Phenanthrene | 2.38E-07 | 2.94E-05 | 7.66E-08 | 9.47E-06 | 3.30E-07 | 4.08E-05 | 3.24E-07 | 4.01E-05 | 2.25E-07 | 2.78E-05 | 3.30E-07 | 4.08E-05 | 3.24E-07 | 4.01E-05 | 2.25E-07 | 2.78E-05 | | | | |
| Pyrene | 3.87E-08 | 4.78E-06 | 1.25E-08 | 1.54E-06 | 3.00E-08 | 3.71E-06 | 2.95E-08 | 3.64E-06 | 2.04E-08 | 2.53E-06 | 3.00E-08 | 3.71E-06 | 2.95E-08 | 3.64E-06 | 2.04E-08 | 2.53E-06 | | | | |
| Toluene | 3.31E-06 | 4.09E-04 | 1.07E-06 | 1.32E-04 | 2.27E-06 | 2.81E-04 | 2.23E-06 | 2.76E-04 | 1.55E-06 | 1.91E-04 | 2.27E-06 | 2.81E-04 | 2.23E-06 | 2.76E-04 | 1.55E-06 | 1.91E-04 | | | | |

# CHAPTER IV

# EMISSION AUTHORIZATIONS

This section answers the question of what is required for the authorization to operate, or a permit, in the United States. All environmental regulatory programs are under the auspices of the EPA. State environmental agencies are delegated authority by the EPA to implement and enforce responsibilities, like the Clean Air Act (CAA). Certain programs remain constant across the US, while others vary and states are able to choose if they not only adopt the same stringency as the EPA but go further in their demands. Although California is the most stringent in the US, I chose not to pursue that route because the rules have forced many industries and companies to relocate outside the state. It may also not be the best to reference in entirety because Lebanon, as discussed in Chapter 2, may not be as receptive. Instead I opted for the Texas Commission on Environmental Quality (TCEQ). As an environmental air compliance specialist, I have worked in fifteen states, not including California. My experience led me to this decision not only because it runs second to California, but the breadth and cover of rules and resources are abundant, a majority of dual EPA-pilot studies are conducted in the state, and it has represented itself as a role model for accommodating citizens, industry, environmental and public health and progression. The following authorizations are in order from most to stringent, as defined by the TCEQ. Policy proposals discussed later are based off these authorizations, and described below. There are two categories of permits, New Source Review (NSR) and Title V.

## A. New Source Review

Within the EPA there are different levels of emission limitations based on threats to health and environment and also general emissions produced from a singular source. A majority of states have two permit categories that relate to the level of emissions, with each category having a set of permits.

### *1. Insignificant Sources*

Insignificant sources (also known as de minimus) are those who include very small additions to background concentrations of air contaminants that cause no discernable or unacceptable impact to public health and for which permitting would be an ineffective use of resources.[55] Some examples of de minimus sources are water heaters, office equipment, and education laboratories/training. No official authorization or registration is needed as long as all emissions associated with a facility meet the following basic criteria:

- Proximity to receptors;
- Rate of emission of air contaminants;
- Engineering judgement of experience; and
- Determination that no adverse toxicological or health effects would occur off property. [56]

### *2. Permit by Rule*

Facilities that do not meet the de minimus criteria but will not make a significant contribution of air contaminants to the atmosphere may be permitted by rule (PBR). All

55 "Air Permitting Basics." Air Permitting 101.
http://www.tceq.texas.gov/assets/public/permitting/air/ap101/ap101basics/index.html.
56 30 Tex. Admin. Code §116.119

PBRs must meet general requirements such as recordkeeping, distance and emission limitations. In addition, sources that are applicable to PBR authorizations may have additional specific emission source requirements that must be met.

Subchapter A of chapter 106 of the Texas Administrative Code (TAC) has the following general requirements that would apply to generators. Table 5.1 list the PBR emission limitations, which are set in accordance with 30 TAC §106.4 under Subchapter A. A copy of the rule is provided in Appendix A, Texas Administrative Code (TAC) Permit by Rules.

**Table 4.1. PBR Emission Limitations.**

| Air Contaminant | Emission Thresholds (tpy)[57] |
|---|---|
| CO or NOx | 250 |
| VOC, $SO_2$ | 25 |
| $PM_{10}$ | 15 |
| $PM_{2.5}$ | 10 |
| All others[58] | 25 |
| HAPs | 25 |

### *3. Standard Permits*

Standard permits may authorize more emissions than that of a PBR. What sets them apart is that they are developed using worst case scenarios. These permits authorize the construction or modification of new or existing facilities to obtain authorization as an alternative to a case-specific air quality permit. Standards permits cannot be used to authorize emissions that will trigger major NSR permitting but they

57 30 Tex. Admin. Code §106.4
58 "All Others" excludes water, nitrogen, ethane, hydrogen, oxygen and GHGs

do require the use of best available control technology (BACT).[59] The most popularly known industrial processes applicable to standard permits are oil and gas facilities, concrete batch plants and electric generating units. Standard permits must be renewed every ten years.

a. Minor New Source Review

Minor NSR Permits are set by case-by-case reviews and are considered if they do not trigger major source permitting and the above-mentioned permits are not attainable. These permits provide more flexibility as they allow for more emissions and, unlike a PBR or standard permit, facility-specific information can be considered during the technical review that includes a BACT and impacts review.[60] Furthermore, unlike the other previously discussed permits NSR permits are subject to public notice and an opportunity for a contested case hearing.[61]

b. Major New Source Review

These are case-by-case permits for major sources that do not trigger the larger Title V permit category. These permits are largely in part determined by whether or not the area (i.e. county, municipality) meets NAAQS. A nonattainment area is a defined region which is designated by the EPA as failing to meet the NAAQS for a pollutant for which a standard exists.[62] The EPA Green Book currently details nonattainment areas

59 "Air Permitting Basics." Air Permitting 101. http://www.tceq.texas.gov/assets/public/permitting/air/ap101/ap101basics/index.html.
60 "Air Permitting Basics." Air Permitting 101. http://www.tceq.texas.gov/assets/public/permitting/air/ap101/ap101basics/index.html.
61 "Air Permitting Basics." Air Permitting 101. http://www.tceq.texas.gov/assets/public/permitting/air/ap101/ap101basics/index.html.
62 30 Tex. Admin. Code § 116.10(12)

for criteria pollutants for the US. Criteria pollutants are $SO_2$, CO, PM, $NO_2$, Lead (Pb), and Ozone.

New major sources and modifications in a designated nonattainment area are required to go through Nonattainment NSR permitting. New emissions must be offset by actual emission reductions achieved elsewhere in the nonattainment area, meaning that one facility can increase emissions if another facility is able to reduce theirs. These type of emission transfers are known as emissions banking and trading.

Another type of major NSR permit is known as the Prevention of Significant Deterioration (PSD). Major new sources and modifications in an attainment area are subject to PSD. A source that emits or has the potential to emit (PTE).[63] a federally regulated NSR pollutant at or above the emission threshold is considered major for PSD pollutants. These permits require the implementation of BACT, air dispersion modeling and possibility of purchasing unused emission credits from another facility (or upgrading a competitor facility). The pyramid below illustrates NSR authorizations in relation to increasing emissions.

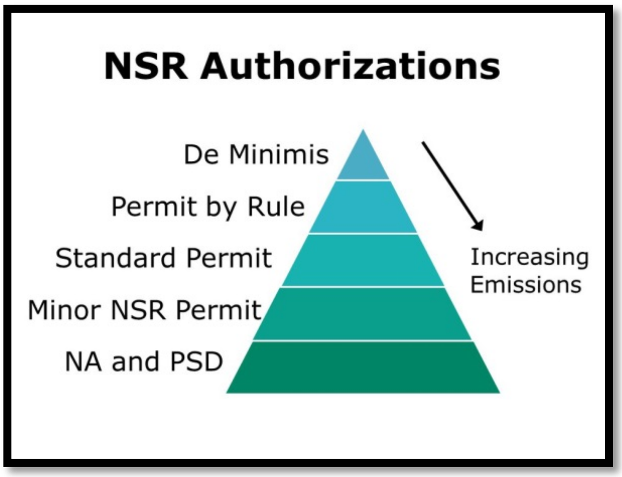


**Figure 4.1. TCEQ NSR Authorization Pyramid.**[64]

63 PTE is the maximum capacity of a stationary source to emit a pollutant under its physical and operational design.
64 "Air Permitting Overview. - Ppt Download." Texas Commission on Environmental Quality, Texas Commission on Environmental Quality Small Business & Local Government Assistance, 2017.

## B. Title V

There are two main types of Title V permits, site operating permits and general operating permits. Both have the same emission limitations. Both permits under this section are subject to public notice, hearings, state and EPA review, and public contest or petition. Typical plants facilities that would most likely be applicable to this category are the power and cement plants.

**Table 4.2. TCEQ NSR Authorization Pyramid.**[65]

| Air Contaminant | Emission Threshold (tpy)[66] |
|---|---|
| HAP (any single) | ≥10 |
| HAPs (any combination) | ≥25 |
| All others | ≥100 |

### *1. Standard Operating Permits*

Site operating permits (SOPs) are permits that contain requirements specific to an individual site and therefore are case-by-case reviews. The permits contain requirements that apply to the site as a whole, as well as requirements that are specific to individual emission units.

### *2. General Operating Permits*

General operating permits (GOPs), like standard permits and PBRs, cover similar sites. Examples of sites include oil and gas, air curtain incinerators and municipal solid waste landfills.

65 "Air Permitting Overview. - Ppt Download." Texas Commission on Environmental Quality, Texas Commission on Environmental Quality Small Business & Local Government Assistance, 2017.
66 30 Tex. Admin. Code § 122.10(13)(A)

# CHAPTER 5

# Al-MINA GENERATOR METHODOLOGY FOR ANALYSIS

In these section three things are presented that make up the overall methodology used to answer the main question of this thesis: collection of data (Field Data), potential emissions analysis, and potential authorization applicability. In the methodology I describe the way I achieved the results presented, which are a combination of the typical field auditing practices and data collecting. In permitting there are two types of emission estimates used to determine applicability, potential to emit (PTE) and actual emissions. Both are needed for the initial registration or application for a new source. Potential to emit is defined in 30 TAC 122 as the maximum capacity of a stationary source to emit any air pollutant under its physical and operational design or configuration. PTE is a theoretical calculation, which may differ from actual emissions used to determine if a site is a major source as described in the previous chapter. Actual emissions are based on the expected daily capacity a stationary source will run under. Major sources are those who emit or have the PTE equal to or greater than the thresholds in Table 4.2. The last section describes the maintenance, reporting and recordkeeping (MRR) practices usually applied to generators, if the Al-Mina generators could or need to apply, or point out critical issues regardless of necessity.

## A. Field Data

When presented with a project as a consultant, I am typically asked "What permit do I need if I need one?" As a former investigator and auditor for oil and gas companies I ask two questions: *What information and materials do you have;* and second, *when can I visit the site?* More than once I had little to know information and had to rely on my personal experience and knowledge, as well as be ready for the expected. In particular, it's very common for generators (regardless of their stationary status), to be uprooted, misplaced between sites, vanished or replaced with a completely unknown new one (as determined but each unique engine serial number). Therefore, as the first step I walked outside and went looking.

### *1. Engine Data*

Generators in Lebanon are not the norm in terms of typical operation design. Usually generators are found in the open, either alone or in a group secluded from other pieces of equipment or in a ventilated overhang or warehouse. Exhaust stacks can be fifteen or more feet high easily recognizable. In Lebanon generators can be found anyway from basements, sidewalks or directly on the outside of the building itself. The stacks are not always visible but the sound and odor will give them away. The photos below represent generator observed but not verified (and subsequently not used in PTEs). Both were located adjacent to walkways and several receptor buildings. These are just an example of the many hundreds of generators that are right next to people, every day.

**Figure 5.1. Generator Examples, Al-Mina**

To determine PTE I needed four things: verification of fuel, daily hours of operation for both the summer and winter, the engine make and model. To accomplish this I requested access from owner to see the inside of the generator and take this engine specific data directly from the source. Every generator has a one or two nameplate that have the make, model, serial number and sometimes supplementary data. For fuel records I requested a copy of a recent fuel purchase. Unless both of these were supplied I did not use the engines specifically in PTE estimates.

Once I obtained that data, any remaining information can be found via a simple online search for manufacturer specifications specific to the model in question. Under the TCEQ, authorizations can come in stages. For new facilities or equipment, a permit application should be submitted before the start of the equipment. Initial mission estimates are required part of the application and involve the correct application of emission factors and most conservative estimate of operational hours to determine them. For calculations, either the manufacturer provides emission factors (which comes with certified performance testing) or I go to alternative sources like the US Air Force guide. The second component, operation hours, the standard 8760 hours is applied. In this case however I used the summer and winter schedules. Explanation of a permit application is relevant because no equipment testing is typically needed at this time, and manufacturer testing will typically suffice. I am trying to establish PTEs, not actuals.

### *2. Maintenance, Recordkeeping, and Reporting*

Maintenance, recordkeeping, and reporting are standard requirements for authorization. Not all generators require continuous emissions monitoring equipment (CEMS) or regular stack testing. The most important of these are maintenance, which is used to confirm optimal operation of the equipment; hours of operation, to determine to the unit is under the limit set by the determination of annual PTE; and fuel records, to ensure that the engine is running on the manufacturer's intended fuel use for the design which also ensures efficiency. Generators owners were reluctant in allowing me to share documents beyond myself, so none are provided. But in general some type of recordkeeping is present. Maintenance may not always be consistent and reporting is not required, the onset to the usage-meters means that each owner – and their subscriber – have records of operating hours.  In these sessions the most important question ask was their feeling and response to any if not all MRR and testing requirements for TCEQ rules. The follow table demonstrates those requirements owners would concede to:

**Table 5.1. Stationary Engine >500 hp Requirements.**

| Source[67] | Description |
|---|---|
| 30 TAC §106.512 (1) | Submit registration for each engine rated above 240 hp. |
| 30 TAC §106.50 | A $100 fee is required if the owner/operator is a small business which has fewer than 100 employees. For all other the fee is a standard $450.* |
| 30 TAC §106.8 (c)(1) | Maintain a copy of the requirements. |
| | Operate and maintain engine according to manufacturer specifications, including the use of diesel fuel as the sole fuel type unless the engine is designed to be duel fueled. |
| | Maintain all records of engine maintenance, fuel consumption (fuel purchases), emissions testing (if available), and manufacturer operations/maintenance manual |
| 30 TAC §106.8 (c)(2) | Maintain records of the general requirements and all applicable PBR conditions |
| 30 TAC §106.8 (c)(3) | Keep all required records at the facility or readily available location |
| 30 TAC §106.8 (c)(4) | Make the records available in a reviewable format |
| 30 TAC §106.261 (2) | Total new emissions shall not exceed 6.0 lb/hr and 10tpy of specified materials |
| 30 TAC §106.512 (2)(C) | Records shall be created and maintained by the owner or operator for two years and made available upon request. |

*From the nine operators spoken to, this was the only requirement that wasn't met with complete agreement, but wasn't ruled out either.

For registration purposes, the following at a minimum should be requested:

1. legal name, address and telephone number of the owner;
2. Legal name, address and telephone number of the owner of the premises on which the subject activity is to take place;
3. Location and address of the premises where the registered activity will be conducted;
4. Intended dates of construction, installation and operation;
5. Make, model and serial number of the generator;
6. Fuel type;
7. Maximum rated fuel-firing rate of the generator;
8. Maximum design gross power output of the subject generator.

67 30 Tex. Admin. Code §106.4, §106.8, §106.512

## B. Emissions Analysis

This section outlines the two steps in determining overall PTE – emission calculations and emission estimates.

### *1. Emission Calculations*

The hourly and annual calculations presented here and in the attached excel file are based on methodologies found in both the *AP-42 Compilation of Air Pollutant Emission Factors* (AP-42) and the TCEQ *Oil & Gas Emissions Spreadsheet.* [68] For greenhouse gases, the formulas are taken from 40 CFR Subpart A Part 98 for Mandatory Greenhouse Gas Reporting.

a. <u>Hourly Emissions</u>

For emission factors in terms of pounds per horsepower-hour (lb/hp-hr) the following equation is used:

Emission Factor (lb/hp-hr) * Rated Capacity (hp) = lb/hr

*Ex:* $SO_2$ *(lb/hr)* = 1.23E-05 lb/hp-hr * 796 hp = 0.01 lb/hr

For emission factors in terms of grams per horsepower-hour (g/hp-hr) the following equation is used:

Emission Factor (g/hp-hr) * Rated Capacity (hp) / Conversion Factor = lb/hr

*Ex: VOC (lb/hr)* = 9.69E-01 g/hp-hr * 796 hp / 453.592 = 1.70 lb/hr

68 "Oil and Gas Emission Calculation Spreadsheet?" What Is the Oil and Gas Emission Calculation Spreadsheet? November 29, 2018. Accessed December 5, 2018. https://www.tceq.texas.gov/permitting/air/newsourcereview/chemical/og-req5.html.

b. Annual Emissions

For emission factors in terms of lb/hp-hr and grams/hp-hr the following equation is used:

Hourly Emissions (lb/ hr) * Operating Hours / Conversion Factor

*Ex: VOC (lb/hr)* = 1.70 lb/hr * 2,190 hrs / 2000 = 1.86 tons per year (tpy)

c. Greenhouse Gas Emissions

GHG emissions are usually expressed in tpy. Global warming potential (GWP) factors, taken from Table A-1 of 40 CFR Subpart A Part 98 for Mandatory Greenhouse Gas Reporting are used to determine GHG emissions in tpy. The basic equation is:

$$CO_2e = CO_2 + (CH_4*25) + (N_2O*298)$$

Where $CO_2$ represents emissions in pounds per hour (lb/hr) or tons per year (tpy).

*Ex: CO2e (tpy) = 1,002.36 + (0.27*25) + (0.05*298) = 1,083 tpy*

d. 30 TAC §106.261(a)(2) Emission Limitations

The emission limitation of this PBR requires that total new or increased emissions, including fugitives, shall not exceed 6.0 lb/hr and 10 tpy of certain materials. Only one chemical applied and it represented in the example. To determine the rates, summer and winter hourly and annual were averaged.

*Ex: (15.68 + 10.45) / 2 = 8.35 lb/hr CO*

e. <u>30 TAC §106.262(a)(2) Emission & Distance Limitations</u>

This PBR requirement confirms the minimum distance requirement to prevent undue exposure to possible receptors. The basic equation, taken directly from the rule, is as follows:

E = L/K

where:

E = maximum allowable hourly emission

L = value as listed or referenced in Table 262

K = value from Figure 1: 30 TAC §106.262(a)(2)

D = distance to the nearest off-plant receptor

*Ex: 100 ft / 326 = 0.03 lb/hr Acetaldehyde*

### *2. Emission Estimates*

The following tables represent those emissions using the above formulas and were applied to generators in AL-Mina. The generators used happened to all be purchased from Europe, designed to meet Tier II standards, and had the following specifications:

**Table 5.2. Al-Mina Engine Specifications.**

| Model | Make | Year | Rating (hp/kw) | Displacement (l) | Fuel Type | No. of Units |
|---|---|---|---|---|---|---|
| Volvo Penta | TAD1642GE | 2007 | 796/585 | 16 | Diesel | 9 |

Generator photos, as available, and manufacturer specifications are provided in Appendix B, Generator Supporting Materials. Based on this data the following factors from Table 5.2 would have been used:

**Table 5.3. USAF Emission Factors for Al-Mina Engines, Expressed in g/hp-hr.**

| VOC | NOx | CO | PM10 | PM2.5 | SO2 | CO2 |
|---|---|---|---|---|---|---|
| 4.88E-04 | 1.76E-02 | 5.75E-03 | 8.09E-04 | 8.09E-04 | 1.23E-05 | 1.15E+00 |

However, these engines, based on the make and model information meet EU Stage II emission standards so those were used in lieu of the USAF emission factors for more accurate PTEs.

**Table 5.4. Tier II Emission Factor Standards, Expressed in g/hp-hr.**

| VOC | NOx | CO | PM10 | PM2.5 | SO2 | CO2 |
|---|---|---|---|---|---|---|
| 9.69E-01 | 6.86E+00 | 3.73E+00 | 4.03E-01 | 4.03E-01 | NA | NA |

Emissions information from equipment vendors, particularly emission performance guarantees or actual test data from similar equipment, are better sources of information than AP-42 or NSPS (i.e. USAF guide). They are more accurate and are a better representation of actual emissions and when available their use is preferred.

Table 5.5 is an example of individual emissions from one generator using excel. This only shows summer emissions, as schedules vary from winter to summer and summer has greater emissions. Table 5.6 shows the winter emissions. The pollutants are listed in orders starting with criteria pollutants and followed by HAPs. To the left are the EFs with the associated unit and then the source of the EF. It is critical to always list the source of the EF and keep the link (if available from an online source) for later review or reference if needed.

Table 5.7 shows the emissions of the same generator in Tables 5.5 and 5.6 but shows the annual emissions, which includes both summer and winter. There are nine generators that supply secondary electricity for Mina, even though only one is shown in the above table. These generators are supplied from the Europe and therefore the specifications are in metric units. Since the EFs and methodology used in this proposal are from the US and will later be held against existing registrations and emission limits approved by the EPA, the engine specifications were converted to the units employed in this proposal. Table 5.8 shows the emission estimates for all nine engines individually and sums the emissions in the bottom row.

*Table 4.10 Summer Individual Emissions*

| Engine Data | | | | | Fuel Data | | | |
|---|---|---|---|---|---|---|---|---|
| EPN | Manufacturer | Model Number | Horsepower (hp) | Hours of Operation | Fuel Type | Fuel Consumption (lb/hp-hr) | Heating Value | Method of Emission Control |
| ENG01 | Volvo Penta | TAD1642GE | 796 | 2,190 | diesel | 46092 | 138,000 | None |

*Generator specifications provided by the owner. See Appendix C for photo verification.*

***Critieria Emissions***

| ENG01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Manufacturer's emission factors | Table 3.3 USAF Criteria Pollutant Emission Factors | Table 3.3 USAF Criteria Pollutant Emission Factors | Control Factor, if control device present (%) | Control Factor, if control device present (g/hp-hr) | Control Factor Used | Emissions | Emissions |
| | (g/hp-hr) | (lb/hp-hr) | (lb/MMBtu) | | | | lb/hr | tpy |
| VOC | 1.36E+00 | 4.88E-04 | 6.03E-02 | 0% | 0 | 0 | **2.39** | **2.61** |
| NOx | 8.16E+00 | 1.76E-02 | 2.18E+00 | 0% | 0 | 0 | **14.32** | **15.68** |
| CO | 4.76E+00 | 5.75E-03 | 7.11E-01 | 0% | 0 | 0 | **8.35** | **9.15** |
| $PM_{10}$ | 2.72E-01 | 8.09E-04 | 1.00E-01 | 0% | 0 | 0 | **0.48** | **0.52** |
| $PM_{2.5}$ | 2.72E-01 | 8.09E-04 | 1.00E-01 | 0% | 0 | 0 | **0.48** | **0.52** |
| $SO_2$ | 0.00E+00 | 1.23E-05 | 1.52E-03 | 0% | 0 | 0 | **0.01** | **0.01** |
| $CO_2$ | 0.00E+00 | 1.15E+00 | 1.64E+02 | 0% | 0 | 0 | **915.40** | **1,002.36** |
| $N_2O$ | 0.00E+00 | | 6.61E-03 | 0% | 0 | 0 | **0.24** | **0.27** |
| $CH_4$ | 0.00E+00 | | 1.32E-03 | 0% | 0 | 0 | **0.05** | **0.05** |
| $CO_2e$ | | | | | | | **989** | **1,083** |

Sample Calculation

For emission factors in terms of lb/hp-hr

Emission Rate (lb/hr) = Emission Factor (g/hp-hr) * Rated Capacity (hp) / 453.592

Emission Rate (tpy): (lb/hr)*(summer operating hours)/2000

For emission factors in terms of lb/MMBtu

(Emission factor) * (Fuel Consumption) * (Horsepower) * (Conversion factor)

(lb/MMBtu) * (Btu/hp-hr) * (hp) * (1 MMBtu/1,000,000 Btu)

GHG ($CO_2e$) Emissions: $CO_2$+($CH_4$*25)+($N_2O$*298)

| HAP EMISSIONS | | | | |
|---|---|---|---|---|
| Pollutant | Table 3.3 USAF Criteria Pollutant Emission Factors | Table 3.3 USAF Criteria Pollutant Emission Factors | ENG01 | |
| | (lb/hp-hr) | (lb/MMBtu) | Emissions lb/hr | Emissions tpy |
| 1,3-Butadiene | --- | --- | 0.00E+00 | 0.00E+00 |
| Acenaphthene | 2.58E-08 | 3.19E-06 | 2.05E-05 | 2.25E-05 |
| Acenaphthylene | 5.08E-08 | 6.28E-06 | 4.04E-05 | 4.43E-05 |
| Acetaldehyde | 1.39E-07 | 1.72E-05 | 1.11E-04 | 1.21E-04 |
| Acrolein | 4.34E-08 | 5.36E-06 | 3.45E-05 | 3.78E-05 |
| Anthracene | 6.77E-09 | 8.37E-07 | 5.39E-06 | 5.90E-06 |
| Benz(a)anthracene | 3.42E-09 | 4.23E-07 | 2.72E-06 | 2.98E-06 |
| Benzene | 4.27E-06 | 5.28E-04 | 3.40E-03 | 3.72E-03 |
| Benzo(a)pyrene | 1.42E-09 | 1.75E-07 | 1.13E-06 | 1.24E-06 |
| Benzo(b)fluoranthene | 6.11E-09 | 7.56E-07 | 4.86E-06 | 5.33E-06 |
| Benzo(g,h,i)perylene | 3.06E-09 | 3.78E-07 | 2.44E-06 | 2.67E-06 |
| Benzo(k)fluoranthene | 1.20E-09 | 1.48E-07 | 9.55E-07 | 1.05E-06 |
| Chrysene | 8.42E-09 | 1.04E-06 | 6.70E-06 | 7.34E-06 |
| Dibenz(a,h)anthracene | 1.91E-09 | 2.36E-07 | 1.52E-06 | 1.66E-06 |
| Fluoranthene | 2.22E-08 | 2.74E-06 | 1.77E-05 | 1.93E-05 |
| Fluorene | 7.05E-08 | 8.71E-06 | 5.61E-05 | 6.14E-05 |
| Formaldehyde | 4.34E-07 | 5.37E-05 | 3.45E-04 | 3.78E-04 |
| Indeno(1,2,3-c,d)pyrene | 2.28E-09 | 2.82E-07 | 1.81E-06 | 1.99E-06 |
| Naphthalene | 7.16E-07 | 8.85E-05 | 5.70E-04 | 6.24E-04 |
| Phenanthrene | 2.25E-07 | 2.78E-05 | 1.79E-04 | 1.96E-04 |
| Pyrene | 2.04E-08 | 2.53E-06 | 1.62E-05 | 1.78E-05 |
| Toluene | 1.55E-06 | 1.91E-04 | 1.23E-03 | 1.35E-03 |
| ***Totals*** | | | 0.01 | 0.01 |

*Table 4.11 Winter Individual Emissions*

| Engine Data | | | | | Fuel Data | | | |
|---|---|---|---|---|---|---|---|---|
| EPN | Manufacturer | Model Number | Horsepower (hp) | Hours of Operation | Fuel Type | Fuel Consumption (lb/hp-hr) | Heating Value | Method of Emission Control |
| ENG01 | Volvo Penta | TAD1642GE | 796 | 1,460 | diesel | 46092 | 138,000 | None |

*Generator specifications provided by the owner. See Appendix C for photo verification.*

***Critieria Emissions***

| ENG01 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Manufacturer's emission factors | Table 3.3 USAF Criteria Pollutant Emission Factors | Table 3.3 USAF Criteria Pollutant Emission Factors | Control Factor, if control device present (%) | Control Factor, if control device present (g/hp-hr) | Control Factor Used | Emissions | Emissions |
| | (g/hp-hr) | (lb/hp-hr) | (lb/MMBtu) | | | | lb/hr | tpy |
| VOC | 1.36 | 4.88E-04 | 6.03E-02 | 0% | 0 | 0 | **2.387** | **1.742** |
| NOx | 8.16 | 1.76E-02 | 2.18E+00 | 0% | 0 | 0 | **14.320** | **10.453** |
| CO | 4.76 | 5.75E-03 | 7.11E-01 | 0% | 0 | 0 | **8.353** | **6.098** |
| $PM_{10}$ | 0.27 | 8.09E-04 | 1.00E-01 | 0% | 0 | 0 | **0.477** | **0.348** |
| $PM_{2.5}$ | 0.27 | 8.09E-04 | 1.00E-01 | 0% | 0 | 0 | **0.477** | **0.348** |
| $SO_2$ | 0.00 | 1.23E-05 | 1.52E-03 | 0% | 0 | 0 | **0.010** | **0.007** |
| $CO_2$ | 0.00 | 1.15E+00 | 1.64E+02 | 0% | 0 | 0 | **915.400** | **668.242** |
| $N_2O$ | 0.00 | | 6.61E-03 | 0% | 0 | 0 | **0.243** | **0.177** |
| $CH_4$ | 0.00 | | 1.32E-03 | 0% | 0 | 0 | **0.049** | **0.035** |
| $CO_2e$ | | | | | | | **989** | **722** |

Sample Calculation
For emission factors in terms of lb/hp-hr
Emission Rate (lb/hr) = Emission Factor (lb/hp-hr) * Rated Capacity (hp)
Emission Rate (tpy): (lb/hr)*(summer operating hours)/2000
For emission factors in terms of lb/MMBtu
(Emission factor) * (Fuel Consumption) * (Horsepower) * (Conversion factor)
(lb/MMBtu) * (Btu/hp-hr) * (hp) * (1 MMBtu/1,000,000 Btu)
GHG ($CO_2e$) Emissions: $CO_2$+($CH_4$*25)+($N_2O$*298)

| HAP EMISSIONS | | | | |
|---|---|---|---|---|
| Pollutant | Table 3.3 USAF Criteria Pollutant Emission Factors | Table 3.3 USAF Criteria Pollutant Emission Factors | ENG01 | |
| | (lb/hp-hr) | (lb/MMBtu) | Emissions lb/hr | Emissions tpy |
| 1,3-Butadiene | --- | --- | 0.00E+00 | 0.00E+00 |
| Acenaphthene | 2.58E-08 | 3.19E-06 | 2.05E-05 | 1.50E-05 |
| Acenaphthylene | 5.08E-08 | 6.28E-06 | 4.04E-05 | 2.95E-05 |
| Acetaldehyde | 1.39E-07 | 1.72E-05 | 1.11E-04 | 8.08E-05 |
| Acrolein | 4.34E-08 | 5.36E-06 | 3.45E-05 | 2.52E-05 |
| Anthracene | 6.77E-09 | 8.37E-07 | 5.39E-06 | 3.93E-06 |
| Benz(a)anthracene | 3.42E-09 | 4.23E-07 | 2.72E-06 | 1.99E-06 |
| Benzene | 4.27E-06 | 5.28E-04 | 3.40E-03 | 2.48E-03 |
| Benzo(a)pyrene | 1.42E-09 | 1.75E-07 | 1.13E-06 | 8.25E-07 |
| Benzo(b)fluoranthene | 6.11E-09 | 7.56E-07 | 4.86E-06 | 3.55E-06 |
| Benzo(g,h,i)perylene | 3.06E-09 | 3.78E-07 | 2.44E-06 | 1.78E-06 |
| Benzo(k)fluoranthene | 1.20E-09 | 1.48E-07 | 9.55E-07 | 6.97E-07 |
| Chrysene | 8.42E-09 | 1.04E-06 | 6.70E-06 | 4.89E-06 |
| Dibenz(a,h)anthracene | 1.91E-09 | 2.36E-07 | 1.52E-06 | 1.11E-06 |
| Fluoranthene | 2.22E-08 | 2.74E-06 | 1.77E-05 | 1.29E-05 |
| Fluorene | 7.05E-08 | 8.71E-06 | 5.61E-05 | 4.10E-05 |
| Formaldehyde | 4.34E-07 | 5.37E-05 | 3.45E-04 | 2.52E-04 |
| Indeno(1,2,3-c,d)pyrene | 2.28E-09 | 2.82E-07 | 1.81E-06 | 1.32E-06 |
| Naphthalene | 7.16E-07 | 8.85E-05 | 5.70E-04 | 4.16E-04 |
| Phenanthrene | 2.25E-07 | 2.78E-05 | 1.79E-04 | 1.31E-04 |
| Pyrene | 2.04E-08 | 2.53E-06 | 1.62E-05 | 1.19E-05 |
| Toluene | 1.55E-06 | 1.91E-04 | 1.23E-03 | 9.01E-04 |
| ***Totals*** | | | 0.01 | 4.42E-03 |

*Table 4.12 Annual Individual Generator Emissions*

| Waste Component | NOx | | CO | | VOC | | $SO_2$ | | PM-10 | | PM-2.5 | | HAPs | | $CO_2$ | | $CH_4$ | | $N_2O$ | | $CO_2e$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy |
| *Summer* | | | | | | | | | | | | | | | | | | | | | | |
| ENG01 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| | | | | | | | | | | | | | | | | | | | | | | |
| *Winter* | | | | | | | | | | | | | | | | | | | | | | |
| ENG01 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| | | | | | | | | | | | | | | | | | | | | | | |
| **Annual Total** | **28.64** | **26.13** | **16.71** | **15.24** | **4.77** | **4.36** | **0.02** | **0.02** | **0.95** | **0.87** | **0.95** | **0.87** | **0.01** | **0.01** | **1831** | **1671** | **0.10** | **0.09** | **0.49** | **0.44** | **1978** | **1805** |

*Table 4.13 Emissions Summary*

| Waste Component | NOx | | CO | | VOC | | $SO_2$ | | PM-10 | | PM-2.5 | | HAPs | | $CO_2$ | | $CH_4$ | | $N_2O$ | | $CO_2e$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy | lb/hr | tpy |
| *Summer* | | | | | | | | | | | | | | | | | | | | | | |
| ENG01 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG02 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG03 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG04 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG05 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG06 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG07 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG08 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| ENG09 | 14.32 | 15.68 | 8.35 | 9.15 | 2.39 | 2.61 | 0.01 | 0.01 | 0.48 | 0.52 | 0.48 | 0.52 | 0.01 | 0.01 | 915 | 1002 | 0.05 | 0.05 | 0.24 | 0.27 | 989 | 1083 |
| | | | | | | | | | | | | | | | | | | | | | | |
| *Summer Total* | *128.88* | *141.12* | *75.18* | *82.32* | *21.48* | *23.52* | *0.09* | *0.10* | *4.30* | *4.70* | *4.30* | *4.70* | *0.05* | *0.06* | *8239* | *9021* | *0.44* | *0.48* | *2.18* | *2.39* | *8900* | *9746* |
| *Winter* | | | | | | | | | | | | | | | | | | | | | | |
| ENG01 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG02 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG03 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG04 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG05 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG06 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG07 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG08 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| ENG09 | 14.32 | 10.45 | 8.35 | 6.10 | 2.39 | 1.74 | 0.01 | 0.01 | 0.48 | 0.35 | 0.48 | 0.35 | 0.01 | 4.42E-03 | 915 | 668 | 0.05 | 0.04 | 0.24 | 0.18 | 989 | 722 |
| | | | | | | | | | | | | | | | | | | | | | | |
| *Winter Total* | *128.88* | *94.08* | *75.18* | *54.88* | *21.48* | *15.68* | *0.09* | *0.06* | *4.30* | *3.14* | *4.30* | *3.14* | *0.05* | *0.04* | *8239* | *6014* | *0.44* | *0.32* | *2.18* | *1.59* | *8900* | *6497* |
| **Annual Total** | **257.76** | **235.20** | **150.36** | **137.20** | **42.96** | **39.20** | **0.18** | **0.16** | **8.59** | **7.84** | **8.59** | **7.84** | **0.11** | **0.10** | **16477** | **15035** | **0.87** | **0.80** | **4.37** | **3.99** | **17801** | **16243** |

### *3. Emissions Analysis Conclusion*

The annual PTE of an individual generator were compared to the emission standards of TCEQ. The result show that the emissions alone meet the emission standard of the smallest permit, the PBR. Table 5.8 compares the annual emissions of one generator. This section answers the first corollary question – Can generators potentially meet existing US emission thresholds? Based on Table 5.9 the answer is theoretically, yes. Specific fuel composition data or lab analysis was not available and it is assumed that all engines were being operated and maintained according to engine specific recommendations.

**Table 5.9. Single Generator Emission Comparison to PBR Limits.**

| Air Contaminant | PBR Limits (tpy)[69] | GEN01 (tpy) |
|---|---|---|
| CO | 250 | 15.24 |
| NOx | 250 | 26.13 |
| VOC | 25 | 4.36 |
| $SO_2$ | 25 | 0.02 |
| PM10 | 15 | 0.87 |
| PM2.5 | 10 | 0.87 |
| HAPs | 25 | .01 |

## C. Authorization Analysis

Permits, or authorizations, have multiple requirements in addition to the emission standards that must be met. Typically, an engine falls under PBR status and

69 30 Tex. Admin. Code §106.4

will be required to comply to several PBRs in which they operate under. This section provides the primary requirements of each permit that is applicable to generators.

### 1. *Texas Administrative Code Title 30, §106.4 General Requirements for Permit by Rule*

This permit is required for all sources attempting to obtain authorization under PBRs. It establishes the emission limits that were used in the previous chapter for emissions comparison. The following is an excerpt from the rule:

(a) To qualify for a permit by rule, the following general requirements must be met.

(1) Total actual emissions authorized under permit by rule from the facility shall not exceed the following limits, as applicable:

(A) 250 tons per year (tpy) of carbon monoxide (CO) or nitrogen oxides ($NO_X$);

(B) 25 tpy of volatile organic compounds (VOC), sulfur dioxide ($SO_2$), or inhalable particulate matter (PM);

(C) 15 tpy of particulate matter with diameters of 10 microns or less ($PM_{10}$);

(D) 10 tpy of particulate matter with diameters of 2.5 microns or less ($PM_{2.5}$); or

(E) 25 tpy of any other air contaminant except:

(i) water, nitrogen, ethane, hydrogen, and oxygen; and

(ii) notwithstanding any provision in any specific permit by rule to the contrary, greenhouse gases.

These are the same standard mentioned in Table 4.1. As determined from the previous section, the engines meet these emissions standards. The table proves the compliance of the Al-Mina with the thresholds in ideal situations.

## *2. Texas Administrative Code Title 30, §106.8 Recordkeeping*

PBR §106.8 of Subchapter A imposes general recordkeeping requirements for owners and/or operators. A copy of the rule is provided in Appendix A, Texas Administrative Code (TAC) Permit by Rules. The rule is as follows:

(c) Owners or operators of all other facilities authorized to be constructed and operate under a PBR must retain records as follows:

(1) maintain a copy of each PBR and the applicable general conditions of §106.4 of this title or the general requirements, if any, in effect at the time of the claim under which the facility is operating. The PBR and general requirements claimed should be the version in effect at the time of construction or installation or changes to an existing facility, whichever is most recent.

(2) maintain records containing sufficient information to demonstrate compliance with the following:

(A) all applicable general requirements of §106.4 of this title or the general requirements, if any, in effect at the time of the claim; and

(B) all applicable PBR conditions;

(3) keep all required records at the facility site. If however, the facility normally operates unattended, records must be maintained at an office [nearby] having day-to-day operational control of the site;

(4) make the records available in a reviewable format at the request of personnel from any air pollution control program having jurisdiction;

(5) beginning April 1, 2002, keep records to support a compliance demonstration for any consecutive 12-month period; and

(6) all records demonstrating compliance must be retained for at least two years.

No type of recordkeeping is currently required. However, during field observations general recordkeeping was minimal and inconsistent in terms of what was kept.

### *3. Texas Administrative Code Title 30, §106.261 Facilities (Emission Limitations)*

PBR §106.261 requires a minimum of 100 feet (ft) from any receptor not owned by the owner or operator of the facility and emission limits of 6.0 lb/hr and 10 tpy of certain chemicals. A copy of the rule is provided in Appendix A, Texas Administrative Code (TAC) Permit by Rules. The applicable parts of the rule are as follows:

(1) The facilities or changes shall be located at least 100 feet from any recreational area or residence or other structure not occupied or used solely by the owner or operator of the facilities or the owner of the property upon which the facilities are located.

(2) Total new or increased emissions, including fugitives, shall not exceed 6.0 pounds per hour (lb/hr) and ten tons per year of the following materials: acetylene, argon, butane, crude oil, refinery petroleum fractions (except for pyrolysis naphthas and pyrolysis gasoline) containing less than ten volume percent benzene, carbon monoxide, cyclohexane, cyclohexene, cyclopentane, ethyl acetate, ethanol, ethyl ether, ethylene, fluorocarbons Numbers 11, 12, 13, 14, 21, 22, 23, 113, 114, 115, and 116, helium, isohexane, isopropyl alcohol, methyl acetylene, methyl chloroform, methyl cyclohexane, neon, nonane, oxides of nitrogen, propane, propyl alcohol, propylene, propyl ether, sulfur dioxide, alumina, calcium carbonate, calcium silicate, cellulose fiber, cement dust, emery dust, glycerin mist, gypsum, iron oxide dust, kaolin,

limestone, magnesite, marble, pentaerythritol, plaster of paris, silicon, silicon carbide, starch, sucrose, zinc stearate, or zinc oxide.

The only chemical listed that applies to the generators is CO. The average hourly projected emission rate is 8.35 lb/hr. The Al-Mina generators, most likely because these are older, uncontrolled engines, are not in compliance with either requirement. Exhaust stacks are also too close to meet the distance requirement.

### 4. *Texas Administrative Code Title 30, §106.262 Facilities (Emission & Distance Limitations)*

PBR §106.262 of Subchapter K also sets facility emission and distance limitations, to which all applicable generators must comply with. The rule is as follows:

> *Emission points associated with the facilities or changes shall be located at least 100 feet (ft) from any off-plant receptor. Off-plant receptor means any recreational area or residence or other structure not occupied or used solely by the owner or operator of the facilities or the owner of the property upon which the facilities are located.*

A copy of the rule is provided in Appendix A, Texas Administrative Code (TAC) Permit by Rules. The 100 ft requirement is crucial because in the second component, 30 TAC §106.262(a)(2):

> *New or increased emissions, including fugitives, of chemicals shall not be emitted in a quantity greater than five tons per year nor in a quantity greater than E as determined using the equation E = L/K [using Figures 1 and 2 of this subpart].*

100 ft is the minimum distance that must be obtained to meet the emission limitations of this PBR. The equation is described as follows:

$$E = L/K$$

where:

E = maximum allowable hourly emission

L = value as listed or referenced in Table 262

K = value from Figure 1: 30 TAC §106.262(a)(2)

D = distance to the nearest off-plant receptor

As long as the 100ft minimum distance is obtained, then typically all subsequent emissions will meet the emissions requirement set forth in this rule. These generators would not meet the requirement because of the distance to the receptor. The distance is the determining factor that considers ambient air quality standards which involve the assumption that an activity is being done far enough that emissions would not exceed acceptable exposure, if any.

**Table 5.10. 30 TAC §106.262(a)(2) Emission & Distance Limitations - Al-Mina Generators.**

***Engine Data***

| Source | Distance to Receptor | K |
|---|---|---|
| | (feet) | |
| ENG01 | 100 | 326 |

Sample Calculation: E = L/K
where:
E = maximum allowable hourly emission
L = value as listed or referenced in Table 262
K = value from Figure 1: §106.262(a)(2)
D = distance to the nearest off-plant receptor

***Emissions***

| Compound | Limit (L) mg/m3 | ENG01 |
|---|---|---|
| Acetaldehyde | 9 | 0.03 |
| 1,3-Butadiene | 4.42 | 0.01 |
| Acenaphthylene | 0.2 | 0.00 |
| Acetaldehyde | 45 | 0.14 |
| Acrolein | 0.23 | 0.00 |
| Anthracene | 0.2 | 0.00 |
| Benz(a)anthracene | 0.2 | 0.00 |
| Benzene | 1.6 | 0.00 |
| Benzo(a)pyrene | 0.2 | 0.00 |
| Benzo(b)fluoranthene | 0.2 | 0.00 |
| Benzo(g,h,i)perylene | 565.11 | 1.73 |
| Chrysene | 0.2 | 0.00 |
| Dibenz(a,h)anthracene | 0.2 | 0.00 |
| Fluoranthene | 0.2 | 0.00 |
| Fluorene | 0.2 | 0.00 |
| Formaldehyde | 0.12 | 0.00 |
| Naphthalene | 10.48 | 0.03 |
| Phenanthrene | 0.2 | 0.00 |
| Pyrene | 0.2 | 0.00 |
| Toluene | 75 | 0.23 |
| Benzene | 3 | 0.01 |

***5. Texas Administrative Code Title 30, §106.512 Stationary Engines and Turbines***

PBR §106.512 stipulates registration requirements, individual NOx limits, recordkeeping and reporting requirements. A copy of the rule is provided in Appendix A, Texas Administrative Code (TAC) Permit by Rules.

Registration requirements refers to a fee which is determined by the size of the operator/owner. Currently there are no registration requirements that mandate a fee, in addition to recordkeeping for maintenance or emissions testing. The NOx limit for all CI engines is 11.0 g/hp-hr. The engine was designed and manufactured to meet the Tier II/III standard of 8.16 g/hp-hr, which is well below the PBR NOx limit, so the Al-Mina engines would comply.

Records are not currently required and maintenance of records for any length of time is not either. This PBR states record maintenance (the keeping of rolling records) to be two years. If generator owners in Lebanon are not periodically prove generator performance, which is the point of recordkeeping of maintenance and fuel purchases, this requirement will be essential.

Biennial emissions measurements are also required for NOx and CO ambient air standards (NAAQS). Under no circumstance is the violation of any NAAQS in the area of the facility is acceptable (§106.512(6)). Lebanon has a long history of corruption and illegal activities with electricity. It has an equally infamous notoriety in substitution and disregard for machinery. In combination with lack of funding, it would probably be more advantageous to do annual, unannounced checks by certified individuals. Stack testing, even within this PBR rule must be done by trained, certified individuals (§106.512(6)(A)).

Stack height, which are required to be twice the height of any surrounding obstruction, and distance is part of the overall determination to NAAQS. Unfortunately, even in the best scenario this would not be achievable. Table 5.11 uses the minimum distance required and puts the generators only meeting part of the requirement. The US standards for NOx is 188 and 100 $mg/m^3$ for the hourly and annual limits. The current Lebanese NAAQS is 200 and 100 $mg/m^3$ so they would still not qualify.

**Table 6.1 Al-Mina $NO_X$ Compliance with US NAAQS**

| Source | Pollutant | Emission Source Parameters | | | | Demonstration of Compliance with 1-hour NAAQS | | | | Demonstration of Compliance with Annual NAAQS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stack Height | Distance to Property Line | Engine Rating | Generic Modeling Value | Nox Emission Rate | Weighted Ratio of Emissions | Ambient Standard | Maximum Allowable Emission Rate | Nox Emission Rate | Weighted Ratio of Emissions | Ambient Standard | Maximum Allowable Emission Rate |
| | | (feet) | (feet) | (HP) | (ug/m3)/(lb/hr) | (lb/hr) | | (ug/m3) | (lb/hr) | (tpy) | | (ug/m3) | (tpy) |
| ENG01 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG02 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG03 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG04 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG05 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG06 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG07 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG08 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| ENG09 | NOx | 12 | 50 | 796 | 25 | 14.32 | 11.11% | 188 | 0.84 | 15.68 | 11.11% | 100 | 24.33 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Totals** | | | | | | **1.29E+02** | **100.00%** | | **7.52** | **141.12** | **100.00%** | | **219.00** |
| | | | | | | **In compliance?:** | | | No | **In Compliance?:** | | | Yes |

1. Generic modeling value obtained from 30 TAC §106.352(m) Table 5C.

### D. Authorization Conclusion

As presented, it is clear that a word-for-word transferal is not an option and was never intended to be. These development of PBRs and subsequent regulations highlight important aspects for optimum equipment performance that ensures emission standards and limitations. It that must be taken which are standardized emission calculations and a functioning permit framework that includes maintenance, recordkeeping and reporting requirements. It also identifies critical issues such as distance, engine age effect and governance obstacles that must be accounted for and addressed. To answer the second corollary question – US authorizations can only be used for some elements, but not all. For those cardinal to permitting like NAAQS, creative thinking geared towards changing engineering elements need to be looked if the generator could not be moved to a more suitable location if available.

# CHAPTER 6

# RESULTS AND DISCUSSION

In the beginning three questions were proposed. The first asked if currently operating generators could meet emission standards, if set in an ideal situation. Based on Section 4 Emissions Analysis and Table 5.8, the answer is yes. Generator reliance as a sole source of energy did not start until the Lebanese civil war ended in 1990. If a majority of generators were purchased after 1996 then it's likely they meet Tier I or II standards. Although it's likely that if stack testing was performed to verify compliance with Tier standards, given maintenance and operation practices noted; it's a good sign for emission standard policy development.

The second question asked if they would qualify for authorization – that is meeting all applicable requirements. Based on observations of documented recordkeeping, operation and maintenance practices the answer is no. No regulatory body requires MRR necessarily outside the meters implemented in 2018. The meter is designed to record electricity consumption and may not be recording actual operating time. The cardinal point determined from the analysis is the compatibility of distance limitations to ambient air quality standards, which is absolutely necessary. The primary reason and existence for environmental, regulatory oversight is to protect public health from exposure to toxins exceeding acceptable exposure levels. Ambient air quality standards, emission standards, and MRR requirements must be a part of policy development, What remains in the final question of this thesis. Considering the cultural, historical and political landscape of generators; observations and knowledge of generators within the country involving maintenance and operations; the perceived severity of air emissions to public health and the necessity of their presence in different sectors how can the authorizations here contribute to air emission policy for generators? To what extent can policy measures in the United States (US) be applied to the state of Lebanon? TCEQ permits discussed above are a combination of four elements: dialogue, regulatory requirements or MRR, emission limits and emission standards.

## A. Standards

Standard involve two parts – fuel standards and emission standards.

### *1. Emission Standards*

First are the traditional emission standards, the Tiers. The USEPA was the first agency to develop and adopt the Tier emission standards, which began phasing in 1996. The EU followed later with similar or more stringent rules (The EPA deadline for Tier IV standards was 2015. In order to match the deadline, some standards may be more stringent to account for the shorter timeframe to achieve that goal for international standardization). For example, the generators document in this study are Tier II. Both the EU and EPA standards set CO at 3.5 g/kWh and PM at 0.2 g/kWh, running at the lower speed of 536 kWh. The main difference between the two standards is the breadth of coverage for all engine power ratings. As of 1998 the EPA mandated standards for all equipment, encompassing the smallest of generators under 8 kW to the largest over 560 kW. This is of significant importance to Lebanon. Most engines are designed with the option of operation at two different speeds, or revolutions per minute (rpm). Engine models could either be manufactured to run at one speed or have the option to do both. This could place a single engine in two different categories of emission standards if they are run at both or the higher.

The EU did not adopt standards for engines over 560 kW until Stage V, which was finalized in 2016 and became effective as of this year. If engines are going to be examined for emission performance based on remote testing, then there need to be standards of comparison for both speeds. If only one standard source is to be adopted, then I recommend looking at the USEPA. The standards between the two entities are typically the same, and engine manufactures globally have largely adhered to the EPA standards since their initial development. The proximity of Lebanon to the EU and the local presence of generator manufacturers who also supply to regional countries that have already adopted the EU Tier standards (or are in the process of) also gives a strong argument to follow the EU. However, it does make sense to do a combination. The EU, until 2016, did not have standards for engines above 560 kW but the EPA does not currently have a Tier V standard in place. The combination will allow both systems to fill in the gaps for each other as necessary. This is the first thing to look before pursuing any type of testing and ELV establishment.

## *2. Fuel Standards*

The Tier $SO_X$ standards were based on the sulfur content of the fuel used. For Tier I & II, the sulfur content of the fuel was 0.1-0.2% (wt.) sulfur content.[70] Most of the producing countries are already in the process of adopting or have adopted EU

70 "United States: Nonroad Diesel Engines." Emission Standards: USA: Nonroad Diesel Engines. December 2017. Accessed May 13, 2019. https://www.dieselnet.com/standards/us/nonroad.php.

diesel fuel quality specifications, which are presented below in Table 6.1. The following tables 6.2 and 6.3 illustrate where countries development programs are at and what fuel standards is currently met.  Lebanon imports diesel and its estimated by 2014) to be at 500 ppm, or 0.05 wt %.

**Table 6.0.1. EU Gasoline and Diesel Fuel Quality Specifications.**[71]

| Petrol/Gasoline | Euro 3 | Euro 4 | Euro 5[a] | Diesel | Euro 3 | Euro 4 | Euro 5[b] |
|---|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2009 | | 2000 | 2005 | 2009 |
| RVP summer kPa, max. | 60 | 60 | 60 | Cetane number, min. | 51 | 51 | 52 |
| Aromatics, % by vol. max. | 42 | 35 | 35 | Density 15 °C Kg/m, max. | 845 | 845 | 837 |
| Benzene, % by vol. max. | 1 | 1 | 1 | Distillation 95% by vol. °C, max. | 360 | 360 | 350 |
| Olefins, % by vol. max. | 18 | 18 | 13 | Polyaromatics, % by vol., max. | 11 | 11 | 6 |
| Oxygen, % by mass max. | 2.7 | 2.7 | 2.7 | | | | |
| Sulphur, ppm | 150 | 50 | 10 | Sulphur, ppm max. | 350 | 50 | 10 |

In terms of policy the sulfur content of the fuel really only affects sulfur oxide emissions. If a Tier standard is going to be adopted, them the correct fuel or a lower sulfur content diesel fuel should be used. Your option is to either correct the fuel of just sulfur oxide emissions based specifically on the fuel sulfur content. Obtaining a lab analysis of the current diesel fuel would be the second step after obtaining a Tier standards.

71 "EU: Nonroad Engines." Emission Standards: Europe: Nonroad Engines. November 2016. Accessed May 13, 2019. https://www.dieselnet.com/standards/eu/nonroad.php#s1.

**Table 6.2. Diesel Fuel Quality Developments in the Arab Region.**[72]

<table>
<tr><th>Country</th><th>'05</th><th>'06</th><th>'07</th><th>'08</th><th>'09</th><th>'10</th><th>'11</th><th>'12</th><th>'13</th><th>'14</th><th>'15</th><th>'16</th><th>'17</th><th>'18</th></tr>
<tr><td>Algeria</td><td colspan="11">Non-compliant with Euro standards</td><td></td><td></td><td></td></tr>
<tr><td>Bahrain</td><td colspan="13">Euro 2</td><td>Euro5</td></tr>
<tr><td>Egypt</td><td colspan="13">Non-compliant with Euro standards</td><td></td></tr>
<tr><td>Iraq</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Jordan</td><td colspan="13">Non-compliant with Euro standards</td><td>Euro 4</td></tr>
<tr><td>Kuwait</td><td colspan="4">Non-compliant with Euro standards</td><td colspan="9">Euro2</td><td>Euro5</td></tr>
<tr><td>Lebanon</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Libya</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mauritania</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Morocco</td><td colspan="4">Euro3 / Non- compliant</td><td colspan="9">Euro4</td><td>Euro5</td></tr>
<tr><td>Oman</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Qatar</td><td colspan="13">Euro 2</td><td>Euro 5</td></tr>
<tr><td>Saudi Arabia[2]</td><td colspan="13">Non-compliant with Euro standards</td><td>Euro 5</td></tr>
<tr><td>Somalia</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sudan</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Syria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Tunisia</td><td colspan="2">Non-compliant with Euro standards</td><td colspan="3">Euro3</td><td colspan="8">Euro4</td><td>Euro5</td></tr>
<tr><td>United Arab Emirates</td><td colspan="2">Non-compliant with Euro standards</td><td colspan="6">Euro2</td><td colspan="5">Euro3 / Euro4</td><td>Euro5</td></tr>
<tr><td>Yemen</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

72 Middle East. Centre for Environment and Development in the Arab Region and Europe. FUEL QUALITY ROADMAP FOR ARAB STATES. By Hossam Allam, Ahmed El-Dorghamy, Sina Hbous, Kamala Ernest, and Angela Bandemehr. March 2015. http://web.cedare.org/wp-content/uploads/cedareimages/sulfur_roadmap_final.pdf.

### 3. *Emission Limits*

Emission limits vary standards as their development is left to further interpretation regarding how stringent emission achievement goals are to international and public health standards. Emission limits, or ELVs in Lebanon, are typically based on the NAAQS. The most recent National Strategy for Air Quality Management (MoEW, 2017) mentioned the current Lebanese NAAQS in need of renewal. Ambient air quality limits are not set in a zero – risk environment but to ensure acceptable exposure levels that are not in direct contact with the source.

Given the location of generators, I believe it makes more sense to establish ELVs for generators based on US Occupational Health and Safety Administrations (OSHA) permissible exposure levels (PELs). OSHA's true intent is ensuring health of workers who are inherently more at risk for chronic exposure due to occupational hazards. Chronic exposure typically occurs in one of two scenarios: either a person works in a field where diesel is used regularly (industry) or subjected to have repeated exposure to diesel fumes over a long period of time. Most individuals and businesses (commercial and industrial) outside of the capital city of Beirut, can experience up to twelve hours of state electricity shortage daily. The conditions reflect personnel whose occupation is inherently assumed or are subject to the risk. If a generator is running for twelve hours a day, that means exposure to exhaust fumes from diesel generators on a daily basis for twelve hours. Human health studies demonstrate a correlation between exposure to diesel exhaust and increased lung cancer rates in occupational settings.[73] In fact, long-term exposure to diesel exhaust particles poses the highest cancer risk of any toxic air

73 Ali, Rashid. "Effect of Diesel Emissions on Human Health: A Review." International Journal of Applied Engineering Research 6, no. 11 (2011): 1333-342. May 2013. https://www.researchgate. net/publication/236897080_Effect_of_Diesel_Emissions_on_Human_Health_A_Review.

contaminant evaluated by the California Office of Environmental Health Hazard Assessment (OEHHA). The exhaust stack is the source of the greatest concentration, which further compels  me to believe to lean in favor of PELs or even time weighted averages (TWAs), which come in time increments that could possibly match up the generator run hour blocks. This is important. You could still use ambient air quality standards but the exhaust is the main source of emissions and that stack, like photos from earlier can be over your head or outside your bedroom window. Ambient air quality usually refers to air quality outside the industrial activity, where there is distance in between to allow for dispersion. OSHA is for the inside of the industrial activity and most closely reflects the situation of Lebanon in either case.

**Table 6.3 NAAQS and OSHA Limit Comparison (µg/m³)**

| POLLUTANT | LR NAAQS (2006) | US NAAQS | OSHA PELs |
|---|---|---|---|
| $SO_2$ | 350 (1 hr)<br>80 (annual) | 86 (1 hr)<br>0.6 (3 hr) | 13 |
| $PM_{10}$ | 80 (24 hr)<br>- | 150 | - |
| $PM_{2.5}$ | -<br>- | 35 (24 hr)<br>12 (annual) | - |
| CO | 30,000 (1 hr)<br>10,000 (8 hr) | 40 (1 hr)<br>11 (8 hr) | 55 |
| $NO_2$ | 200 (1hr)<br>100 (annual) | 188 (1 hr)<br>100 (annual) | 9.41 |
| Benzene | 16.2 | - | 3.19 |

## B. Regulatory Requirement – Engineering Practices

This section reviews two regulatory elements – engineering and administrative. Engineering applies directly to the engine and includes exhaust stack placement, generator acquisition according Tier standards, and abatement controls. Most generators within Lebanon are noted to be older models, like the ones present in this study. A recent 2018 study between the American University of Beirut (AUB) and the Lebanese Ministry of Environment (MOE) cited that in a survey conducted in the Hamra area of Beirut, 25% of 469 noted generators were found to be greater than ten years old. Older generators preceding ten years don't have the same advanced design technologies and also may not have emission controls (abatement) incorporated into the design or may not be able to accommodate them. As generator policy is looked into further, it is recommended to look at these three elements to find the best combination of elements to protect public health while maintaining consumer demand.

### *1. Exhaust Stack Placement*

In Chapter 6 for both rules §106.261 and §106.262, the Al-Mina engines were identified to not meet the emission and distance limitations because of the exhaust stacks' proximity to receptors. The distance is set to achieve safe pollutant exposure levels equivalent to or more than that of the NAAQS. It is not likely that the generators themselves can be physically moved – but it is possible for the exhaust stacks. A study published in 2015 examined local air quality impacts of diesel backup generators in New York City as they relate to stack location, the influence of different sized building up and downwind, and exhaust momentum ratio (stack exit velocity/ambient wind velocity).

#### a. Stack Location

A large percentage of diesel backup generators that are in use are Tier I, Tier II or older, which have considerably higher emission rates than those of the latest models.[74] In similar fashion, the units are located in densely populated urban areas and short stack heights. Model evaluations, or air dispersion modeling, was performed that took account for building parameters, meteorology and the exhaust stack. Different scenarios were tested – a baseline were the stack is located upwind of surrounding buildings and therefore above the roof recirculation zone; Scenario B - an adjacent downwind building is significantly taller than the generator building; Scenario C - a tall building is upwind of the exhaust stack, which creates a recirculation zone between the upwind and downwind building of the stack; Scenario D - where the upwind and downwind building of the stack are the same as Scenario C but the backup generator building is taller than the upwind building and outside the recirculation zone.[75] The location of the surrounding buildings play a significant role in the plume dispersion as it exists the exhaust stack of the generator and is carried away from the point of origin. The following table excerpted from the study first shows the building landscape, upwind and downwind. The following images illustrate the effects of those buildings on the upwind and downwind dispersion of air pollutants and pollutant concentration.

74 Zhang, Xiyue, and K. Max Zhang. "Demand Response, Behind-the-Meter Generation and Air Quality." Environmental Science & Technology 49, no. 3 (2015): 1260-267. doi:10.1021/es505007m.
75 Tong, Zheming, and K. Max Zhang. "The Near-source Impacts of Diesel Backup Generators in Urban Environments." Atmospheric Environment 109 (2015): 262-71. doi:10.1016/j.atmosenv.2015.03.020.

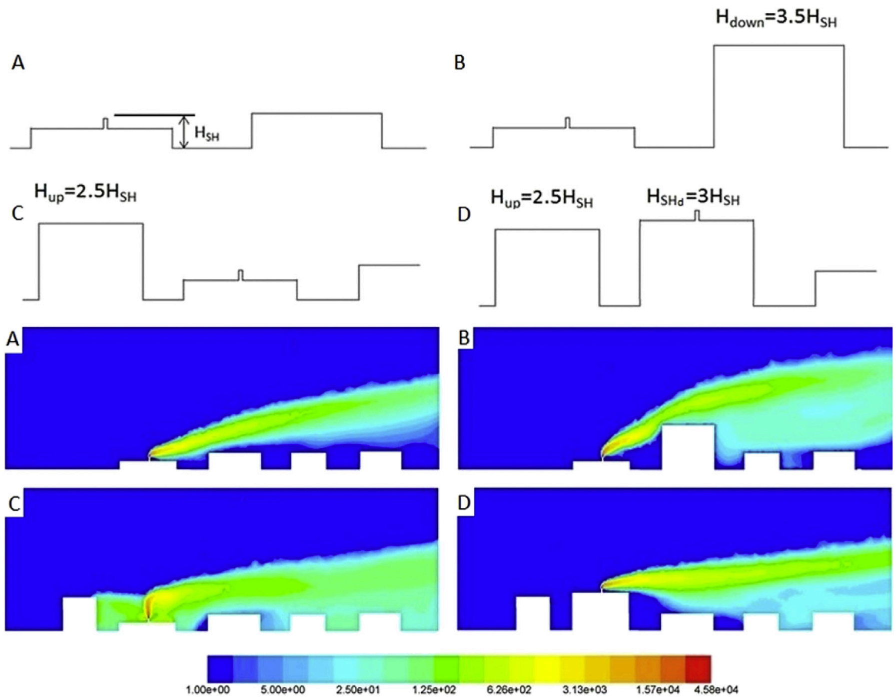


**Figure 6.1. Configurations and Corresponding Contour Plots of PM2.5 Concentrations**[76]

According to the analysis, the near- source air quality impacts of diesel backup generator emissions depended strongly on urban configurations and meteorological conditions.[77] In the best-case scenario emissions, particularly NOx and PM, can be reduced to lessen impacts on public health but not meet exposure limits.

<u>b. Exhaust Momentum Ratio</u>

Exhaust momentum ratio is an engineering technique to increase the exit velocity of the gas leaving the stack. In some cases when facilities are in the construction phase, or installing new equipment in limited space, NAAQS may not be achievable based on the unit as it comes from the manufacturer. There are special cases, reviewed case-by-case, that allow for facilities to move forward if they can demonstrate

76 Zhang, Xiyue, and K. Max Zhang. "Demand Response, Behind-the-Meter Generation and Air Quality." Environmental Science & Technology 49, no. 3 (2015): 1260-267. doi:10.1021/es505007m.
77 Tong, Zheming, and K. Max Zhang. "The Near-source Impacts of Diesel Backup Generators in Urban Environments." Atmospheric Environment 109 (2015): 262-71. doi:10.1016/j.atmosenv.2015.03.020.

clients using air dispersion models that changes in the design or engineering practices can still meet the NAAQS.

The study chose to look at dropping the exhaust momentum ratio below a baseline standard, and then do the same when they increased it. Decreasing exhaust momentum ratio draws more exhaust into the recirculation zone and reduces the effective stack height, which results in elevated near-ground concentrations inside downwind street canyons.[78] On the opposite side, increasing the ratio projected emissions further up into the atmosphere and greatly reducing emission concentrations at the source and downwind. See Figure 6.2, M=76.

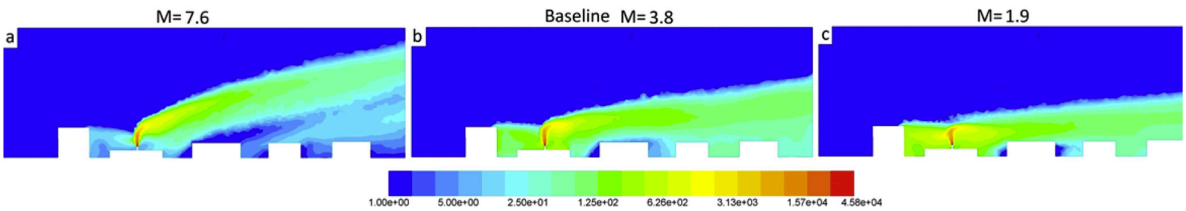


**Figure 6.2. Contour plots of primary PM2.5 concentration for Three Exhaust Momentum Ratio.[79]**

Based on the study, the stack location (and generators) and its should be carefully selected based on the surrounding environment. Furthermore, increasing exhaust momentum ratios also play an equally significant role.

For the permitting, it is common to include best engineering practices and air dispersion modelling. In particular, whether the generator and itself are new or an

78 Zhang, Xiyue, and K. Max Zhang. "Demand Response, Behind-the-Meter Generation and Air Quality." Environmental Science & Technology 49, no. 3 (2015): 1260-267. doi:10.1021/es505007m.
79 Zhang, Xiyue, and K. Max Zhang. "Demand Response, Behind-the-Meter Generation and Air Quality." Environmental Science & Technology 49, no. 3 (2015): 1260-267. doi:10.1021/es505007m.

existing generator is being relocated exhaust placement and the exhaust momentum ration should be considered as requirements for review.

### *2. Phasing to Newer Models*

Referring back to the 2015 study, the authors also applied USEPA Tier 4 emission standards to the best-case scenario study. Older generators may not have emission abatement control in the design or post-combustion. With each passing emission standard manufacturers are forced to design more fuel efficient and cleaner burning engines. These engines use advanced filters and combinations of different abatement controls. To accommodate the transition from Tier III to IV emission standards, manufacturers are seen applying advanced particulate filters, advanced EGR, DPF and SCRs. In the 2015 study the application of Tier IV standards resulted in significant emission reductions. Albeit significant, the emissions were not quite at the point that made it acceptable. However, it further demonstrates the need to consider phasing out older generators in addition to stack placement.

Phasing out inherently has significant benefits in regards to health. Tier IV engines require the reduction of NOx and PM by almost 90% from the previous standards, and in total almost 99% from its initial start.[80] When the full inventory of older nonroad engines are replaced by Tier IV engines in the US, annual emission reductions are estimated at 738,000 tons of NOx and 129,000 tons of PM.[81] By 2030, 12,000

80 Ueno, Christine. "Understanding Tier 4 Interim and Tier 4 Final EPA Regulations for Generator Set Applications." MTU Onsite Energy. 2010. https://www.mtu-online.com/uploads/tx_templavoila/WhitePaper_Tier4i_and_Tier4_02.pdf.
81 "United States: Nonroad Diesel Engines." Emission Standards: USA: Nonroad Diesel Engines. December 2017. Accessed May 13, 2019. https://www.dieselnet.com/standards/us/nonroad.php

premature deaths would be prevented annually due to the implementation of the proposed standards.[82]

If generator emissions are going to be dealt with, then it is recommended that regulating future generator purchases in favor of new models, as well as phasing out older ones, is considered.

### *3. Abatement Technologies*

Abatement technologies typically target criteria pollutants, as these are the ones that increasingly limited with each passing of an emission standard. Typically, they are directed at $NO_X$, PM, and CO. Emission controls can either be categorized as engine design or exhaust aftertreatment. Although these technologies are being applied directly to the design and manufacturing of engines to meet emission standards, but they can be applied separately. Tables 6.3 and 6.4 illustrate the two categories of abatement controls.

[82] "United States: Nonroad Diesel Engines." Emission Standards: USA: Nonroad Diesel Engines. December 2017. Accessed May 13, 2019. https://www.dieselnet.com/standards/us/nonroad.php

## Table 6.4. Engine Design Technologies for Emission Reduction.[83]

| NOx Abatement Method | Technique | Significance |
|---|---|---|
| Fuel injection | Capabilities have evolved significantly. Significant improvements in injection technology started in the 1990s with widespread implementation of systems capable of variable injection timing through the use of electronic controls. Engines with EGR place the highest demand on fuel injection pressure. Light-duty vehicles use the most demanding multiple injection strategies. | |
| *injection timing* | Primarily used to limit NOx emissions | Injection timing affects combustion phasing; retarding the combustion phasing can be used to limit NOx emissions. |
| *injection pressure* | Primarily used to limit soot (PM) emissions | Higher injection pressure can lower soot emissions; especially important when combined with NOx control technologies such as EGR that would otherwise increase soot emissions. |
| *multiple injections* | Various | Multiple injections strategies have been developed to lower NOx, soot, HC and CO emissions. |
| Exhaust gas recirculation (EGR) | In diesel engines, primary application is to control NOx emissions | Commonly used in many light- and heavy-duty diesel engines. High pressure EGR delivery can introduce a fuel consumption penalty through higher pumping losses. Low pressure EGR has lower pumping losses but is more difficult to control during transient operation. Other measures to limit potential increases in soot and possibly HC and CO can be required. |
| Intake boosting | Primary emissions impact is to lower soot (PM) production. Also important for efficiency gains. | Higher intake pressure increases air/fuel ratio for given fuel injection amount and lowers soot production. Can be an important measure to offset unwanted decreases in performance and increased emissions with NOx control measures such as EGR. Often accompanied by improved intake charge cooling capabilities. Enables engine downsizing for efficiency gains. Introduces challenges such as turbocharger lag that can require complex solutions. |
| Intake temperature management | Most direct impact on NOx emissions. Can lower soot emissions as well. | Increased boosting and/or EGR can increase intake manifold temperature. Intake charge cooling capability improvements are required to limit intake charge temperature and minimize associated NOx emission increases, reductions in air-fuel ratio and losses in power density. |
| Combustion chamber design | Important soot control measure | Combustion chamber design changes are commonly used to offset increases in soot emissions when measures are taken to limit NOx emissions. In many cases, improvements enhance mixing late in the combustion process to improve soot burn-out. |

83 Majewski, Addy W., and Hannu Jääskeläinen. "Engine Emission Control – Table 1." DieselNet Technology Guide. https://dieselnet.com/tech/engine_emission-control.php.

**Table 6.5. Exhaust Aftertreatment Technologies.**[84]

| NOx Abatement Method | Technique | Significance |
|---|---|---|
| Diesel oxidation catalyst (DOC) | High reduction of HC/CO emissions, small to moderate PM conversion. The oxidation of NO to $NO_2$ enhances the performance of SCR/DPF systems. | Widely used on Euro 2/3 cars and on some US1994 and later heavy- and medium-duty diesel engines. In modern engines, used as an auxiliary catalyst in SCR/DPF aftertreatment systems ($NO_2$generation, ammonia slip control). |
| Particle oxidation catalysts | Up to ~50% PM emission reduction | Limited commercial application in selected (EGR-equipped) Euro IV heavy-duty truck engines, as well as in some light-duty and nonroad engines. |
| Diesel particulate filters (DPF) | 90%+ PM emission reduction | Mainstream technology used on all Euro 5 and US Tier 2 and later light-duty diesels; in all US2007 and Euro VI and later heavy-duty engines; in all Stage V nonroad engines; in retrofit programs worldwide. |
| Urea-SCR catalysts | 90%+ NOx reduction | Mainstream technology used in US2010, Euro V and later heavy-duty engines; in US Tier 2 and Euro 5/6 and later light-duty diesel vehicles; in nonroad, marine, and stationary engines. |
| NOx adsorber catalysts | Up to ~70-90% NOx reduction, depends on the drive cycle | Used as a stand-alone NOx reduction catalyst in some US Tier 2 and Euro 5/6 light-duty vehicles. Used as a cold-start NOx reduction catalyst on some Euro 6 vehicles with SCR. |
| Lean NOx catalysts (HC-SCR) | NOx reduction potential of ~10-20% in passive systems, up to 50% in active systems | Limited OEM and retrofit commercial application, mostly in the 2000s. |

### 4. *Regulatory Requirements - MRR*

Emissions are ensured by regulating maintenance and operation practices that are set by the generator design and manufacturer specifications, as well as any industry-specific practices that could be present. Recordkeeping is an additional requirement that is important to keep. Within the US operators who do not maintain records of maintenance, operation specifics, fuel records and lab/testing analyses can prove that their engine is meeting the specified emission limitations and typically there are

84 Majewski, Addy W., and Hannu Jääskeläinen. "Engine Emission Control – Table 3." DieselNet Technology Guide. https://dieselnet.com/tech/engine_emission-control.php.

penalties for this. Penalties are not being suggested at this time, but recordkeeping protects operators and public health. Proper maintenance and operation practices also protects operators' interests. Diesel generators can range from a few thousand to well over fifteen thousand. Improper maintenance and operation results in excess emissions, hundreds to thousands of dollars of repair costs and decreased generator lifetime. The following requirements summarize what should be required:

i. Record Keeping:

   a. Monthly fuel consumption and operating hours

   b. Annual fuel consumption and operating hours

   c. Receipt of fuel purchases

   d. Maintenance records

   e. Manufacturer specifications

ii. Availability of records. Owners should maintain records for at minimum, consecutive 12 months.

## 5. *Methodology*

Once emissions standards and generator requirements are out of the way - How is it determined that a given engine meets the emission standard? The calculations above are standardized in the US and EU, and should also be in Lebanon, to the best extent as possible. Most state EPA's provide excel calculation workbooks that do this. Appendix C holds the workbook designed to calculate potential (and actual) emissions Any additional emission factors or variables needed are stored in the workbook, which can be updated, modified, simplified or adapted as needed. All emission tables presented in this discussion were taken from this file. The file will automatically generate emission estimates for summer and winter, hourly and annual, with all associated criteria and HAP pollutants once the engine parameters are inserted into the first tab "Data Input. What is important about standardizing here is that all entities, regardless of being in the private or public sector, a government official, industry representative, or common layman – is that any of them have access to the same tools as everyone else.

In §106.512, reporting is required every two years. In Lebanon, with the tampering of equipment and fuel, poor maintenance and operating practices, it is recommended that stack test and ambient testing be conducted on an annual basis. Within the EPA testing can be performed at different intervals, but they always must be done be certified personnel who are trained in using, maintaining, and calibrating equipment.

### *6. Dialogue*

The final component is dialogue. Dialogue allows policy makes know what can expected, find solutions to disagreements, and establish timeframes for policy goals. For owners, dialogue is a forum to learn and seek information, have their voices, concerns and opinions heard and acknowledged. Conversation allows the opportunity for some level of cooperation which is essential. In addition to obtaining generator specific data, I also spoke with nine owners about what they would accept initially requirements. This was achieved by using forms and rules (provided in Appendix A) used by the TCEQ, discussing them and noting which ones had potential or not. I explained that as of now the most important goal is to operate generators correctly, reducing costs on both sides (owners financial responsibilities and public health). Table 6.1 summarizes requirements that are accepted and can be implemented.

**Table 6.6. Stationary Engine >500 hp Requirements.**

| Source[85] | Description |
|---|---|
| 30 TAC §106.512 (1) | Submit registration for each engine rated above 240 hp. |
| 30 TAC §106.50 | A $100 fee is required if the owner/operator is a small business which has fewer than 100 employees. For all other the fee is a standard $450.* |
| 30 TAC §106.8 (c)(1) | Maintain a copy of the requirements. |
| | Operate and maintain engine according to manufacturer specifications, including the use of diesel fuel as the sole fuel type unless the engine is designed to be duel fueled. |
| | Maintain all records of engine maintenance, fuel consumption (fuel purchases), emissions testing, and manufacturer operations/maintenance manual |
| 30 TAC §106.8 (c)(2) | Maintain records of the general requirements and all applicable PBR conditions |
| 30 TAC §106.8 (c)(3) | Keep all required records at the facility or readily available location |
| 30 TAC §106.8 (c)(4) | Make the records available in a reviewable format |
| 30 TAC §106.261 (2) | Total new emissions shall not exceed 6.0 lb/hr and 10tpy of specified materials |
| 30 TAC §106.512 (2)(C) | Records shall be created and maintained by the owner or operator for two years and made available upon request. |

*From the nine operators spoken to, this was the only requirement that wasn't met with complete agreement, but wasn't ruled out either.

For registration purposes, the following at a minimum should be requested:

i. legal name, address and telephone number of the owner;

ii. Legal name, address and telephone number of the owner of the premises on which the subject activity is to take place;

iii. Location and address of the premises where the registered activity will be conducted;

iv. Intended dates of construction, installation and operation;

85 30 Tex. Admin. Code §106.4, §106.8, §106.512

v. Make, model and serial number of the generator;
vi. Fuel type;
vii. Maximum rated fuel-firing rate of the generator;
viii. Maximum design gross power output of the subject generator.

## C. Conclusion

The purpose for this study is to examine possibilities for emission limit values based on the current landscape; provide a methodology for estimating pollutants through traditional methods and field checks, and providing a monitoring structure through policy implementation. These have been provided through three questions. Could generators meet emission standards? Yes. Would they meet TCEQ permit authorizations? No. Can US generator policy measures help Lebanon? Definitely. Perhaps not in word for word context, but the permits target critical items that have to be addressed. First is the adoption of policy schedules for adopting Tier standards and use of appropriate fuels to meet the engine requirements and establishment of point source specific ELVs for generators (NAAQS vs occupational limits). The second is the issuance of permits overseeing optimal performance insurances through maintenance - manufacturer provided maintenance schedules; initial demonstration of compliance and annual compliance stack to ELVs; reporting stack testing results; and recordkeeping of maintenance, operation, and reporting. The following table lists the elements discussed above specific requirements.

## Table 6.7 Generator Regulations Summary - Policy and Regulations

| Policy Implementation | Description |
|---|---|
| Implement Tier Standards | Conduct generator composition survey. Conduct lab analysis of diesel fuel to determine composition. Assess strategy to adopt appropriate Tier schedule. |
| Assess Fuel Content | Conduct lab analysis of diesel fuel to determine composition. Assess compatibility with current generators. |
| Establish ELVs | Conduct ambient and exhaust testing to establish appropriate ELVs for generators. |
| ***Permit Application*** | |
| Registration | Registration for all current and new engines with engine rating over 178 kW (240 hp) |
| Fee | Submit a $100 fee for each individual generator application |
| Requirements | Application must include:<br>legal name, address and telephone number of the owner;<br>Legal name, address and telephone number of the owner of the premises on which the subject activity is to take place;<br>Location and address of the premises where the registered activity will be conducted;<br>Intended dates of construction, installation and operation;<br>Make, model and serial number of the generator;<br>Fuel type;<br>Maximum rated fuel-firing rate of the generator;<br>Maximum design gross power output of the subject generator;<br>Estimated emissions based on hours of operation. |
| ***Permit Requirements - Maintenance*** | |
| | Operate and maintain engine according to manufacturer specifications, including the use of diesel fuel as the sole fuel type unless the engine is designed to be duel fueled. |
| | Owner will be subject to stack testing twice the first year after startup, and once every year following. |
| | Initial stack testing for demonstration of compliance shall be done within first 60 days after startup ,and submitted within 90 days after startup |
| | Annual compliance with ELVs must be determined by performance of stack testing. |
| | Testing shall be performed by a qualified individual with certification. |
| | Annual compliance testing shall be submitted to the appropriate authority before 30 days of the date the initial permit was received. |
| ***Permit Requirements – Reporting*** | |
| | Owner shall submit all required emissions testing within 90 days of initial startup or before 30 days from the date the initial permit was received, which ever applies. |
| ***Permit Requirements – Recordkeeping*** | |
| | Maintain a copy of the requirements. |
| | Maintain all records of engine maintenance, fuel consumption (fuel purchases), emissions testing, and manufacturer operations/maintenance manual |
| 30 TAC §106.8 (c)(3) | Keep all required records at the facility or readily available location |
| | Make the records available in a reviewable format |
| | Records shall be created and maintained by the owner or operator for two years and made available upon request. |

The framework and an emissions tool are provided. They can be adjusted to fit the end implementation plan that will be formally adopted based on the specific needs and composition of the targeted emission source – generators – regardless of their location, service, or application. What remains is research into specific indicators that will determine the foundation of air emission regulation – emission standards and emission limits values.

Emission Tier standards may be the easiest to adopt, but where they start and how long each phase is given still needs to be determined through field surveys. There isn't enough data to explicitly say what the current age composition is so where to start isn't clear. In addition, policy implementation has not been proven successful when deadlines are immediate and affect the majority of targeted units. If engines will be limited to an age of 15 years and most engines are found to be at the Tier II standard, if will subject the majority of units to the Tier IV standard. Standard adoption will be more successful if a greater percentage of engines meet the initial standard, allowing for consistent intervals of engines being replaced or modified to meet the new emission limit values. Actual emissions and associated health impact probability may also influence what the standard schedule may look like. Perhaps Tier II is the starting point, but it could be that Tier III is skipped in favor of Tier IV.

Emission limit values will need more research gathered from physical emissions testing. ELVs need real data, both at the ground level and at the stack exhaust end to get a real sense of air emission levels and what standards would be the appropriate comparison for guidance. Not everyone is living next to a tank farm, but they are living next to generators. OSHA limits apply in industry, not residential neighborhoods; but the circumstances are close enough to warrant adherence to exposure limits and not ambient air quality standards. Stacks are located next to windows, above people's heads as they walk or sit outside a nursery with a room full of children.

The establishment of ELVs is going to impact the capacity of existing and future generators to meet these standards. o aid in emissions reduction is not just moving the generators but will most likely involve an analysis of the appropriate combination of engine age and engineering controls like the application of abatement controls and increasing performance parameters like exit velocity.

The goal is to regulate generators but to do so in the best interest of people without causing undue burden on their owners. Generators are called mafias for a reason and can have significant power and authority – but the provide a role that is necessary and could not be filled otherwise should it stop altogether. The implications of this research are significant and their implementation is not merely the act of installing a meter but a complete analysis of a person's income and must be treated with respect. Electricity blackouts have occurred for meters – what would happen for this? It's a delicate balance, people need power but they are paying a potentially heavy price. I hope that this thesis can provide some answers for generator policy development going forward.

# CHAPTER 7

# RECOMMENDATIONS

As mentioned in Limitations, I was not present to conduct any form of air testing either stack testing or ambient air testing. Air dispersion modeling was also not done. Before any real step is taken a survey of generators must be performed that provide an accurate representation of generator composition within the country.

## A. Engine Composition Survey

A few items need to be looked at when conducting engine surveys. The first component that should be recorded are the make and model information for each generator. This will later serve to establish a timeline for phase-ins of new generators for old ones. If most generators are older than 2007, but not before 2000, it is reasonable to assume that starting with a Tier II or III is acceptable. A standard that fits the majority of the landscape will be received with more openness that enforcing the hardest one, which may come with significant cost and backlash.

Second thing to look for are signs, or lack of, good housekeeping, maintenance and operational practices. If an area is clean is most likely the equipment is well maintained. Oil and lubricants can stain cement, and a distinct hydrocarbon smell is typically present. Signs of any fuel containers are also signs for proper or improper use of alternative fuels to diesel. Questions need to be asked – are records of any type kept? What are they and what information do they provide? Being present during operation and visually observances could also be beneficial. Most crucial bit of information that also needs to be documented is operating hours. Schedules can range from two to twelve hours a day for consumer demand, but there are other instances that generators could run.

## B. Establishment of Emissions Baseline

In addition to a survey of engine models, air testing would be the next step. The first is the establishment of baseline emissions from generators based on real-time measurements. Baseline emissions benefit the development of permit limits, provide accurate representation of air pollutants from generators and can contribute to the redevelopment of the Lebanese NAAQS. Emission sampling should be to assess ambient air quality standards – located around the base of the generator; and also at the stack, where the emissions are at their most concentrated. Generator manufacturers in the country like Jubaili, export generators to surrounding countries, like the Gulf states. Several of these countries have adopted the Tier standards. Therefore, generators must be tested and certified to reach those standards before even leaving the manufacturer. Testing equipment could likely be provided by these companies.

## C. Air Dispersion Modeling

Monitoring and modeling of classic and emerging pollutants is vital to our knowledge of health outcomes in exposed subjects and to our ability to predict them. AERMOD is a widely accepted EPA model for air dispersion modeling although there are many others.86 The Comprehensive Turbulent Aerosol Dynamics and Gas Chemistry (CTAG) model is designed to resolve the flow field including flows, aerosol

86 Conti, Gea Oliveri, Behzad Heibati, Itai Kloog, Maria Fiore, and Margherita Ferrante. "A Review of AiQ Models and Their Applications for Forecasting the Air Pollution Health Outcomes." Environmental Sci Pollut Res, January 4, 2017, 6426-445. doi:10.1007/s11356-016-8180-1.

dynamics and gas chemistry in complex urban environment. Large Eddy System (LES) is commonly used for modeling turbulent flow and dispersion also. The study conducted on back-up generators in New York City illustrates the benefits of these programs (Zhang, 2015). Like this study, the CTAG model or similar would be better as it specializes in near-source microenvironments. Criteria such as exact emissions, exact coordinates, stack measurements, heights of buildings in the surrounding areas and meteorological information will need to be accounted for.

For countries like Lebanon, who face singular challenges to air quality in a unique environment that is more akin to Delhi and perhaps even US cities that utilize demand response programs for annual blackouts (i.e., complex urban environments subject to inadequate power) the contribution from modeling is unequivocal. Over the past few years, modeling approaches based on mathematical and numerical techniques have been used more often to explore the relationships between air pollution and diseases.87 Internationally air quality goals for improving air quality have increasingly stresses the importance and need for improving air quality monitoring and assessment. Their use can also impact for the better, the possibility of policy and implementation of better engineering controls.

**D. Fuel Analysis**

Fuel analysis was also neglected in this study. The estimates generated are based on Tier standards which used a lower sulfur fuel percentage than Lebanon is estimated to use. Diesel fuel testing is indispensable for monitoring auxiliary and standby power

87 Conti, Gea Oliveri, Behzad Heibati, Itai Kloog, Maria Fiore, and Margherita Ferrante. "A Review of AiQ Models and Their Applications for Forecasting the Air Pollution Health Outcomes." Environmental Sci Pollut Res, January 4, 2017, 6426-445. doi:10.1007/s11356-016-8180-1.

systems in commercial and industrial applications. It also provides a detailed, accurate way to estimate sulfur emission. If Tier standards are adopted the fuel should accommodate the standards.

**E. Phasing – In**

Tier emission standards are implemented over a period of time. The EPA adopted the first standard in 1994, but it was implemented until 1996. Even at that point manufacturers had two years to fully comply with Tier I, and a total of four years (1996-2000) to prepare for the next standard. With the final standard, Tier IV, ending in 2015, a total of twenty years was afforded to phase out generators existing before the first standards. Older generators get replaced with new ones as their feasibility and cost from age dwindle and slowly the age of current generators is younger. The tier standards are intended to eventually cycle out new generators, but additional measures like ban the import of generators manufactured for 2007 for example and/or replacing critical old and defunct generators with new ones. A study from 2001 on the phase-out of leaded gasoline in Lebanon illustrated the effect of a ban on the import of cars greater than eight years old. In essence, within a scope of five to six years the expected age of the vehicle fleet within the country was expected to drop to ten to twelve years.[88] The AUB study mentioned previously found that 25% of all generators observed in the Hamra area as of 2018 when the study was released where more than ten years old. If this assumption was applied across the board, that means that 75% meet at minimum Tier III standards which have a sixty percent reduction in NOx and PM emissions than previous

88 EL-FADEL, MUTASEM, and ZAHER HASHISHO. "PHASE-OUT OF LEADED GASOLINE IN DEVELOPING COUNTRIES: APPROACHES AND PROSPECTS FOR LEBANON." Journal of Environmental Assessment Policy and Management 3, no. 1 (2001): 35-59. http://www.jstor.org/stable/enviassepolimana.3.1.35.

models. This assumptions suggests a requirement that the first phase to be adopted are Tier III and only 25% must be phased out.

Phasing out could just imply engine upgrades or application of abatement controls, but it also means the complete exchange of an old engine for a new one. It also implies that no new generators coming in, even if not being used as a replacement, must also meet at minimum the Tier II standard. There are car buy-back models that could assist with this and could possibly be applied directly to manufactures. For instance, California and Texas has car buy-back programs known as "cash for clunkers". It is a flat fee, but is something to offset the cost on purchasing a new generator. Texas has an additional program for buying fuel efficient vehicles. These vehicles are specific in design to produce little to none exhaust emissions (Nissan Electric Leaf). After purchase a voucher is provided that is correlated to the value of the car. It is possible that the government could implement a program following these principles or even contact a third party who buys and resells generators, but going directly to the manufacture could also be an option.

Back in the introduction I discussed different scenarios involving generators. On scenario involved their removal from a town and the second involved enforcement of consumption meters. In these scenarios, and many other as simple as banning indoor smoking, results in some form of unrest or retaliation. Having the right information of generators in the country and explaining not just health benefits but long-term investment security ensures that the rights steps are taken to avoid too many being subject to immediate change or replacement of their engine.

In conclusion, it is worth investing into surveys, modeling and testing for various reasons including the contribution to NAAQS development, understanding actual emissions, and the possibility of engineering practices to mitigate undue pollution exposure. If not for these reasons, then the safety and well-being of public health to all Lebanese.

# APPENDICES

# APPENDIX A

# TEXAS ADMINISTRATIVE CODE (TAC) RULES

# Texas Administrative Code

| | |
|---|---|
| TITLE 30 | ENVIRONMENTAL QUALITY |
| PART 1 | TEXAS COMMISSION ON ENVIRONMENTAL QUALITY |
| CHAPTER 106 | PERMITS BY RULE |
| SUBCHAPTER A | GENERAL REQUIREMENTS |
| RULE §106.4 | Requirements for Permitting by Rule |

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(a) To qualify for a permit by rule, the following general requirements must be met.

(1) Total actual emissions authorized under permit by rule from the facility shall not exceed the following limits, as applicable:

(A) 250 tons per year (tpy) of carbon monoxide (CO) or nitrogen oxides ($NO_X$);

(B) 25 tpy of volatile organic compounds (VOC), sulfur dioxide ($SO_2$), or inhalable particulate matter (PM);

(C) 15 tpy of particulate matter with diameters of 10 microns or less ($PM_{10}$);

(D) 10 tpy of particulate matter with diameters of 2.5 microns or less ($PM_{2.5}$); or

(E) 25 tpy of any other air contaminant except:

(i) water, nitrogen, ethane, hydrogen, and oxygen; and

(ii) notwithstanding any provision in any specific permit by rule to the contrary, greenhouse gases as defined in §101.1 of this title (relating to Definitions).

(2) Any facility or group of facilities, which constitutes a new major stationary source, as defined in §116.12 of this title (relating to Nonattainment and Prevention of Significant Deterioration Review Definitions), or any modification which constitutes a major modification, as defined in §116.12 of this title, under the new source review requirements of the Federal Clean Air Act (FCAA), Part D (Nonattainment) as amended by the FCAA Amendments of 1990, and regulations promulgated thereunder, must meet the permitting requirements of Chapter 116, Subchapter B of this title (relating to New Source Review Permits) and cannot qualify for a permit by rule under this chapter. Persons claiming a permit by rule under this chapter should see the requirements of §116.150 of this title (relating to New Major Source or Major Modification in Ozone Nonattainment Areas) to ensure that any applicable netting requirements have been satisfied.

(3) Any facility or group of facilities, which constitutes a new major stationary source, as defined in 40 Code of Federal Regulations (CFR) §52.21, or any change which constitutes a major modification, as defined in 40 CFR §52.21, under the new source review requirements of the FCAA, Part C (Prevention of Significant Deterioration) as amended by the FCAA Amendments of 1990, and regulations promulgated thereunder because of emissions of air contaminants other than greenhouse gases, must meet the permitting requirements of Chapter 116, Subchapter B of this title and cannot qualify for a permit by rule under this chapter. Notwithstanding any provision in any specific permit

by rule to the contrary, a new major stationary source or major modification which is subject to Chapter 116, Subchapter B, Division 6 of this title due solely to emissions of greenhouse gases may use a permit by rule under this chapter for air contaminants that are not greenhouse gases. However, facilities or projects which require a prevention of significant deterioration permit due to emissions of greenhouse gases may not commence construction or operation until the prevention of significant deterioration permit is issued.

(4) Unless at least one facility at an account has been subject to public notification and comment as required in Chapter 116, Subchapter B or Subchapter D of this title (relating to New Source Review Permits or Permit Renewals), total actual emissions from all facilities permitted by rule at an account shall not exceed 250 tpy of CO or $NO_X$ ; or 25 tpy of VOC or $SO_2$ or PM; or 15 tpy of $PM_{10}$ ; or 10 tpy of $PM_{2.5}$ ; or 25 tpy of any other air contaminant except water, nitrogen, ethane, hydrogen, oxygen, and GHGs (as specified in §106.2 of this title (relating to Applicability)).

(5) Construction or modification of a facility commenced on or after the effective date of a revision of this section or the effective date of a revision to a specific permit by rule in this chapter must meet the revised requirements to qualify for a permit by rule.

(6) A facility shall comply with all applicable provisions of the FCAA, §111 (Federal New Source Performance Standards) and §112 (Hazardous Air Pollutants), and the new source review requirements of the FCAA, Part C and Part D and regulations promulgated thereunder.

(7) There are no permits under the same commission account number that contain a condition or conditions precluding the use of a permit by rule under this chapter.

(8) The proposed facility or group of facilities shall obtain allowances for $NO_X$ if they are subject to Chapter 101, Subchapter H, Division 3 of this title (relating to Mass Emissions Cap and Trade Program).

(b) No person shall circumvent by artificial limitations the requirements of §116.110 of this title (relating to Applicability).

(c) The emissions from the facility shall comply with all rules and regulations of the commission and with the intent of the Texas Clean Air Act (TCAA), including protection of health and property of the public, and all emissions control equipment shall be maintained in good condition and operated properly during operation of the facility.

(d) Facilities permitted by rule under this chapter are not exempted from any permits or registrations required by local air pollution control agencies. Any such requirements must be in accordance with Texas Health and Safety Code, §382.113 and any other applicable law.

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**Source Note:** The provisions of this §106.4 adopted to be effective November 15, 1996, 21 TexReg 10881; amended to be effective April 7, 1998, 23 TexReg 3502; amended to be effective September 4, 2000, 25 TexReg 8653; amended to be effective March 29, 2001, 26 TexReg 2396; amended to be effective May 15, 2011, 36 TexReg 2852; amended to be effective April 17, 2014, 39 TexReg 2891

# Texas Administrative Code

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| TITLE 30 | ENVIRONMENTAL QUALITY |
| PART 1 | TEXAS COMMISSION ON ENVIRONMENTAL QUALITY |
| CHAPTER 106 | PERMITS BY RULE |
| SUBCHAPTER A | GENERAL REQUIREMENTS |
| RULE §106.8 | Recordkeeping |

(a) Owners or operators of facilities and sources that are de minimis as designated in §116.119 of this title (relating to De Minimis Facilities or Sources) are not subject to this section.

(b) Owners or operators of facilities operating under a permit by rule (PBR) in Subchapter C of this chapter (relating to Domestic and Comfort Heating and Cooling) or under those PBRs that only name the type of facility and impose no other conditions in the PBR itself do not need to comply with specific recordkeeping requirements of subsection (c) of this section. A list of these PBRs will be available through the commission's Austin central office, regional offices, and the commission's website. Upon request from the commission or any air pollution control program having jurisdiction, claimants must provide information that would demonstrate compliance with §106.4 of this title (relating to Requirements for Permitting by Rule), or the general requirements, if any, in effect at the time of the claim, and the PBR under which the facility is authorized.

(c) Owners or operators of all other facilities authorized to be constructed and operate under a PBR must retain records as follows:

(1) maintain a copy of each PBR and the applicable general conditions of §106.4 of this title or the general requirements, if any, in effect at the time of the claim under which the facility is operating. The PBR and general requirements claimed should be the version in effect at the time of construction or installation or changes to an existing facility, whichever is most recent. The PBR holder may elect to comply with a more recent version of the applicable PBR and general requirements;

(2) maintain records containing sufficient information to demonstrate compliance with the following:

(A) all applicable general requirements of §106.4 of this title or the general requirements, if any, in effect at the time of the claim; and

(B) all applicable PBR conditions;

(3) keep all required records at the facility site. If however, the facility normally operates unattended, records must be maintained at an office within Texas having day-to-day operational control of the plant site;

(4) make the records available in a reviewable format at the request of personnel from the commission or any air pollution control program having jurisdiction;

(5) beginning April 1, 2002, keep records to support a compliance demonstration for any consecutive 12-month period. Unless specifically required by a PBR, records regarding the quantity

of air contaminants emitted by a facility to demonstrate compliance with §106.4 of this title prior to April 1, 2002 are not required under this section; and

(6) for facilities located at sites designated as major in accordance with §122.10(13) of this title (relating to General Definitions) or subject to or potentially subject to any applicable federal requirement, retain all records demonstrating compliance for at least five years. For facilities located at all other sites, all records demonstrating compliance must be retained for at least two years. These record retention requirements supercede any retention conditions of an individual PBR.

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**Source Note:** The provisions of this §106.8 adopted to be effective November 1, 2001, 26 TexReg 8518

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| TITLE 30 | ENVIRONMENTAL QUALITY |
| PART 1 | TEXAS COMMISSION ON ENVIRONMENTAL QUALITY |
| CHAPTER 106 | PERMITS BY RULE |
| SUBCHAPTER K | GENERAL |
| RULE §106.261 | Facilities (Emission Limitations) |

---

(a) Except as specified under subsection (b) of this section, facilities, or physical or operational changes to a facility, are permitted by rule provided that all of the following conditions of this section are satisfied.

(1) The facilities or changes shall be located at least 100 feet from any recreational area or residence or other structure not occupied or used solely by the owner or operator of the facilities or the owner of the property upon which the facilities are located.

(2) Total new or increased emissions, including fugitives, shall not exceed 6.0 pounds per hour (lb/hr) and ten tons per year of the following materials: acetylene, argon, butane, crude oil, refinery petroleum fractions (except for pyrolysis naphthas and pyrolysis gasoline) containing less than ten volume percent benzene, carbon monoxide, cyclohexane, cyclohexene, cyclopentane, ethyl acetate, ethanol, ethyl ether, ethylene, fluorocarbons Numbers 11, 12, 13, 14, 21, 22, 23, 113, 114, 115, and 116, helium, isohexane, isopropyl alcohol, methyl acetylene, methyl chloroform, methyl cyclohexane, neon, nonane, oxides of nitrogen, propane, propyl alcohol, propylene, propyl ether, sulfur dioxide, alumina, calcium carbonate, calcium silicate, cellulose fiber, cement dust, emery dust, glycerin mist, gypsum, iron oxide dust, kaolin, limestone, magnesite, marble, pentaerythritol, plaster of paris, silicon, silicon carbide, starch, sucrose, zinc stearate, or zinc oxide.

(3) Total new or increased emissions, including fugitives, shall not exceed 1.0 lb/hr of any chemical having a limit value (L) greater than 200 milligrams per cubic meter ($mg/m^3$) as listed and referenced in Table 262 of §106.262 of this title (relating to Facilities (Emission and Distance Limitations)) or of any other chemical not listed or referenced in Table 262. Emissions of a chemical with a limit value of less than 200 $mg/m^3$ are not allowed under this section.

(4) For physical changes or modifications to existing facilities, there shall be no changes to or additions of any air pollution abatement equipment.

(5) Visible emissions, except uncombined water, to the atmosphere from any point or fugitive source shall not exceed 5.0% opacity in any six-minute period.

(6) For emission increases of five tons per year or greater, notification must be provided using Form PI-7 within ten days following the installation or modification of the facilities. The notification shall include a description of the project, calculations, data identifying specific chemical names, limit values, and a description of pollution control equipment, if any.

(7) For emission increases of less than five tons per year, notification must be provided using either:

(A) Form PI-7 within ten days following the installation or modification of the facilities. The notification shall include a description of the project, calculations, data identifying specific chemical names, limit values, and a description of pollution control equipment, if any; or

(B) Form PI-7 by March 31 of the following year summarizing all uses of this permit by rule in the previous calendar year. This annual notification shall include a description of the project, calculations, data identifying specific chemical names, limit values, and a description of pollution control equipment, if any.

(b) The following are not authorized under this section:

(1) construction of a facility authorized in another section of this chapter or for which a standard permit is in effect; and

(2) any change to any facility authorized under another section of this chapter or authorized under a standard permit.

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**Source Note:** The provisions of this §106.261 adopted to be effective March 14, 1997, 22 TexReg 2439; amended to be effective December 24, 1998, 23 TexReg 12925; amended to be effective September 4, 2000, 25 TexReg 8653; amended to be effective November 1, 2003, 28 TexReg 9279

Figure 1: 30 TAC §106.262(a)(2)

| D, Feet | K |
|---|---|
| 100 | 326 |
| 200 | 200 |
| 300 | 139 |
| 400 | 104 |
| 500 | 81 |
| 600 | 65 |
| 700 | 54 |
| 800 | 46 |
| 900 | 39 |
| 1,000 | 34 |
| 2,000 | 14 |
| 3,000 or more | 8 |

E = maximum allowable hourly emission, and never to exceed 6 pounds per hour.

L = value as listed or referenced in Table 262

K = value from the table on this page. (interpolate intermediate values)

D = distance to the nearest off-plant receptor.

Figure 2: 30 TAC §106.262(a)(2)

TABLE 262
LIMIT VALUES (L) FOR USE WITH EXEMPTIONS FROM PERMITTING §106.262

The values are not to be interpreted as acceptable health effects values relative to the issuance of any permits under Chapter 116 of this title (relating to Control of Air Pollution by Permits for New Construction or Modification).

| Compound | Limit (L) Milligrams Per Cubic Meter |
|---|---|
| Acetone | 590. |
| Acetaldehyde | 9. |
| Acetone Cyanohydrin | 4. |
| Acetonitrile | 34. |
| Acetylene | 2662. |
| N-Amyl Acetate | 2.7 |
| Sec-Amyl Acetate | 1.1 |
| Benzene | 3. |
| Beryllium and Compounds | 0.0005 |
| Boron Trifluoride, as HF | 0.5 |
| Butyl Alcohol, - | 76. |
| Butyl Acrylate | 19. |
| Butyl Chromate | 0.01 |
| Butyl Glycidyl Ether | 30. |
| Butyl Mercaptan | 0.3 |
| Butyraldehyde | 1.4 |
| Butyric Acid | 1.8 |
| Butyronitrile | 22. |
| Carbon Tetrachloride | 12. |

| | |
|---|---|
| Chloroform | 10. |
| Chlorophenol | 0.2 |
| Chloroprene | 3.6 |
| Chromic Acid | 0.01 |
| Chromium Metal, Chromium II and III Compounds | 0.1 |
| Chromium VI Compounds | 0.01 |
| Coal Tar Pitch Volatiles | 0.1 |
| Creosote | 0.1 |
| Cresol | 0.5 |
| Cumene | 50. |
| Dicyclopentadiene | 3.1 |
| Diethylaminoethanol | 5.5 |
| Diisobutyl Ketone | 63.9 |
| Dimethyl Aniline | 6.4 |
| Dioxane | 3.6 |
| Dipropylamine | 8.4 |
| Ethyl Acrylate | 0.5 |
| Ethylene Dibromide | 0.38 |
| Ethylene Glycol | 26. |
| Ethylene Glycol Dinitrate | 0.1 |
| Ethylidene-2-norbornene, 5- | 7. |
| Ethyl Mercaptan | 0.08 |
| Ethyl Sulfide | 1.6 |
| Glycolonitrile | 5. |
| Halothane | 16 |
| Heptane | 350. |

| | |
|---|---|
| Hexanediamine, 1,6- | 0.32 |
| Hydrogen Chloride | 1. |
| Hydrogen Fluoride | 0.5 |
| Hydrogen Sulfide | 1.1 |
| Isoamyl Acetate | 133. |
| Isoamyl Alcohol | 15. |
| Isobutyronitrile | 22. |
| Kepone | 0.001 |
| Kerosene | 100. |
| Malononitrile | 8. |
| Mesityl Oxide | 40. |
| Methyl Acrylate | 5.8 |
| Methyl Amyl Ketone | 9.4 |
| Methyl-t-butyl ether | 45. |
| Methyl Butyl Ketone | 4. |
| Methyl Disulfide | 2.2 |
| Methylenebis (2-chloroaniline) (MOCA) | 0.003 |
| Methylene Chloride | 26. |
| Methyl Isoamyl Ketone | 5.6 |
| Methyl Mercaptan | 0.2 |
| Methyl Methacrylate | 34. |
| Methyl Propyl Ketone | 530. |
| Methyl Sulfide | 0.3 |
| Mineral Spirits | 350. |
| Naphtha | 350. |
| Nickel, Inorganic Compounds | 0.015 |

| | |
|---|---|
| Nitroglycerine | 0.1 |
| Nitropropane | 5. |
| Octane | 350. |
| Parathion | 0.05 |
| Pentane | 350. |
| Perchloroethylene | 33.5 |
| Petroleum Ether | 350 |
| Phenyl Mercaptan | 0.4 |
| Propionitrile | 14. |
| Propyl Acetate | 62.6 |
| Propylene Oxide | 20. |
| Propyl Mercaptan | 0.23 |
| Silica-amorphous- precipitated, silica gel | 4. |
| Silicon Carbide | 4. |
| Stoddard Solvent | 350. |
| Styrene | 21. |
| Succinonitrile | 20. |
| Tolidine | 0.02 |
| Trichloroethylene | 135. |
| Trimethylamine | 0.1 |
| Valeric Acid | 0.34 |
| Vinyl Acetate | 15. |
| Vinyl Chloride | 2. |

NOTE: The time weighted average (TWA) Threshold Limit Value (TLV) published by the American Conference of Governmental Industrial Hygienists (ACGIH), in its TLVs and BEIs guide (1997 Edition) shall be used for compounds not included in the table. The Short Term Exposure Level (STEL) or Ceiling Limit (annotated with a "C") published by the ACGIH shall be used for compounds that do not have a published TWA TLV. This section cannot be used if the compound is not listed in the table or does not have a published TWA TLV, STEL, or Ceiling Limit in the ACGIH TLVs and BEIs guide.

# Texas Administrative Code

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| TITLE 30 | ENVIRONMENTAL QUALITY |
| PART 1 | TEXAS COMMISSION ON ENVIRONMENTAL QUALITY |
| CHAPTER 106 | PERMITS BY RULE |
| SUBCHAPTER K | GENERAL |
| RULE §106.262 | Facilities (Emission and Distance Limitations) |

(a) Facilities, or physical or operational changes to a facility, are permitted by rule provided that all of the following conditions of this section are satisfied.

(1) Emission points associated with the facilities or changes shall be located at least 100 feet from any off-plant receptor. Off-plant receptor means any recreational area or residence or other structure not occupied or used solely by the owner or operator of the facilities or the owner of the property upon which the facilities are located.

(2) New or increased emissions, including fugitives, of chemicals shall not be emitted in a quantity greater than five tons per year nor in a quantity greater than E as determined using the equation E = L/K and the following table.

Attached Graphic

Attached Graphic

(3) Notification must be provided using Form PI-7 within ten days following the installation or modification of the facilities. The notification shall include a description of the project, calculations, and data identifying specific chemical names, L values, D values, and a description of pollution control equipment, if any.

(4) The facilities in which the following chemicals will be handled shall be located at least 300 feet from the nearest property line and 600 feet from any off-plant receptor and the cumulative amount of any of the following chemicals resulting from one or more authorizations under this section (but not including permit authorizations) shall not exceed 500 pounds on the plant property and all listed chemicals shall be handled only in unheated containers operated in compliance with the United States Department of Transportation regulations (49 Code of Federal Regulations, Parts 171-178): acrolein, allyl chloride, ammonia (anhydrous), arsine, boron trifluoride, bromine, carbon disulfide, chlorine, chlorine dioxide, chlorine trifluoride, chloroacetaldehyde, chloropicrin, chloroprene, diazomethane, diborane, diglycidyl ether, dimethylhydrazine, ethyleneimine, ethyl mercaptan, fluorine, formaldehyde (anhydrous), hydrogen bromide, hydrogen chloride, hydrogen cyanide, hydrogen fluoride, hydrogen selenide, hydrogen sulfide, ketene, methylamine, methyl bromide, methyl hydrazine, methyl isocyanate, methyl mercaptan, nickel carbonyl, nitric acid, nitric oxide, nitrogen dioxide, oxygen difluoride, ozone, pentaborane, perchloromethyl mercaptan, perchloryl fluoride, phosgene, phosphine, phosphorus trichloride, selenium hexafluoride, stibine, liquified sulfur dioxide, sulfur pentafluoride, and tellurium hexafluoride. Containers of these chemicals may not be vented or opened directly to the atmosphere at any time.

(5) For physical changes or modifications to existing facilities, there shall be no changes or additions of air pollution abatement equipment.

(6) Visible emissions, except uncombined water, to the atmosphere from any point or fugitive source shall not exceed 5.0% opacity in any six-minute period.

(b) The following are not authorized under this section except as noted in subsection (c) of this section:

(1) construction of a facility authorized in another section of this chapter or for which a standard permit is in effect; and

(2) any change to any facility authorized under another section of this chapter or authorized under a standard permit.

(c) If a facility has been authorized under another section of this chapter or under a standard permit, subsection (a)(2) and (3) of this section may be used to qualify the use of other chemicals at the facility.

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**Source Note:** The provisions of this §106.262 adopted to be effective March 14, 1997, 22 TexReg 2439; amended to be effective December 24, 1998, 23 TexReg 12925; amended to be effective September 4, 2000, 25 TexReg 8653; amended to be effective November 1, 2003, 28 TexReg 9279

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| TITLE 30 | ENVIRONMENTAL QUALITY |
| PART 1 | TEXAS COMMISSION ON ENVIRONMENTAL QUALITY |
| CHAPTER 106 | PERMITS BY RULE |
| SUBCHAPTER W | TURBINES AND ENGINES |
| RULE §106.512 | Stationary Engines and Turbines |

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Gas or liquid fuel-fired stationary internal combustion reciprocating engines or gas turbines that operate in compliance with the following conditions of this section are permitted by rule.

(1) The facility shall be registered by submitting the commission's Form PI-7, Table 29 for each proposed reciprocating engine, and Table 31 for each proposed gas turbine to the commission's Office of Permitting, Remediation, and Registration in Austin within ten days after construction begins. Engines and turbines rated less than 240 horsepower (hp) need not be registered, but must meet paragraphs (5) and (6) of this section, relating to fuel and protection of air quality. Engine hp rating shall be based on the engine manufacturer's maximum continuous load rating at the lesser of the engine or driven equipment's maximum published continuous speed. A rich-burn engine is a gas-fired spark-ignited engine that is operated with an exhaust oxygen content less than 4.0% by volume. A lean-burn engine is a gas-fired spark-ignited engine that is operated with an exhaust oxygen content of 4.0% by volume, or greater.

(2) For any engine rated 500 hp or greater, subparagraphs (A) - (C) of this paragraph shall apply.

(A) The emissions of nitrogen oxides ($NO_x$) shall not exceed the following limits:

(i) 2.0 grams per horsepower-hour (g/hp-hr) under all operating conditions for any gas-fired rich-burn engine;

(ii) 2.0 g/hp-hr at manufacturer's rated full load and speed, and other operating conditions, except 5.0 g/hp-hr under reduced speed, 80-100% of full torque conditions, for any spark-ignited, gas-fired lean-burn engine, or any compression-ignited dual fuel-fired engine manufactured new after June 18, 1992;

(iii) 5.0 g/hp-hr under all operating conditions for any spark-ignited, gas-fired, lean-burn two-cycle or four-cycle engine or any compression-ignited dual fuel-fired engine rated 825 hp or greater and manufactured after September 23, 1982, but prior to June 18, 1992;

(iv) 5.0 g/hp-hr at manufacturer's rated full load and speed and other operating conditions, except 8.0 g/hp-hr under reduced speed, 80-100% of full torque conditions for any spark-ignited, gas-fired, lean-burn four-cycle engine, or any compression-ignited dual fuel-fired engine that:

(I) was manufactured prior to June 18, 1992, and is rated less than 825 hp; or

(II) was manufactured prior to September 23, 1982;

(v) 8.0 g/hp-hr under all operating conditions for any spark-ignited, gas-fired, two-cycle lean-burn engine that:

(I) was manufactured prior to June 18, 1992, and is rated less than 825 hp; or

(II) was manufactured prior to September 23, 1982;

(vi) 11.0 g/hp-hr for any compression-ignited liquid-fired engine.

(B) For such engines which are spark-ignited gas-fired or compression-ignited dual fuel-fired, the engine shall be equipped as necessary with an automatic air-fuel ratio (AFR) controller which maintains AFR in the range required to meet the emission limits of subparagraph (A) of this paragraph. An AFR controller shall be deemed necessary for any engine controlled with a non-selective catalytic reduction (NSCR) converter and for applications where the fuel heating value varies more than ± 50 British thermal unit/standard cubic feet from the design lower heating value of the fuel. If an NSCR converter is used to reduce $NO_x$ , the automatic controller shall operate on exhaust oxygen control.

(C) Records shall be created and maintained by the owner or operator for a period of at least two years, made available, upon request, to the commission and any local air pollution control agency having jurisdiction, and shall include the following:

(i) documentation for each AFR controller, manufacturer's, or supplier's recommended maintenance that has been performed, including replacement of the oxygen sensor as necessary for oxygen sensor-based controllers. The oxygen sensor shall be replaced at least quarterly in the absence of a specific written recommendation;

(ii) documentation on proper operation of the engine by recorded measurements of $NO_x$ and carbon monoxide (CO) emissions as soon as practicable, but no later than seven days following each occurrence of engine maintenance which may reasonably be expected to increase emissions, changes of fuel quality in engines without oxygen sensor-based AFR controllers which may reasonably be expected to increase emissions, oxygen sensor replacement, or catalyst cleaning or catalyst replacement. Stain tube indicators specifically designed to measure $NO_x$ and CO concentrations shall be acceptable for this documentation, provided a hot air probe or equivalent device is used to prevent error due to high stack temperature, and three sets of concentration measurements are made and averaged. Portable $NO_x$ and CO analyzers shall also be acceptable for this documentation;

(iii) documentation within 60 days following initial engine start-up and biennially thereafter, for emissions of $NO_x$ and CO, measured in accordance with United States Environmental Protection Agency (EPA) Reference Method 7E or 20 for $NO_x$ and Method 10 for CO. Exhaust flow rate may be determined from measured fuel flow rate and EPA Method 19. California Air Resources Board Method A-100 (adopted June 29, 1983) is an acceptable alternate to EPA test methods. Modifications to these methods will be subject to the prior approval of the Source and Mobile Monitoring Division of the commission. Emissions shall be measured and recorded in the as-found operating condition; however, compliance determinations shall not be established during start-up, shutdown, or under breakdown conditions. An owner or operator may submit to the appropriate regional office a report of a valid emissions test performed in Texas, on the same engine, conducted no more than 12 months prior to the most recent start of construction date, in lieu of performing an emissions test within 60 days following engine start-up at the new site. Any such engine shall be sampled no less frequently than biennially (or every 15,000 hours of elapsed run time, as recorded by an elapsed run time meter) and upon request of the executive director. Following the initial compliance test, in lieu of performing stack sampling on a biennial calendar basis, an owner or operator may elect to install and operate an elapsed operating time meter and shall test the engine within 15,000 hours of engine operation after the previous emission test. The owner or operator who elects to test on an operating hour schedule shall submit in writing, to the appropriate regional office, biennially after initial sampling, documentation of the actual recorded hours of engine operation since the previous emission test, and an estimate of the date of the next required sampling.

(3) For any gas turbine rated 500 hp or more, subparagraphs (A) and (B) of this paragraph shall apply.

(A) The emissions of $NO_x$ shall not exceed 3.0 g/hp-hr for gas-firing.

(B) The turbine shall meet all applicable $NO_x$ and sulfur dioxide ($SO_2$) (or fuel sulfur) emissions limitations, monitoring requirements, and reporting requirements of EPA New Source Performance Standards Subpart GG--Standards of Performance for Stationary Gas Turbines. Turbine hp rating shall be based on turbine base load, fuel lower heating value, and International Standards Organization Standard Day Conditions of 59 degrees Fahrenheit, 1.0 atmosphere and 60% relative humidity.

(4) Any engine or turbine rated less than 500 hp or used for temporary replacement purposes shall be exempt from the emission limitations of paragraphs (2) and (3) of this section. Temporary replacement engines or turbines shall be limited to a maximum of 90 days of operation after which they shall be removed or rendered physically inoperable.

(5) Gas fuel shall be limited to: sweet natural gas or liquid petroleum gas, fuel gas containing no more than ten grains total sulfur per 100 dry standard cubic feet, or field gas. If field gas contains more than 1.5 grains hydrogen sulfide or 30 grains total sulfur compounds per 100 standard cubic feet (sour gas), the engine owner or operator shall maintain records, including at least quarterly measurements of fuel hydrogen sulfide and total sulfur content, which demonstrate that the annual $SO_2$ emissions from the facility do not exceed 25 tons per year (tpy). Liquid fuel shall be petroleum distillate oil that is not a blend containing waste oils or solvents and contains less than 0.3% by weight sulfur.

(6) There will be no violations of any National Ambient Air Quality Standard (NAAQS) in the area of the proposed facility. Compliance with this condition shall be demonstrated by one of the following three methods:

(A) ambient sampling or dispersion modeling accomplished pursuant to guidance obtained from the executive director. Unless otherwise documented by actual test data, the following nitrogen dioxide ($NO_2$)/$NO_x$ ratios shall be used for modeling $NO_2$ NAAQS;

Attached Graphic

(B) all existing and proposed engine and turbine exhausts are released to the atmosphere at a height at least twice the height of any surrounding obstructions to wind flow. Buildings, open-sided roofs, tanks, separators, heaters, covers, and any other type of structure are considered as obstructions to wind flow if the distance from the nearest point on the obstruction to the nearest exhaust stack is less than five times the lesser of the height, Hb, and the width, Wb, where:

Attached Graphic

(C) the total emissions of $NO_x$ (nitrogen oxide plus $NO_2$ ) from all existing and proposed facilities on the property do not exceed the most restrictive of the following:

(i) 250 tpy;

(ii) the value (0.3125 D) tpy, where D equals the shortest distance in feet from any existing or proposed stack to the nearest property line.

(7) Upon issuance of a standard permit for electric generating units, registrations under this section for engines or turbines used to generate electricity will no longer be accepted, except for:

(A) engines or turbines used to provide power for the operation of facilities registered under the Air Quality Standard Permit for Concrete Batch Plants;

(B) engines or turbines satisfying the conditions for facilities permitted by rule under Subchapter E of this title (relating to Aggregate and Pavement); or

(C) engines or turbines used exclusively to provide power to electric pumps used for irrigating crops.

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**Source Note:** The provisions of this §106.512 adopted to be effective March 14, 1997, 22 TexReg 2439; amended to be effective September 4, 2000, 25 TexReg 8653; amended to be effective June 13, 2001, 26 TexReg 4108

# APPENDIX B

# GENERATOR SUPPORTING MATERIALS

# VOLVO PENTA GENSET ENGINE

# TAD1642GE

536 kW (729 hp) at 1500 rpm, 585 kW (796 hp) at 1800 rpm, acc. ISO 3046


The TAD1642GE is a powerful, reliable and economical Generating Set Diesel Engine built on the dependable in-line six design.

## Durability & low noise

Designed for easiest, fastest and most economical installation. Well-balanced to produce smooth and vibration-free operation with low noise level.

To maintain a controlled working temperature in cylinders and combustion chambers, the engine is equipped with piston cooling. The engine is also fitted with replaceable cylinder liners and valve seats/guides to ensure maximum durability and service life of the engine.

## Low exhaust emission

The state of the art, high-tech injection and charging system with low internal losses contributes to excellent combustion and low fuel consumption.

The TAD1642GE complies with EU Stage 2 exhaust emission regulations.

## Easy service & maintenance

Easily accessible service and maintenance points contribute to the ease of service of the engine.

## Features

- Maintained performance, air temp 40°C
- Tropical cooling system (55°C)
- Fully electronic with Volvo Penta EMS 2
- Dual frequency switch (between 1500 rpm and 1800 rpm)
- High power density
- Emission compliant
- Low noise levels
- Gen Pac configuration

## Technical description

### Engine and block

- Optimized cast iron cylinder block with optimum distribution of forces without the block being unnessarily heavy.
- Wet, replaceable cylinder liners
- Piston cooling for low piston temperature and reduced ring temperature
- Tapered connecting rods for reduce risk of piston cracking
- Crankshaft induction hardened bearing surfaces and fillets with seven bearings for moderate load on main and high-end bearings
- Case hardened and Nitrocarburized transmission gears for heavy duty operation
- Keystone top compression rings for long service life
- Viscous type crankshaft vibration dampers to withstand single bearing alternator torsional vibrations
- Replaceable valve guides and valve seats
- Over head camshaft and four valves per cylinder

### Lubrication system

- Full flow oil cooler
- Full flow disposable spin-on oil filter, for extra high filtration
- The lubricating oil level can be measured during operation
- Gear type lubricating oil pump, gear driven by the transmission

### Fuel system

- Non-return fuel valve
- Electronic unit injectors
- Fuel prefilter with water separator and water-in-fuel indicator / alarm
- Gear driven low-pressure fuel pump
- Fine fuel filter with manual feed pump and fuel pressure switch
- Fuel shut-off valve, electrically operated

### Cooling system

- Efficient cooling with accurate coolant control through a water distribution duct in the cylinder block. Reliable sleeve thermostat with minimum pressure drop
- Gear driven, maintenance-free coolant pump with high degree of efficiency
- Coolant filter as standard

### Turbo charger

- Efficient and reliable turbo charger
- Extra oil filter for the turbo charger

### Electrical system

- Engine Management System 2 (EMS 2), an electronically controlled processing system which optimizes engine performance. It also includes advanced facilities for diagnostics and fault tracing
- The instruments and controls connect to the engine via the CAN SAE J1939 interface, either through the Control Interface Unit (CIU) or the Digital Control Unit (DCU). The CIU converts the digital CAN bus signal to an anolog signal, making it possible to connect a variety of instruments. The DCU is a control panel with display, engine control, monitoring, alarm, parameter setting and diagnostic functions. The DCU also presents error codes in clear text.
- Sensors for oil pressure, oil temp, boost pressure, boost temp, coolant temp, fuel temp, water in fuel, fuel pressure and two speed sensors.

VOLVO PENTA

# TAD1642GE

## Technical Data

**General**

| | |
|---|---|
| Engine designation | TAD1642GE |
| No. of cylinders and configuration | in-line 6 |
| Method of operation | 4-stroke |
| Bore, mm (in.) | 144 (5.67) |
| Stroke, mm (in.) | 165 (6.50) |
| Displacement, l (in³) | 16.12 (983.7) |
| Compression ratio | 16.5:1 |
| Dry weight, kg (lb) | 1480 (3263) |
| Dry weight with Gen Pac, kg (lb) | 1910 (4211) |
| Wet weight, kg (lb) | 1550 (3417) |
| Wet weight with Gen Pac, kg (lb) | 2020 (4453) |

| **Performance** | **1500 rpm** | **1800 rpm** |
|---|---|---|
| with fan, kW (hp) at: | | |
| Prime Power | 485 (660) | 532 (724) |
| Max Standby Power | 536 (729) | 585 (796) |

| **Lubrication system** | **1500 rpm** | **1800 rpm** |
|---|---|---|
| Oil consumption, liter/h (US gal/h) at: | | |
| Prime Power | 0.10 (0.026) | 0.11 (0.029) |
| Max Standby Power | 0.11 (0.029) | 0.12 (0.032) |
| Oil system capacity incl filters, liter | | 42 |

| **Fuel system** | **1500 rpm** | **1800 rpm** |
|---|---|---|
| Specific fuel consumption at: | | |
| Prime Power, g/kWh (lb/hph) | | |
| 25 % | 218 (0.353) | 229 (0.371) |
| 50 % | 201 (0.326) | 202 (0.327) |
| 75 % | 195 (0.316) | 197 (0.319) |
| 100 % | 200 (0.324) | 206 (0.334) |
| Max Standby Power, g/kWh (lb/hph) | | |
| 25 % | 213 (0.345) | 222 (0.360) |
| 50 % | 197 (0.319) | 200 (0.324) |
| 75 % | 195 (0.316) | 198 (0.321) |
| 100 % | 202 (0.327) | 210 (0.340) |

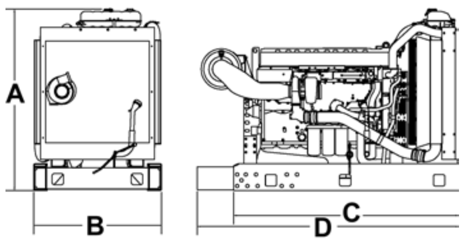
| **Intake and exhaust system** | **1500 rpm** | **1800 rpm** |
|---|---|---|
| Air consumption, m³/min (cfm) at: | | |
| Prime Power | 37 (1307) | 44 (1554) |
| Max Standby Power | 39 (1377) | 46 (1624) |
| Max allowable air intake restriction, kPa (In wc) | 5 (20.1) | 5 (20.1) |
| Heat rejection to exhaust, kW (BTU/min) at: | | |
| Prime Power | 375 (21326) | 439 (24965) |
| Max Standby Power | 426 (24226) | 500 (28435) |
| Exhaust gas temperature after turbine, °C (°F) at: | | |
| Prime Power | 480 (896) | 455 (851) |
| Max Standby Power | 500 (932) | 505 (941) |
| Max allowable back-pressure in exhaust line, kPa (In wc) | 10 (40.2) | 10 (40.2) |
| Exhaust gas flow, m³/min (cfm) at: | | |
| Prime power | 90.0 (3178) | 105 (3708) |
| Max Standby Power | 98.0 (3461) | 115 (4061) |

| **Cooling system** | **1500 rpm** | **1800 rpm** |
|---|---|---|
| Heat rejection radiation from engine, kW (BTU/min) at: | | |
| Prime Power | 31 (1763) | 33 (1877) |
| Max Standby Power | 32 (1820) | 34 (1934) |
| Heat rejection to coolant kW (BTU/min) at: | | |
| Prime Power | 184 (10464) | 199 (11317) |
| Max Standby Power | 190 (10805) | 214 (12170) |
| Fan power consumption, kW (hp) | 11 (15) | 19 (26) |

## Standard equipment

| | Engine | Gen Pac |
|---|---|---|
| **Engine** | | |
| Automatic belt tensioner | • | • |
| Lift eyelets | • | • |
| **Flywheel** | | |
| Flywheel housing with conn. acc. to SAE 1 | • | • |
| Flywheel for 14" flex. plate and flexible coupling | • | • |
| Vibration dampers | • | • |
| **Engine suspension** | | |
| Fixed front suspension | • | • |
| **Lubrication system** | | |
| Oil dipstick | • | • |
| Full-flow oil filter of spin-on type | • | • |
| By-pass oil filter of spin-on type | • | • |
| Oil cooler, side mounted | • | • |
| Low noise oil sump | • | • |
| **Fuel system** | | |
| Fuel filters of disposable type | • | • |
| Electronic unit injectors | • | • |
| Pre-filter with water separator | • | • |
| **Intake and exhaust system** | | |
| Air filter with replaceable paper insert | • | • |
| Air restriction indicator | • | • |
| Air cooled exhaust manifold | • | • |
| Connecting flange for exhaust pipe | • | • |
| Exhaust flange with v-clamp | • | • |
| Turbo charger, low right side | • | • |
| **Cooling system** | | |
| Tropical radiator incl intercooler | •1) | • |
| Gear driven coolant pump | • | • |
| Fan hub | • | • |
| Thrust fan | •1) | • |
| Fan guard | – | • |
| Belt guard | – | • |
| **Control system** | | |
| Engine Management System (EMS) with CAN-bus interface SAE J1939 | • | • |
| CIU, Control Interface Unit | – | – |
| **Alternator** | | |
| Alternator 60A / 24 V | • | • |
| **Starting system** | | |
| Starter motor, 7.0kW, 24 V | • | • |
| Connection facility for extra starter motor | • | • |
| **Instruments and senders** | | |
| Temp.- and oil pressure for automatic stop/alarm 103°C | • | • |
| **Other equipment** | | |
| Expandable base frame | – | • |
| **Engine Packing** | | |
| Plastic warpping | • | • |

1) must be ordered, se order specification
– optional equipment or not applicable
• included in standard specification




A* = 1587 mm / 62.5 in
B* = 1120 mm / 44.1 in
C* = 1976 mm / 77.8 in
D = 2296 mm / 90.5 in (During transport)
D = Max 3311 mm / 130.5 in
* Including radiator and intercooler

Note! Not all models, standard equipment and accessories are available in all countries.
All specifications are subject to change without notice.
The engine illustrated may not be entirely identical to production standard engines.

**Power Standards**
The engine performance corresponds to ISO 3046, BS 5514 and DIN 6271. The technical data applies to an engine without cooling fan and operating on a fuel with calorific value of 42.7 MJ /kg (18360 BTU/lb) and a density of 0.84 kg/liter (7.01 lb/US gal), also where this involves a deviation from the standards. Power output guaranteed within 0 to +2% att rated ambient conditions at delivery. Ratings are based on ISO 8528. Engine speed governing in accordance with ISO 3046/IV, class A1 and ISO 8528-5 class G3

**Exhaust emissions**
The engine complies with EU stage 2 emission legislation according to the Non Road Directive EU 97/68/EEC. The engine also complies with TA-luft -50% exhaust emission regulations.

**Rating Guidelines**
PRIME POWER rating corresponds to ISO Standard Power for continuous operation. It is applicable for supplying electrical power at variable load for an unlimited number of hours instead of commercially purchased power. A10 % overload capability for govering purpose is available for this rating.
MAXIMUM STANDBY POWER rating corresponds to ISO Standard Fuel Stop Power. It is applicable for supplying standby electrical power at variable load in areas with well established electrical networks in the event of normal utility power failure. No overload capability is available for this rating.
1 hp = 1 kW x 1.36

**Information**
For more technical data and information, please look in the Generating Set Engines Sales Guide.

VOLVO PENTA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# Texas Commission on Environmental Quality
# Table 29 Reciprocating Engines

## I. Engine Data

| Manufacturer: | Model No. | Serial No. | Manufacture Date: |
|---|---|---|---|
| Rebuilds Date: | No. of Cylinders: | Compression Ratio: | EPN: |

**Application:** ☐ Gas Compression ☐ Electric Generation ☐ Refrigeration ☐ Emergency/Stand by

☐ 4 Stroke Cycle ☐ 2 Stroke Cycle ☐ Carbureted ☐ Spark Ignited ☐ Dual Fuel ☐ Fuel Injected

☐ Diesel ☐ Naturally Aspirated ☐ Blower /Pump Scavenged ☐ Turbo Charged and I.C. ☐ Turbo Charged

☐ Intercooled ☐ I.C. Water Temperature ☐ Lean Burn ☐ Rich Burn

| **Ignition/Injection Timing:** | Fixed: | Variable: |
|---|---|---|

| Manufacture Horsepower Rating**:** | Proposed Horsepower Rating: |
|---|---|

**Discharge Parameters**

| Stack Height (Feet) | Stack Diameter (Feet) | Stack Temperature ($^oF$) | Exit Velocity (FPS) |
|---|---|---|---|
| | | | |

## II. Fuel Data

Type of Fuel: ☐ Field Gas ☐ Landfill Gas ☐ LP Gas ☐ Natural Gas ☐ Digester Gas ☐ Diesel

| Fuel Consumption (BTU/bhp-hr): | Heat ing Value: | Lower Heating Value: |
|---|---|---|

Sulfur Content (grains/100 scf - weight %):

## III. Emission Factors (Before Control)

| $NO_X$ | | CO | | $SO_2$ | | VOC | | Formaldehyde | | $PM_{10}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv |
| | | | | | | | | | | | |

Source of Emission Factors: ☐ Manufacturer Data ☐ AP-42 ☐ Other (specify):

## IV. Emission Factors (Post Control)

| $NO_X$ | | CO | | $SO_2$ | | VOC | | Formaldehyde | | $PM_{10}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv | g/hp-hr | ppmv |
| | | | | | | | | | | | |

Method of Emission Control: ☐ NSCR Catalyst ☐ Lean Operation ☐ Parameter Adjustment

☐ Stratified Charge ☐ JLCC Catalyst ☐ Other (Specify):______________________________

***Note:*** *Must submit a copy of any manufacturer control information that demonstrates control efficiency.*

Is Formaldehyde included in the VOCs? ☐ Yes ☐ No

## V. Federal and State Standards (Check all that apply)

☐ NSPS JJJJ ☐ MACT ZZZZ ☐ NSPS IIII ☐ Title 30 Chapter 117 - List County: ____________________

## VI. Additional Information

1. Submit a copy of the engine manufacturer's site rating or general rating specification data.
2. Submit a typical fuel gas analysis, including sulfur content and heating value. For gaseous fuels, provide mole percent of constituents.
3. Submit description of air/fuel ratio control system (manufacturer information is acceptable).

Reset Form | Print Form

# Texas Commission on Environmental Quality
# Stationary Engines and Turbines
# Air Permits by Rule (PBR) Checklist
# Title 30 Texas Administrative Code § 106.512

Check the most appropriate answer and include any additional information in the spaces provided. If additional space is needed, please include an extra page and reference the question number. The permit by rule (PBR) forms, tables, checklists, and guidance documents are available from the Texas Commission on Environmental Quality (TCEQ), Air Permits Division Web site at: www.tceq.texas.gov/permitting/air/nav/air_pbr.html.

This PBR (§ 106.512) requires registration with the commission's Office of Air in Austin before construction if the horsepower (hp) of the facility is greater than 240 hp. Registration of the facility can be performed by completing a Form PI-7, "Registration for Permits by Rule," or Form PI-7-CERT, "Registration and Certification for Permits by Rule." This checklist should accompany the registration form.

For additional assistance with your application, including resources to help calculate your emissions, please visit the Small Business and Local Government Assistance (SBLGA) webpage at the following link: www.TexasEnviroHelp.org

## Definitions:

The following words and terms, when used in this section, shall have the following meanings, unless the context clearly indicates otherwise.

A. **Rich-burn Engine**: A rich-burn engine is a gas-fired, spark-ignited engine that is operated with an exhaust oxygen content less than four percent by volume.

B. **Lean-burn Engine**: A lean-burn engine is a gas-fired, spark-ignited engine that is operated with an exhaust oxygen content of four percent by volume, or greater.

C. **Rated Engine Horsepower**: Engine rated horsepower shall be based on the engine manufacturer's maximum continuous load rating at the lesser of the engine or driven equipment's maximum published continuous speed.

D. **Turbine Horsepower**: Turbine rated horsepower shall be based on turbine base load, fuel power heating value, and International Standards Organization Standard Day Conditions of 59 degrees Fahrenheit, 1.0 atmosphere pressure, and 60 percent relative humidity.

| **Questions/Description and Response** | | |
|---|---|---|
| Will the engine or turbine be used as a replacement at an oil and gas site and does it meet all the requirements of the policy memo entitled, "Replacement of All Engine and Turbine Components for Oil and Gas Production?" | | ☐ YES ☐ NO |
| *If "YES," registration is not required for like-kind replacements of engine or turbine components.*<br>*If "NO," please continue.* | | |
| **Rule** | **Introduction** | |
| (1) | Is the engine or turbine rated less than 240 hp? | ☐ YES ☐ NO |
| *If "YES," then registration is not required, but the facility must comply with conditions (5) and (6) of this rule.*<br>*If "NO," then registration is required and the facility must be registered by submitting a completed Form PI-7 and Table 29 or Table 31, as applicable, within 10 days after construction begins.* | | |
| Indicate the type of equipment (pick one):<br>☐ Engine ☐ Turbine | | |
| *If an engine, continue to the questions regarding "Engines."*<br>*If a turbine, skip to the questions regarding "Gas Turbines."* | | |
| **Rule** | **Engines** | |
| (2) | Is the engine rated at 500 hp or greater? | ☐ YES ☐ NO |
| *If "NO," the engine is between 240 hp and 500 hp. The engine must be registered by submitting a completed Form PI-7 and a Table 29 within 10 days after construction begins and must comply with the conditions in §§ 106.512(5) and (6). Skip to the questions regarding § 106.512(4).*<br>*If "YES," in addition to registration, the engine must operate in compliance with the following nitrogen ($NO_x$) emission limit(s). Check the limit(s) applicable to this engine by answering the following:* | | |
| (2)(A)(i) | The engine is a gas-fired, rich-burn engine and will not exceed 2.0 grams per horsepower hour (g/hp-hr) under all operating conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:________________ (g/hp-hr) | | |
| (2)(A)(ii) | The engine is a spark-ignited, gas-fired, lean-burn engine or any compression-ignited, dual fuel-fired engine manufactured new after June 18, 1992, and will not exceed 2.0 g/hp-hr $NO_x$ at manufacturer's rated full load and speed at all times; except, the engine will not exceed 5.0 g/hp-hr $NO_x$ under reduced speed and 80% and 100% of full torque conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:________________ (g/hp-hr) | | |

| **Questions/Description and Response** | | |
|---|---|---|
| **Rule** | **Engines (*continued*)** | |
| (2)(A)(iii) | The engine is any spark-ignited, lean-burn two-cycle or four-cycle engine or any compression-ignited, dual fuel-fired engine rated 825 hp or greater and manufactured between September 23, 1982 and June 18, 1992, and will not exceed 5.0 g/hp-hr $NO_x$ under all operating conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:__________ g/hp-hr | | |
| (2)(A)(iv) | The engine is any spark-ignited, gas-fired, lean-burn, four-cycle engine or compression-ignited, dual-fuel-fired engine that was manufactured before June 18, 1992, and is rated less than 825 hp, or was manufactured before September 23, 1982, and will not exceed 5.0 g/hp-hr $NO_x$ at manufacturer's rated full load and speed at all times; except, the engine will not exceed 8.0 g/hp-hr $NO_x$ under reduced speed and 80% and 100% of full torque conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:__________ g/hp-hr | | |
| (2)(A)(v) | The engine is any spark-ignited, gas-fired, two-cycle, lean-burn engine that was manufactured before June 18, 1992, and is rated less than 825 hp, or was manufactured before September 23, 1982, and will not exceed 8.0 g/hp-hr $NO_x$ under all operating conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:__________ g/hp-hr | | |
| (2)(A)(vi) | The engine is any compression-ignited, liquid-fired engine and will not exceed 11.0 g/hp-hr $NO_x$ under all operating conditions. | ☐ YES ☐ NO |
| Indicate grams per horsepower hour $NO_x$:__________ g/hp-hr | | |
| (2)(B) | Does the engine require an automatic air-fuel ratio controller to meet the $NO_x$ limit(s) above? | ☐ YES ☐ NO |
| (2)(B) | For spark-ignited gas-fired or compression-ignited dual fuel-fired engines, is the engine required to have an automatic air-fuel ratio controller under condition (2)(B) of the PBR? | ☐ YES ☐ NO |
| (2)(C) | Are you aware of and accept responsibility for the record and testing requirements as specified in (2)(C) of the PBR? | ☐ YES ☐ NO |

# Texas Commission on Environmental Quality
# Stationary Engines and Turbines
# Air Permits by Rule (PBR) Checklist
# Title 30 Texas Administrative Code § 106.512

| **Questions/Description and Response** | | |
|---|---|---|
| **Rule** | **Gas Turbines** | |
| (3) | Is the turbine rated 500 hp or more? | ☐ YES ☐ NO |
| *If "NO," the turbine is between 240 hp and 500 hp. The engine only needs to be registered by submitting a completed Form PI-7 and a Table 31 within 10 days after construction begins.*<br>*If "YES," in addition to registration, the turbine must operate in compliance with the following emission limit(s) and must comply with the conditions in §§ 106.512(5)(6). Skip to questions regarding "Additional Requirements."* | | |
| (3)(A) | Will the emissions of $NO_x$ exceed 3.0 g/hp-hr for gas firing? | ☐ YES ☐ NO |
| (3)(B) | Will the turbine meet all applicable $NO_x$ and sulfur dioxide (or fuel sulfur) emission limitations, monitoring requirements, and reporting requirements of 40 CFR Part 60, NSPS Subpart GG? | ☐ YES ☐ NO |
| **Rule** | **Additional Requirements** | |
| (4) | Is the engine or turbine rated less than 500 hp or used for temporary replacement purposes? | ☐ YES ☐ NO |
| *If "NO," continue to next question.*<br>*If "YES," the equipment does not have to meet the emission limits of §§ 106.512(2) and (3). However, the temporary replacement equipment can only remain in service for a maximum of 90 days.* | | |
| (5) | What type of fuel will be used and will the fuel meet the requirements of the PBR? | ☐ YES ☐ NO |
| Indicate the fuel(s) used.<br>☐ Natural gas ☐ Liquid Petroleum gas ☐ Field gas ☐ Liquid fuel | | |
| (6) | Does the installation comply with the National Ambient Air Quality Standards (NAAQS)? | ☐ YES ☐ NO |
| Indicate which method is used and attach the modeling report and/or calculations and diagrams to support the selected method.<br>☐ Modeling ☐ Stack height ☐ Facility emissions and property line distance | | |
| (6) | Have you included a modeling report and/or calculations and diagrams to support the selected NAAQS compliance determination method? | ☐ YES ☐ NO |
| **Rule** | **Other Applicable Rules and Regulations** | |
| For the following four questions, please refer to the Electric Generators under Permit by Rule policy memo from October 2006. | | |
| Is the engine or turbine used to generate electricity? | | ☐ YES ☐ NO |
| *If "NO," the following do not apply.* | | |

| **Questions/Description and Response** | | |
|---|---|---|
| **Rule** | **Other Applicable Rules and Regulations (continued)** | |
| Will the engine or turbine be used to generate electricity to operate facilities authorized by a New Source Review Permit? | | ☐ YES ☐ NO |
| *If "YES," the engine or turbine does not qualify for this PBR and authorization must be obtained through a permit amendment.* | | |
| If the engine or turbine is used to generate electricity, will it be exclusively for on-site use at locations which cannot be connected to an electric grid? | | ☐ YES ☐ NO |
| *If "YES," describe why access to the electric grid is not available.*<br>*If "NO," the engine or turbine does not qualify for this PBR.* | | |
| Has an Electric Generating Unit Standard Permit been issued for one of the following activities for which the engine or turbine will only be used to generate electricity? | | ☐ YES ☐ NO |
| ☐ Engines or turbines used to provide power for the operation of facilities registered under the Air Quality Standard Permit for Concrete Batch Plants.<br>☐ Engines or turbines satisfying the conditions for facilities permitted by rule under 30 TAC Chapter 106, Subchapter E (relating to Aggregate and Pavement).<br>☐ Engines or turbines used exclusively to provide power to electric pumps used for irrigating crops | | |
| *If "NO," the engine or turbine does not qualify for this PBR.* | | |
| If the engine or turbine is located in the Houston/Galveston nonattainment area, is the site subject to the Mass Emission Cap and Trade Program? | | ☐ YES ☐ NO |
| Why or Why Not: | | |
| Is the facility subject to 30 TAC Chapter 115? | | ☐ YES ☐ NO |
| Why or Why Not: | | |
| Is the facility subject to 30 TAC Chapter 117? | | ☐ YES ☐ NO |
| Why or Why Not: | | |

| **Other Applicable Rules and Regulations (continued)** | |
|---|---|
| Is the facility subject to 40 CFR Part 60, NSPS Subpart D? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 60, NSPS Subpart Da? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 60, NSPS Subpart Db? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 60, NSPS Subpart Dc? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 60, NSPS Subpart GG? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 63, MACT Subpart YYYY? | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 63, MACT Subpart ZZZZ | ☐ YES ☐ NO |
| Why or Why Not: | |
| Is the facility subject to 40 CFR Part 63, MACT Subpart PPPPP? | ☐ YES ☐ NO |
| Why or Why Not: | |

**Record Keeping:** In order to demonstrate compliance with the general and specific requirements of this PBR, sufficient records must be maintained to demonstrate that all requirements are met at all times. If the engine or turbine is rated greater than 500 horsepower, all records must be maintained as required by 30 TAC § 106.512(2)(C). The registrant should also become familiar with the additional record keeping requirements in 30 TAC § 106.8. The records must be made available immediately upon request to the commission or any air pollution control program having jurisdiction. If you have any questions about the type of records that should be maintained or testing requirements, contact the Air Program in the TCEQ Regional Office for the region in which the site is located.

**Recommended Calculation Method:** In order to demonstrate compliance with this PBR, emission factors for each air contaminant from the EPA Compilation of Air Pollutant Emission Factors (AP-42), Fifth Edition, Volume 1, Section 3.1: Stationary Gas Turbines for Electricity Generation at: www.epa.gov/ttn/chief/ap42/index.html should be used, including, the specific air contaminant's emission limit listed on the table below.

PRINT FORM    RESET FORM

| **TCEQ Exemption 30 TAC §106.512 General Guidelines** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $NO_X$ g/hp-hr Emission Limits | | | | | | | | | | |
| Date Original Manufacture | | N/A | NA | Before 09/23/82 | | 09/23/82 to 06/18/92 | | | After 06/18/92 | |
| Mfg. Rated Horsepower | | X < 240 | 240< X<500 | X >500* | | 500 ≤ X ≤824* | | X >825 | X >500* | |
| Operating Speed | | N/A | N/A | Full | Reduced | Full | Reduced | N/A | Full | Reduced |
| Operating Torque | | N/A | N/A | N/A | 80-100% | N/A | 80-100% | N/A | N/A | 80-100% |
| Ignition Type | | *Engine Combustion Design* | | | | | | | | |
| Spark | Rich Burn †† | N/A | N/A | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Spark | Lean Burn** | N/A | N/A | 5.0 | 8.0 | 5.0 | 8.0 | 5.0 | 2.0 | 5.0 |
| Spark | 2-Cycle | N/A | N/A | 8.0 | 8.0 | 8.0 | 8.0 | 5.0 | 2.0 | 5.0 |
| Compression | Dual Fuel | N/A | N/A | 5.0 | 8.0 | 5.0 | 8.0 | 5.0 | 2.0 | 5.0 |
| Compression | Liquid Fuel | N/A | N/A | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| Turbines† | | NA | NA | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| PI-7 Registration | | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Emission Testing | | No | No | Biennial | Biennial | Biennial | Biennial | Biennial | Biennial | Biennial |

**Notes:**

* Lower emission rates apply to lean-burn engine operating: Full Speed & Any Torque or Any Speed & <80% or >100% Torque
† Turbine emissions are also regulated by EPA NSPS Standards for $NO_X$ and $SO_2$
** Lean Burn > 4% exhaust $0_2$
†† Rich Burn = ≤ 4% exhaust $0_2$

# APPENDIX C

# EMISSION CALCULATION WORKBOOK

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