Attachment 8

Best Available Control Technology Documents

MAJOR PROJECTS CONTRACTOR DOCUMENT FRONT COVER SHEET

Contract Number and Description: 2024-97582 DS - RFP for 150 MW Combustion Turbine Plant– Front End Engineering and Design Project	**Project Number:** 12972390
Contractor Name: Hatch Ltd.	**Contractor Address:** 80 Hebron Way, Suite 100 St. John's, NL A1A 0L9
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Comments:	**Equipment Tag:**

REVIEW DOES NOT CONSTITUTE APPROVAL OF DESIGN DETAILS, CALCULATIONS, TEST METHODS, OR MATERIAL DEVELOPED AND/OR SELECTED BY THE CONTRACTOR, NOR DOES IT RELIEVE THE CONTRACTOR FROM FULL COMPLIANCE WITH CONTRACTUAL OR OTHER OBLIGATIONS.

- ☐ **01 REVIEWED AND ACCEPTED – NO COMMENTS**
- ☐ **02 REVIEWED – INCORPORATE COMMENTS, REVISE AND RESUBMIT**
- ☐ **03 REVIEWED – NOT ACCEPTED**
- ☐ **04 INFORMATION ONLY**
- ☐ **05 NOT REVIEWED**

NLH Lead Reviewer	Date (DD-MMM-YYYY)	NLH Project Manager	Date (DD-MMM-YYYY)

General Comments:

Newfoundland & Labrador Hydro – 150 MW Combustion Turbine Plant FEED Study
Project Memo
H373979

Best Available Control Technology Memorandum

[redacted]

			[redacted]		
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HATCH					

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This memo was prepared by Hatch Ltd. ("Hatch") for the sole and exclusive use of Newfoundland and Labrador Hydro. (the "Client") for the purpose of assisting the Client as part of H/373979 to assess the associated candidate turbine packages as Best Available Controls Technology for emissions abatement, in support of an application to the Newfoundland and Labrador Public Utilities Board. This memo must not be used by the Client for any other purpose, or provided to, relied upon or used by any other person without Hatch's prior written consent.

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Best Available Control Technology Memorandum

1. Background

Hatch is providing a FEED Study for the addition of 150MW of combustion turbine sourced power generation for Newfoundland Labrador Hydro. The FEED Study includes a review of combustion turbine options and the combustion and emissions controls technologies that are available to ensure the proposed facility utilizes the best available control technology (BACT).

BACT are those technologies that are known to reduce emissions to the greatest extent while also providing cost effective and reliable operation for the power generation station. The details of the BACT Analysis and the proposed combustion turbine equipment are discussed over the remainder of the memorandum.

2. BACT Analysis

The BACT is defined by the Province of Newfoundland Labrador Regulation 11/22, Section 6 within Air Pollution Control Regulations, 2022, under the Environmental Protection Act as noted below:

(4) Best available control technology shall be acceptable to the department and shall, in that particular circumstance, be

(a) the most effective emission control device or technique;

(b) the most stringent emission control device or technique;

(c) proven reliable in comparable processes; and

(d) economically feasible as determined by the minister in light of industry standards after consultation with the particular owner or operator.

Newfoundland Labrador Regulation 11/22 does not provide stack emissions standards for nitrogen oxides (NOx) from gas turbine sources. In the absence of published limits from the Province Hatch has considered the limits offered by the Province of Ontario in document *Guideline A-5 Atmospheric Emissions from Stationary Combustion Turbines.* The guidelines for power only simple cycle gas turbines are provided in Table 1.

Table 1: Ontario Guideline Emissions Standards for NOx from gas turbine generators

Table 5: Emission limits for NOX – concentration-based method for liquid fuels for POSC SCT Application	Turbine Power Rating (MW)	NOx emission limits (ppmvd) @ 15% O2
Non-peaking - mechanical drive	≥ 1 and < 4	113
Non-peaking - electricity generation	≥ 1 and < 4	63
Peaking*	≥ 1 and < 4	Not applicable
Non-peaking and peaking*	≥ 4 and ≤ 70	38
Non-peaking*	> 70	23
Peaking*	> 70	38

* Combustion turbine system used for either mechanical drive or electricity generation

Hatch has reviewed the available technologies provided by the equipment vendors and also considered any additional control technologies that may be applied to ensure the proposed installation meets the emissions guidelines.

3. Generation Equipment Considered

The generation equipment considered for this review are gas turbine generators in the 50-150MW range of capability. This range of gas turbines is supported by aerospace technology derived machines and industrial machines, commonly known as aeroderivative and industrial gas turbines. The two technologies have benefited from advances in each area of development with compressor designs from the aeroderivative field helping industrial machines and low emissions burner technologies from the industrial field helping aeroderivative machines. The gas turbine generators considered for this application are liquid fuel burning turbines that have the ability to be converted to natural gas or other green fuel sources at a later time. Liquid fuel combustion utilizes a diffusion type flame that burns hotter and therefore generates higher levels of NOx than low emissions technologies that are deployed on gaseous fuels. Liquid fuel combustion emissions are improved through the use of steam or water injection. Both are utilized to lower the flame temperature and thereby lower the production of NOx. An additional post combustion treatment system, such as selective catalytic reduction (SCR), is not recommended for fuel oil fired gas turbines due to potential oil and sulphur contamination of the catalyst system.

The gas turbine generators in consideration are noted within this section with a short discussion on their technology and emissions performance. Each machine has a unique approach in gas turbine and combustion design with varying impact on the generation and emissions performance.

3.1 [redacted]

The [redacted] has been deployed globally since being introduced to the power generation market in the 1990's. Currently more than [redacted] examples of the [redacted] have been placed in operation and the fleet has accumulated over 40 million operating hours. The [redacted] is derived from the [redacted], with over 3,500 [redacted] engines being on order or in use currently.

The [redacted] has high market utilization and is considered to be industry standard power generation equipment for the aero derivative engine segment in the [redacted] range of combustion turbine generators.

The [redacted] is available with two types of combustion systems. One system is the single annular combustor (SAC) system that is derived from the combustion systems utilized in aircraft applications. The other system is dry low emissions (DLE) system that is derived from industrial combustion turbine technology. The application for NLH is not initially being considered for gaseous fuel, therefore there is no benefit to utilizing the DLE system, which only benefits gaseous fuel combustion emissions. Based on use of SAC the turbine is proposed to produce NOx emission of 38ppm with the use of water injection.

3.2 [redacted]

The [redacted] has been deployed globally with over [redacted] units within the product family installed globally. The current offering includes a high pressure and low pressure turbine. The high pressure turbine utilizes a design from [redacted] largest turbine aircraft engine. The low pressure turbine utilizes a specialized design that is based on industrial gas turbine engines. The high and low pressure turbine combine to make the gas generator portion of the unit. The gas generator is aerodynamically coupled to a power turbine or turbines when utilized in a twin pack configuration.

The [redacted] has high market utilization and is considered to be industry standard power generation equipment for the aero derivative engine segment in the [redacted] range of combustion turbine generators.

The [redacted] utilizes an annular combustion system with [redacted] external radially mounted fuel nozzles for liquid fuel operations. The combustion system is based on aircraft engine design and is available with water injection to control NOx emissions. The [redacted] is capable of producing NOx emissions of 42ppm.

3.3 [redacted]

The [redacted] has been deployed globally with over [redacted] units sold and currently has [redacted] range of industrial gas turbine generators. The gas turbine is an industrial type and does not utilize aeroderivative technology.

The [redacted] has high market utilization and is considered to be industry standard power generation equipment in the small industrial turbine segment for combustion turbine generators.

The [redacted] utilizes a [redacted] annular combustion system with radially mounted fuel nozzles for liquid fuel operations. The combustion system is available with dry low emissions combustors for natural gas operations and the unit has been approved for operation with 75% by volume hydrogen blending with natural gas. The [redacted] is capable of producing NOx emissions of 42ppm.

4. Summary

A summary of the generating units considered for this application and the associated emissions limits for the guideline from the federal government are noted in Table 2.

Table 2: Summary Emissions Review

Gas Turbine Generator	Capacity (MW)	Water Injection	NOx Emission on Fuel Oil (ppmvd)	NOx Ontario Compliance (ppmvd)
[redacted]	[redacted]	Yes	38*	38 – Pass
[redacted]	[redacted]	Yes	42	38 – Fail
[redacted]	[redacted]	No	42	38 – Fail

*Guarantee provided with firm pricing

5. Conclusions

[redacted] has provided a guarantee the [redacted] offered will produce 38ppm NOx with water injection. All other units in consideration are not capable of meeting the NOx emissions limits set forth by the by Ontario guidelines without the use of additional emissions controls equipment. Two of the units require water injection to lower emissions to stated levels. The unit selected by the owner will need to be evaluated for any additional BACT in coordination with the Newfoundland Labrador Provincial Government to determine if any additional measures are required for permitting.

BEST AVAILABLE CONTROL TECHNOLOGY ASSESSMENT - THE NEW AVALON COMBUSTION TURBINES AT THE HOLYROOD THERMAL GENERATING STATION

REPORT PREPARED FOR:

newfoundland labrador hydro
a nalcor energy company

4th Level Hydro Place, 500 Columbus Drive
St. John's, Newfoundland and Labrador
A1B 4K7

PREPARED BY:

IEC

Independent Environmental Consultants
582 St Clair Avenue West, Box 221
Toronto, Ontario, M6C 1A6

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Acronyms

ACT	Avalon Combustion Turbine
BACT	Best Available Control Technology
CO	Carbon Monoxide
COPD	chronic obstructive pulmonary disease
CIMAC	Conseil International des Machines à Combustion
CRT	Continuously Regenerating Trap
DOCs	Diesel Oxidation Catalysts
DPFs	Diesel Particulate Filters
DLE	Dry Low Emissions
DLN	Dry Low NO_X
ESPs	Electrostatic Precipitators
EPA	Environmental Protection Agency
HTGS	Holyrood Thermal Generating Station
IEC	Independent Environmental Consultants
LNBs	Low-NO_X Burners
LSD	Low-Sulphur Diesel
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
OSTI	Office of Scientific and Technical Information
PM	Particulate Matter
ppmv	Parts Per Million by Volume
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SAC	Single Annular Combustion
SO_2	Sulphur Dioxide
SO_3	Sulphur Trioxide
ULN	Ultra-Low NO_X
ULNBs	Ultra-Low NO_X Burners
ULSD	Ultra-Low-Sulphur Diesel
WHO	World Health Organization

1 INTRODUCTION

Independent Environmental Consultants (IEC) was retained by Newfoundland and Labrador Hydro (NL Hydro) to perform an assessment of the Best Available Control technology (BACT) for the proposed expansion of the Holyrood Thermal Generating Station (HTGS or the Facility). The HTGS is currently comprised of three (3) oil-fired thermal generators (Units 1, 2 and 3), a 123 MW diesel-fired gas turbine generator (the GT) and six (6) diesel-fired black start generators (each having a nominal rating of 2 MW). Together, the HTGS, GT and black start diesel generators comprise the existing power generating station at the Facility. To meet projected future demand and to retire the existing thermal generators, NL Hydro is proposing to install three (3) new combustion turbines (CTs) as well as install two (2) new black start diesel generators and referred to as the Avalon Combustion Turbine (ACT) Project. The new black start generators would be installed to fire up the new CTs and not connected to the grid. Figure 1-1 shows the general location of the HTGS and the location of the new Combustion Turbines and black start generators. Figure 1-2 shows the layout of the turbine generators.

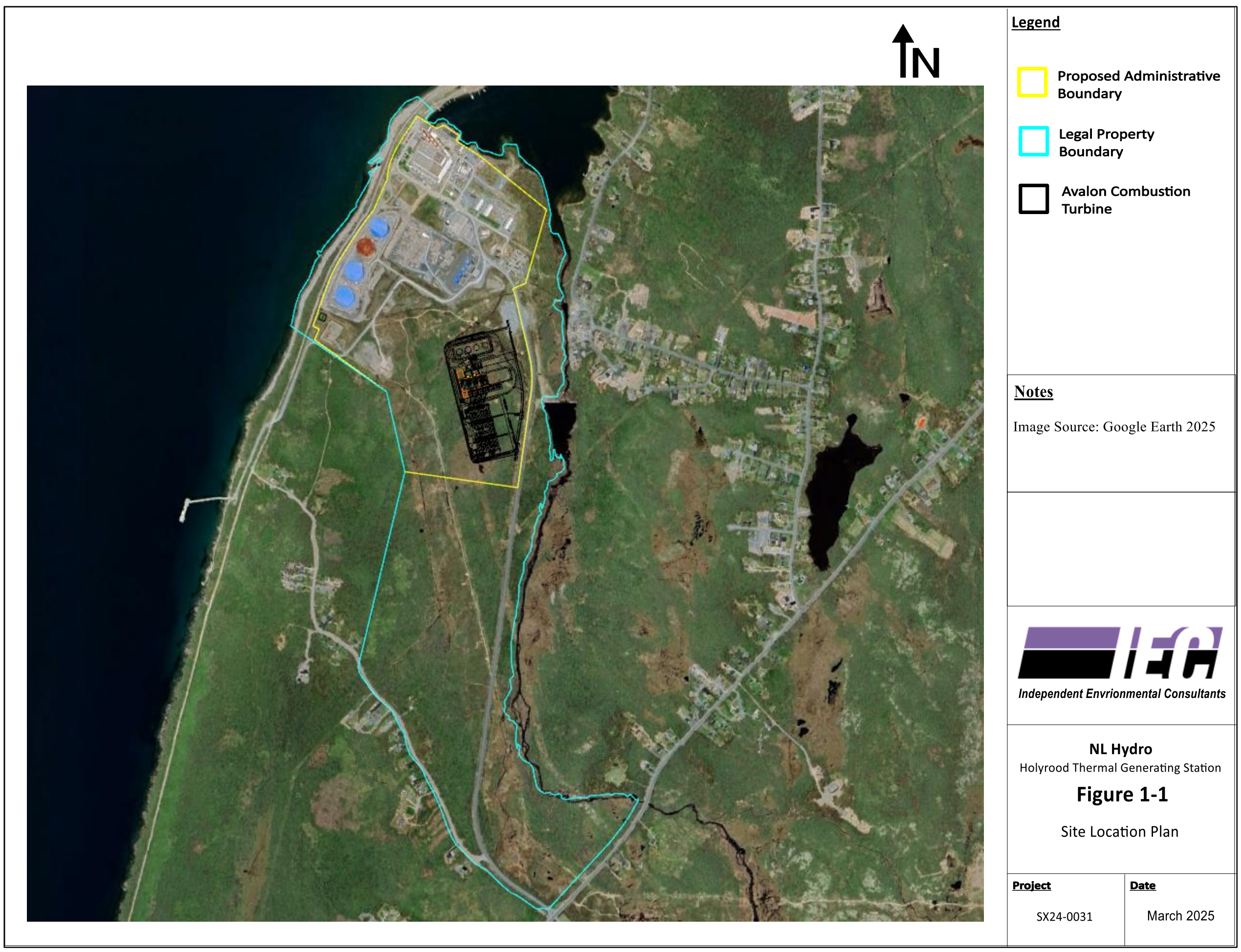

Figure 1-1: Site Location Plan

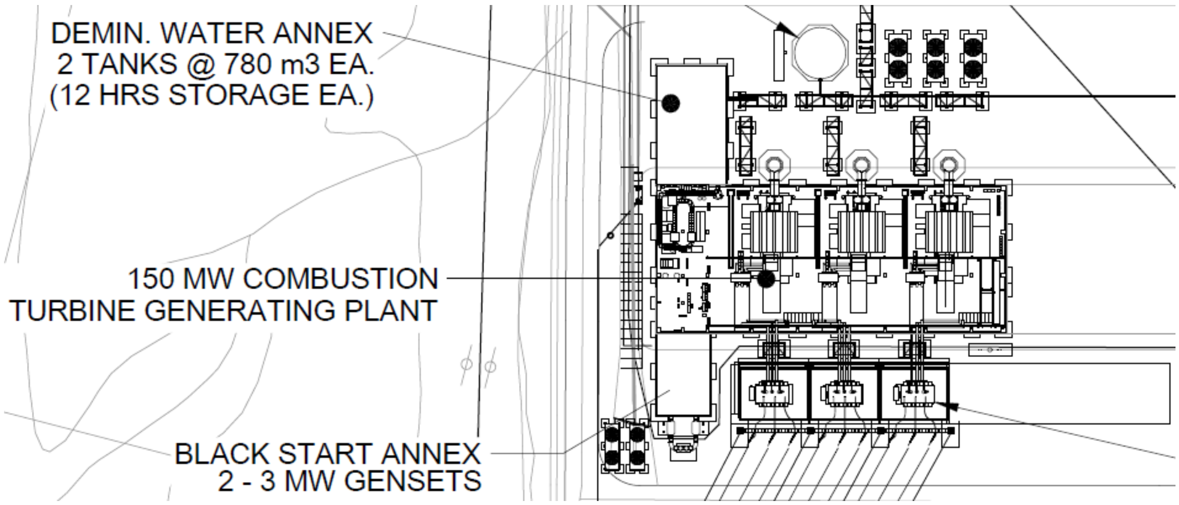

Figure 1-2: Turbine Generators layout

1.1 DESCRIPTION OF THE NEW COMBUSTION TURBINES

The Project involves constructing a 150 MW (nominal) CTs adjacent to the existing HTGS, aimed at improving the reliability of the province's electricity supply by addressing anticipated demand increases and ensuring stability during peak periods. The Project includes three new simple cycle diesel-fired 46.6 MW CTs located southeast of the existing 123 MW diesel-fired gas turbine generator near the access road. Each of these turbines will exhaust through its own stack, further contributing to the overall capacity and operational flexibility of the site. The CTs will operate on diesel fuel but will be designed for future conversion or retrofitting to run on natural gas, hydrogen-natural gas blends, biofuels, and/or renewable diesel. In the worst-case scenario, the CTs are expected to operate for up to six weeks per year.

1.2 SCOPE AND OBJECTIVES OF THE ASSESSMENT

The scope of this assessment is the three new simple cycle diesel-fired 46.6 MW CTs and the objective is to identify the Best Available Control Technologies (BACT) that can be deployed to the CTs to ensure that emissions from the CTs comply with applicable environmental standards and reflect the highest practicable level of emissions control. According to the Air Pollution Control Regulations 11/22 BACT shall, in that particular circumstance, be the most effective and stringent, proven reliable, economically feasible, and acceptable to the Department of Environment and Climate Change (Newfoundland and Labrador, 2022).

1.3 STRUCTURE AND CONTENT OF THIS REPORT

This report is structured to provide a comprehensive assessment of the BACT for the ACT at the HTGS. The document is organized into the following sections:

- **Section 1: Introduction** – This section outlines the purpose of the report, the project description, and the structure of the document.
- **Section 2: Environmental Impacts of Emissions** – This section evaluates the environmental and health impacts of emissions from combustion turbines, focusing on nitrogen oxides (NOX) and particulate matter (PM).

- **Section 3: NOX Emissions from Turbines** – This section details the mechanisms of NOX formation in combustion turbines, factors influencing emissions, and regulatory emission limits.
- **Section 4: PM Emissions from Turbines** – This section analyzes sources of PM emissions, influencing parameters, and regulatory considerations.
- **Section 5: Options for NOX Control** – This section presents and evaluates various NOX reduction technologies, including dry low NOX combustors, water/steam injection, and post-combustion controls.
- **Section 6: Options for PM and $PM_{2.5}$ Control** – This section discusses available control technologies for PM emissions, such as Diesel Particulate Filters (DPFs), Diesel Oxidation Catalysts (DOCs), and Electrostatic Precipitators (ESPs).
- **Section 7: BACT for NOX and PM Emissions** – This section synthesizes the findings and identifies the most effective and feasible emission control technologies for the ACT.
- **Section 8: References** – This section provides a list of sources and literature reviewed in the preparation of this report.

Each section is designed to build upon the previous one, providing an assessment of emission impacts and control technologies for the proposed ACT.

1.4 REGULATORY FRAMEWORK

The regulatory framework for BACT in Newfoundland and Labrador is primarily governed by two key pieces of legislation: the Air Pollution Control Regulations, 2022 under the Environmental Protection Act and the Management of Greenhouse Gas Regulations under the *Management of Greenhouse Gas Act* (Newfoundland and Labrador, 2018a).

1.3.1 Air Pollution Control Regulations

According to Section 6 of Regulation 11/22 (Newfoundland and Labrador, 2022):

(1) An owner or operator who installs a new or modified emission source shall employ the best available control technology.

(2) Notwithstanding subsection (1), an owner or operator may install a new or modified emission source which does not comply with that subsection with the written approval of the minister.

(3) Notwithstanding subsection (1), best available control technology shall not apply to

a. routine maintenance, repair and parts replacement;

b. normal increases in production rates unless otherwise prohibited;

c. increases in hours of operation unless otherwise prohibited; or

d. use of an alternative cleaner fuel or raw material.

(4) Best available control technology shall be acceptable to the department and shall, in that particular circumstance, be

a. the most effective emission control device or technique;

b. the most stringent emission control device or technique;

c. proven reliable in comparable processes; and
d. economically feasible as determined by the minister in light of industry standards after consultation with the particular owner or operator.

However, exceptions are allowed for routine maintenance, minor production increases, and the use of cleaner fuels, provided these do not undermine overall emission control standards. Written approval from the Minister is required if an emission source does not comply with the prescribed BACT standards.

1.3.2 Management of Greenhouse Gas Regulations

In addition, Regulation 116/18 outlines (Newfoundland and Labrador, 2018b) the specific requirements for industrial facilities under the *Management of Greenhouse Gas Act*. The Project is expected to emit 15,000 tonnes of carbon dioxide equivalent or more of greenhouse gas. According to Section 4 of *the Act*, the Project is subject to *the Act* and is required to submit BACT information at the time of registration or project description submission to ensure compliance with emission control standards. According to Section 12.1 (4) of the Regulations: An industrial facility is considered to meet the best available control technology requirements where the Lieutenant-Governor in Council is satisfied that the combination of machinery and equipment in the industrial facility

a) has the most effective greenhouse gas emissions control;
b) has proven performance and reliability in comparable industrial facilities;
c) is economically feasible, based on consultation with the operator; and
d) complies with an Act or regulation relating to air pollution, occupational health and safety and fire and life safety.

Ultimately, the regulations aim to mitigate environmental impacts by enforcing the adoption of the most advanced and reliable control technologies while maintaining economic feasibility and regulatory compliance.

2 ENVIRONMENTAL IMPACTS OF THE EMISSIONS

2.1 ENVIRONMENTAL IMPACTS OF NO_X

Nitrogen oxides (NO_X) are a group of gases primarily composed of nitric oxide (NO) and nitrogen dioxide (NO_2). They are mainly produced during high-temperature combustion processes when the nitrogen in the air and fuel reacts to form NO and NO_2. The higher the combustion temperature, the greater the formation of NO_X. This process is significant in both natural and anthropogenic emissions, with recent studies highlighting that non-thermal sources, such as photochemical reactions, also play an increasing role in NO_X formation, particularly in urban areas with low-emission vehicles and alternative fuels. Additionally, alternative fuels like biofuels can also contribute to NO_X emissions, albeit at different levels compared to traditional fossil fuels (EPA, 2020; Zhang et al., 2021).

Emissions of nitrogen oxides have significant adverse effects on human health and the environment. Health impacts include increased incidence of respiratory diseases such as asthma and bronchitis, as well as cardiovascular issues, particularly from long-term exposure to NO_X and associated fine particulate matter ($PM_{2.5}$) (Brook et al., 2019). NO_X is also a precursor to ground-level ozone, which contributes to smog and has harmful effects on air quality and public health. On the environmental side, NO_X emissions contribute to acid deposition, eutrophication of water bodies, and visibility degradation. Recent studies have shown that NO_X emissions continue to cause eutrophication in both freshwater and coastal ecosystems (Holland et al., 2020). Although significant reductions in acid rain have been achieved in regions like North America and Europe due to emissions controls, NO_X remains a threat to ecosystems in parts of the world that are not yet experiencing such reductions (Davidson & Seitzinger, 2019). Furthermore, NO_X -related aerosols play a role in both warming and cooling the atmosphere, contributing to the complex dynamics of climate change (Liu et al., 2020).

2.2 ENVIRONMENTAL IMPACTS OF PARTICULATE MATTER

Particulate matter (PM) refers to a mixture of solid particles and liquid droplets found in the air, which vary in size, composition, and source. PM is typically classified by its size, with PM10 representing particles with a diameter of 10 micrometers or less, and $PM_{2.5}$ referring to particles with a diameter of 2.5 micrometers or less. $PM_{2.5}$ particles are of particular concern because they can penetrate deep into the lungs and even enter the bloodstream, posing significant health risks. These fine particles originate from combustion sources, including vehicles, power plants, industrial processes, and residential heating. Non-combustion sources such as dust, construction activities, and wildfires also contribute to PM levels.

Exposure to PM, especially $PM_{2.5}$, is associated with a wide range of adverse health effects, including respiratory and cardiovascular diseases, cancer, and premature death (Brook et al., 2019). The World Health Organization (WHO) has classified $PM_{2.5}$ as a human carcinogen due to its ability to penetrate deep into lung tissues and reach the bloodstream, causing both short-term and long-term health effects (WHO, 2021). Studies have shown that long-term exposure to $PM_{2.5}$ is linked to an increased risk of stroke, heart attacks, and lung diseases such as chronic obstructive pulmonary disease (COPD). In addition to health impacts, PM also has significant environmental consequences, contributing to visibility impairment and acid deposition. PM can alter the atmospheric radiation balance, influencing climate change by both cooling and warming the atmosphere depending on the composition of the particles (Matsuki et al., 2020). Recent research has also shown the role of PM in eutrophication and its impact on aquatic ecosystems, further highlighting its widespread environmental effects (Baker et al., 2020).

3 NOX EMISSION FROM TURBINES

Large quantities of NO_X are formed in most combustion processes, primarily due to high-temperature reactions between nitrogen (N_2) and oxygen (O_2) in the air. The formation of NO_X involves the dissociation of molecular nitrogen and oxygen into their atomic forms, which then react to produce various nitrogen oxides, including NO, NO_2, NO_3, N_2O, N_2O_3, N_2O_4, and N_2O_5. Among these, NO, N_2O, and NO_2 are the most prevalent and environmentally significant compounds, responsible for most of the regulatory and air quality concerns.

NO_X formation occurs through three primary mechanisms: thermal NO_X, fuel NO_X, and prompt NO_X.

- **Thermal NO_X:** Thermal NO_X is the most common and significant type of NO_X produced in high-temperature combustion processes. It occurs when N_2 from the combustion air reacts with O_2 at very high temperatures, typically above 1,300°C. At these elevated temperatures, the strong molecular bonds of nitrogen break, allowing the free nitrogen atoms to combine with oxygen and form nitrogen oxides. The Zeldovich mechanism describes this process through a series of reactions that result in the formation of NO and NO_2. Since the formation of thermal NO_X is highly temperature-dependent, the hotter the flame, the more NO_X is produced. This makes controlling flame temperature and optimizing the air-to-fuel ratio critical for reducing thermal NO_X emissions. Technologies like low- NO_X (LNBs) burners and Dry Low Emission (DLE) burners are commonly used to manage and minimize this type of NO_X.
- **Fuel NO_X:** Fuel NO_X is generated from the oxidation of nitrogen compounds that are chemically bound in the fuel itself, such as coal, oil, and some heavy hydrocarbons. During combustion, as the fuel breaks down, the nitrogen it contains is released and reacts with oxygen to form NO_X. Fuel NO_X formation tends to happen at lower temperatures compared to thermal NO_X and depends on the nitrogen content of the fuel, combustion temperature, and oxygen availability. There are two primary pathways for fuel NO_X production: the conversion of volatile nitrogen released in the early stages of combustion and the oxidation of nitrogen remaining in the char after devolatilization. Fuel NO_X is often controlled using techniques like low- NO_X burners (LNBs) and fuel pre-treatment processes that lower the nitrogen content in the fuel.
- **Prompt NO_X:** Prompt NO_X forms through a less common but still important mechanism, especially in fuel-rich combustion environments. It results from the rapid reaction of atmospheric nitrogen with hydrocarbon radicals (like CH and CH_2) present early in the combustion process, before the flame reaches its peak temperature. This mechanism is most noticeable in fuel-rich flames and low-temperature combustion zones. The hydrogen cyanide produced in these initial reactions is subsequently oxidized to form NO. While prompt NO_X usually contributes a smaller share of overall NO_X emissions compared to thermal and fuel NO_X, it can become significant in specific types of burners or industrial processes where fuel-rich conditions are present.

3.1 PARAMETERS INFLUENCING NO_X EMISSIONS

The level of NO_X formation, and thus NO_X emission, in a turbine depends on the combustor design, the types of fuel being burned, ambient conditions, operating cycles and the power output level (as a percentage of the rated full power output of the turbine).

3.1.1 Combustor Design

The combustor design is a critical factor in NO_X formation in diesel-fired turbines. Thermal NO_X formation is primarily influenced by flame temperature and residence time. Combustion parameters, such as equivalence ratios and the introduction of cooling air, have a significant impact on thermal NO_X emissions. Incomplete fuel/air mixing can create local fuel-rich zones and hot spots, leading to higher thermal NOx production. Thermal NO_X formation is highly sensitive to flame temperature (Nussbaumer, 2003).

3.1.2 Type of Fuel

The type of fuel used in diesel-fired turbines greatly affects NO_X emissions. Diesel fuel typically contains higher carbon content than gaseous fuels, leading to higher flame temperatures and increased NO_X emissions. Fuels with higher sulphur content can also contribute to the formation of sulphur-based aerosols, which may indirectly affect NO_X emissions. Conversely, using lower-sulphur diesel or alternative fuels may help reduce NO_X formation by lowering flame temperatures (Hassan et al., 2005).

3.1.3 Ambient Conditions

The new CTs are located on the coast, where humidity levels are higher. Therefore, it is important to examine the effect of ambient conditions on emissions. Ambient conditions, particularly humidity, temperature, and pressure, influence NO_X formation in diesel turbines. Water vapour acts as an inert substance, reducing flame temperature and thereby decreasing NO_X emissions. At low humidity, NO_X emissions increase with higher ambient temperatures. However, at high humidity, the effect of temperature on NO_X emissions varies: at low ambient temperatures, NO_X emissions rise with increasing temperature, while at higher temperatures (above 10°C or 50°F), NO_X emissions typically decrease (Vogt et al., 2008) (Berkowicz et al., 1997).

3.1.4 Operating Cycles

In diesel-fired turbines, NO_X emissions are primarily determined by the combustion process, not by downstream conditions. In simple and cogeneration cycles, NO_X emissions are similar because they are formed only in the combustor. In regenerative cycles, NO_X emissions do not increase, as the firing temperature remains constant despite reduced fuel usage due to the higher inlet temperature in the combustion chamber (Perry et al., 2010).

3.1.5 Power Output Level

NOx emissions in diesel turbines are correlated with the power output level. At lower power outputs, the flame temperature is reduced, leading to lower NO_X emissions. Conversely, at higher power outputs, increased flame temperatures lead to higher NO_X emissions (Ferguson et al., 2016a).

3.2 Uncontrolled Emission Factors

The uncontrolled NO_X emission factors for diesel-fired turbines typically range between 300 and 800 ppmv, depending on the manufacturer, turbine design, and power output levels (U.S. EPA, 2004; Li et al., 2017). The emissions factors are generally applicable to internal combustion engines and combustion sources, including both diesel engines and turbines. However, they are not specifically focused solely on diesel-fired turbines but rather encompass broader combustion technologies, including diesel engines and stationary combustion sources.

3.3 Regulation

In the United States, the proposed federal New Source Performance Standards (NSPS) under 40 CFR Part 60, Subpart KKKK, established by the U.S. Environmental Protection Agency (EPA), sets emission standards for stationary combustion turbines, including those firing diesel fuel. For diesel-fired turbines with a heat input between 50 MMBtu/h and 850 MMBtu/h, the NO_X emission limit is 74 ppmv at 15% O_2. These standards reflect the higher NO_x emissions typically associated with diesel combustion compared to natural gas. (U.S. EPA, 2024).

In Canada, the Canadian Council of Ministers of the Environment (CCME) established the National Emission Guidelines for Stationary Combustion Turbines in 1992, outlining recommended nitrogen oxides (NO_X) emission limits for stationary natural gas turbines (CCME 1992). These guidelines specify output-based limits measured in grams per gigajoule (g/GJ) of energy output, which can be converted to concentration-based limits expressed in ppmv at 15% O_2. For non-peaking stations with a power output between 9 MW and less than 50 MW, the guideline sets a NO_x emission limit of 0.20 g NO_x/GJ, approximately equivalent to 55 ppmv at 15% O_2.

While CCME guidelines apply to stationary natural gas turbines irrespective of fuel type, diesel-fired turbines face unique challenges in meeting NO_X emission limits due to higher baseline emissions. Natural gas turbines and diesel turbines differ significantly in their emissions of NO_X, primarily due to differences in combustion technology and fuel characteristics.

Newfoundland and Labrador's Air Pollution Control Regulations primarily focus on ambient air quality standards, setting limits for PM, $PM_{2.5}$, and NO_X concentrations in the surrounding environment. Rather than specifying exhaust gas concentration limits for combustion sources like diesel turbines, the regulations emphasize maintaining overall air quality. The Air Pollution Control Regulations, 2022 require the application of BACT for emission control from regulated sources, as outlined in Section 1.3.

The Project is expected to emit 15,000 tonnes of carbon dioxide equivalent or more of greenhouse gas and according to Section 4 of the Act, it is subject to the Act and is required to submit BACT information at the time of registration or project description submission to ensure compliance with emission control standards.

4 PM EMISSION FROM TURBINES

For diesel-fueled turbines burning regular diesel, PM emissions consist mainly of two components: soot particles and sulfate particles. Soot is formed from the incomplete combustion of diesel fuel, while sulfate particles result from the oxidation of sulphur compounds in the fuel. The proportion of these particles varies based on sulphur content, combustion efficiency, and operating conditions. Diesel turbines emit higher amounts of PM and $PM_{2.5}$ compared to natural gas turbines due to the nature of diesel combustion, which generates more carbonaceous and sulfate particles. The sulphur content in the diesel fuel plays a crucial role in determining the quantity and composition of these emissions (U.S. EPA, 2024).

4.1 PARAMETERS INFLUENCING PM AND $PM_{2.5}$ EMISSIONS

Several parameters influence both the quantity and composition of PM emissions. These factors are described in the following section.

4.1.1 Diesel Sulphur Content

The use of Low-Sulphur Diesel (LSD) and Ultra-Low-Sulphur Diesel (ULSD) significantly reduces PM and $PM_{2.5}$ emissions compared to regular diesel with higher sulphur content. This reduction occurs because high sulphur content contributes to the formation of sulfate particles during combustion. With ULSD (≤15 ppm sulphur), even greater emission reductions are possible.

The impact on soot particles, which are primarily composed of elemental carbon from incomplete combustion, is less direct. While lower sulphur content reduces sulfate-based PM, it does not directly decrease soot formation.

4.1.2 Combustion Efficiency

The efficiency of the combustion process plays a significant role in determining PM and $PM_{2.5}$ emissions. Incomplete combustion, which occurs at lower combustion temperatures or with insufficient oxygen, results in the formation of soot particles. High combustion temperatures typically result in fewer emissions due to more complete oxidation of the fuel. However, excessive combustion temperatures can also lead to the formation of ultrafine particles via nucleation processes. Therefore, maintaining an optimal combustion temperature and sufficient oxygen supply is crucial for minimizing particulate emissions (Nussbaumer, 2003).

4.1.3 Turbine Design and Engine Load

The design of the diesel turbine, including its operating parameters such as pressure, temperature, and speed, significantly affects the formation of PM. High-pressure and high-temperature environments facilitate the nucleation and agglomeration of particles. As the engine load increases, the combustion temperature rises, which can lead to higher formation of ultrafine particles. Under low load conditions, engines may not reach sufficient temperatures for complete combustion, leading to higher soot formation (Tian et al., 2013).

4.1.4 Fuel Injection and Quality

Diesel fuel properties, such as its sulphur content, viscosity, and cetane number, have a direct impact on PM emissions. Higher sulphur content contributes to the formation of sulfate aerosols through the oxidation of sulphur compounds in the exhaust. Fuel quality is a key factor influencing the size and composition of particulate emissions, as lower-quality fuels tend to produce higher amounts of soot (Hassan et al., 2005). The use of alternative low-sulphur fuels or biodiesel blends can help mitigate PM emissions, as they generally produce fewer particulate pollutants compared to conventional diesel fuel (Baumgardner et al., 2006).

4.1.5 Ambient Conditions

The new CTs are located on the coast, where humidity levels are higher. Therefore, it is important to examine the effect of ambient conditions on PM emissions. Atmospheric conditions such as temperature and humidity influence both the nucleation and growth of $PM_{2.5}$ particles. For instance, higher humidity can lead to the condensation of water vapour onto particles, increasing their size and weight. This can contribute to higher levels of secondary PM, especially sulfate aerosols, when sulphur compounds in the exhaust interact with water vapour (Vogt et al., 2008). In case of LSD or ULSD use, this effect is negligible.

5 OPTIONS FOR NO_X CONTROL

NOx emissions from combustion processes can be controlled through a variety of technologies, broadly categorized into dry combustion controls, dry post combustion controls, and wet controls. As the CTs primary fuel is diesel, the emission control technologies discussed in this section are specific to turbines burning diesel fuel.

- Dry combustion control technologies focus on minimizing NO_X formation during the combustion process by altering the combustion environment. LNBs are one of the most common methods in this category, reducing NO_X emissions by 40–60% through precise control of air-fuel mixing and limiting peak flame temperatures (World Bank Group, 1998; CIMAC, 2008). DLN combustors take this a step further by pre-mixing air and fuel, achieving up to 90% NO_X reduction and producing emissions as low as 9 ppmv in some advanced systems (U.S. EPA, 2000; Schorr & Chalfin, 2022). Ultra-Low NO_X burners (ULNBs) represent a further advancement, providing significant NO_X reductions by ensuring thorough pre-mixing and optimized combustion (Sargent & Lundy, LLC, 2022). Some of ULN technologies use catalytic oxidation to reduce flame temperature and NO_X and CO formation.
- Dry post combustion control technologies primarily include post-combustion treatments designed to chemically reduce NOx emissions. Selective Catalytic Reduction (SCR) is one of the most effective and widely used techniques in this category, achieving over 90% NOx reduction by injecting ammonia or urea into the exhaust stream and passing it through a catalyst (Richards & Schell, 2000; U.S. EPA, 1993; Smith, 2022). Although highly efficient, SCR systems require substantial capital investment and ongoing operational costs (RTP Environmental Associates Inc., 2015).
- Wet control technologies lower NO_X emissions through water or steam injection. These technologies are applicable to both natural gas and diesel-fired turbines. These technologies work by lowering the peak combustion temperature, which reduces thermal NO_X formation regardless of the fuel type. This approach typically achieves 40–60% NOx reduction, though it may increase carbon monoxide (CO) emissions as a trade-off (U.S. EPA, 2000; World Bank Group, 1998). The effectiveness of water and steam injection depends on factors such as the water-to-fuel ratio and combustion system configuration (Sargent & Lundy, LLC, 2022; U.S. EPA, 1993).

In practice, selecting the appropriate NOx control technology depends on various factors, including fuel type, combustion system design, emission reduction goals, and economic considerations. While SCR remains the gold standard for maximum NOx reduction, advancements in combustion control technologies like DLN and ULN offer efficient alternatives with lower capital costs and operational complexity.

5.1 DRY COMBUSTION CONTROL TECHNOLOGIES

5.1.1 Low NOx Burners (LNB)

LNBs reduce NOX emissions primarily by using staged combustion, where the fuel and air are introduced in separate zones to control flame temperature and reduce the formation of thermal NO_X. In the first stage, fuel-rich combustion occurs at a lower temperature, and in the subsequent stages, additional air is introduced to complete combustion. This process limits the peak flame temperature and reduces oxygen availability during the hottest part of the burn, both of which are key contributors to NO_X formation. LNBs can be applied to both natural gas and liquid-fired turbines, including diesel, making them a more flexible but somewhat less effective option for NO_X control.

5.1.2 Dry Low Emissions (DLE) and Dry Low NO_X (DLN) Burners

Dry Low Emission (DLE) and Dry Low NO_X (DLN) are essentially the same in principle, but the terminology varies slightly depending on the manufacturer and context. DLN is the term commonly used by General Electric (GE), while DLE is used more broadly by other manufacturers like Siemens, Solar Turbines, and Mitsubishi. DLE and DLN burners represent advanced low-NOx combustion technologies that use lean premixed combustion technology, specifically designed for natural gas turbines. These systems reduce NOx emissions by carefully managing the air-fuel mixture and maintaining lower flame temperatures during combustion (U.S. Environmental Protection Agency, 2000). Unlike older systems that rely on water or steam injection for NOx control, DLE and DLN systems achieve substantial emission reductions without additional cooling agents, enhancing efficiency and reducing operational costs (Schorr & Chalfin, 2022).

DLE systems primarily use lean premixed combustion, where fuel and air are thoroughly mixed before ignition. This creates a more uniform and cooler flame, significantly minimizing NOx formation. As a result, DLE systems often achieve NO_X emissions in the range of 9–25 parts per million (ppm) without the need for water or steam injection. These systems are widely used in aeroderivative turbines such as the GE LM6000, Solar Mars 100, and Siemens SGT-800 (Smith, 2022). In contrast, DLN systems—GE's proprietary technology for their heavy-duty natural gas turbines—employ staged combustion. By burning fuel in multiple zones, DLN technology carefully controls temperature and NOx production, often achieving NOx levels as low as 9 ppm without external cooling (U.S. Environmental Protection Agency, 1993).

DLE and DLN technologies are primarily developed for and widely used in natural gas turbines, where lean premixed combustion can be effectively implemented. These technologies are technically feasible for diesel-fired turbines; however, their application would require significant modifications to the burners.

5.1.3 Ultra-Low NOx Burners (ULNB)

Ultra-Low NOx Burners (ULNB) are advanced combustion systems designed to minimize NO_X emissions by optimizing the air-fuel mixture and controlling the combustion temperature. Unlike traditional burners, ULNBs use techniques like staged combustion, flue gas recirculation, and lean premixed combustion to achieve more complete and efficient fuel burning, which significantly reduces the formation of NO_X. These systems are particularly effective in industrial natural gas turbines and large-scale power generation applications, often achieving NOx emission levels as low as 9–15 parts per million (ppm) when firing natural gas (U.S. EPA, 1993). ULNBs offer several advantages, including improved thermal efficiency and reduced greenhouse gas emissions compared to conventional combustion systems. Additionally, they eliminate the need for water or steam injection, avoiding the operational complexities, increased water demand, and potential maintenance issues associated with wet NOx control technologies (CIMAC, 2008). By combining low emissions with efficient performance, ULNBs are increasingly becoming the preferred choice for meeting stringent environmental regulations in both simple- and combined-cycle power plants. Similar to DLE and DLN, this technology is technically feasible for diesel-fired turbines; however, its application would require significant modifications to the burners.

5.1.4 Catalytic Combustion

Catalytic combustion is an advanced emission control approach that uses catalysts to promote cleaner and more efficient fuel combustion, significantly reducing Nox Emission. XONON, developed by Mitsubishi Power, a subsidiary of Mitsubishi Heavy Industries, is an example of catalytic combustion technology specifically designed for natural gas turbines. This technology uses a proprietary catalyst to convert NOx into nitrogen and water vapour and CO into carbon dioxide. Although XONON offers high emission reduction efficiency and operational simplicity, considerations such as catalyst longevity, operational costs, and compatibility with existing turbine systems are important when assessing its suitability.

Notably, XONON is designed for natural gas turbines and is not typically applied to diesel turbines, which often require different emission control technologies tailored to their unique combustion processes.

5.2 WET CONTROL TECHNOLOGIES

5.2.1 Water or Steam Injection

Water or steam injection is a well-established method for controlling NO_X emissions in GE LM6000 gas turbines, commonly used in both simple-cycle and combined-cycle power plants operating on diesel or natural gas. NOx formation in natural gas turbines primarily results from the high combustion temperatures where nitrogen and oxygen from the air react to produce NOx. In turbines like the GE LM6000, water or steam is injected directly into the combustor's flame zone to reduce peak combustion temperatures by absorbing heat. This also increases the mass flow rate through the turbine without additional fuel input, further cooling the flame and slowing the rate of NOx production. Steam injection, in particular, can enhance power output and efficiency because the steam expands through the turbine like combustion gases. This technique can lower NOx emissions by up to 70% to 90%, depending on the water-to-fuel ratio and system configuration (CIMAC, 2008). However, these benefits come with trade-offs, including increased demand for high-purity water, potential efficiency losses due to energy used in heating and vaporizing water, and higher maintenance requirements resulting from the risk of corrosion and deposits caused by added moisture. The efficiency losses from water injection can be notable, contributing to lower efficiency levels compared to dry low-emissions systems (CIMAC, 2008).

5.2.2 Single Annular Combustion (SAC)

Single Annular Combustion (SAC) is a burner design, not an emission control method. It features a ring-shaped combustion chamber with fuel injectors and flame zones arranged in an annular configuration. Since SAC designs do not inherently support lean premixed combustion, they are often paired with water or steam injection systems to control NO_X emissions by lowering flame temperatures. While SAC technology is proven and capable of handling a wide range of fuels, it has drawbacks, including high water demand, increased operational costs, and maintenance issues related to potential corrosion and deposits from water injection (CIMAC, 2008). SAC systems also typically exhibit lower efficiency because of the energy required to vaporize water. In contrast, DLE systems achieve combined-cycle efficiencies as high as 56% without the need for water or steam injection (OSTI, n.d.), making them more attractive for reducing both emissions and operational complexity.

5.2.3 Factors Affecting the Performance of Wet Controls

The water-to-fuel ratio (WFR) is the most important parameter affecting the performance of water or steam injection systems. Higher WFRs generally lead to greater NOx reduction efficiency, with reductions of 70% to 90% commonly achieved. Water is a more effective heat sink than steam because it absorbs additional energy during vaporization, so higher levels of steam than water must be injected to achieve the same NOx reduction. Combustor geometry and the design of the injection nozzles also play a critical role in performance. Proper atomization and a well-distributed spray pattern are essential to ensure a homogeneous mixture of water droplets and fuel, which prevents localized hot spots that could lead to increased NOx emissions. Additionally, the fuel type impacts emission performance, with lower NOx levels typically achieved when using gaseous fuels compared to liquid fuels (CIMAC, 2008).

5.2.4 Achievable NOx Emissions Levels Using Wet Controls

Guaranteed NOx emission levels provided by natural gas turbine manufacturers for wet controls typically range around 25 to 42 ppmv for most natural gas turbines and 42 to 75 ppmv for most oil-fired turbines, depending on system configuration and water-to-fuel ratios (WFR). The actual percent reduction in NOx emissions using water or steam injection generally ranges from 70 to 90 percent, depending on the turbine's uncontrolled emission levels and the specific injection method applied (CIMAC, 2008).

Emission test data for water injection on natural gas turbines indicate NOx emissions ranging from approximately 20 ppm to 105 ppm, with WFRs between 0.16 and 1.32. These tests cover a wide range of turbine sizes, from 2.8 MW to 97 MW, demonstrating that water injection is effective across various natural gas turbine models. NOx emission levels consistently decrease as the WFR increases, though the extent of reduction also depends on factors like turbine design, efficiency, firing temperature, and the extent of combustion controls incorporated into the combustor design.

For steam injection, NOx emission test data show emissions ranging from approximately 40 ppm to 80 ppm, with WFRs between 0.50 and 1.02. These results are based on turbines firing natural gas with power outputs ranging from 30 MW to 70 MW. Steam injection not only reduces NOx emissions but can also improve turbine efficiency and power output by expanding through the turbine like combustion gases (CIMAC, 2008).

Water injection can reduce NO_X emissions in diesel-fired turbines by approximately 50–70%, which is comparable to the reduction efficiency observed in natural gas turbines on a percentage basis. However, due to the inherently higher baseline NO_X emissions in diesel combustion—often ranging from 300 to 800 ppm—the absolute post-injection NO_X levels in diesel turbines tend to remain higher than those in g natural gas units. While extensive emission test data exist for natural gas turbines, data specific to diesel-fired turbines are limited, though available studies and guidance documents (CIMAC, 2008, U.S.EPA) suggest similar relative performance in NO_X reduction using water injection.

5.2.5 Impact on Hydrocarbon and Carbon Monoxide Emissions

Wet control technologies, such as water or steam injection, primarily target NO_X reduction in gas turbines, but they can also influence hydrocarbon and CO emissions. In diesel-fired turbines, the injection of water or steam lowers the peak combustion temperature, which reduces NOx formation but often results in incomplete combustion. This incomplete combustion can lead to an increase in hydrocarbons and CO emissions, as the cooler flame temperature may prevent the complete oxidation of fuel (CIMAC, 2008). As a result, while NOx emissions are significantly reduced—often by 70 to 90 percent—the trade-off is a potential rise in unburned hydrocarbons and CO, which can affect overall air quality and compliance with emission standards. The impact of water or steam injection on hydrocarbon and CO emissions is generally similar for both natural gas- and diesel-fired turbines, but the effect can be more significant in diesel turbines due to less efficient combustion.

5.2.6 Impact on Turbine Performance:

The use of water or steam injection in diesel-fired turbines also impacts turbine performance, particularly in terms of efficiency and power output. Steam injection can enhance power output and thermal efficiency because the injected steam expands through the turbine alongside combustion gases, contributing to increased mass flow and mechanical work (OSTI, n.d.). However, water injection generally results in a slight decrease in thermal efficiency, as energy is diverted to vaporize the water, reducing the available energy for power generation. Despite these performance impacts, wet controls remain a widely used NOx reduction strategy due to their proven effectiveness and operational flexibility in various turbine configurations.

5.2.7 Impact on Maintenance Requirements:

Wet control systems in diesel-fired turbines introduce additional maintenance challenges due to the presence of moisture in the combustion system. The continuous injection of water or steam increases the risk of corrosion and deposits in the hot section of the turbine, particularly around the combustor and turbine blades (CIMAC, 2008). The need for high-purity water to avoid mineral buildup adds complexity to water treatment and supply systems, increasing operational costs and requiring frequent inspections and cleaning. Furthermore, erosion of turbine components can occur over time, potentially reducing equipment lifespan and increasing downtime for maintenance.

The U.S.EPA (U.S.EPA 1993) summarized the maintenance impacts provided by some turbine manufacturers. These impacts are shown in Table 5-1. The table shows that the maintenance impact, if any, varies from manufacturer to manufacturer and model to model. Some manufacturers stated that there is no impact on maintenance intervals associated with water or steam injection for their turbine models. Data were provided only for operation with natural gas. There is no information regarding the effect of injection of steam on the maintenance of the natural gas turbines firing fuel oil.

Table 5-1: Impacts of Wet Controls on Natural Gas Turbine Maintenance

	NO_x Emissions, ppmv at 15% O_2			Inspection Interval, Hours		
Manufacturer/ Model	**Standard Combustor**	**Water Injection**	**Steam Injection**	**Standard Combustor**	**Water Injection**	**Steam Injection**
General Electric						
LM1600	133	42/25	25	25,000	16,000[a]	25,000
LM2500	174	42/25	25	25,000	16,000[a]	25,000
LM5000	185	42/25	25	25,000	16,000[a]	25,000
LM6000	220	42/25	25	25,000	16,000[a]	25,000
MS5001P	142	42	42	12,000	6,000	6,000
MS6001B	148	42	42	12,000	6,000	8,000
MS7001E	154	42	42	8,000	6,500	8,000
MS7001F	179	42	42	8,000	8,000	8,000
MS9001E	176	42	42	8,000	6,500	8,000
MS9001F	176	42	42	8,000	8,000	8,000
Asea Brown Boveri						
GT10	150	25	42	80,000[b]	80,000[b]	80,000[b]
GT8	430	25	29	24,000	24,000	24,000
GT11N	400	25	25	24,000	24,000	24,000
GT35	300	42	60	80,000[b]	80,000[b]	80,000[b]
GT24	25[e]	NA[d]	25[e]	24,000[b]	NA[d]	24,000[b]
Siemens Power Corp.						
V84.2	212	42	55	25,000	25,000	25,000
V94.2	212	55	55	25,000	25,000	25,000
V64.3	380	75	75	25,000	25,000	25,000
V84.3	380	75	75	25,000	25,000	25,000
V94.3	380	75	75	25,000	25,000	25,000
Solar Turbines, Inc.						
T-1500 Saturn	99	42	NA[c]	NA[d]	NA[d]	NA[c]
T-4500 Centaur	150	42	NA[c]	NA[d]	NA[d]	NA[c]
Type H Centaur	105	42	NA[c]	NA[d]	NA[d]	NA[c]
Taurus	114	42	NA[c]	NA[d]	NA[d]	NA[c]
T-12000 Mars	178	42	NA[c]	NA[d]	NA[d]	NA[c]
T-14000 Mars	199	42	NA[c]	NA[d]	NA[d]	NA[c]

Allison/ General Motors						
501-KB5	155	42	NA[c]	25,000	17,000	NA[d]
501-KC5	174	42	NA[c]	30,000	22,000	NA[d]
501-KH	155	42	25	25,000	17,000	20,000
570-K	101	42	NA[c]	20,000	12,000	NA[d]
571-K	101	42	NA[c]	20,000	12,000	NA
Westinghouse						
251B11/12	220	42	25	8,000	8,000	8,000
501D5	190	25	25	8,000	8,000	8,000

Notes: Details of steam injection maintenance intervals are subject to confirmation with each manufacturer.

[a] Applies only to 25 ppmv level. No impact for 42 ppmv.

[b] This interval applies to time between overhaul (TBO).

[c] Steam injection is not available for this model.

[d] Data not available.

[e] No NO_x reduction quoted for steam injection

5.3 DRY POST COMBUSTION CONTROL TECHNOLOGIES

5.3.1 Selective Catalytic Reduction (SCR)

SCR is a proven post-combustion technology used to reduce NO_X emissions from diesel-fired turbines. SCR systems convert NO_X into nitrogen and water by introducing ammonia (NH_3) or ammonia-producing compounds like urea into the exhaust stream in the presence of a catalyst. These systems typically operate within a temperature range of 200°C to 400°C (392°F to 752°F), depending on exhaust conditions, with catalyst materials like base metals (e.g., titanium or vanadium oxides), noble metals, or zeolites providing high surface area and minimal obstruction to flue gas flow (CIMAC, 2008b).

For diesel-fired turbines, the primary NO_X reduction reactions involve the conversion of NO NO_2 with ammonia. Given that NO makes up the majority of NO_X emissions, the efficiency of this reaction is critical. However, the presence of sulphur in diesel fuel introduces additional complexity. Sulphur dioxide (SO_2) in the exhaust can oxidize to sulphur trioxide (SO_3), which reacts with ammonia to form ammonium bisulfate and ammonium sulfate at lower temperatures. These byproducts can lead to fouling, increased backpressure, and corrosion of downstream equipment, particularly in heat recovery systems (CIMAC, 2008c).

SCR systems can be applied to diesel-fired turbines across various configurations, but their effectiveness depends on exhaust temperature, fuel composition, and operational conditions. Diesel turbines often operate with variable exhaust temperatures, which can fall outside the optimal range for catalyst performance. Base-metal catalysts typically function best between 260°C and 400°C (500°F to 800°F), while zeolite catalysts extend this range up to 590°C (1100°F), offering more flexibility in high-temperature applications (CIMAC, 2008b).

5.3.2 Factors Affecting SCR Performance

The performance of SCR systems in diesel-fired turbines depends on several factors. Catalyst material and condition play a key role, with base metals like vanadium and tungsten oxides and zeolites being the most commonly used. These materials offer varying resistance to degradation caused by contaminants in diesel exhaust, such as sulphur compounds and particulates. Over time, the catalyst's efficiency may decrease due to masking, poisoning, or sintering, resulting in reduced NO_x conversion rates (CIMAC, 2008a).

Maintaining the reactor temperature within the catalyst's optimal operating range is also crucial, as deviations can lead to lower NO_x reduction efficiency and increased ammonia slip—where unreacted ammonia escapes into the atmosphere as a secondary emission (U.S. EPA, 1999).

Space velocity, defined as the volumetric flow rate of exhaust gas divided by the catalyst volume, further influences SCR performance. Lower space velocities allow for longer residence times of gases within the catalyst, enhancing NO_x reduction efficiency but necessitating larger catalyst volumes (CIMAC, 2008b). The NH_3/NO_x ratio is equally important, with a typical operating ratio of around 1.0 to balance effective NO_x reduction with minimal ammonia slip. Deviations from this stoichiometric balance can either compromise emission control efficiency or lead to excess ammonia emissions (CIMAC, 2008c).

5.3.3 Achievable NO_X Emission Reduction Efficiency Using SCR

Most SCR systems achieve NO_x reduction efficiencies typically between 70% and 95%, with ammonia slip levels reported as high as 20–25 ppm (CIMAC, 2008b; U.S. EPA, 1999). When combined with technologies like water or steam injection and DLN combustors, SCR can reduce NO_x emissions to as low as 2.5–4.2 ppmv for natural gas and 4.2–11.0 ppmv for oil fuels (U.S. EPA, 1999).

5.3.4 Application and Challenges of SCR for Diesel Turbines

SCR is one of the most widely used post-combustion technologies for controlling NO_X emissions from combustion engines, including diesel turbines. However, its application in diesel-fired turbines faces several technical and environmental challenges. Diesel turbines often burn heavier fuels, leading to higher levels of PM and sulphur oxides (SO_X), which can foul the SCR catalyst and reduce its efficiency and lifespan (CIMAC, 2008a). In contrast, natural gas turbines typically use cleaner fuels like natural gas, producing fewer contaminants and allowing SCR systems to operate more efficiently over longer periods (CIMAC, 2008b).

A significant challenge lies in the exhaust temperature characteristics of diesel turbines. SCR systems require exhaust temperatures between 250°C and 450°C for optimal ammonia-NO_x reactions. Diesel turbines often operate at lower exhaust temperatures, which can fall outside this optimal range, requiring additional preheating or system modifications to maintain performance (CIMAC, 2008c). This adds complexity and increases operational costs and energy consumption.

Despite these challenges, SCR is used in large stationary diesel turbines where strict NO_x regulations apply, particularly in power generation and industrial co-generation applications. Advanced filtration systems like Diesel Particulate Filters (DPFs) or Electrostatic Precipitators (ESPs) are often installed upstream of the SCR system to reduce particulate load and protect the catalyst, helping maintain SCR efficiency but requiring significant investment in equipment and maintenance (OSTI, n.d.).

5.3.4.1 Environmental and Operational Considerations

SCR systems, while effective at reducing NO_x emissions, introduce their own environmental and operational challenges. Ammonia, the reducing agent used in SCR systems, is a toxic substance requiring special handling and permitting. The risk of leakage or accidental release during delivery adds environmental hazards, and ammonia slip — the release of unreacted ammonia — is regulated as a toxic emission in most jurisdictions (U.S. EPA, 1999). Ammonia slip can also lead to the formation of secondary pollutants like ammonium sulfate or ammonium nitrate, increasing operational complexity (CIMAC, 2008b). Managing ammonia slip requires precise control and monitoring systems, adding to maintenance requirements.

SCR catalysts often contain toxic metals like vanadium and tungsten, which are classified as hazardous waste at the end of their operational life. Proper disposal requires adherence to stringent hazardous waste management protocols, increasing both environmental impact and cost (CIMAC, 2008c). Failure to manage spent catalysts responsibly can lead to soil and water contamination.

Fuel quality also significantly impacts SCR performance in diesel turbines. High-sulphur diesel fuels increase SO_3 formation, leading to ammonium salt deposition and catalyst fouling. This results in more frequent maintenance, reduced efficiency, and potential damage to exhaust components. Ammonia slip exacerbates this issue by accelerating salt buildup (CIMAC, 2008c).

Retrofitting SCR systems on diesel-fired turbines can be challenging and costly. Simple-cycle diesel turbines often require additional heat exchangers to bring exhaust temperatures within the catalyst's effective range, while combined heat and power (CHP) systems may require significant modifications to existing heat recovery equipment (CIMAC, 2008a). These capital and operational costs often make SCR less feasible for smaller or mobile diesel turbine applications, limiting its use to larger, stationary installations where strict emission standards justify the investment (OSTI, n.d.).

Recent advancements in SCR technology have focused on improving catalyst durability, expanding effective temperature ranges, and integrating emission control systems. Enhanced catalysts with higher thermal stability and resistance to poisoning have extended operational lifespans and maintained efficiency in varying conditions (CIMAC, 2008b). Modern diesel-fired turbines increasingly adopt combined emission control systems, integrating SCR with Exhaust Gas Recirculation (EGR) and particulate filters. This approach effectively addresses multiple pollutants, including NO_x, SO_x, and PM, ensuring compliance with evolving emission standards (U.S. EPA, 1996).

5.3.4.2 Technical and Measurement Challenges

Beyond environmental and cost considerations, SCR systems face technical challenges related to emission measurement and system performance. Achieving single-digit NO_x levels (below 9 ppmv) can be difficult due to variability and uncertainty in current measurement methodologies. Factors such as exhaust flow calculation errors, ambient atmospheric conditions, and measurement instrument variability can introduce significant uncertainty, sometimes as high as 50% (CIMAC, 2008a). These issues complicate the enforcement of ultra-low NO_x limits and require advanced monitoring systems to ensure compliance.

The efficiency and reliability of SCR systems can also be compromised by the mechanical and operational demands of diesel turbines. Aggressive emission targets often lead to combustor oscillations, adversely affecting energy conversion efficiency and increasing wear on turbine components (OSTI, n.d.). Maintaining both low emissions and high operational reliability requires careful balancing of system design and performance parameters.

5.3.5 SCONOX

SCONOX is a catalytic air pollution control technology originally designed for natural gas turbines. It reduces NO_X and CO emissions without using ammonia, offering high efficiency and dual pollutant control. However, its sensitivity to sulphur and particulate matter makes it technically impractical for diesel-fired turbines, which typically burn higher-sulphur fuels and generate more PM. As such, SCONOX is not suitable for diesel applications without extensive fuel and exhaust treatment.

5.3.6 Selective Non-Catalytic Reduction (SNCR)

Selective Non-Catalytic Reduction (SNCR) is a post-combustion technology that reduces NO_X emissions by injecting NH_3 or urea into the flue gas within a specific temperature range, typically between 870°C and

1,200°C (1,600°F to 2,200°F). Within this range, NH_3 reacts with NO_X to form nitrogen and water without the need for a catalyst. The optimal temperature window is crucial; injecting NH_3 above 1,200°C can lead to increased NO_X formation, while temperatures below 870°C result in reduced reaction efficiency. Introducing hydrogen (H_2) alongside NH_3 can lower the effective temperature window to 700°C (1,300°F), enhancing flexibility in various applications (U.S. EPA, 2016a).

Despite its economic advantages over SCR due to the absence of catalyst costs, SNCR faces challenges when applied to natural gas turbines. According to manufacturers data, both diesel and Natural gas turbine exhaust temperatures typically do not exceed 600°C (1,100°F), which is below the effective range for SNCR reactions. Additionally, the required residence time for the reaction is approximately 0.3 to 1 second, which is relatively long given the high flow velocities in natural gas turbine operations. These factors limit the practicality of SNCR in both diesel and natural gas turbine applications (U.S. EPA, 2016b).

5.4 SUMMARY OF NO_X CONTROL TECHNOLOGIES

Table 5-2 Summary of Feasible and Viable NO_X control technologies for diesel turbines.

Table 5-2: Feasible and Viable NO_X control Technologies for Diesel Turbines

Emission Control Technology	NO_X Reduction Efficiency	Why It's Feasible for Diesel Turbines	Key Considerations
Selective Catalytic Reduction (SCR)	80% to 95%	Most effective NO_X reduction, works well with ULSD	Requires ammonia or urea injection; sensitive to sulphur and PM; catalyst maintenance necessary
Dry Low NO_X **(DLN) Combustors**	50% to 75%	Achieves low NO_X without water/steam injection; improves efficiency	Not compatible with water/steam injection; requires stable high-temperature operation. DLN uses premixed air and fuel mixture. Water or steam injection will interfere with the accurate control of burners.
Water or Steam Injection (SAC)	50% to 70%	Simple and widely used; effective in reducing combustion temperature	High water demand; increased maintenance from corrosion and deposits
Selective Non-Catalytic Reduction (SNCR)	30% to 60%	Lower-cost alternative to SCR; no catalyst required	Requires precise temperature control (900°C to 1100°C); less effective at lower exhaust temperatures
Ultra-Low NO_X **Burners (ULNB)**	75% to 90%	Advanced prevention-based technology; reduces NO_X during combustion	Requires specific turbine design; high initial cost but lower operational complexity

6 OPTIONS FOR PM AND $PM_{2.5}$ CONTROL

Controlling PM and $PM_{2.5}$ requires efficient aftertreatment technologies tailored to the unique characteristics of diesel turbine exhaust, including high flow rates, variable temperatures, and the potential for increased sulphur and soot content. Three primary technologies used for PM control in diesel-fired turbines are DPFs, Diesel Oxidation Catalysts (DOCs), and ESPs, each with distinct mechanisms, efficiencies, and operational considerations. Besides DPFs, DOCs, and ESPs, several other control technologies can be applied to reduce PM emissions from diesel turbines. Each has its own advantages and limitations based on efficiency, cost, operational conditions, and compatibility with diesel turbine exhaust characteristics.

6.1 DIESEL PARTICULATE FILTERS (DPF)

DPFs are highly effective in capturing and reducing PM emissions by physically trapping soot and fine particles within a porous ceramic or metal filter structure. Wall-flow DPFs can achieve up to 98% efficiency for soot removal, with some tests showing solid particulate removal rates around 98.9% (Ferguson et al., 2016b). These filters use regeneration methods to burn off accumulated soot, minimizing backpressure and maintaining engine efficiency.

6.1.1 Regeneration Methods:

- Active Regeneration: Involves raising exhaust temperatures through engine throttling or fuel injection to oxidize soot. This process can increase fuel consumption and operational complexity. In the case of peaking operation of diesel turbines, it presents challenges. In diesel-fired turbines, active regeneration of Diesel Particulate Filters (DPFs) involves increasing the exhaust temperature to oxidize accumulated soot, typically by injecting additional fuel upstream of the DPF and combusting it using a Diesel Oxidation Catalyst (DOC). This process raises the exhaust temperature to approximately 600–700°C, allowing soot to be burned off and preventing excessive backpressure. Unlike engines, turbines operate more steadily, enabling more predictable regeneration cycles, though careful system design is needed to manage high exhaust flowrates and avoid turbine performance degradation. Active regeneration systems for turbines must also accommodate the turbine’s sensitivity to pressure drops and thermal stress (U.S. EPA, 2002; Johnson Matthey, 2018).
- Passive Catalyzed Regeneration: Uses catalysts like cerium to lower the temperature needed for soot oxidation, enabling regeneration at around 300°C.
- Continuously Regenerating Trap (CRT): Combines oxidation catalysts with the DPF, promoting soot oxidation at lower temperatures and reducing PM emissions by 50–70%.

Despite their high efficiency, DPFs are less common in diesel turbines due to several technical challenges. Diesel turbines produce high exhaust flow rates and variable exhaust temperatures, often falling below the 350°C needed for passive regeneration. This can lead to soot buildup, clogging, and increased maintenance. Additionally, high pressure drop across a DPF reduces the efficiency of diesel turbines by increasing backpressure, which lowers power output and raises fuel consumption. This can lead to more frequent regeneration cycles, higher operating and maintenance costs, and potential performance derating—especially problematic during peaking operations where efficiency is critical.

6.2 DIESEL OXIDATION CATALYST (DOC)

DOCs reduce PM emissions by oxidizing the volatile organic fraction of PM, hydrocarbons, and CO over a catalytic surface (typically platinum or palladium). DOCs are more effective at addressing the soluble organic portion of PM rather than solid soot, making them suitable for applications where hydrocarbon reduction is a priority.

6.2.1 DOC Efficiency and Performance:

- PM Reduction: 20% to 40% in diesel internal combustion engines (ICEs) and 10% to 25% in diesel turbines.
- Optimal Temperature Range: 200°C to 500°C, aligning well with the steady-state operation of diesel ICEs but less effective in variable-load diesel turbines.
- Pressure Sensitivity: DOCs impose low backpressure, which is manageable in ICEs but can significantly affect turbine efficiency.

In diesel turbines, DOCs face challenges such as high exhaust flow rates, temperature variability, and lower soluble organic fractions in PM. These factors limit DOC efficiency and increase maintenance needs due to catalyst fouling from soot and sulphur content. DOCs are more common in stationary diesel turbines with consistent high exhaust temperatures and ULSD fuels.

6.3 Electrostatic Precipitators (ESP)

ESPs are well-established technologies for removing PM from industrial exhaust streams. ESPs use an electric field to charge and capture PM on collection plates, achieving high filtration efficiency without significant pressure drop.

6.3.1 ESP Efficiency and Performance:

- PM Removal Efficiency: Over 95% (U.S. Environmental Protection Agency, 2021).
- Applicability: Effective for large-scale stationary diesel turbines and industrial facilities with high exhaust flow rates.
- Maintenance: Requires periodic cleaning of collection plates but offers long operational life with minimal backpressure impact.

Compared to DPFs and DOCs, ESPs provide a non-contact method for PM removal, avoiding issues like pressure buildup and soot clogging. They are particularly suitable for diesel turbines operating under variable loads and temperatures, where passive regeneration of DPFs is less reliable.

6.4 Baghouse (Fabric Filters)

Baghouse filters offer excellent PM control efficiency, often exceeding 99%, including for fine and ultrafine particles. However, their high-pressure drop can significantly affect diesel turbine efficiency, making them less practical for turbine applications. Additionally, the large size and maintenance needs of baghouses make them more common in industrial boilers and stationary combustion systems than in diesel-fired turbines, where space and efficiency are critical considerations.

6.5 Wet Scrubbers

Wet scrubbers use water or chemical solutions to capture PM and soluble gases from exhaust streams, achieving PM removal efficiencies between 80–95%. They are more commonly used in systems where both PM and acidic gases (like SO_X) need control. For diesel turbines, their high-water consumption, wastewater treatment requirements, and potential for corrosion make them less common.

6.6 SUMMARY OF PM AND M2.5 CONTROL TECHNOLOGIES

Table 6-1 Feasible PM and $PM_{2.5}$ Control Technologies for Diesel Turbines.

Table 6-1: Feasible PM and $PM_{2.5}$ Control Technologies for Diesel Turbines

Emission Control Technology	PM Reduction Efficiency	$PM_{2.5}$ Reduction Efficiency	Why It's Feasible for Diesel Turbines	Key Considerations
Diesel Particulate Filters (DPFs)	80% to 98%	80% to 98%	Highly effective; captures fine particles; works with low-sulphur fuel	High-pressure drop; requires consistent high exhaust temperatures for regeneration. Simple cycle generator data from manufacturers show lower exhaust temps and would need catalyst to reach regeneration temperature.
Electrostatic Precipitators (ESPs)	90%+	90%+	Ideal for high exhaust flow rates; minimal pressure drop	High capital and operational costs; large space requirement
Diesel Oxidation Catalysts (DOCs)	20% to 40%	10% to 25%	Reduces volatile PM fraction; low backpressure	Limited $PM_{2.5}$ control; more effective on soluble organic fraction than solid soot
Wet Scrubbers	80% to 95%	80% to 95%	Effective for both PM and sulphur-based aerosols	High-water demand; wastewater treatment required; potential for corrosion

7 CAPITAL AND OPERATING COSTS OF CONTROL TECHNOLOGIES

This section presents an analysis of the capital and operational costs associated with NO_X and PM control technologies for diesel turbines. The cost data is primarily sourced from the U.S. EPA Control Cost Manual (U.S. EPA 1996), ensuring a standardized basis for comparison. While cost-effectiveness is a common metric in industrial applications where large quantities of pollutants are removed, it is less relevant for turbines due to their relatively low emissions volumes. Instead, capital and operating costs provide a more meaningful indicator for decision-making.

It should be noted that the capital and operating costs of some technologies not commonly used in diesel turbines are very limited and carry significant uncertainty. As such, the information presented in this section is intended to provide a general understanding and a high-level analysis for the selection of BACT technology. In addition, the cost implications resulting from lower power generation efficiency and increased emissions of other contaminants are not discussed due to the lack of accurate cost information.

7.1 NOX CONTROL TECHNOLOGIES

7.1.1 Water or Steam Injection

- Capital Cost: The U.S. EPA Control Cost Manual estimates capital costs for water injection systems at approximately $12,000–$25,000 per MW, depending on system complexity and water treatment requirements.
- Operating Cost: Operating costs primarily include water consumption, which ranges from 1.2 to 2.5 gallons per MMBtu of fuel burned, and potential efficiency losses of 1–3%, leading to increased fuel costs. The additional maintenance costs due to corrosion and deposits in the combustion system are estimated at $1,000–$3,000 per year per MW.

7.1.2 SCR

- Capital Cost: The EPA estimates SCR capital costs for turbines at $40,000–$100,000 per MW, depending on system size, catalyst material, and integration complexity.
- Operating Cost: Costs include ammonia or urea supply, catalyst replacement, and maintenance. Ammonia costs range from $0.50–$1.50 per lb of NOx removed, while catalyst replacement costs $50,000–$100,000 every 3–5 years.

7.2 LNB, DLE, ULNB COMBUSTION

- Capital Cost: LNB systems range from $5,000–$15,000 per MW. DLE and ULN systems, if applicable, range from $15,000–$30,000 per MW.
- Operating Cost: Minimal for LNB; higher for DLE/ULN due to tighter control requirements and potential flame instability issues.

7.3 PM CONTROL TECHNOLOGIES

7.3.1 DPFs

- Capital Cost: Data on DPF costs for turbines is scarce, but for stationary diesel engines, capital costs range from $5,000–$25,000 per MW.

- Operating Cost: Maintenance costs can be high due to filter cleaning or replacement, estimated at $2,000–$5,000 per year per MW. Fuel penalties due to backpressure may lead to efficiency losses of 1–2%.

7.3.2 ESPs

- Capital Cost: $75,000–$200,000 per MW, varying with system design and size.
- Operating Cost: $0.003–$0.005 per kWh, including energy consumption, maintenance, and periodic cleaning of collection plates.

7.4 DOCs

- Capital Cost: $5,000–$15,000 per MW.
- Operating Cost: Low; includes minimal maintenance and periodic catalyst replacement.

A summary of control technology costs is provided in Table 7-1and Table 7-2 for NO_X and PM, respectively.

Table 7-1: NOx Control Technologies

Technology	Capital Cost ($/MW)	Operating Cost
Water/Steam Injection	$12,000–$25,000	$1,000–$3,000/year + water costs
SCR	$40,000–$100,000	$0.50–$1.50/lb NO_X removed + maintenance
LNB	$5,000–$15,000	Minimal
DLE/ULN	$15,000–$30,000	Moderate (control systems)
SNCR	$30,000–$60,000	$0.002–$0.004/kWh

Table 7-2: PM Control Technologies

Technology	Capital Cost ($/MW)	Operating Cost
DOC	$5,000–$15,000	Low
DPF (Active Regeneration)	$5,000–$25,000	$2,000–$5,000/year
ESP	$75,000–$200,000	$0.003–$0.005/kWh

8 BEST AVAILABLE CONTROL TECHNOLOGIES FOR NO_X AND PM EMISSIONS

It is important to note that ACTs use LSD or ULSD as fuel and operate as peaking units, with a typical annual run time of 270 hours and a worst-case contingency scenario of up to six weeks per year.

Accurate fuel–air ratio, effective operating controls, and regular maintenance are critical for minimizing emissions in diesel-fired turbines. Proper fuel–air mixing ensures complete combustion, reducing the formation of NO_X, and unburned hydrocarbons. Advanced control systems help maintain optimal combustion conditions across varying loads, while routine maintenance prevents issues like fouled injectors or degraded components that can increase emissions.

When low-sulphur diesel fuel is used in diesel-fueled turbines, emission control challenges related to catalyst poisoning are significantly reduced. This reduction minimizes the risk of catalyst fouling and lowers maintenance requirements, making it possible to adopt a broader range of emission control technologies.

Key considerations for selecting feasible and viable NO_X control technologies for diesel turbines are:

- SCR remains the most efficient NO_X control for diesel turbines but faces challenges with ammonia slip, sulphur content, and catalyst fouling — making it best suited for large stationary applications (25 MW and above) with low-sulphur diesel. Limited space availability poses technical challenges for using this technology, and capital and operational cost poses challenges for economic feasibility of this technology given that the ACTs are used as peaking units with typical annual run time of 270 hours and a worst-case contingency scenario of less than six weeks per year.
- ULNB and DLN combustors provide high efficiency and NO_X control without the water demand of SAC, but they require optimized air-fuel mixing and cannot operate alongside water/steam injection. Water injection is incompatible with DLN because it interferes with the carefully controlled lean premixed combustion process, risking flame instability, increased emissions, and operational challenges. DLN is designed specifically to avoid the need for water or steam injection.
- Water/Steam Injection (SAC) is widely used but brings increased maintenance and lower efficiency due to corrosion and water handling. However, it provides an economically and technically viable solution for diesel turbines.

  In addition, Newfoundland and Labrador Hydro has significant experience with the operation of SAC technology at its facilities.

When low-sulphur diesel fuel is used in diesel-fueled turbines, emission control challenges related to PM and SO_X emissions are significantly reduced. This reduction minimizes the risk of catalyst fouling and lowers maintenance requirements, making it possible to adopt a broader range of emission control technologies.

As previously explained, particulate emissions from turbines are influenced by the design of the combustion system, fuel characteristics, and operating conditions. In some jurisdictions, sulfuric acid and liquid unburned hydrocarbons may also be classified as particulate matter. Feasible control options for particulate emissions are generally limited—particularly for peaking units that operate less than six weeks per year. With the exception of smoke, most particulate components are managed through fuel composition control. While smoke emissions are also influenced by fuel type, they are primarily minimized through advanced combustor design. For turbines fired with light oil, smoke is typically not a concern and, when it does occur, is usually limited to startup or shutdown periods.

Modern turbines incorporate advanced combustor designs that result in minimal particulate emissions when using low-sulfur diesel or ultra-low-sulfur diesel. Post-combustion particulate control systems are not commonly applied to simple-cycle turbine installations.

Key considerations for selecting feasible and viable PM and $PM_{2.5}$ control technologies for diesel turbines are:

- DPFs and ESPs are the most effective for PM control, with ESPs being preferable for high-flow, variable-load diesel turbines due to their lower pressure drop. The space limitations and cost implications are important factors. ESPs, while highly effective for PM removal, are impractical for ACTs due to their large footprint, which is incompatible with the space limitations in the turbine generator area. ESPs also require significant energy input and complex maintenance, making them less attractive for a peaking project focused on efficiency and reliability with typical annual run time of 270 hours and a worst-case contingency scenario of less than 6 weeks per year.
- DPF pressure drop poses a significant drawback for diesel turbine applications.
- DOCs are more effective at reducing hydrocarbons than solid PM, making them a supplementary but not primary PM control method for diesel turbines. However, it features low capital and operating cost.
- Wet scrubbers offer very high PM control but are less practical for diesel turbines due to space requirements, pressure drop, and operational complexity.

Given the constraints and considerations provided above, as well as the cost information provided in Section 7, BACT for NO_X in diesel turbines is mostly achieved through:

- Water or Steam Injection (SAC): Reduces peak flame temperature, lowering thermal NO_X formation; still compatible with diffusion flame combustion used in diesel turbines. Newfoundland and Labrador Hydro has significant experience with the operation of SAC technology at its facilities.
- Use of ULSD: Minimizes sulphur content, which can indirectly help reduce NO_x and prevent damage to any downstream emissions control devices.
- Good Combustion Practices: Optimized air-fuel ratios, advanced fuel injection, and regular maintenance to ensure clean, complete combustion.

Given the constraints and considerations provided above, as well as the cost information provided in Section 7, BACT for PM in diesel-fired turbines is most commonly achieved through:

- Use of ultra-low sulphur diesel (ULSD) to minimize PM formation at the source.
- Good combustion practices, including proper turbine tuning and maintenance to optimize fuel–air mixing and reduce PM generation.
- High-efficiency DOCs may be considered a supplementary technology for reducing organic PM (e.g., soluble organic fraction), provided proper catalyst maintenance is ensured. However, since ACTs are peaking units with a typical annual run time of 270 hours and a worst-case contingency scenario of up to six weeks per year, DOCs may not be considered BACT, as the incremental emission reductions come at a cost that is not economically feasible.

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