HAP SPECIATION PROFILES FOR NATURAL GAS-FIRED TURBINES AND RECIPROCATING ENGINES

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Prepared by:
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EXECUTIVE SUMMARY

A. BACKGROUND

This report presents the hazardous air pollutant (HAP) speciation profiles developed for natural gas-fired turbines and reciprocating engines, based on the available emission test data for the target pollutants and Source Classification Codes (SCCs) listed in Table ES-1 and Table ES-2, respectively. The EPA uses SCCs to organize data for anthropogenic air pollutant sources that have similar production and emissions characteristics into related groups or source categories. SCCs are either an 8- or 10-digit code that corresponds to a 4-level definition of the emissions process, with the first level (L1) providing the most general information regarding the emissions category and descending to the fourth level (L4) which provides the most detailed description of the emissions.

Table ES-1. List of Target Pollutants

Pollutant Name
• 2,2,4-Trimethylpentane
• Acetaldehyde
• Acrolein
• Benzene
• Carbonyl Sulfide
• Formaldehyde
• Methanol
• n-Hexane
• Toluene
• Xylenes
• Total organic carbon (TOC)
• Volatile organic compounds (VOC)

Table ES-2. SCCs for Natural Gas-Fired, Internal Combustion Engines[a]

SCC	L2 Description	L4 Description
20100201	Electric Generation	Turbine
20100202		Reciprocating
20100205		Reciprocating: Crankcase Blowby
20100206		Reciprocating: Evaporative Losses (Fuel Delivery System)
20100207		Reciprocating: Exhaust
20100209		Turbine: Exhaust
20200201	Industrial	Turbine
20200202		Reciprocating
20200203		Turbine: Cogeneration
20200204		Reciprocating: Cogeneration
20200205		Reciprocating: Crankcase Blowby
20200207		Reciprocating: Exhaust
20200209		Turbine: Exhaust

SCC	L2 Description	L4 Description
20200251		2-cycle Rich Burn
20200252		2-cycle Lean Burn
20200253		4-cycle Rich Burn
20200254		4-cycle Lean Burn
20200255		2-cycle Clean Burn
20200256		4-cycle Clean Burn
20300201		Reciprocating
20300202		Turbine
20300203		Turbine: Cogeneration
20300204	Commercial/Institutional	Reciprocating: Cogeneration
20300205		Reciprocating: Crankcase Blowby
20300207		Reciprocating: Exhaust
20300209		Turbine: Exhaust

[a] The L1 and third level (L3) descriptions for all SCCs presented in Table ES-3 are “Internal Combustion Engines” and “Natural Gas”, respectively.

This report discusses the data collection activities and information obtained and presents the calculation methodologies and the resulting HAP speciation profiles developed for natural gas-fired turbines and reciprocating engines.

Table ES-3 shows the HAP speciation profiles developed for natural gas-fired turbines by SCC and control status from available WebFIRE and stack test data, with AP-42 profiles provided for comparison. Updated profile data could not be found for the following pollutants: 2,2,4-trimethylpentane; methanol; n-hexane; and xylene. No profile data could be found for carbonyl sulfide.

Table ES-3. HAP Speciation Profiles for Natural Gas-Fired Turbines

SCC	Control Status	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Data Source
20100201[a]	Uncontrolled	0.44%	0.08%	0.13%	1.74%	1.71%	WebFIRE[b]
20200201[a]	Uncontrolled	0.46%	0.09%	0.15%	1.25%	2.06%	WebFIRE[b]
20200203[a]	Uncontrolled	0.46%	0.09%	0.15%	1.25%	2.06%	WebFIRE[b]
20300202[a]	Uncontrolled	0.77%	0.15%	0.25%	2.11%	3.46%	WebFIRE[b]
20300203[a]	Uncontrolled	0.50%	0.09%	0.16%	1.37%	2.26%	WebFIRE[b]
20100201[c]	Uncontrolled	0.44%	0.08%	0.13%	1.71%	1.71%	WebFIRE[b]
20200201[c]	Uncontrolled	0.46%	0.09%	0.15%	1.35%	2.06%	WebFIRE[b]
20200203[c]	Uncontrolled	0.46%	0.09%	0.15%	1.35%	2.06%	WebFIRE[b]
20300202[c]	Uncontrolled	0.77%	0.15%	0.25%	2.28%	3.46%	WebFIRE[b]
20300203[c]	Uncontrolled	0.50%	0.09%	0.16%	1.48%	2.26%	WebFIRE[b]
20100201[c]	Uncontrolled	0.36%	0.06%	0.11%	6.45%	1.18%	AP-42[b]
20200201[c]	Uncontrolled	0.36%	0.06%	0.11%	6.45%	1.18%	AP-42[a]
20200203[c]	Uncontrolled	0.36%	0.06%	0.11%	6.45%	1.18%	AP-42[b]
20300202[c]	Uncontrolled	0.36%	0.06%	0.11%	6.45%	1.18%	AP-42[b]
20300203[c]	Uncontrolled	0.36%	0.06%	0.11%	6.45%	1.18%	AP-42[b]
20100201[c]	Uncontrolled	1.90%	0.30%	0.57%	33.81%	6.19%	AP-42[d]
20200201[c]	Uncontrolled	1.90%	0.30%	0.57%	33.81%	6.19%	AP-42[d]
20200203[c]	Uncontrolled	1.90%	0.30%	0.57%	33.81%	6.19%	AP-42[d]

SCC	Control Status	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Data Source
20300202[c]	Uncontrolled	1.90%	0.30%	0.57%	33.81%	6.19%	AP-42[d]
20300203[c]	Uncontrolled	1.90%	0.30%	0.57%	33.81%	6.19%	AP-42[d]
20200201	Dry low emissions combustion for NO_x control	Not available (NA)	NA	NA	24.8%	NA	Wyoming DEQ[d]

[a] Data are for all engine loads.

[b] HAP speciation profiles expressed as a percent of lb TOC/MMBtu heat input.

[c] Data are for engine loads ≥ 80%.

[d] HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

Table ES-4 shows the HAP speciation profiles developed for natural gas-fired engines by SCC and control status from available WebFIRE and stack test data, with AP-42 profiles provided for comparison. Updated profile data could not be found for the following pollutants: 2,2,4-trimethylpentane; methanol; n-hexane; and xylene. No profile data could be found for carbonyl sulfide.

Table ES-4. HAP Speciation Profiles for Natural Gas-Fired Engines

SCC	Control Status	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Data Source
20200252[a]	Uncontrolled	0.78%	0.73%	0.44%	5.73%	0.16%	AP-42[b]
20200253[a]	Uncontrolled	0.57%	0.35%	0.03%	3.59%	0.03%	AP-42[b]
20200254[a]	Uncontrolled	6.47%	6.48%	1.62%	46.00%	0.80%	AP-42[b]
20200252[a]	Uncontrolled	9.43%	8.89%	5.34%	69.26%	1.89%	AP-42[c]
20200253[a]	Uncontrolled	7.08%	4.36%	0.37%	44.75%	0.35%	AP-42[c]
20200254[a]	Uncontrolled	0.78%	0.73%	0.44%	5.73%	0.16%	AP-42[b]
20200253	Non-selective catalytic reduction (NSCR)	NA	NA	NA	6.6%	NA	TCEQ
20200253	NSCR	NA	NA	NA	17.9%	NA	Wyoming DEQ
20200254	Uncontrolled/ Not specified	NA	NA	NA	42.9%	NA	TCEQ
20200254	Oxidation catalyst	NA	NA	NA	46.4%	NA	TCEQ
20200254	Oxidation catalyst	NA	NA	NA	19.7%	NA	Wyoming DEQ

[a] Data are for all engine loads.

[b] HAP speciation profiles expressed as a percent of lb TOC/MMBtu heat input.

[c] HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

I. INTRODUCTION

A. BACKGROUND

Internal natural gas combustion sources emit significant amounts of HAP emissions. The primary sources of natural gas internal combustion HAP emission factors are the *Compilation of Air Pollutant Emission Factors* (*AP-42*) from the United States Environmental Protection Agency (EPA), and the Web Factor and Information Retrieval System (WebFIRE), which is EPA's online emission factor repository. *AP-42* emission factors for internal combustion engines were last updated over 20 years ago, and much of WebFIRE is still based on these factors. Also, there are no *AP-42* or WebFIRE factors or speciation profiles for controlled rich-burn engines which are a large portion of the engine fleet. Finally, due to more recent regulatory requirements, a significant amount of formaldehyde test data has been generated since the *AP-42* sections were last updated, which could impact the accuracy of EPA factors. Similar information on other HAPs may also be available.

This report presents the HAP speciation profiles developed for natural gas-fired turbines and reciprocating engines, expressed as a percent of total VOC and/or TOC, based on the available information. The profiles can be used to improve point and area source emissions inventories with respect to WebFIRE data for natural gas-fired internal combustion sources and recent stack test data for the formaldehyde profile from turbines and large, 4-cycle lean and rich burn engines.

B. REPORT ORGANIZATION

Chapter II of this report summarizes the approach for identifying and collecting data to update the HAP speciation profiles for natural gas-fired turbines and reciprocating engines.

Chapter III presents the emissions data obtained from the data collection activities.

Chapter IV presents the HAP speciation profiles and supporting calculations.

Chapter V discusses the findings and conclusions of this report.

Appendix A and Appendix B list the references returned from the *ProQuest* database for turbines and reciprocating engines, respectively.

Appendix C lists the trade associations identified for the oil and gas sector.

Appendix D presents the facility types contained in the Open Air database maintained by the Wyoming Department of Environmental Quality (DEQ).

Appendix E presents the turbines and reciprocating engine emissions factors used by the Michigan Air Emissions Reporting System (MAERS) maintained by the Michigan Department of Environment, Great Lakes, and Energy (EGLE).

Appendix F presents the HAP speciation profiles developed for turbines and reciprocating engines.

Appendix G, Appendix H, and Appendix I contain the test report data and calculations used to develop the HAP speciation profiles from the WebFIRE, TCEQ, and Wyoming DEQ data, respectively.

C. REPORT TERMINOLOGY

The analyses presented in Chapter III of this report use the statistical terminology for "median" and "average" with the following definitions:

- The median is the number separating the higher half of a sample from the lower half. The median of a list of numbers can be found by arranging all the observations from the lowest to the highest value and selecting the middle one (or the average of the two middle values).
- The average is the sum of the observations divided by the number of observations.

II. DATA COLLECTION APPROACH

To identify and obtain data for use in updating the HAP speciation profiles for natural gas-fired turbines and reciprocating engines, ERG searched the following information sources:

- Test reports available in EPA's WebFIRE report database and obtained from the TCEQ project manager.
- Publicly available publications (e.g., peer-reviewed journals, technical reports, scientific manuals).
- Federal, state, and local regulatory agency websites.
- Oil and gas sector trade organization websites.

A. TEST REPORTS

ERG searched EPA's WebFIRE, an online repository of environmental reports and emissions factors, for test reports containing emissions data for the target pollutants shown in Table II-1 and the Source Classification Codes (SCCs) shown in Table II-2. The EPA uses the SCCs to organize data for anthropogenic air pollutant sources that have similar production and emissions characteristics into related groups or source categories. The SCCs are either an 8- or 10-digit code that corresponds to a 4-level definition of the emissions process, with the first level (L1) providing the most general information on the emissions category and descending to the fourth level (L4) providing the most detailed description of the emissions. The L1 and third level (L3) descriptions for all SCCs presented in Table II-2 are "Internal Combustion Engines" and "Natural Gas", respectively, and are not explicitly included in Table II-2.

The TCEQ project manager also provided results from publicly available test reports that contained both formaldehyde and VOC data identified from the agency's online records. Updated profile data could not be found for the following pollutants: 2,2,4-trimethylpentane; methanol; n-hexane; and xylene. No profile data could be found for carbonyl sulfide.

Table II-1. List of Target Pollutants

Pollutant Name
• 2,2,4-Trimethylpentane
• Acetaldehyde
• Acrolein
• Benzene
• Carbonyl Sulfide
• Formaldehyde
• Methanol
• n-Hexane
• Toluene
• Xylenes
• Total organic carbon (TOC)
• Volatile organic compounds (VOC)

Table II-2. SCCs Related to Natural Gas-Fired Internal Combustion Engines[a]

SCC	L2 Description	L4 Description
20100201	Electric Generation	Turbine
20100202		Reciprocating
20100205		Reciprocating: Crankcase Blowby
20100206		Reciprocating: Evaporative Losses (Fuel Delivery System)
20100207		Reciprocating: Exhaust
20100209		Turbine: Exhaust
20200201	Industrial	Turbine
20200202		Reciprocating
20200203		Turbine: Cogeneration
20200204		Reciprocating: Cogeneration
20200205		Reciprocating: Crankcase Blowby
20200207		Reciprocating: Exhaust
20200209		Turbine: Exhaust
20200251		2-cycle Rich Burn
20200252		2-cycle Lean Burn
20200253		4-cycle Rich Burn
20200254		4-cycle Lean Burn
20200255		2-cycle Clean Burn
20200256		4-cycle Clean Burn
20300201	Commercial/ Institutional	Reciprocating
20300202		Turbine
20300203		Turbine: Cogeneration
20300204		Reciprocating: Cogeneration
20300205		Reciprocating: Crankcase Blowby
20300207		Reciprocating: Exhaust
20300209		Turbine: Exhaust

[a] The L1 and third level (L3) descriptions for all SCCs presented in Table ES-3 are "Internal Combustion Engines" and "Natural Gas", respectively.

B. LITERATURE SEARCH

To identify publications (e.g., peer-reviewed journals, technical reports, scientific manuals) that could be applicable to updating the HAP speciation profiles, ERG queried *ProQuest*, an online collection of publication databases, for references published between 2010 and 2022 using the search terms "natural gas turbines" and "natural gas reciprocating engines" and each of the target HAPs (e.g., "natural gas turbines" plus "acetaldehyde", "natural gas turbines" plus "benzene"). ERG limited the search to those references that were publicly available and free of charge. Appendix A and Appendix B present the references returned for turbines and reciprocating engines from the search of the *ProQuest* databases, respectively.

To flag each reference obtained from the initial search for further evaluation, ERG reviewed the title, abstract, and usage of the search terms to exclude resources that did not contain sufficient data or information relevant to updating the HAP speciation profiles (e.g., the reference contained the search term "acrolein", but the HAP name appears only in a sentence noting the types of pollutants generally emitted from turbines without any emissions measurement or quantification).

C. WEBSITE SEARCH

ERG reviewed the websites maintained by federal and state regulatory agencies to identify emissions test data and resources related to estimating emissions of target HAP for natural gas-fired turbines and reciprocating engines. To focus the searches of regulatory agency websites, ERG identified the states that had the highest number of natural gas-fired turbines and reciprocating engines in the 2017 National Emissions Inventory (NEI) based on the counts of the SCCs listed in Table II-2 at the emissions unit/process level. Table II-3 shows the top 10 states based on the percent of total target SCCs (with counts excluding SCCs associated with offshore platforms).

Table II-3. Top 10 States with Target SCCs

State	Percent of Total SCC Counts in NEI	State Regulatory Agency	EPA Region
TX	17%	Texas Commission on Environmental Quality	6
OK	12%	Oklahoma Department of Environmental Quality	6
CA	11%	California Air Resources Board	9
LA	5%	Louisiana Department of Environmental Quality	6
CO	5%	Colorado Department of Public Health and Environment	8
WY	4%	Wyoming Department of Environmental Quality	8
MI	3%	Michigan Department of Environment, Great Lakes, and Energy	5
KS	3%	Kansas Department of Health and Environment	7
PA	3%	Pennsylvania Department of Environmental Protection	3
IL	2%	Illinois Environmental Protection Agency	5
Total for 10 States	**65%**		

D. TRADE ASSOCIATIONS

ERG conducted Google searches to compile a list of nationally recognized trade organization websites associated with the oil and gas sector (e.g., American Petroleum Institute). Appendix C presents the list of identified trade associations.

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III. AVAILABLE EMISSIONS DATA

This chapter describes the information obtained from ERG's review of test reports and the literature, website, and trade association searches.

A. TEST REPORTS

WEBFIRE

ERG's search of the WebFIRE database for the target SCCs and pollutants identified a limited number of test reports. The EPA used the test reports contained in WebFIRE to support emissions factor development for Section 3.1 (Stationary Gas Turbines) and Section 3.2 (Natural Gas-Fired Reciprocating Engines) of *AP-42*. All the test report submissions to WebFIRE were in spreadsheet form rather than the EPA's Electronic Reporting Tool[1] (ERT), which is a Microsoft Access database. The EPA developed the spreadsheet template to allow companies, associations, and agencies to provide EPA with emissions data collected prior to 2012 and data that are infeasible to document in the ERT (e.g., data collected using a test method not supported by the ERT).

ERG's review of the WebFIRE test reports identified several potential issues with the submitted data. First, the WebFIRE submissions contained multiple duplicate records (i.e., identical SCC, emissions values, and test report reference). Table III-1 summarizes the test report data available from WebFIRE after removing the duplicate records for SCCs where TOC or VOC data were available. Each submission using the template is for a single pollutant; therefore, the number of submissions shown in Table III-1 do not directly indicate the number of test reports (i.e., a single test report could potentially contain emissions data for more than one pollutant).

Table III-1. Number of WebFIRE Test Report Submissions by Pollutant and SCC

Pollutant	20100201	20200201	20200203	20200252	20200253	20200254	20300202	20300203
2,2,4-Trimethylpentane	0	0	0	6	0	3	0	0
Acetaldehyde	7	6	6	13	6	24	6	6
Acrolein	6	9	5	19	11	28	5	5
Benzene	8	13	7	16	33	10	7	7
Formaldehyde	16	13	13	38	21	37	13	13
Methanol	0	0	0	17	4	13	0	0
n-Hexane	0	0	0	23	0	4	0	0
Toluene	5	8	4	24	31	10	4	4
Xylenes	0	0	0	10[a]	0	0	0	0
TOC[b]	10	10	10	0	0	6[c]	9	9
VOC	1	0	0	0	0	0	0	0

a Test reports are for o-xylene.

b The WebFIRE test reports define TOC as Total Organic Compounds.

c Test reports are for total non-methane organic compounds (TNMOC).

[1] https://www.epa.gov/electronic-reporting-air-emissions/electronic-reporting-tool-ert

The spreadsheet template includes fields for the SCC, pollutant, pollutant units, control devices, and a Uniform Resource Locator (URL) link for the full test report in Portable Document Format (PDF). All the test data available from WebFIRE are expressed in terms of pounds of pollutant per million British thermal units of heat input (lb/MMBtu).

Second, it appears that the WebFIRE spreadsheets repeated the average value from each test report three times to simulate data at the test run level, rather than providing three separate measurements, which reduces the number of unique data points available for analysis.

Third, the TOC data collection occurred independently of the HAP data collection. All TOC data in the WebFIRE spreadsheets were collected during nine sampling events from 1985 through 1988 and the results were submitted by one organization (i.e., the American Gas Association's Pipeline Research Committee) without attribution to specific facilities. The HAP data were collected from 1990 to 1998 and were site specific.

Fourth, the WebFIRE spreadsheets used the same data sets to represent more than one SCC and operating condition of the emissions source. The WebFIRE spreadsheets use the same TOC data set to represent SCCs 20100201, 20200201, and 20200203 and the same data sets for acetaldehyde, acrolein, benzene, formaldehyde, and toluene to represent SCCs 20200201, 20200203, 20300202, and 20300203. The WebFIRE spreadsheets for turbines also used the same HAP data sets to represent the different operating conditions of the emission source (i.e., "All Loads" and "High Load: ≥80 percent"), except for formaldehyde. For this pollutant, the WebFIRE spreadsheets contained submissions from three facilities that reported different emissions values for the two operating conditions.

Finally, the WebFIRE spreadsheets did not contain TOC or VOC data for reciprocating engine SCCs that could be used to develop HAP speciation profiles.

TCEQ

ERG used the results from ten stack tests provided by the TCEQ. Of the ten tests, two tests covered 4-cycle rich burn engines with non-selective catalytic reduction and eight tests covered 4-cycle lean burn engines with catalysts; there were no tests found that included VOC and formaldehyde for 2-cycle engines. The two rich burn test reports covered Waukesha engines; the eight lean burn test reports covered Caterpillar engines. All engines had manufacturer ratings above 500 horsepower.

B. LITERATURE SEARCH

The search of the *ProQuest* databases returned 366 references for turbines (Appendix B) and 215 references for reciprocating engines (Appendix C). Although the references contained one or more of the search terms, none of the references identified contained actual emissions data for the target pollutants and combustion sources, based on ERG's review of the reference titles, abstracts, and usage of the search terms.

C. WEBSITE SEARCH

Federal Regulatory Agencies

Environmental Protection Agency (EPA) Headquarters

EPA Headquarters maintains the Clearinghouse for Inventories and Emissions Factors (CHIEF) website which contains links for resources related to air emissions inventories, emissions factors, and emissions quantification. None of the links provided emissions data for natural gas-fired turbines or reciprocating engines, except for the previously identified links to *AP-42* and WebFIRE. Sections 3.1 and 3.2 of *AP-42* provide emissions factors for air toxics, VOC, and TOC for natural gas-fired turbines and reciprocating engines, respectively; however, EPA has not revised these sections since 2000. WebFIRE contains *AP-42* emissions factors and test reports.

SPECIATE[2] is EPA's repository for organic gas and particulate matter speciation profiles for air pollution sources. This database contains a profile code for natural gas-fired turbines and a speciation profile for formaldehyde; however, the date of the profile is 1989. SPECIATE does not contain profiles for natural gas-reciprocating engines (the only occurrence of "recip" is for diesel and distillate oil).

EPA Regional Offices

The webpages for the EPA regional offices that cover the ten states shown in Table II-3 have similar layouts with links to region-specific topics of interest, air-related issues and links to resources provided by the EPA headquarters websites. The websites for EPA Regions 3, 5, 6, 7, 8, and 9 (i.e., the EPA regions identified in Table II-3) did not provide any resources specific to emissions from natural gas-fired turbines or reciprocating engines.

State Regulatory Agencies

ERG's review of the state agency websites listed in Table II-3 identified that only the Wyoming (DEQ) and the Michigan EGLE websites provide resources that contain emissions data for the target HAPs and combustion sources.

Wyoming DEQ

Wyoming DEQ maintains the Open Air[3] database, which is a portal for the public to view the contents of the agency's online Inventory, Monitoring, Permitting, and Compliance Tracking (IMPACT) data system. Open Air is searchable by facility criteria (e.g., facility name, company name, address) and includes emissions inventories and reviewed test reports. Appendix D presents the facility types contained in the Open Air database.

ERG searched the Open Air database for emission tests available for facility types identified as "Engine, Stationary" and "Compressor Stations". The search identified 21 test reports from one facility for natural gas-fired turbines, five test reports for 4-cycle rich burn engines (for two manufacturers) from two facilities, and 198 tests for 4-cycle lean burn engines (for two

[2] https://www.epa.gov/air-emissions-modeling/speciate.

[3] https://openair.wyo.gov.

manufacturers and 18 engine models) from 39 facilities. However, nine tests could not be used, leaving 189 tests for 4-cycle lean burn engines. All turbine and engine test reports from the Open Air database contained emissions data for VOC and formaldehyde.

The five test reports for 4-cycle rich burn engines provide emissions in units of g/bhp-hr and reflect controlled emissions with catalytic converters to reduce NO_x, carbon monoxide, and hydrocarbon emissions. Of the 189 test reports for the lean burn engines, all engine tests reflect controlled emissions with catalytic oxidation to reduce carbon monoxide and hydrocarbon emissions. Only two engines tested, both lean burn, had maximum ratings below 500 hp. The test reports for the engines expressed emissions in units of lb/MMBtu and/or g/bhp-hr.

Michigan EGLE

Michigan EGLE maintains MAERS, which is an online application for regulated facilities to submit annual emissions estimates. Reporting emissions of air toxics to MAERS by regulated facilities is optional and, in cases where facility-specific data are not available, EGLE develops estimates for air toxics using emissions factors. Appendix E presents the emissions factors, expressed in terms of pounds per million standard cubic feet of natural gas combusted (lb/MMscf), for the target pollutants and SCCs. The MAERS user guide[4] notes that the emissions factors are either from EPA or EGLE.

D. TRADE ASSOCIATIONS

None of the trade association websites reviewed by ERG (listed in Appendix A) provided publicly available emissions data or information that could be used to update the HAP speciation profiles. The trade association websites focused primarily on promoting industry, providing guidance for permitting and regulatory compliance activities, and lobbying policy makers.

[4] https://www.michigan.gov/documents/deq/deq-oppca-workbook-maers_307061_7.pdf, p. 54

IV. CALCULATIONS AND HAP SPECIATION PROFILES

Appendix F presents the HAP speciation profiles developed for natural gas-fired turbines and reciprocating engines, based on the data obtained from the WebFIRE, TCEQ, and Wyoming DEQ test reports. The following subsections of this report discuss the methodologies ERG followed to derive the HAP speciation profiles from each data source.

A. WEBFIRE DATA

To develop the HAP speciation profiles for turbine SCCs from the available WebFIRE data, ERG calculated the average emissions value for each pollutant using the test run-level data and divided those values by the average TOC emissions. Because VOC data were not available for all SCCs (i.e., only one test report was available for a single SCC), ERG did not develop HAP speciation profiles based on VOC emissions.

Table IV-1 presents the uncontrolled turbine HAP speciation profiles for all-load and high-load (80%) conditions. Because of the duplications in the WebFIRE data sets, the HAP speciation profiles for both load conditions are the same, except for the profiles for formaldehyde which differ slightly between the two load conditions. Appendix G contains the test report data and the calculations ERG used to develop the HAP speciation profiles using the data extracted from the WebFIRE spreadsheet submissions.

Table IV-1. Uncontrolled Turbine HAP Speciation Profiles[a] Based on WebFIRE Data

SCC	Engine Load	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene
20100201	All	0.44%	0.08%	0.13%	1.74%	1.71%
20200201	All	0.46%	0.09%	0.15%	1.25%	2.06%
20200203	All	0.46%	0.09%	0.15%	1.25%	2.06%
20300202	All	0.77%	0.15%	0.25%	2.11%	3.46%
20300203	All	0.50%	0.09%	0.16%	1.37%	2.26%
20100201	≥80%	0.44%	0.08%	0.13%	1.71%	1.71%
20200201	≥80%	0.46%	0.09%	0.15%	1.35%	2.06%
20200203	≥80%	0.46%	0.09%	0.15%	1.35%	2.06%
20300202	≥80%	0.77%	0.15%	0.25%	2.28%	3.46%
20300203	≥80%	0.50%	0.09%	0.16%	1.48%	2.26%

[a] HAP speciation profiles are for uncontrolled emissions expressed as a percent of lb TOC/MMBtu heat input.

ERG also developed HAP speciation profiles using the TOC, VOC, and target HAP emissions factors for turbines and engines presented in Section 3.1 of AP-42 and Section 3.2, respectively. Section 3.1 of AP-42 does not provide emissions factors for turbines under all load conditions. Section 3.2 of AP-42 provides emissions factors for engines under all load conditions. Table IV-2 shows the HAP speciation profiles derived from the AP-42 emissions factors.

Table IV-2. Uncontrolled Turbine and Engine HAP Speciation Profiles Based on AP-42 Emissions Factors

SCC	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene
20100201[a,b]	0.36%	0.06%	0.11%	6.45%	1.18%
20200201[a,b]	0.36%	0.06%	0.11%	6.45%	1.18%
20200203[a,b]	0.36%	0.06%	0.11%	6.45%	1.18%
20300202[a,b]	0.36%	0.06%	0.11%	6.45%	1.18%
20300203[a,b]	0.36%	0.06%	0.11%	6.45%	1.18%
20100201[b,c]	1.90%	0.30%	0.57%	33.81%	6.19%
20200201[b,c]	1.90%	0.30%	0.57%	33.81%	6.19%
20200203[b,c]	1.90%	0.30%	0.57%	33.81%	6.19%
20300202[b,c]	1.90%	0.30%	0.57%	33.81%	6.19%
20300203[b,c]	1.90%	0.30%	0.57%	33.81%	6.19%
20200252[a,d]	0.47%	0.47%	0.12%	3.37%	0.06%
20200253[a,d]	0.78%	0.73%	0.44%	5.73%	0.16%
20200254[a,d]	0.57%	0.35%	0.03%	3.59%	0.03%
20200252[a,d]	6.47%	6.48%	1.62%	46.00%	0.80%
20200253[a,d]	9.43%	8.89%	5.34%	69.26%	1.89%
20200254[a,d]	7.08%	4.36%	0.37%	44.75%	0.35%

[a] HAP speciation profiles expressed as a percent of lb TOC/MMBtu heat input.

[b] Data are for engine loads ≥ 80%.

[c] HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

[d] Data are for all engine loads.

For turbines, the formaldehyde speciation profile developed using the WebFIRE data was less than half that of the value developed using the AP-42 emissions factors. For acetaldehyde, acrolein, benzene, and toluene associated with SCCs 20100201, 20200201, 20200203, and 20300203, the HAP speciation profiles developed from the AP-42 emissions factors are comparable to the profiles developed from the WebFIRE data. However, for SCC 20300202, commercial/industrial turbines, the speciation profiles developed using the AP-42 emissions factors for these pollutants are less than half the values developed from the WebFIRE data. Also, for all SCCs covered by the WebFIRE data, the speciation profiles for toluene are lower than the profiles developed from the WebFIRE data. For engines, the WebFIRE data did not include TOC or VOC emissions; therefore, ERG could not compare the HAP speciation profiles developed from the two data sources.

ERG reviewed the background document for AP-42 Section 3.1 to determine the cause of the differences between the HAP speciation profiles developed using the two data sources. Although Tables 2.2-1 and 2.2-2 of the AP-42 background document identify the data sources EPA included and excluded from the AP-42 emissions factors, respectively, there are inconsistencies between the test report references and test dates provided in the WebFIRE data and the AP-42 background document. Consequently, ERG was unable to identify the reasons for the differences between the HAP speciation profiles developed from the WebFIRE data and the AP-42 emissions factors.

B. TCEQ TEST REPORTS

The TCEQ test report results for engines provided values for VOC in units of lb/hr and g/hp-hr and for formaldehyde in units of lb/hr. Some test reports also provided the fuel consumption rates, expressed in million British thermal units of heat input per hour (MMBtu/hr) or in standard cubic feet of natural gas per hour (scf/hr). ERG converted the VOC and formaldehyde emissions data for 4-cycle lean burn engines to lb/MMBtu by dividing the lb/hr emission rate by the MMBtu/hr heat input rate reported for each test run. However, some test report results for the engines did not provide the fuel heat input rate used during the test. To calculate the fuel heat input rate (MMBtu/hr) for each test run, ERG converted the VOC emissions to lb/MMBtu using an average conversion factor for natural gas-fired reciprocating engines (7,858 Btu/hp-hr) obtained from the *Compendium of Greenhouse Gas Emission Estimation Methodologies for the Oil and Natural Gas Industry* (August 2009) published by the American Petroleum Institute (API). ERG also converted the fuel usage data in scf/hr to MMBtu/hr using the conversion factor of 1,030 Btu/scf from the U.S. Energy Information Administration (EIA). ERG then estimated the fuel heat input rate for each test run by dividing the reported VOC lb/hr emission rate by the estimated VOC lb/MMBtu emission rate. ERG used the fuel heat input rate estimated for each test run to convert the reported formaldehyde lb/hr emission rate data to units of lb/MMBtu.

To develop the speciation profiles for formaldehyde presented in Table IV-3 from the TCEQ test report data, ERG divided the average lb/MMBtu formaldehyde emission rate by the average lb/MMBtu VOC emission rate for each test report and then calculated the overall average percent. ERG assigned the SCCs for the formaldehyde speciation profiles based on the engine type description (i.e., 4-cycle rich and lean burn units). Appendix H contains the data and calculations ERG used to develop the formaldehyde speciation profiles using the TCEQ test reports.

Table IV-3. Engine HAP Speciation Profiles[a] Using TCEQ Data

SCC	Formaldehyde	Control Status
20200253	6.6%	NSCR
20200254	42.9%	Uncontrolled/Not specified
20200254	46.4%	Oxidation catalyst

* HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

C. WYOMING DEQ TEST REPORTS

The Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (40 CFR part 60, subpart JJJJ) specify that facilities should not include formaldehyde when calculating VOC emissions from affected sources. Consequently, the VOC emissions in the test reports for turbines and engines submitted to the Open Air database maintained by Wyoming DEQ do not include formaldehyde.

To develop the speciation profiles for formaldehyde from the Wyoming DEQ test report data, ERG converted the VOC and formaldehyde emission rate data expressed in grams per brake horsepower-hour (g/bhp-hr) to lb/MMBtu using the average conversion factor for natural gas-fired reciprocating engines (7,858 Btu/hp-hr) obtained from API. For natural gas-fired turbines, the test reports contained VOC and formaldehyde emission rates in lb/hr; however, only 13 out of the 21 test reports also provided data regarding engine load (although none of the 21 test reports provided fuel usage data). ERG divided the VOC and formaldehyde lb/hr data by the engine load (bhp) and converted these values to lb/MMBtu using the API conversion factor (7,858 Btu/hp-hr). Next, ERG grouped the lb/MMBtu data by SCC and control device type. ERG used the SCCs assignments from the Open Air database to group the test report data. ERG then divided the formaldehyde emissions (lb/MMBtu) by the sum of VOC and formaldehyde emission rates (lb/MMBtu) to obtain the speciation profile for each test report in the data group. Finally, ERG calculated the formaldehyde speciation profiles as the overall average of the test-level profiles.

The formaldehyde speciation profile for natural gas-fired turbines is shown in Table IV-4. Table IV-5 presents the formaldehyde speciation profiles developed for engines. Appendix I contains the data and calculations ERG used to develop the formaldehyde speciation profiles using the Wyoming DEQ test reports.

Table IV-4. Turbine Speciation Profiles Developed from Wyoming DEQ Data[a]

SCC	Formaldehyde	Control Device
20200201	24.8%	Dry low emissions combustion for NO_x control

[a] HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

Table IV-5. Engine Speciation Profiles Developed from Wyoming DEQ Data[a]

SCC	Formaldehyde	Control Status
20200253	17.9%	NSCR
20200254	20.9%	Oxidation catalyst

[a] HAP speciation profiles expressed as a percent of lb VOC/MMBtu heat input.

V. CONCLUSIONS AND FINDINGS

The availability of emissions data to develop speciation profiles for the target SCCs and HAPs, other than formaldehyde, is limited. Updated profile data could not be found for the following pollutants: 2,2,4-trimethylpentane; methanol; n-hexane; and xylene. No profile data could be found for carbonyl sulfide. For natural gas-fired turbines, although WebFIRE contains test report data for acetaldehyde, acrolein, benzene, formaldehyde, and toluene for several turbine SCCs, ERG identified several issues with the WebFIRE test data that potentially limit the useability of the resulting HAP speciation profiles (see Section IV.A of this report), most notably the lack of coincident TOC and HAP test data (i.e., the TOC and HAP data were collected during different sampling events). The test reports available from the Wyoming DEQ provide coincident VOC and HAP data; however, the data are available only for VOC and formaldehyde for a single turbine SCC (20200201).

For natural gas-fired reciprocating engines, the available data from TCEQ and the Wyoming DEQ for developing the HAP speciation profiles are for VOC and formaldehyde associated with two engine SCCs (20200253 and 20200254). For SCC 20200253, ERG based the formaldehyde speciation profiles on a fairly small data set (two tests from TCEQ and five tests from Wyoming DEQ). In contrast, the data set for SCC 20200254, although still limited to only VOC and formaldehyde, includes emissions data from eight TCEQ test reports and 189 Wyoming DEQ test reports.

VI. REFERENCES

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U.S. Environmental Protection Agency (EPA). Compilation of Air Emissions Factors (AP-42). https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

U.S. EPA. SPECIATE Database. https://www.epa.gov/air-emissions-modeling/speciate.

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Wyoming Department of Environmental Quality. Open Air Database. https://openair.wyo.gov/disclaimer.jsf.

APPENDIX A. PROQUEST REFERENCES FOR TURBINES

Appendix A - ProQuest References for Turbines

Reference	ERG Review Note
"A New Commerce Operation Model for Integrated Energy System Containing the Utilization of Bio-Natural Gas", 2020, Energies, vol. 13, no. 24, pp. 6607.	MeOH referenced as a product.
"Advances in Mineral Processing and Hydrometallurgy", 2021, Metals, vol. 11, no. 9, pp. 1393.	Not related to emissions from NG turbines.
"Biomethane in Poland—Current Status, Potential, Perspective and Development", 2021, Energies, vol. 14, no. 6, pp. 1517.	Not U.S. based
"Can Green Hydrogen Production Be Economically Viable under Current Market Conditions", 2020, Energies, vol. 13, no. 24, pp. 6599.	Not U.S. based
"Challenges and Barriers for Net-Zero/Positive Energy Buildings and Districts—Empirical Evidence from the Smart City Project SPARCS", 2021, Buildings, vol. 11, no. 2, pp. 78.	One reference to "micro-turbines".
"Characteristics and Health Risks of Polycyclic Aromatic Hydrocarbons and Nitro-PAHs in Xinxiang, China in 2015 and 2017", 2021, International Journal of Environmental Research and Public Health, vol. 18, no. 6, pp. 3017.	Not U.S. based
"Climate Policy Imbalance in the Energy Sector: Time to Focus on the Value of CO2 Utilization", 2021, Energies, vol. 14, no. 2, pp. 411.	Reference to wind turbines.
"Computer Technologies of 3D Modeling by Combustion Processes to Create Effective Methods of Burning Solid Fuel and Reduce Harmful Dust and Gas Emissions into the Atmosphere", 2021, Energies, vol. 14, no. 5, pp. 1236.	Not related to emissions from NG turbines.
"Conceptual Design Development of Coal-to-Methanol Process with Carbon Capture and Utilization", 2020, Energies, vol. 13, no. 23, pp. 6421.	Reference contained one entry with "turbine".
"Covid-19's Impact on European Power Sectors: An Econometric Analysis", 2021, Energies, vol. 14, no. 6, pp. 1639.	Not U.S. based
"Effects of Pyrolysis Bio-Oils on Fuel Atomisation—A Review", 2021, Energies, vol. 14, no. 4, pp. 794.	MeOH used as a polar solvent.
"Energy Development and Production in the Great Plains: Implications and Mitigation Opportunities", 2021, Rangeland Ecology and Management, vol. 78, pp. 257-272.	Related to wind turbines.
"Energy Harvesting Strategies for Wireless Sensor Networks and Mobile Devices: A Review", 2021, Electronics, vol. 10, no. 6, pp. 661.	Related to wind turbines.
"Energy—Water Nexus: Integration, Monitoring, KPIs Tools and Research Vision", 2020, Energies, vol. 13, no. 24, pp. 6697.	One reference to a steam-turbine.
"ESICM 2012 MONDAY SESSIONS 15 October, 2012", 2012, Intensive care medicine, vol. 38, pp. 1-327.	One mention of turbine
"Evaluation of Energy Transition Pathways to Phase out Coal for District Heating in Berlin", 2020, Energies, vol. 13, no. 23, pp. 6394.	Not U.S. based
"Modern Small and Microcogeneration Systems—A Review", 2021, Energies, vol. 14, no. 3, pp. 785.	MeOH reference to fuel cell type
"Moisture Removal Techniques for a Continuous Emission Monitoring System: A Review", 2021, Atmosphere, vol. 12, no. 1, pp. 61.	One mention of gas turbines moisture control
"Pulp and Paper Industry: Decarbonisation Technology Assessment to Reach CO0RW1S34RfeSDcfkexd09rT421RW1S34RfeSDcfkexd09rT4 Neutral Emissions—An Austrian Case Study", 2021, Energies, vol. 14, no. 4, pp. 1161.	Not U.S. based
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"State of Art of Using Biofuels in Spark Ignition Engines", 2021, Energies, vol. 14, no. 3, pp. 779.	One mention of turbines in references.
"Techno-Economic Assessment of Different Heat Exchangers for CO2 Capture", 2020, Energies, vol. 13, no. 23, pp. 6315.	Not related to air toxic emissions from NG turbines.
"The Enhancement of Energy Efficiency in a Wastewater Treatment Plant through Sustainable Biogas Use: Case Study from Poland", 2020, Energies, vol. 13, no. 22, pp. 6056.	Not U.S. based
"The Role of Green and Blue Hydrogen in the Energy Transition—A Technological and Geopolitical Perspective", 2021, Sustainability, vol. 13, no. 1, pp. 298.	Not related to air toxic emissions from NG turbines.
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Reference	ERG Review Note
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Akaev, A.A. & Davydova, O.I. 2021, "Mathematical Description of Energy Transition Scenarios Based on the Latest Technologies and Trends", Energies, vol. 14, no. 24, pp. 8360.	Related to wind turbines
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Alexandre Mendonça Teixeira, Lara de, O.A., de Medeiros, J.L. & Ofélia de Queiroz Fernandes Araújo 2019, "Offshore Natural Gas Conditioning and Recovery of Methanol as Hydrate Inhibitor with Supersonic Separators: Increasing Energy Efficiency with Lower CO2 Emissions"	MeOH as thermodynamic hydrate inhibitor.
Al-Ghamdi, S., Boulfrad, S. & Koç, M. 2021, "Life Cycle Assessment for Integration of Solid Oxide Fuel Cells into Gas Processing Operations", Energies, vol. 14, no. 15, pp. 4668.	Not related to air toxic emissions from NG turbines. VOC only in acronym list.
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Reference	ERG Review Note
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Biswas, B. & Gresshoff, P.M. 2014, "The Role of Symbiotic Nitrogen Fixation in Sustainable Production of Biofuels", International Journal of Molecular Sciences, vol. 15, no. 5, pp. 7380-7397.	One mention of wind turbines.
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Calise, F., Costa, M., Wang, Q., Zhang, X. & Duić, N. 2018, "Recent Advances in the Analysis of Sustainable Energy Systems", Energies, vol. 11, no. 10.	Not U.S. based
Calise, F., Vicidomini, M., Costa, M., Wang, Q., Poul Alberg Østergaard & Duić, N. 2019, "Toward an Efficient and Sustainable Use of Energy in Industries and Cities", Energies, vol. 12, no. 16.	Methanol used a fuel.
Calvo, L.F., García, ,A.I. & Otero, M. 2013, "An Experimental Investigation of Sewage Sludge Gasification in a Fluidized Bed Reactor", The Scientific World Journal, vol. 2013.	Not related to emissions from NG turbines.
Campbell, R.M., Anderson, N.M., Daugaard, D.E. & Naughton, H.T. 2018, "Technoeconomic and Policy Drivers of Project Performance for Bioenergy Alternatives Using Biomass from Beetle-Killed Trees", Energies, vol. 11, no. 2, pp. 293.	Not related to emissions from NG turbines.

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Reference	ERG Review Note
Cann, D. & Udemu, C. 2021, "Review of Cryogenic Carbon Capture Innovations and Their Potential Applications", C, vol. 7, no. 3, pp. 58.	Not related to emissions from NG turbines.
Capron, M.E., Stewart, J.R., Antoine de Ramon N'Yeurt, Chambers, M.D., Kim, J.K., Yarish, C., Jones, A.T., Blaylock, R.B., James, S.C., Fuhrman, R., Sherman, M.T., Piper, D., Harris, G. & Hasan, M.A. 2020, "Restoring Pre-Industrial CO2 Levels While Achieving Sustainable Development Goals".	Not related to emissions from NG turbines.
Changxing, J., Xiaotian, M., Yijie, Z., Ruirui, Z., Xiaoxu, S., Tianzuo, Z. & Jinglan, H. 2020, "Environmental impact assessment of galvanized sheet production: a case study in Shandong Province, China", The International Journal of Life Cycle Assessment,	Not U.S. based
Chen, H., Yan, S.-., Ye, Z.-., Meng, H.-. & Zhu, Y.-. 2012, "Utilization of urban sewage sludge: Chinese perspectives", Environmental science and pollution research international, vol. 19, no. 5, pp. 1454-63.	Not U.S. based
Chen, L., Feng, H. & Xie, Z. 2016, "Generalized Thermodynamic Optimization for Iron and Steel Production Processes: Theoretical Exploration and Application Cases", Entropy, vol. 18, no. 10, pp. 353.	Not related to emissions from NG turbines.
Chia-Nan, W., Quoc-Chien Luu & Thi-Kim-Lien, N. 2018, "Estimating Relative Efficiency of Electricity Consumption in 42 Countries during the Period of 2008–2017", Energies, vol. 11, no. 11.	Not related to gas turbines.
Chu, S. & Majumdar, A. 2012, "Opportunities and challenges for a sustainable energy future", Nature, vol. 488, no. 7411, pp. 294-303.	Conversion of natural gas to liquid (methanol).
Chua, C.B., Hong, Lee, H.M., Low, J.S. & Choong 2010, "Life cycle emissions and energy study of biodiesel derived from waste cooking oil and diesel in Singapore", The International Journal of Life Cycle Assessment, vol. 15, no. 4, pp. 417-423.	Not U.S. based
Cigolotti, V., Genovese, M. & Fragiacomo, P. 2021, "Comprehensive Review on Fuel Cell Technology for Stationary Applications as Sustainable and Efficient Poly-Generation Energy Systems", Energies, vol. 14, no. 16, pp. 4963.	Not related to emissions from NG turbines.
Contreras, Z., Ancev, T. & Betz, R. 2014, "Evaluation of Environmental Taxation on Multiple Air Pollutants in the Electricity Generation Sector - Evidence from New South Wales, Australia", Economics of Energy & Environmental Policy, vol. 3, no. 2.	Not U.S. based
Cosar, G., Pooyanfar, M., Amirabedin, E. & Topal, H. 2013, "Design and Economic Analysis of a Heating/Absorption Cooling System Operating with Municipal Solid Waste Digester: A Case Study of Gazi University", Rigas Tehniskas Universitates Zinatniskie Raks	Not U.S. based
Crimmann, M. & Madlener, R. 2021, "Assessing Local Power Generation Potentials of Photovoltaics, Engine Cogeneration, and Heat Pumps: The Case of a Major Swiss City", Energies, vol. 14, no. 17, pp. 5432.	Not U.S. based
Csedő, Z., Máté Zavarkó, Vaszkun, B. & Koczkás, S. 2021, "Hydrogen Economy Development Opportunities by Inter-Organizational Digital Knowledge Networks", Sustainability, vol. 13, no. 16, pp. 9194.	One mention of wind turbines.
Cunliff, C. 2019, "An Innovation Agenda for Hard-to-Decarbonize Energy Sectors", Issues in Science and Technology, vol. 36, no. 1, pp. 74-79.	Not related to emissions from NG turbines.
Dahmen, N., Henrich, E., Dinjus, E. & Weirich, F. 2012, "The bioliq(R) bioslurry gasification process for the production of biosynfuels, organic chemicals, and energy", Energy, Sustainability and Society, vol. 2, no. 1, pp. 1-44.	One mention of turbines.
Dale, A.T., de, A.F.P., Marriott, J., Cesar, B.S.M., Schaeffer, R. & Bilec, M.M. 2013, "Modeling Future Life-Cycle Greenhouse Gas Emissions and Environmental Impacts of Electricity Supplies in Brazil", Energies, vol. 6, no. 7, pp. 3182-3208.	Not U.S. based
Daramola, M.O., Olawale, O. & Abu, Y. 2017, "Nanocomposite sodalite/ceramic membrane for pre-combustion CO2 capture: synthesis and morphological characterization", International Journal of Coal Science & Techn	One mention of a gas turbine.
De Vos, Y., Jacobs, M., Van Der Voort, P., Isabel, V.D., Snijkers, F. & Verberckmoes, A. 2020, "Development of Stable Oxygen Carrier Materials for Chemical Looping Processes—A Review", Catalysts, vol. 10, no. 8, pp. 926.	Not related to emissions from NG turbines.
De, D.K., Ikono, U.I. & Akinmeji, S.O. 2018, "Health, Environmental Effects, the Control of Emission from Power Plants and the Need for a New Emission Capture Technology", Journal of Physics: Conference Series, vol. 1072, no. 1.	Not related to air toxic emissions from turbines.
Dias, J.M.S. & Costa, V. 2021, "Modeling and Analysis of a Coated Tube Adsorber for Adsorption Heat Pumps", Energies, vol. 14, no. 21, pp. 6878.	One mention of a steam turbine.
Dimanchev, E.G., Paltsev, S., Yuan, M., Rothenberg, D., Tessum, C.W., Marshall, J.D. & Selin, N.E. 2019, "Health co-benefits of sub-national renewable energy policy in the US", Environmental Research Letters, vol. 14, no. 8.	One mention of a wind turbine.

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Dong, X., Tian, Q., Zhang, Y.G. & Bai, H.F. 2016, "Study on impact of energy price comparison on energy saving benefits of heat pump in North China", IOP Conference Series.Earth and Environmental Science, vol. 40, no. 1.	Not U.S. based
Dorning, M.A., Diffendorfer, J.E., Loss, S.R. & Bagstad, K.J. 2019, "Review of indicators for comparing environmental effects across energy sources", Environmental Research Letters, vol. 14, no. 10.	Not related to gas turbines.
Dulin, V., Chikishev, L., Sharaborin, D., Lobasov, A., Tolstoguzov, R., Liu, Z., Shi, X., Li, Y. & Markovich, D. 2021, "On the Flow Structure and Dynamics of Methane and Syngas Lean Flames in a Model Gas-Turbine Combustor", Energies, vol. 14, no. 24, pp.	Formaldehyde in title of reference.
Đurđević, D., Blecich, P. & Jurić, Ž. 2019, "Energy Recovery from Sewage Sludge: The Case Study of Croatia", Energies, vol. 12, no. 10, pp. 1927.	Not U.S. based
Đurđević, D., Blecich, P. & Jurić, Ž. 2019, "Energy Recovery from Sewage Sludge: The Case Study of Croatia", Energies, vol. 12, no. 10.	Not U.S. based
Ebenezer, L.O., Chinchong, B.B., Abiodun, P.O., Ogundokun, R.O., Aremu, C.O., Sonibare, J.A., Oreoluwa, T.A., Adeniyi, T.O. & Bamidele, S.F. 2021, "Assessment of the contribution of TEX air pollutants from Nigeria's petroleum refineries to the ambient air	Not U.S. based
Edwin, E.B., Guillermo, V.O. & Jorge, D.F. 2020, "Thermodynamic, Exergy and Environmental Impact Assessment of S-CO2 Brayton Cycle Coupled with ORC as Bottoming Cycle", Energies, vol. 13, no. 9, pp. 2259.	Not related to air toxic emissions from turbines.
El-Amary, N., Balbaa, A., Swief, R.A. & Abdel-Salam, T. 2018, "A Reconfigured Whale Optimization Technique (RWOT) for Renewable Electrical Energy Optimal Scheduling Impact on Sustainable Development Applied to Damietta Seaport, Egypt", Energies, vol. 11,	Not U.S. based
Eloka-Eboka, A. & Chetty, R. 2019, "The Contribution of Bioenergy in the Renewable Energy Technology Mix: Research Perspective", Journal of Physics: Conference Series, vol. 1378, no. 2.	Not related to emissions from NG turbines.
Epstein, D., Jackson, R. & Braithwaite, P. 2011, "Delivering London 2012: sustainability strategy", Proceedings of the Institution of Civil Engineers, vol. 164, no. 5, pp. 27-33.	Not related to emissions from NG turbines.
Ericsson, K. 2021, "Potential for the Integrated Production of Biojet Fuel in Swedish Plant Infrastructures", Energies, vol. 14, no. 20, pp. 6531.	Not U.S. based
Esmaeilion, F., Ahmadi, A. & Dashti, R. 2021, "Exergy-economic-environment optimization of the waste-to-energy power plant using Multi-Objective Particle-Swarm Optimization (MOPSO)", Scientia Iranica.Transaction B, Mechanical Engineering, vol. 28, no. 5,	Not related to emissions from NG turbines.
Eveloy, V. & Gebreegziabher, T. 2018, "A Review of Projected Power-to-Gas Deployment Scenarios", Energies, vol. 11, no. 7, pp. 1824.	Not related to emissions from NG turbines.
Farmaki, P., Tranoulidis, A., Kouletsos, T., Giourka, P. & Katarachia, A. 2021, "Mining Transition and Hydropower Energy in Greece—Sustainable Governance of Water Resources Management in a Post-Lignite Era: The Case of Western Macedonia, Greece", Water, v	Not U.S. based
Farzad, S., Mohsen, A.M. & Görgens, J.,F. 2016, "A critical review on biomass gasification, co-gasification, and their environmental assessments", Biofuel Research Journal, vol. 3, no. 4, pp. 483-495.	Not related to air toxic emissions from turbines.
Font-Palma, C. 2019, "Methods for the Treatment of Cattle Manure—A Review", C, vol. 5, no. 2, pp. 27.	One mention of a gas turbine.
Frantál, B. & Nováková, E. 2014, "A Curse of Coal? Exploring Unintended Regional Consequences of Coal Energy in The Czech Republic", Moravian Geographical Reports, vol. 22, no. 2, pp. 55-65.	Not U.S. based
Frantzi, D. & Zabaniotou, A. 2021, "Waste-Based Intermediate Bioenergy Carriers: Syngas Production via Coupling Slow Pyrolysis with Gasification under a Circular Economy Model", Energies, vol. 14, no. 21, pp. 7366.	Not related to emissions from NG turbines.
Frilingou, N. 2020, "Effects of Building Energy Efficiency Measures on Air Quality at the Neighborhood Level in Athens, Greece", Energies, vol. 13, no. 21, pp. 5689.	Not U.S. based
Gandhi, K.H. & Huda, M. 2021, "Business analysis of implementation of UCG technology in Indonesia", IOP Conference Series.Earth and Environmental Science, vol. 882, no. 1.	Not U.S. based
García-Mariaca, A. & Llera-Sastresa, E. 2021, "Review on Carbon Capture in ICE Driven Transport", Energies, vol. 14, no. 21, pp. 6865.	Not related to emissions from NG turbines.
Garmsiri, S., Rosen, M.A. & Smith, G.R. 2014, "Integration of Wind Energy, Hydrogen and Natural Gas Pipeline Systems to Meet Community and Transportation Energy Needs: A Parametric Study", Sustainability, vol. 6, no. 5, pp. 2506-2526.	Not related to emissions from NG turbines.
Gerbens-Leenes, W. & Holtz, K. 2020, "Consequences of Transport Low-Carbon Transitions and the Carbon, Land and Water Footprints of Different Fuel Options in The Netherlands", Water, vol. 12, no. 7, pp. 1968.	Not U.S. based
Gilmore, E.A., Adams, P.J. & Lave, L.B. 2010, "Using Backup Generators for Meeting Peak Electricity Demand: A Sensitivity Analysis on Emission Controls, Location, and Health Endpoints", Journal of the Air & Waste Management Association, vol. 60, no. 5, pp	Does not provide emissions data for NG turbines.

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Reference	ERG Review Note
Girardi, P., Gargiulo, A. & Brambilla, P.C. 2015, "A comparative LCA of an electric vehicle and an internal combustion engine vehicle using the appropriate power mix: the Italian case study", The International Journal of Life Cycle Assessment, vol. 20, no	Not U.S. based
Glushkov, D., Kuznetsov, G. & Paushkina, K. 2020, "Switching Coal-Fired Thermal Power Plant to Composite Fuel for Recovering Industrial and Municipal Waste: Combustion Characteristics, Emissions, and Economic Effect", Energies, vol. 13, no. 1, pp. 259.	Refers to used turbine oil.
Glushkov, D., Nyashina, G., Shvets, A., Pereira, A. & Ramanathan, A. 2021, "Current Status of the Pyrolysis and Gasification Mechanism of Biomass", Energies, vol. 14, no. 22, pp. 7541.	Not related to emissions from NG turbines.
Greer, F., Rakas, J. & Horvath, A. 2020, "Airports and environmental sustainability: a comprehensive review", Environmental Research Letters, vol. 15, no. 10.	One mention of turbine in reference.
Grljusic, M., Medica, V. & Racic, N. 2014, "Thermodynamic Analysis of a Ship Power Plant Operating with Waste Heat Recovery through Combined Heat and Power Production", Energies, vol. 7, no. 11, pp. 7368-7394.	Use of toluene as a working fluid.
Gryz, J., Król, K., Witkowska, A. & Ruszel, M. 2021, "Mobile Nuclear-Hydrogen Synergy in NATO Operations", Energies, vol. 14, no. 23, pp. 7955.	One mention of a turbine.
Guevara, M., Tena, C., Porquet, M., Jorba, O. & Carlos Pérez García-Pando 2020, "HERMESv3, a stand-alone multi-scale atmospheric emission modelling framework – Part 2: The bottom–up module", Geoscientific Model Development, vol. 13, no. 3, pp. 873-903.	Cites turbine as an engine type.
Guo, D., Yu, J. & Ban, M. 2018, "Security-Constrained Unit Commitment Considering Differentiated Regional Air Pollutant Intensity", Sustainability, vol. 10, no. 5, pp. 1433.	References to wind turbines.
Guo, Y., Jinping, T. & Lyujun, C. 2020, "Managing energy infrastructure to decarbonize industrial parks in China", Nature Communications, vol. 11, no. 1.	Not U.S. based
Guo, Z., Sun, Y., Shu-Yuan, P. & Pen-Chi Chiang 2019, "Integration of Green Energy and Advanced Energy-Efficient Technologies for Municipal Wastewater Treatment Plants", International Journal of Environmental Research and Public Health, vol. 16, no. 7.	References to wind turbines.
Gurieff, N., Green, D., Koskinen, I., Lipson, M., Baldry, M., Maddocks, A., Menictas, C., Noack, J., Moghtaderi, B. & Doroodchi, E. 2020, "Healthy Power: Reimagining Hospitals as Sustainable Energy Hubs", Sustainability, vol. 12, no. 20, pp. 8554.	Not related to emissions from NG turbines.
Hamaguchi, M., Cardoso, M. & Vakkilainen, E. 2012, "Alternative Technologies for Biofuels Production in Kraft Pulp Mills-Potential and Prospects", Energies, vol. 5, no. 7, pp. 2288-2309.	One mention of a turbine.
Handayani, K., Filatova, T. & Krozer, Y. 2019, "The Vulnerability of the Power Sector to Climate Variability and Change: Evidence from Indonesia", Energies, vol. 12, no. 19, pp. 3640.	Not U.S. based
Hanif, M.A., Naimah, I. & Abdul, J.A. 2020, "Sulfur dioxide removal: An overview of regenerative flue gas desulfurization and factors affecting desulfurization capacity and sorbent regeneration", Environmental science and pollution research international,	One mention of a turbine.
Hardisty, P.E., Clark, T.S. & Hynes, R.G. 2012, "Life Cycle Greenhouse Gas Emissions from Electricity Generation: A Comparative Analysis of Australian Energy Sources", Energies, vol. 5, no. 4, pp. 872-897.	Not U.S. based
Hatami, M.M., Arash, H., Mohsen, M., Hossein, A. & Safar, M. 2021, "Seasonal variations of polycyclic aromatic hydrocarbons in coastal sediments of a marine resource hot spot: the case of pars special economic energy zone, Iran", Environmental Geochemistr	Not U.S. based
He, X. & Hägg, M. 2012, "Membranes for Environmentally Friendly Energy Processes", Membranes, vol. 2, no. 4, pp. 706-726.	Not related to emissions from NG turbines.
Heidari, S. 2020, "How Strategic Behavior of Natural Gas Exporters Can Affect the Sectors of Electricity, Heating, and Emission Trading during the European Energy Transition", Energies, vol. 13, no. 19, pp. 5040.	Not U.S. based
Hillen, L. & Degirmenci, V. 2021, "Hierarchical Mesoporous SSZ-13 Chabazite Zeolites for Carbon Dioxide Capture", Catalysts, vol. 11, no. 11, pp. 1355.	One mention of a turbine.
Hinkley, J.T. 2021, "A New Zealand Perspective on Hydrogen as an Export Commodity: Timing of Market Development and an Energy Assessment of Hydrogen Carriers", Energies, vol. 14, no. 16, pp. 4876.	Not U.S. based
Hnydiuk-Stefan, A., Otawa, A., Stefan, K. & Zmarzły, D. 2021, "Technical and Economic Analysis of Low-Emissions Modernization of Existing Heating Plants in Poland", Energies, vol. 14, no. 21, pp. 7426.	Not U.S. based
Holappa, L. 2020, "A General Vision for Reduction of Energy Consumption and CO2 Emissions from the Steel Industry", Metals, vol. 10, no. 9, pp. 1117.	One mention of turbine.
Hosseini, S.E., Wahid, M.A. & Salehirad, S. 2013, "Environmental Protection and Fuel Consumption Reduction by Flameless Combustion Technology: A Review", Applied Mechanics and Materials, vol. 388, pp. 292.	Turbine mention in references.

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Hou, S., Wei-Cheng, H. & Ta-Hui, L. 2017, "Co-Combustion of Fast Pyrolysis Bio-Oil Derived from Coffee Bean Residue and Diesel in an Oil-Fired Furnace", Applied Sciences, vol. 7, no. 10, pp. 1085.	One mention of turbine.
Hu, S., Yang, Z., Li, J. & Duan, Y. 2021, "A Review of Multi-Objective Optimization in Organic Rankine Cycle (ORC) System Design", Energies, vol. 14, no. 20, pp. 6492.	Benzene and toluene as working fluids.
Hu, Z., Feng, K., Liu, P. & Jia, Y. 2019, "Optimal Design Model of the Energy Systems in Iron and Steel Enterprises", Applied Sciences, vol. 9, no. 22, pp. 4778.	Turbine used once in acronym list.
Huckabee, G.M. 2018, "Ethics and Justice - What Penalty Should Volkswagen Be Compelled to Pay for its Unethical and Unlawful Conduct, and on What Basis?", Journal of Leadership, Accountability and Ethics, vol. 15, no. 4, pp. 155-182.	Not related to emissions from NG turbines.
Hyder, Z., Ripepi, N.S. & Karmis, M.E. 2016, "A life cycle comparison of greenhouse emissions for power generation from coal mining and underground coal gasification", Mitigation and Adaptation Strategies for Global Change, vol. 21, no. 4, pp. 515-546.	Does not provide emissions data for NG turbines.
Ingham, A. 2017, "Reducing the Carbon Intensity of Methanol for Use as a Transport Fuel: Impact of technology choice on greenhouse gas emissions when producing methanol from natural gas", Johnson Matthey Technology Review, vol. 61, no. 4, pp. 297-307.	Use of methanol as a transport fuel.
Invernizzi, C.M., Ayub, A., Marcoberardino, G.D. & Iora, P. 2019, "Pure and Hydrocarbon Binary Mixtures as Possible Alternatives Working Fluids to the Usual Organic Rankine Cycles Biomass Conversion Systems", Energies, vol. 12, no. 21.	Toluene used in reference title.
Issakhov, A., Alimbek, A. & Issakhov, A. 2020, "A numerical study for the assessment of air pollutant dispersion with chemical reactions from a thermal power plant", Engineering Applications of Computational Fluid Mechanics, vol. 14, no. 1, pp. 1035-1061.	Not related to air toxic emissions from NG turbines.
Jabeen, S., Malik, S., Khan, S., Khan, N., Qureshi, M.I. & Mohd Shamsuri, M.S. 2021, "A Comparative Systematic Literature Review and Bibliometric Analysis on Sustainability of Renewable Energy Sources", International Journal of Energy Economics and Policy	Related to wind turbines.
Jadidi, E., Mohammad Hasan, K.M., Delpisheh, M. & Viviani, C.O. 2021, "Advanced Exergy, Exergoeconomic, and Exergoenvironmental Analyses of Integrated Solar-Assisted Gasification Cycle for Producing Power and Steam from Heavy Refinery Fuels", Energies, vo	Methanol used a feedstock.
Jahirul, M.I., Rasul, M.G., Chowdhury, A.A. & Ashwath, N. 2012, "Biofuels Production through Biomass Pyrolysis -A Technological Review", Energies, vol. 5, no. 12, pp. 4952-5001.	Not related to air toxic emissions from turbines.
Jaskólski, M. & Bućko, P. 2021, "Modelling Long-Term Transition from Coal-Reliant to Low-Emission Power Grid and District Heating Systems in Poland", Energies, vol. 14, no. 24, pp. 8389.	Not U.S. based
Jeleński, T., Dendys, M., Radziszewska-Zielina, E. & Fedorczak-Cisak, M. 2021, "Inclusion of Renewable Energy Sources in Municipal Environmental Policy—The Case Study of Kraków, Poland", Energies, vol. 14, no. 24, pp. 8573.	Not U.S. based
Jéssica, M.B., Bruno, C.K., Mateus, F.C., Marcos Djun, B.W., Isabelle Lobo de, M.S., Bonomi, A., Edvaldo Rodrigo, d.M. & Cavalett, O. 2020, "Techno-Economic and Environmental Assessment of Biomass Gasification and Fischer–Tropsch Synthesis Integrated to Sugarcane Biorefineries".	Not related to air toxic emissions from turbines.
Jialin, J., Wang, S., Yilan, M., Lu, C., Tian, L. & Ruiqin, Z. 2020, "Pollutant emission reduction of energy efficiency enhancement and energy cascade utilization in an energy-intensive industrial park in China", Environmental science and pollution resear	Not U.S. based
Johannes, L.H. & Jacobus, C.E. 2019, "Noise Sources and Control, and Exposure Groups in Chemical Manufacturing Plants", Applied Sciences, vol. 9, no. 17, pp. 3523.	Not related to emissions from NG turbines.
Jones, D.L. 2010, "Potential Air Emission Impacts of Cellulosic Ethanol Production at Seven Demonstration Refineries in the United States", Journal of the Air & Waste Management Association, vol. 60, no. 9, pp. 1118-43.	One mention of a turbine.
Jung, G., Fang, L., Chiou, M., Nguyen, X., Su, A., Lee, W., Chang, S., Kao, I. & Yu, J. 2014, "Effects of Pretreatment Methods on Electrodes and SOFC Performance", Energies, vol. 7, no. 6, pp. 3922-3933.	Not related to emissions from NG turbines.
Junne, T., Simon, S., Buchgeister, J., Saiger, M., Baumann, M., Haase, M., Wulf, C. & Naegler, T. 2020, "Environmental Sustainability Assessment of Multi-Sectoral Energy Transformation Pathways: Methodological Approach and Case Study for Germany", Sustain	Not U.S. based
Kalina, J. 2011, "Modelling of fluidized bed biomass gasification in the quasi-equilibrium regime for preliminary performance studies of energy conversion plants", Chemical and Process Engineering, vol. 32, no. 2, pp. 73.	Not related to emissions from NG turbines.
Kamal Chowdhury, A.F.M., Dang, T.D., Nguyen, H.T.T., Koh, R. & Galelli, S. 2021, "The Greater Mekong's Climate-Water-Energy Nexus: How ENSO-Triggered Regional Droughts Affect Power Supply and CO2 Emissions", Earth's Future, vol. 9, no. 3.	Not U.S. based
Katz, D. & Shafran, A. 2019, "Transboundary Exchanges of Renewable Energy and Desalinated Water in the Middle East", Energies, vol. 12, no. 8, pp. 1455.	Not U.S. based

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Kern, C. 2021, "Reducing Global Greenhouse Gas Emissions to Meet Climate Targets—A Comprehensive Quantification and Reasonable Options", Energies, vol. 14, no. 17, pp. 5260.	Mentions wind turbines.
Kim, H., Kasipandi, S., Kim, J., Suk-Hwan Kang, Jin-Ho, K., Jae-Hong, R. & Bae, J. 2020, "Current Catalyst Technology of Selective Catalytic Reduction (SCR) for NOx Removal in South Korea", Catalysts, vol. 10,	Not U.S. based
Klaudt, D.W. 2018, "Can Canada's "Living Tree" Constitution and Lessons from Foreign Climate Litigation Seed Climate Justice and Remedy Climate Change?", Journal of Environmental Law and Practice, vol. 31, no. 3, pp. 185-243.	Not U.S. based
Klavins, M., Bisters, V. & Burlakovs, J. 2018, "Small Scale Gasification Application and Perspectives in Circular Economy", Rigas Tehniskas Universitates Zinatniskie Raksti, vol. 22, no. 1, pp. 42-54.	Not related to emissions from NG turbines.
Klein-Banai, C. 2010, "RESEARCH ARTICLE: A Greenhouse Gas Inventory as a Measure of Sustainability for an Urban Public Research University", Environmental Practice, vol. 12, no. 1, pp. 35-47.	Not related to air toxic emissions from turbines.
Klemeš, J.J., Petar, S.V., Ocłoń, P. & Hon, H.C. 2019, "Towards Efficient and Clean Process Integration: Utilisation of Renewable Resources and Energy-Saving Technologies", Energies, vol. 12, no. 21.	Not related to emissions from NG turbines.
Kositkanawuth, K., Gangupomu, R.H., Sattler, M.L., Dennis, B.H., MacDonnell, F.M., Billo, R. & Priest, J.W. 2012, "Air impacts from three alternatives for producing JP-8 jet fuel", Journal of the Air & Waste Management Association, vol. 62, no. 10, pp. 11	One mention of a turbine.
Kotowicz, J., Michalski, S. & Brzęczek, M. 2019, "The Characteristics of a Modern Oxy-Fuel Power Plant", Energies, vol. 12, no. 17, pp. 3374.	Use of methanol in reference.
Kuparinen, K., Vakkilainen, E. & Tynjälä, T. 2019, "Biomass-based carbon capture and utilization in kraft pulp mills", Mitigation and Adaptation Strategies for Global Change, vol. 24, no. 7, pp. 1213-1230.	Not related to emissions from NG turbines.
Kupecki, J. 2019, "Sensitivity analysis of main parameters of pressurized SOFC hybrid system", Journal of Power Technologies, vol. 99, no. 2, pp. 115-122.	Use of methanol as a fuel.
Labordena, M., , D.N., Folini, D., Patt, A. & Lilliestam, J. 2018, "Blue skies over China: The effect of pollution-control on solar power generation and revenues", PLoS One, vol. 13, no. 11.	Not U.S. based
Lage, S., Gojkovic, Z., Funk, C. & Gentili, F.G. 2018, "Algal Biomass from Wastewater and Flue Gases as a Source of Bioenergy", Energies, vol. 11, no. 3, pp. 664.	One mention of steam turbine.
Leckner, B. 2016, "Developments in fluidized bed conversion of solid fuels", Thermal Science, vol. 20, pp. S1-S18.	Not related to emissions from NG turbines.
Li, C., Wang, N., Zhang, H., Liu, Q., Chai, Y., Shen, X., Yang, Z. & Yang, Y. 2019, "Environmental Impact Evaluation of Distributed Renewable Energy System Based on Life Cycle Assessment and Fuzzy Rough Sets", Energies, vol. 12, no. 21.	One reference to benzene.
Li, C.L., Foscoli, B., Mastorakos, E. & Evans, S. 2021, "A Comparison of Alternative Fuels for Shipping in Terms of Lifecycle Energy and Cost", Energies, vol. 14, no. 24, pp. 8502.	Not related to emissions from NG turbines.
Li, J., Yu, Z., Du, Z., Ji, Y. & Liu, C. 2020, "Standoff Chemical Detection Using Laser Absorption Spectroscopy: A Review", Remote Sensing, vol. 12, no. 17, pp. 2771.	Turbine used in references.
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Liang, F., Ryvak, M., Sayeed, S. & Zhao, N. 2012, "The role of natural gas as a primary fuel in the near future, including comparisons of acquisition, transmission and waste handling costs of as with competitive alternatives", Chemistry Central Journal, v	Not related to emissions from NG turbines.
Liao, M. & Yao, Y. 2021, "Applications of artificial intelligence-based modeling for bioenergy systems: A review", Global Change Biology.Bioenergy, vol. 13, no. 5, pp. 774-802.	Not related to emissions from NG turbines.
Liao, X. & Hall, J.W. 2018, "Drivers of water use in China's electric power sector from 2000 to 2015", Environmental Research Letters, vol. 13, no. 9.	Not U.S. based
Liao, Y., Fang, H., Zhang, H., Yu, Z., Liu, Z. & Ma, X. 2017, "Energy Analysis and Environmental Impacts of Hybrid Giant Napier (Pennisetum Hydridum) Direct-fired Power Generation in South China", IOP Conference Series.Materials Science and Engineering, v	Not U.S. based

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Lin, R., Liu, Y., Man, Y. & Ren, J. 2019, "Towards a sustainable distributed energy system in China: decision-making for strategies and policy implications", Energy, Sustainability and Society, vol. 9, no. 1, pp. 1-25.	Not U.S. based
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Liu, B., Fu, Z., Wang, P., Liu, L., Gao, M. & Liu, J. 2018, "Big-Data-Mining-Based Improved K-Means Algorithm for Energy Use Analysis of Coal-Fired Power Plant Units: A Case Study", Entropy, vol. 20, no. 9.	Not related to emissions from NG turbines.
Liu, D., Gege, L., Zeng, W., Sun, M. & Cunbin, L. 2019, "Research on Comprehensive Benefit Post Evaluation of Photovoltaic Poverty Alleviation Projects Based on FCM and SVM", IOP Conference Series.Earth and Environmental Science, vol. 281, no. 1.	Turbine used in references.
Liu, L., Wang, K., Wang, S., Zhang, R. & Tang, X. 2019, "Exploring the Driving Forces and Reduction Potential of Industrial Energy-Related CO0RW1S34RfeSDcfkexd09rT421RW1S34RfeSDcfkexd09rT4 Emissions during 2001–2030: A Case Study for Henan Province, China	Not U.S. based
Liu, W., Zhang, X., Zhao, N., Shu, C., Zhang, S., Ma, Z. & Han, J. 2018, "Performance analysis of organic Rankine cycle power generation system for intercooled cycle gas turbine", Advances in Mechanical Engineering, vol. 10, no. 8.	Toluene used as working fluid.
Liyanage, D.R., Hewage, K., Karunathilake, H., Chhipi-Shrestha, G. & Sadiq, R. 2021, "Carbon Capture Systems for Building-Level Heating Systems—A Socio-Economic and Environmental Evaluation", Sustainability, vol. 13, no. 19, pp. 10681.	Not related to emissions from NG turbines.
Lu, Y., Tian, A., Zhang, J., Tang, Y., Shi, P., Tang, Q. & Huang, Y. 2020, "Physical and Chemical Properties, Pretreatment, and Recycling of Municipal Solid Waste Incineration Fly Ash and Bottom Ash for Highway Engineering: A Literature Review", Advances	One mention of steam turbine.
Mančić, M.,V., Živković, D.,S., Đorđević, M.L. & Rajić, M.,N. 2016, "OPTIMIZATION OF A POLYGENERATION SYSTEM FOR ENERGY DEMANDS OF A LIVESTOCK FARM", Thermal Science, vol. 20, pp. S1285-S1300.	One mention of turbine.
Máté Zavarkó, Imre, A.R., Pörzse, G. & Csedő, Z. 2021, "Past, Present and Near Future: An Overview of Closed, Running and Planned Biomethanation Facilities in Europe", Energies, vol. 14, no. 18, pp. 5591.	Not U.S. based
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McDonald-Buller, E., McGaughey, G., Grant, J., Shah, T., Kimura, Y. & Yarwood, G. 2021, "Emissions and Air Quality Implications of Upstream and Midstream Oil and Gas Operations in Mexico", Atmosphere, vol. 12, no. 12, pp. 1696.	Not U.S. based
Mesfun, S., Matsakas, L., Rova, U. & Christakopoulos, P. 2019, "Technoeconomic Assessment of Hybrid Organosolv–Steam Explosion Pretreatment of Woody Biomass", Energies, vol. 12, no. 21.	Not related to emissions from NG turbines.
Mikielewicz, D. & Mikielewicz, J. 2016, "Criteria for selection of working fluid in low-temperature ORC", Chemical and Process Engineering, vol. 37, no. 3, pp. 429-440.	Not related to emissions from NG turbines.
Milledge, J.J., Smith, B., Dyer, P.W. & Harvey, P. 2014, "Macroalgae-Derived Biofuel: A Review of Methods of Energy Extraction from Seaweed Biomass", Energies, vol. 7, no. 11, pp. 7194-7222.	One mention of turbine.
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Ming-Hong, C., Yau-Pin Chyou & Wang, T. 2019, "Simulation of Coal Gasification in a Low-Temperature, High-Pressure Entrained-Bed Reactor with a Volatiles Condensation and Re-Evaporation Model", Applied Sciences, vol. 9, no. 3.	One mention of turbine.
Mittlefehldt, S. 2018, "Wood Waste and Race: The Industrialization of Biomass Energy Technologies and Environmental Justice", Technology and Culture, vol. 59, no. 4, pp. 875-898.	Not related to emissions from NG turbines.
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Moiseev, Y., Afxentiou, N. & Fokaides, P.A. 2021, "The State of the Art Overview of the Biomass Gasification Technology", Current Sustainable / Renewable Energy Reports, vol. 8, no. 4, pp. 282-295.	One mention of turbine.
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Morenov, V., Leusheva, E., Buslaev, G. & Gudmestad, O.T. 2020, "System of Comprehensive Energy-Efficient Utilization of Associated Petroleum Gas with Reduced Carbon Footprint in the Field Conditions", Energies, vol. 13, no. 18, pp. 4921.	Methanol as a chemical product.

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Mostafa, M., Varela, C., Franke, M.B. & Zondervan, E. 2021, "Dynamic Modeling and Control of a Simulated Carbon Capture Process for Sustainable Power-to-X", Applied Sciences, vol. 11, no. 20, pp. 9574.	Not related to emissions from NG turbines.
Mudgal, D., Singh, S. & Prakash, S. 2014, "Corrosion Problems in Incinerators and Biomass-Fuel-Fired Boilers", International Journal of Corrosion, vol. 2014.	Not related to emissions from NG turbines.
Muhammed, N.H., Tivander, J., Treyer, K., Lévová, T., Valsasina, L. & Tillman, A. 2019, "Life cycle inventory of power producing technologies and power grids at regional grid level in India", The International Journal of Life Cycle Assessment, vol. 24, no	Not U.S. based
Nagano, N. & Delage, R. 2021, "Optimal Design and Analysis of Sector-Coupled Energy System in Northeast Japan", Energies, vol. 14, no. 10, pp. 2823.	Not U.S. based
Naims, H. 2016, "Economics of carbon dioxide capture and utilization--a supply and demand perspective", Environmental science and pollution research international, vol. 23, no. 22, pp. 22226-22241.	Not related to emissions from NG turbines.
Nakaten, N. & Kempka, T. 2019, "Techno-Economic Comparison of Onshore and Offshore Underground Coal Gasification End-Product Competitiveness", Energies, vol. 12, no. 17, pp. 3252.	Methanol as a chemical product.
Nami, H., Anvari-Moghaddam, A. & Arabkoohsar, A. 2020, "Thermodynamic, Economic, and Environmental Analyses of a Waste-Fired Trigeneration Plant", Energies, vol. 13, no. 10, pp. 2476.	Methanol used in references.
Nanda, S., Reddy, S.N., Mitra, S.K. & Kozinski, J.A. 2016, "The progressive routes for carbon capture and sequestration", Energy Science & Engineering, vol. 4, no. 2, pp. 99-122.	One mention of turbines.
Nandakishora, Y., Sahoo, R.K. & Murugan, S. 2021, "Review on Waste Heat Recovery from Flue Gas and Its Application in CO2 Capture", IOP Conference Series.Materials Science and Engineering, vol. 1130, no. 1.	Not related to emissions from NG turbines.
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Nikolakaki, G. 2016, "2. Court of Justice of the European Union (CJEU)", Yearbook of International Environmental Law, vol. 27, pp. 409-423.	Not U.S. based
Nyakuma, B.B., Aliyu, J., Akinyemi, S.A., Faizal, H.M., Nasirudeen, M.B., Fuad Muhammad Ariff, H.M. & Olagoke, O. 2021, "Physicochemical, mineralogy, and thermo-kinetic characterisation of newly discovered Nigerian coals under pyrolysis and combustion con	Not U.S. based
Ohler, A.M. 2015, "Factors affecting the rise of renewable energy in the U.S.: Concern over environmental quality or rising unemployment?", The Energy Journal, vol. 36, no. 2.	One mention of turbine.
Olabi, A.G., Wilberforce, T., Enas, T.S., Elsaid, K. & Mohammad, A.A. 2020, "Prospects of Fuel Cell Combined Heat and Power Systems", Energies, vol. 13, no. 16, pp. 4104.	Two mentions of microturbines.
Olaguer, E.P., Knipping, E., Shaw, S. & Ravindran, S. 2016, "Microscale air quality impacts of distributed power generation facilities", Journal of the Air & Waste Management Association, vol. 66, no. 8, pp. 795-806.	Emissions data not provided for turbines.
Olsen, D.B., Kohls, M. & Arney, G. 2010, "Impact of Oxidation Catalysts on Exhaust NO2/Nox Ratio from Lean-Burn Natural Gas Engines", Journal of the Air & Waste Management Association, vol. 60, no. 7, pp. 867-74.	Turbine used in references.
Omer, A.M. 2012, "APPLICATIONS OF BIOGAS: STATE OF THE ART AND FUTURE PROSPECTIVE", Blue Biotechnology Journal, vol. 1, no. 3, pp. 335-383.	Not U.S. based
Omer, A.M. 2014, "ENERGY EFFICIENCY IMPROVEMENT UTILISING HIGH TECHNOLOGY: THE PATH FORWARD FOR RENEWABLE ENERGY USE IN INDUSTRY, BUILDINGS AND SUSTAINABLE DEVELOPMENT", Blue Biotechnology Journal, vol. 3, no. 2, pp. 183-250.	Not related to emissions from NG turbines.
Oniemola, P.K. 2016, "Why Should Oil Rich Nigeria Make A Law for the Promotion of Renewable Energy in the Power Sector?", Journal of African Law, vol. 60, no. 1, pp. 29-55.	Not U.S. based
Orović, J., Mrzljak, V. & Poljak, I. 2018, "Efficiency and Losses Analysis of Steam Air Heater from Marine Steam Propulsion Plant", Energies, vol. 11, no. 11.	Toluene used as working fluid.
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Ozawa, A., Inoue, M., Kitagawa, N., Muramatsu, R., Anzai, Y., Genchi, Y. & Kudoh, Y. 2017, "Assessing Uncertainties of Well-To-Tank Greenhouse Gas Emissions from Hydrogen Supply Chains", Sustainability, vol. 9, no. 7, pp. 1101.	Not related to air toxic emissions from NG turbines. Toluene used as reactant.
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Pang, M., Zhang, L., Wang, C. & Liu, G. 2015, "Environmental life cycle assessment of a small hydropower plant in China", The International Journal of Life Cycle Assessment, vol. 20, no. 6, pp. 796-806.	Not U.S. based
Papailias, G. & Mavroidis, I. 2018, "Atmospheric Emissions from Oil and Gas Extraction and Production in Greece", Atmosphere, vol. 9, no. 4, pp. 152.	Not U.S. based
Pau, L.S., Tang, M.S.Y., Nagarajan, D., Tau, C.L., Chien-Wei, O. & Jo-Shu, C. 2017, "A Holistic Approach to Managing Microalgae for Biofuel Applications", International Journal of Molecular Sciences, vol. 18, no. 1, pp. 215.	One mention of turbine.
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Perić, M.,M., Komatina, M.S., Antonijević, D., Bugarski, B.M. & Dželetović, Ž.,S. 2019, "Diesel production by fast pyrolysis of Miscanthus giganteus, well-to-pump analysis using the greet model", Thermal Science, vol. 23, no. 1, pp. 365-378.	Not related to emissions from NG turbines.
Pieri, T., Nikitas, A., Castillo-Castillo, A. & Angelis-Dimakis, A. 2018, "Holistic Assessment of Carbon Capture and Utilization Value Chains", Environments, vol. 5, no. 10.	One mention of turbine.
Portugal-Pereira, J., Koberle, A., Lucena, A.F.P., Rochedo, P.R.R., Império, M., Ana, M.C., Schaeffer, R. & Rafaj, P. 2018, "Interactions between global climate change strategies and local air pollution: lessons learnt from the expansion of the power sector in Brazil".	Not U.S. based
Prasad, R. & Singh, P. 2011, "Applications and Preparation Methods of Copper Chromite Catalysts: A Review", Bulletin of Chemical Reaction Engineering & Catalysis, vol. 6, no. 2, pp. 63-113.	Not related to emissions from NG turbines.
Puettmann, M.E. & Milota, M. 2017, "Life-Cycle Assessment for Wood-Fired Boilers Used in the Wood Products Industry *", Forest Products Journal, vol. 67, no. 5, pp. 381-389.	One mention of turbine.
Rajvikram, M.E., Selvamanohar, L., Raju, K., Raghavendra, R.V., Subburaj, R., Nurunnabi, M., Irfan, A.K., Afridhis, S., Hariharan, A., Pugazhendhi, R., Subramaniam, U. & Das, N. 2020, "A Holistic Review of the Present and Future Drivers of the Renewable Energy Mix in Maharashtra, State of India".	Not U.S. based
Ranisau, J., Barbouti, M., Trainor, A., Juthani, N., Salkuyeh, Y.K., Maroufmashat, A. & Fowler, M. 2017, "Power-to-Gas Implementation for a Polygeneration System in Southwestern Ontario", Sustainability, vol. 9, no. 9, pp. 1610.	Not U.S. based
Rashid, F. & Fazal, N. 2017, "Study of environmental indicators in a thermal power plant in Lahore, Pakistan", Management of Environmental Quality, vol. 28, no. 6, pp. 930-945.	Not U.S. based
Rashid, M., Naseem, S. & Ramzan, N. 2014, "Coal as an Energy Source for Mitigating Energy Crisis in Pakistan", Journal of Engineering and Technology, vol. 4, no. 2.	Not U.S. based
Ratner, S., Gomonov, K., Revinova, S. & Lazanyuk, I. 2020, "Eco-Design of Energy Production Systems: The Problem of Renewable Energy Capacity Recycling", Applied Sciences, vol. 10, no. 12, pp. 4339.	Refers to wind turbines.
Raugei, M., Kamran, M. & Hutchinson, A. 2020, "A Prospective Net Energy and Environmental Life-Cycle Assessment of the UK Electricity Grid", Energies, vol. 13, no. 9, pp. 2207.	Not U.S. based
Ray, A., Jana, K., Assadi, M. & De, S. 2018, "Distributed polygeneration using local resources for an Indian village: multiobjective optimization using metaheuristic algorithm", Clean Technologies and Environmental Policy, vol. 20, no. 6, pp. 1323-1341.	Not U.S. based
Reid, G. & Wynn, G. 2015, "The Future of Solar Power in the United Kingdom", Energies, vol. 8, no. 8, pp. 7818-7832.	Not U.S. based
Ren, L., Liu, J. & Wang, H. 2020, "Thermodynamic Optimization of a Waste Heat Power System under Economic Constraint", Energies, vol. 13, no. 13, pp. 3388.	Toluene used as working fluid.
Restrepo-Valencia, S. & Walter, A. 2019, "Techno-Economic Assessment of Bio-Energy with Carbon Capture and Storage Systems in a Typical Sugarcane Mill in Brazil", Energies, vol. 12, no. 6.	Not U.S. based
Ritter, D., Meyer, R., Koch, M., Haller, M., Bauknecht, D. & Heinemann, C. 2019, "Effects of a Delayed Expansion of Interconnector Capacities in a High RES-E European Electricity System", Energies, vol. 12, no. 16, pp. 3098.	Not U.S. based

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Robinson, A.L., Grieshop, A.P., Donahue, N.M. & Hunt, S.W. 2010, "Updating the Conceptual Model for Fine Particle Mass Emissions from Combustion Systems", Journal of the Air & Waste Management Association, vol. 60, no. 10, pp. 1204-22.	Not related to gaseous emissions from turbines.
Rohr, A.C., Campleman, S.L., Long, C.M., Peterson, M.K., Weatherstone, S., Quick, W. & Lewis, A. 2015, "Potential Occupational Exposures and Health Risks Associated with Biomass-Based Power Generation", International Journal of Environmental Research and	One mention of turbine.
Rokni, M. 2016, "Performance Comparison on Repowering of a Steam Power Plant with Gas Turbines and Solid Oxide Fuel Cells", Energies, vol. 9, no. 6, pp. 399.	Methanol as a fuel.
Roshchanka, V. & Evans, M. 2014, "Incentives for methane mitigation and energy-efficiency improvements in the case of Ukraine's natural gas transmission system", Earth's Future, vol. 2, no. 6, pp. 321-330.	Not U.S. based
Rozzi, E., Minuto, F.D., Lanzini, A. & Leone, P. 2020, "Green Synthetic Fuels: Renewable Routes for the Conversion of Non-Fossil Feedstocks into Gaseous Fuels and Their End Uses", Energies, vol. 13, no. 2, pp. 420.	Not related to emissions from NG turbines.
Rudolf, R. 2021, "German energy transition (Energiewende) and what politicians can learn for environmental and climate policy", Clean Technologies and Environmental Policy, vol. 23, no. 2, pp. 305-342.	Not U.S. based
Rui, N.R. 2017, "The Role of Synthetic Fuels for a Carbon Neutral Economy", C, vol. 3, no. 2.	Methanol as product and fuel.
Rupp, J.A. & Graham, J.D. 2021, "Contrasting Public and Scientific Assessments of Fracking", Sustainability, vol. 13, no. 12, pp. 6650.	One mention of turbine.
Sadollah, A., Nasir, M. & Zong, W.G. 2020, "Sustainability and Optimization: From Conceptual Fundamentals to Applications", Sustainability, vol. 12, no. 5, pp. 2027.	Refers to wind turbines.
Sahoo, D., Petersen, B. & Miles, P.C. 2011, "Measurement of Equivalence Ratio in a Light-Duty Low Temperature Combustion Diesel Engine by Planar Laser Induced Fluorescence of a Fuel Tracer", SAE International Journal of Engines, vol. 4, no. 2, pp. 2312-23	Not related to emissions from NG turbines.
Sahu, S.K., Ohara, T. & Beig, G. 2017, "The role of coal technology in redefining India's climate change agents and other pollutants", Environmental Research Letters, vol. 12, no. 10.	Not U.S. based
Saługa, P.,W., Grzesiak, P. & Kamiński, J. 2020, "Valuation of Decision Flexibility and Strategic Value in Coal Gasification Projects with the Option-To-Switch between Different Outputs", Energies, vol. 13, no. 11, pp. 2826.	One mention of turbine.
Sanchez Moore, C.C. & Kulay, L. 2019, "Effect of the Implementation of Carbon Capture Systems on the Environmental, Energy and Economic Performance of the Brazilian Electricity Matrix", Energies, vol. 12, no. 2, pp. 331.	Not U.S. based
Sangster, R.C. 2015, "Formation of Silicon Nitride From the 19th to the 21st Century: A Comprehensive Summary and Guide to The World Literature", Materials Science Foundations, vol. 84/85, pp. I,II,III,IV,V,VI,1-135,137-487,489-537,539-587,589-711,713-979	Not related to emissions from NG turbines.
Sarmiento, L., Burandt, T., Löffler, K. & Pao-Yu Oei 2019, "Analyzing Scenarios for the Integration of Renewable Energy Sources in the Mexican Energy System—An Application of the Global Energy System Model (GENeSYS-MOD)", Energies, vol. 12, no. 17, pp. 32	Not U.S. based
Scanlon, B.R., Reedy, R.C. & Nicot, J.P. 2014, "Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?", Environmental Research Letters, vol. 9, no. 12.	One mention of turbine.
Schmitt, C.C., Frederico, G.F., Campos Fraga, M.,M., Alberto WisniewskiJr, Karp, S., Álvaro Henrique Mello José, Rita, C.L.B.R., Moreira, R., Hirayama, D.E., Raffelt, K. & Dahmen, N. 2021, "Thermochemical and Catalytic Conversion Technolo	One mention of turbine.
Schütze, K., Wilson, J.C., Weinbruch, S., Benker, N., Ebert, M., Gebhard Günther, Weigel, R. & Borrmann, S. 2017, "Sub-micrometer refractory carbonaceous particles in the polar stratosphere", Atmospheric Chemistry and Physics, vol. 17, no. 20, pp. 12475-1	Turbine used in references.
SEKAR, S., KARTHIKEYAN, S. & IYAPPAN, P. 2010, "Trends in patenting and commercial utilisation of poultry farm excreta", World's poultry science journal, vol. 66, no. 3, pp. 533-572.	Not related to emissions from NG turbines.
Serrano-Sanchez, C., Olmeda-Delgado, M. & Petrakopoulou, F. 2019, "Exergy and Economic Evaluation of a Hybrid Power Plant Coupling Coal with Solar Energy", Applied Sciences, vol. 9, no. 5.	Methanol mentioned in references.
Sewastianik, S. & Gajewski, A. 2021, "An Environmental Assessment of Heat Pumps in Poland", Energies, vol. 14, no. 23, pp. 8104.	Not U.S. based
Shang, X., Song, S. & Yang, J. 2020, "Comparative Environmental Evaluation of Straw Resources by LCA in China", Advances in Materials Science and Engineering, vol. 2020, pp. 16.	Not U.S. based
Sharafodini, R., Habibi, M.R. & Pirmohammadi, M. 2020, "Numerical Study of Water Vapor Injection in the Combustion Chamber to Reduce Gas Turbine Fuel Consumption", Journal of Applied Fluid Mechanics, vol. 13, no. 3, pp. 1047-1054.	Hexane used as fuel

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Sharma, D., Sharma, J.K., Srivastava, B.K. & Sinha, S. 2021, "Usage of solar over nuclear as an alternate energy source in support of Green & Sustainable supply chain practices in India", Turkish Journal of Computer and Mathematics Education, vol. 12, no.	Not U.S. based
Sharp, T., P.E., Haase, M., PhD., Zhivov, A., PhD., Rismanchi, B., PhD., Lohse, R., Rose, J. & Nord, N., PhD. 2020, "Energy Master Planning: Identifying Framing Constraints that Scope Your Technology Options", ASHRAE Transactions, vol. 126, pp. 789-806.	One mention of wind turbine.
Shi, Y., Wen, J., Cui, F. & Wang, J. 2019, "An Optimization Study on Soot-Blowing of Air Preheaters in Coal-Fired Power Plant Boilers", Energies, vol. 12, no. 5.	One mention of turbine.
Silva, S., Laranjeira, E. & Soares, I. 2021, "Health Benefits from Renewable Electricity Sources: A Review", Energies, vol. 14, no. 20, pp. 6678.	One mention of turbine.
Simon, S., Naegler, T. & Gils, H.C. 2018, "Transformation towards a Renewable Energy System in Brazil and Mexico-Technological and Structural Options for Latin America", Energies, vol. 11, no. 4, pp. 907.	Not U.S. based
Singh, S.K. 2017, "Policy and Regulatory Issues for Underground Coal Gasification in India", IOP Conference Series.Earth and Environmental Science, vol. 76, no. 1.	Not U.S. based
Singh, T., Muataz, A.A., Al-Ansari, T., Abdul, W.M. & McKay, G. 2020, "The Role of Nanofluids and Renewable Energy in the Development of Sustainable Desalination Systems: A Review", Water, vol. 12, no. 7, pp. 2002.	One mention of turbine.
Sivabalan, K., Hassan, S., Ya, H. & Pasupuleti, J. 2021, "A review on the characteristic of biomass and classification of bioenergy through direct combustion and gasification as an alternative power supply", Journal of Physics: Conference Series, vol. 183	Two mentions of steam turbines.
Skabelund, B.B., Elio, J. & Milcarek, R.J. 2021, "Techno-Economic Assessment of a Hybrid Gas Tank Hot Water Combined Heat and Power System", Sustainability, vol. 13, no. 23, pp. 13040.	Not related to emissions from NG turbines.
Smit, S., Sterling, R. & Loureiro, T. 2021, "Overview of the Enablers and Barriers for a Wider Deployment of CSP Tower Technology in Europe", Clean Technologies, vol. 3, no. 2, pp. 377.	Not U.S. based
Solomin, E., Sirotkin, E., Cuce, E., Selvanathan, S.P. & Kumarasamy, S. 2021, "Hybrid Floating Solar Plant Designs: A Review", Energies, vol. 14, no. 10, pp. 2751.	Methanol as a product.
Sööt, P., Voll, H. & Kõiv, T. 2012, "UTILIZATION OF OIL SHALE RETORT GAS", Oil Shale, vol. 29, no. 3, pp. 248-267.	Not related to emissions from NG turbines.
Sornek, K. & Filipowicz, M. 2019, "Study of the operation of straw-fired boiler dedicated to steam generation for micro-cogeneration system", IOP Conference Series.Earth and Environmental Science, vol. 214, no. 1.	Not related to emissions from NG turbines.
Spallina, V., Melchiori, T., Gallucci, F. & Annaland, M.V. 2015, "Auto-Thermal Reforming Using Mixed Ion-Electronic Conducting Ceramic Membranes for a Small-Scale H2 Production Plant", Molecules, vol. 20, no. 3, pp. 4998-5023.	Methanol used in references.
Spence, D.B. 2011, "Regulation, "Republican Moments," and Energy-Policy Reform", Brigham Young University Law Review, vol. 2011, no. 5, pp. 1561-1623.	One mention of turbine.
Springsteen, B., Christofk, T., Eubanks, S., Mason, T., Clavin, C. & Storey, B. 2011, "Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning", Journal of the Air & Waste Management Association, vol. 61, no. 1, pp. 63-8.	One mention of turbine.
Staroń, A., Kowalski, Z., Staroń, P. & Banach, M. 2019, "Studies on CWL with glycerol for combustion process", Environmental science and pollution research international, vol. 26, no. 3, pp. 2835-2844.	One mention of turbine.
Sterner, M. & Specht, M. 2021, "Power-to-Gas and Power-to-X—The History and Results of Developing a New Storage Concept", Energies, vol. 14, no. 20, pp. 6594.	Not related to emissions from NG turbines.
Stoltmann, A., Jaskólski, M. & Bućko, P. 2019, "Optimization of combined heat and power (CHP) market allocation: The case of Poland", IOP Conference Series.Earth and Environmental Science, vol. 214, no. 1.	Not U.S. based
Stoumpos, S., Theotokatos, G., Mavrelos, C. & Boulougouris, E. 2020, "Towards Marine Dual Fuel Engines Digital Twins—Integrated Modelling of Thermodynamic Processes and Control System Functions", Journal of Marine Science and Engineering, vol. 8, no. 3, p	Methanol as fuel.
Sundseth, K., Pacyna, J.M., Pacyna, E.G. & Panasiuk, D. 2012, "Substance Flow Analysis of Mercury Affecting Water Quality in the European Union", Water, Air and Soil Pollution, vol. 223, no. 1, pp. 429-442.	Not U.S. based
Syah, R., Davarpanah, A., Nasution, M.K.M., Faisal, A.T., Meysam, M.N. & Nesaht, M. 2021, "A Comprehensive Thermoeconomic Evaluation and Multi-Criteria Optimization of a Combined MCFC/TEG System", Sustainability, vol. 13, no. 23, pp. 13187.	One mention of turbine.
Talbot, R., Mao, H., Feddersen, D., Smith, M., Kim, S.Y., Sive, B., Haase, K., Ambrose, J., Zhou, Y. & Russo, R. 2011, "Comparison of Particulate Mercury Measured with Manual and Automated Methods", Atmosphere, vol. 2, no. 1, pp. 1-20.	One mention of wind turbine.

Appendix A - ProQuest References for Turbines

Reference	ERG Review Note
Tanaka, H., Somezawa, S., Sako, T., Sakai, Y., Ando, H. & Kuwahara, K. 2014, "Fuel Design Concept for Robust Ignition in HCCI Engine and Its Application to Optimize Methane-Based Blend", SAE International Journal of Engines, vol. 7, no. 2, pp. 807-819.	Not U.S. based
Tande, L.N., Resendiz-Mora, E. & Dupont, V. 2021, "Bioh2, Heat and Power from Palm Empty Fruit Bunch via Pyrolysis-Autothermal Reforming: Plant Simulation, Experiments, and CO2	Not related to emissions from NG turbines.
Tang, H., Jiang, P., He, J. & Ma, W. 2020, "Synergies of Cutting Air Pollutants and CO0RW1S34RfeSDcfkexd09rT421RW1S34RfeSDcfkexd09rT4 Emissions by the End-of-Pipe Treatment Facilities in a Typical Chinese Integrated Steel Plant", Sustainability, vol. 12,	One mention of turbine.
Tang, L., Xiaoda, X., Jiabao, Q., Zhifu, M., Xin, B., Chang, X., Shouyang, W., Shibei, L., Weigeng, C. & Guangxia, D. 2020, "Air pollution emissions from Chinese power plants based on the continuous emission monitoring systems network", Scientific Data, v	Not U.S. based
Tang, M. & Mudd, G.M. 2014, "Canadian Power Stations and the National Pollutant Release Inventory (NPRI): A Success Story for Pollution Intensity?", Water, Air and Soil Pollution, vol. 225, no. 10, pp. 1-17.	Not U.S. based
Tang, M. & Mudd, G.M. 2015, "The pollution intensity of Australian power stations: a case study of the value of the National Pollutant Inventory (NPI)", Environmental science and pollution research international, vol. 22, no. 23, pp. 18410-18424.	Not U.S. based
Tatarewicz, I., Lewarski, M., Skwierz, S., Krupin, V., Jeszke, R., Pyrka, M., Szczepański, K. & Sekuła, M. 2021, "The Role of BECCS in Achieving Climate Neutrality in the European Union", Energies, vol. 14, no. 23, pp. 7842.	Not U.S. based
Teresa, A.B., Fornai, B., Colla, V., Maria, I.P., Eros, L.F., Cirilli, F. & Schröder, A.J. 2021, "Industrial Symbiosis and Energy Efficiency in European Process Industries: A Review", Sustainability, vol. 13, no. 16, pp. 9159.	Not U.S. based
Thales, A.F., Soares, V.P. & Andreoli, E. 2015, "Pentaethylenehexamine-C60 for Temperature Consistent Carbon Capture", C, vol. 1, no. 1, pp. 16-26.	One mention of turbine.
Thunman, H., Seemann, M., Teresa, B.V., Maric, J., Pallares, D., Ström, H., Berndes, G., Knutsson, P., Larsson, A., Breitholtz, C. & Santos, O. 2018, "Advanced biofuel production via gasification – lessons learned from 200 man-years of research activity w	One mention of turbine.
Tokimatsu, K., Endo, E., Murata, A., Okajima, K. & Nomura, N. 2016, "An Integrated Assessment by Models for Energy Systems Analysis and Life-Cycle Assessment with a Case Study of Advanced Fossil-Fired Power Plants in China", Environmental Modeling & Asses	Not U.S. based
Torresi, M., Fornarelli, F., Fortunato, B., Camporeale, S.M. & Saponaro, A. 2017, "Assessment against Experiments of Devolatilization and Char Burnout Models for the Simulation of an Aerodynamically Staged Swirled Low-NOx Pulverized Coal Burner", Energies	Turbine used in references.
Tramošljika, B., Bonefačić, I. & Glažar, V. 2021, "Advanced Ultra-Supercritical Coal-Fired Power Plant with Post-Combustion Carbon Capture: Analysis of Electricity Penalty and CO2 Emission Reduction", Sustaina	Methanol as product.
Trieu-Vuong Dinh 2021, "Moisture Removal Techniques for a Continuous Emission Monitoring System: A Review", Atmosphere, vol. 12, no. 1, pp. 61.	One mention of turbine.
Tsai, W. 2012, "An Analysis of the Use of Biosludge as an Energy Source and Its Environmental Benefits in Taiwan", Energies, vol. 5, no. 8, pp. 3064-3073.	Not U.S. based
Tun, T.Z., Sebastien, B. & Gheewala, S.H. 2020, "Life cycle assessment of Portland cement production in Myanmar", The International Journal of Life Cycle Assessment, vol. 25, no. 11, pp. 2106-2121.	Not U.S. based
Unger, D. 2010, "Innovation And Market Entry In The Energy Industry: Lessons For Fuel Cells And New Technologies", Journal of Business & Economics Research, vol. 8, no. 10, pp. 63-72.	Methanol used in references.
Urbán, A. & Józsa, V. 2018, "Investigation of Fuel Atomization with Density Functions", Periodica Polytechnica.Engineering.Mechanical Engineering, vol. 62, no. 1, pp. 33-41.	One reference to bio-methanol.
Valencia, G., Fontalvo, A., Cárdenas, Y., Duarte, J. & Isaza, C. 2019, "Energy and Exergy Analysis of Different Exhaust Waste Heat Recovery Systems for Natural Gas Engine Based on ORC", Energies, vol. 12, no. 12.	Not related to emissions from NG turbines.
van der, A.R.J., de Laat, A.T.J., Ding, J. & Eskes, H.J. 2020, "Connecting the dots: NO0RW1S34RfeSDcfkexd09rT20RW1S34RfeSDcfkexd09rT4x1RW1S34RfeSDcfkexd09rT21RW1S34RfeSDcfkexd09rT4 emissions along a West Siberian natural gas pipeline", NPJ Climate and Atm	Not U.S. based
Variny, M., Jediná, D., Rimár, M., Kizek, J. & Kšiňanová, M. 2021, "Cutting Oxygen Production-Related Greenhouse Gas Emissions by Improved Compression Heat Management in a Cryogenic Air Separation Unit", International Journal of Environmental Research and	Not related to air toxic emissions from turbines.
Vershinina, K., Dorokhov, V., Romanov, D., Nyashina, G. & Kuznetsov, G. 2020, "Multi-Criteria Efficiency Analysis of Using Waste-Based Fuel Mixtures in the Power Industries of China, Japan, and Russia", Applied Sciences, vol. 10, no. 7, pp. 2460.	Not U.S. based

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Reference	ERG Review Note
Vutukuru, S., Carreras-Sospedra, M., Brouwer, J. & Dabdub, D. 2011, "Future Impacts of Distributed Power Generation on Ambient Ozone and Particulate Matter Concentrations in the San Joaquin Valley of California", Journal of the Air & Waste Management Asso	Does not provide emissions data for NG turbines.
Wajahat Ullah, K.T., Dilbar, M.T., Farhan, M., Muhammad, A.N., Ali, W.D., Kamran, A.M., Mekhilef, S., Seyedmahmoudian, M., Horan, B., Muhammad, A. & Aamir, M. 2020, "Present Status and Potential of Biomass Energy in Pakistan Based on Existing and Future R	Not U.S. based
Walvekar, P.P. & Gurjar, B.R. 2013, "Formulation, application and evaluation of a stack emission model for coal-based power stations", International Journal of Environmental Science and Technology : (IJEST), vol. 10, no. 6, pp. 1235-1244.	One mention of turbine.
Wang, C. & Mu, D. 2014, "An LCA study of an electricity coal supply chain", Journal of Industrial Engineering and Management, vol. 7, no. 1, pp. 311-335.	Not related to emissions from NG turbines.
Wang, J. & Shisen, X. 2014, "CO2 capture RD&D proceedings in China Huaneng Group", International Journal of Coal Science & Technology, vol. 1, no. 1, pp. 129-134.	Not U.S. based
Wang, L., Watanabe, T. & Xu, Z. 2015, "Monetization of External Costs Using Lifecycle Analysis-A Comparative Case Study of Coal-Fired and Biomass Power Plants in Northeast China", Energies, vol. 8, no. 2, pp. 1440-1467.	Not U.S. based
Wang, P. & Li, M. 2019, "Scenario Analysis in the Electric Power Industry under the Implementation of the Electricity Market Reform and a Carbon Policy in China", Energies, vol. 12, no. 11, pp. 2152.	Not U.S. based
Wang, P. & Massoudi, M. 2013, "Slag Behavior in Gasifiers. Part I: Influence of Coal Properties and Gasification Conditions", Energies, vol. 6, no. 2, pp. 784-806.	Not related to emissions from NG turbines.
Wang, W., Li, Z., Lyu, J., Zhang, H., Yue, G. & Ni, W. 2019, "An overview of the development history and technical progress of China's coal-fired power industry", Frontiers in Energy, , pp. 1-10.	Not U.S. based
Waqar, A., Muhammad, S.T., Ahmad, J., Aamir, M., Yaqoob, M. & Anwar, F. 2017, "Multi-Objective Analysis of a CHP Plant Integrated Microgrid in Pakistan", Energies, vol. 10, no. 10.	Not U.S. based
Warshay, B., Brown, J.J. & Sgouridis, S. 2017, "Life cycle assessment of integrated seawater agriculture in the Arabian (Persian) Gulf as a potential food and aviation biofuel resource", The International Journal of Life Cycle Assessment, vol. 22, no. 7,	Not U.S. based
Werle, S. 2011, "Estimation of reburning potential of syngas from sewage sludge gasification process", Chemical and Process Engineering, vol. 32, no. 4, pp. 411.	One mention of turbine.
Willis, J.L., Al-Omari, A., Bastian, R., Brower, B., DeBarbadillo, C., Murthy, S., Peot, C. & Yuan, Z. 2017, "A greenhouse gas source of surprising significance: anthropogenic CO2 emissions from use of methanol in sewage treatment", Water Science and Tech	Not related to emissions from NG turbines.
Wiseman, H.J. 2014, "REMEDYING REGULATORY DISECONOMIES OF SCALE", Boston University Law Review, vol. 94, no. 1, pp. 235-304.	One mention of wind turbine.
Woolsey, R.J., Kleinfeld, R. & Sexton, C. 2010, "NO STRINGS ATTACHED: The Case for a Distributed Grid and a Low-Oil Future", World Affairs, vol. 173, no. 3, pp. 59-71.	Not related to emissions from NG turbines.
Xiao, M., Wetzel, M., Pregger, T., Simon, S. & Scholz, Y. 2020, "Modeling the Supply of Renewable Electricity to Metropolitan Regions in China", Energies, vol. 13, no. 12, pp. 3042.	Not U.S. based
Xie, K., Cui, Y.J., Qiu, X.Q. & Wang, J.X. 2020, "Effect of Air Quantity Distribution Ratio on Flame Height of Flue Gas Self-Circulation Burner", Journal of Applied Fluid Mechanics, vol. 13, no. 1, pp. 233-243.	One mention of turbine.
Xu, H., Liu, F., Wang, Z., Ren, X., Chen, J., Li, Q. & Zhu, Z. 2021, "A Detailed Numerical Study of NOx Kinetics in Counterflow Methane Diffusion Flames: Effects of Fuel-Side versus Oxidizer-Side Dilution", Journal of Combustion, vol. 2021.	Not related to emissions from NG turbines.
XU, J., Assenova, A. & Erokhin, V. 2018, "Renewable Energy and Sustainable Development in a Resource-Abundant Country: Challenges of Wind Power Generation in Kazakhstan", Sustainability, vol. 10, no. 9, pp. 3315.	Not U.S. based
Yan, X. & Boies, A.M. 2013, "Quantifying the uncertainties in life cycle greenhouse gas emissions for UK wheat ethanol", Environmental Research Letters, vol. 8, no. 1.	Not U.S. based
Yang, D., Xi, Y. & Cai, G. 2017, "Day-Ahead Dispatch Model of Electro-Thermal Integrated Energy System with Power to Gas Function", Applied Sciences, vol. 7, no. 12, pp. 1326.	Not related to emissions from NG turbines.
Yang, S., Zhang, D. & Li, D. 2019, "A Calculation Model for CO0RW1S34RfeSDcfkexd09rT421RW1S34RfeSDcfkexd09rT4 Emission Reduction of Energy Internet: A Case Study of Yanqing", Sustainability, vol. 11, no. 9.	Not U.S. based
Yang, Y., Li, Y., Yan, X., Zhao, J. & Zhang, C. 2021, "Development of Thermochemical Heat Storage Based on CaO/CaCO3 Cycles: A Review", Energies, vol. 14, no. 20, pp. 6847.	Not related to air toxic emissions from turbines.
Yangaz, M.U., Çiftçioğlu, ,G.A. & Kadırgan, ,M.A.N. 2019, "Comparison of Conventional and Modified Burners in Performance with Different Fuels using a Linear and a Non-linear Eddy-viscosity Turbulence Model", Journal of Applied Fluid Mechanics, vol. 12, n	One mention of turbine.

Appendix A - ProQuest References for Turbines

Reference	ERG Review Note
Ye, Q., Pi, Y., Jia, Z.Z. & Wang, H.Z. 2013, "Coal Mine Methane Drainage and Comprehensive Utilization in China", Applied Mechanics and Materials, vol. 295-298, pp. 3023.	Not U.S. based
Yoro, K.O. & Sekoai, P.T. 2016, "The Potential of CO0RW1S34RfeSDcfkexd09rT421RW1S34RfeSDcfkexd09rT4 Capture and Storage Technology in South Africa's Coal-Fired Thermal Power Plants", Environments, vol. 3, no. 3.	Not U.S. based
Yu, H., Yan, Y. & Dong, S. 2019, "A System Dynamics Model to Assess the Effectiveness of Governmental Support Policies for Renewable Electricity", Sustainability, vol. 11, no. 12.	Not related to emissions from NG turbines.
Yuan, P., Qiu, Z. & Liu, J. 2017, "Recent enlightening strategies for co2 capture: a review", IOP Conference Series.Earth and Environmental Science, vol. 64, no. 1.	One mention of turbine.
Yuksel, B., Gunerhan, H. & Hepbasli, A. 2020, "Assessing Exergy-Based Economic and Sustainability Analyses of a Military Gas Turbine Engine Fueled with Various Fuels", Energies, vol. 13, no. 15, pp. 3823.	Methanol used in references.
Zamasz, K., Kapłan, R., Kaszyński, P. & Saługa, P.,W. 2020, "An Analysis of Support Mechanisms for New CHPs: The Case of Poland", Energies, vol. 13, no. 21, pp. 5635.	Not U.S. based
Zarębska, J., Zarębski, A. & Adamczyk, J. 2019, "Positive energy practice in Lubuskie District - a case study", IOP Conference Series.Earth and Environmental Science, vol. 214, no. 1.	Not U.S. based
Zhang, G., Dou, L. & Xu, Y. 2019, "Opportunities and challenges of natural gas development and utilization in China", Clean Technologies and Environmental Policy, vol. 21, no. 6, pp. 1193-1211.	Not U.S. based
Zhang, H., Lu, Y., Zhang, X., Xing, W., Wang, Y., Bai, P., Zhang, L., Li, Y., Hayakawa, K., Toriba, A. & Tang, N. 2021, "Characteristics and Health Risks of Polycyclic Aromatic Hydrocarbons and Nitro-PAHs in Xinxiang, China in 2015 and 2017", Internationa	Not U.S. based
Zhang, L., Gao, W., Yang, Y. & Qian, F. 2020, "Impacts of Investment Cost, Energy Prices and Carbon Tax on Promoting the Combined Cooling, Heating and Power (CCHP) System of an Amusement Park Resort in Shanghai", Energies, vol. 13, no. 16, pp. 4252.	Not U.S. based
Zhang, L., Li, F., Sun, B. & Zhang, C. 2019, "Integrated Optimization Design of Combined Cooling, Heating, and Power System Coupled with Solar and Biomass Energy", Energies, vol. 12, no. 4.	Not related to emissions from NG turbines.
Zhang, M., Wang, C., Wang, S., Wang, K. & Ruiqin, Z. 2020, "Assessment of greenhouse gas emissions reduction potential in an industrial park in China", Clean Technologies and Environmental Policy, vol. 22, no. 7, pp. 1435-1448.	Not U.S. based
Zhang, X., Li, S. & Jin, H. 2014, "A Polygeneration System Based on Multi-Input Chemical Looping Combustion", Energies, vol. 7, no. 11, pp. 7166-7177.	Not related to emissions from NG turbines.
Zhang, Y., Wang, S., Shao, W. & Hao, J. 2021, "Feasible Distributed Energy Supply Options for Household Energy Use in China from a Carbon Neutral Perspective", International Journal of Environmental Research and Public Health, vol. 18, no. 24, pp. 12992.	Not U.S. based
Ziembicki, P., Kozioł, J., Bernasiński, J. & Nowogoński, I. 2019, "Innovative System for Heat Recovery and Combustion Gas Cleaning", Energies, vol. 12, no. 22.	One mention of turbine.
Zigan, L. 2018, "Overview of Electric Field Applications in Energy and Process Engineering", Energies, vol. 11, no. 6, pp. 1361.	Not related to emissions from NG turbines.

APPENDIX B. PROQUEST REFERENCES FOR RECIPROCATING ENGINES

Appendix B - ProQuest References for Reciprocating Engines

Reference	ERG Review Note
"73rd STLE ANNUAL MEETING AND EXHIBITION", 2018, Tribology & Lubrication Technology, vol. 74, no. 1, pp. AM1-AM36.	No mention of HAPS or VOCs or NG or emissions
"A Comprehensive Review of the Application Characteristics of Biodiesel Blends in Diesel Engines", 2020, Applied Sciences, vol. 10, no. 22, pp. 8015.	One mention of Toluene as a harmful gas.
"A Self-Powered and Highly Accurate Vibration Sensor Based on Bouncing-Ball Triboelectric Nanogenerator for Intelligent Ship Machinery Monitoring", 2021, Micromachines, vol. 12, no. 2, pp. 218.	No mention of HAPS or VOCs or NG or emissions
"Biogas Upgrading Approaches with Special Focus on Siloxane Removal—A Review", 2020, Energies, vol. 13, no. 22, pp. 6088.	Mentions engines and turbines, removal of siloxane in biogas.
"Dual and Ternary Biofuel Blends for Desalination Process: Emissions and Heat Recovered Assessment", 2021, Energies, vol. 14, no. 1, pp. 61.	studied biofuel blends to operate the (spark) engines used in the desalianation process-pumps, compressors, internal combustion engines, measured CO, CO2 and Unburned HC
"Energy—Water Nexus: Integration, Monitoring, KPIs Tools and Research Vision", 2020, Energies, vol. 13, no. 24, pp. 6697.	Lifecycle Assessment for Sustainable Metropolitan Water, tool kits
"Modern Small and Microcogeneration Systems—A Review", 2021, Energies, vol. 14, no. 3, pp. 785.	review of small/micro energy systems:Stirling engines, gas and steam microturbines, various types of volumetric expanders (vane, lobe, screw, piston, Wankel, gerotor) and fuel cells
"Optimisation of Engine Performance Variables Using Taguchi and Grey Relational Analysis", 2013, National Journal on Advances in Building Sciences and Mechanics, vol. 4, no. 2.	Modelling of perfomance variables for engines.
"Overview of the Development and Application of the Twin Screw Expander", 2020, Energies, vol. 13, no. 24, pp. 6586.	Studied fuel leaks of a twin screw expander for rotor style engines
"Society of General Internal Medicine: 34th Annual Meeting, Phoenix, Arizona, May 4-7, 2011", 2011, Journal of General Internal Medicine, vol. 26, pp. 1-620.	No mention of HAPS or VOCs or NG or emissions
"Southern Regional Meeting Abstracts", 2010, Journal of Investigative Medicine, vol. 58, no. 2, pp. 357.	No mention of HAPS, VOCs or NG
"The Problem of Removing Seaweed from the Beaches: Review of Methods and Machines", 2021, Water, vol. 13, no. 5, pp. 736.	water pollutants, seaweed sieving
"Transesterification of Sunflower Oil over Waste Chicken Eggshell-Based Catalyst in a Microreactor: An Optimization Study", 2021, Micromachines, vol. 12, no. 2, pp. 120.	uses methanol in the process
Aidoun, Z., Falsafioon, M. & Badache, M. 2019, "Current Advances in Ejector Modeling, Experimentation and Applications for Refrigeration and Heat Pumps. Part 1: Single-Phase Ejectors", Inventions, vol. 4, no. 1, pp. 15.	review of heat-driven ejectors and ejector-based machines, using low boiling point working fluids
AKRAMI, A., DOOSTIZADEH, M. & AMINIFAR, F. 2019, "Power system flexibility: an overview of emergence to evolution", Journal of Modern Power Systems and Clean Energy, vol. 7, no. 5, pp. 987-1007.	review of use of renewable energy resources to generate power
Alazizi, A., Barthel, A.J., Surdyka, N.D., Luo, J. & Kim, S.H. 2015, "Vapors in the ambient--A complication in tribological studies or an engineering solution of tribological problems?", Friction, vol. 3, no. 2, pp. 85-114.	No mention of HAPS, VOCs or NG
Aliehyaei, M., Atabi, F., Khorshidvand, M. & Rosen, M.A. 2015, "Exergy, Economic and Environmental Analysis for Simple and Combined Heat and Power IC Engines", Sustainability, vol. 7, no. 4, pp. 4411-4424.	model for IC engines, economic analysis, no emisisons measured
Aljaberi, H.A., Hairuddin, A.A. & Aziz, N.A. 2017, "The use of different types of piston in an HCCI engine: A review", International Journal of Automotive and Mechanical Engineering, vol. 14, pp. 4348.	Homogeneous charge ignition review of uses and designs to improve engine performance.
Alshammari, F., Karvountzis-Kontakiotis, A., Pesyridis, A. & Usman, M. 2018, "Expander Technologies for Automotive Engine Organic Rankine Cycle Applications", Energies, vol. 11, no. 7, pp. 1905.	Benzene and toluene mentioned in one sentence.
Anastopoulos, G., Kaligeros, S., Schinas, P., Zannikou, Y., Karonis, D. & Zannikos, F. 2017, "The Impact of Fatty Acid Diisopropanolamides on Marine Gas Oil Lubricity", Lubricants, vol. 5, no. 3, pp. 28.	lubricant study on marine engines
Anfilatova, N.S., Likhanov, V.A., Lopatin, O.P. & Yurlov, A.S. 2021, "The study of the toxicity of exhaust gases of a diesel engine when operating on methanol and methyl ester of rapeseed oil", Journal of Physics: Conference Series, vol. 1889, no. 4.	bench analysis of alternate fuels for diesel engines
APEX EXPANSION PROJECT, NEVADA, UTAH, WYOMING. [Part 7 of 8]2010, .	Environmental Impact statement for NG pipeline in WY, UT, NV
Arno, d.K. 2015, "Engineering evaluation of direct methane to methanol conversion", Energy Science & Engineering, vol. 3, no. 1, pp. 60-70.	method to convert methane from NG extraction to Methanol, provides generic HC composition of NG
Aziz, M. 2021, "Liquid Hydrogen: A Review on Liquefaction, Storage, Transportation, and Safety", Energies, vol. 14, no. 18, pp. 5917.	lit review on H2 energy storage
Aziz, M., Agung, T.W. & Asep Bayu, D.N. 2020, "Ammonia as Effective Hydrogen Storage: A Review on Production, Storage and Utilization", Energies, vol. 13, no. 12, pp. 3062.	No mention of HAPS or VOCs or NG or emissions
Balanescu, D.T., Homutescu, V.M., Panaite, C.E. & Popescu, A. 2019, "Study on performance of an innovative power system for hybrid propulsion consisting in a gas turbine with heat exchanger and steam turbine", IOP Conference Series.Materials Science and E	micro gas and steam turbine system operating with compressed natural gas is proposed, no emissions
Bamatov, I.M. & Bamatov, D.M. 2019, "Individual components for combined heat and power distillation to produce electricity", Journal of Physics: Conference Series, vol. 1399, no. 3.	review of components in an EGU cogen
Banawan, A.A., El Gohary, ,M.M. & Sadek, I.S. 2010, "Environmental and economical benefits of changing from marine diesel oil to natural-gas fuel for short-voyage high-power passenger ships", Proceedings of the Institution of Mechanical Engineers, vol. 22	studied emission reductions of vessels using NG instead of Diesel to power small ships, NO(x), SO(x), particulate matter, and CO(2) emissions were reduced by 72 per cent, 91 per cent, 85 per cent, and 10 per cent, emission factors
Bauen, A., Bitossi, N., German, L., Harris, A. & Leow, K. 2020, "Sustainable Aviation Fuels: Status, challenges and prospects of drop-in liquid fuels, hydrogen and electrification in aviation", Johnson Matthey Technology Review, vol. 64, no. 3, pp. 263-27	hydrogen as a fuel source
Bayona-Roa, C., Solís-Chaves, ,J.S., Bonilla, J., Rodriguez-Melendez, A. & Castellanos, D. 2019, "Computational Simulation of PT6A Gas Turbine Engine Operating with Different Blends of Biodiesel—A Transient-Response Analysis", Energies, vol. 12, no. 22.	modeling gas turbine engine w/ blended biodiesel, no emissions
Belmonte, M. & Miranzo, P. 2021, "Applications of Ceramic/Graphene Composites and Hybrids", Materials, vol. 14, no. 8, pp. 2071.	lite review of ceramic metal oxide application
Bhutta, M.U., Khan, Z.A., Garland, N. & Ghafoor, A. 2018, "A Historical Review on the Tribological Performance of Refrigerants used in Compressors", Tribology in Industry, vol. 40, no. 1, pp. 19-51.	No mention of HAPS or VOCs or NG or emissions
Bodunrin, M.O., Burman, N.W., Croft, J., Engelbrecht, S., Goga, T., Ladenika, A.O., MacGregor, O.S., Maepa, M. & Harding, K.G. 2018, "The availability of life-cycle assessment, water footprinting, and carbon footprinting studies in Brazil", The Internatio	literature review for life cycle assessment data

Appendix B - ProQuest References for Reciprocating Engines

Reference	ERG Review Note
Boulmrharj, S., Khaidar, M., Bakhouya, M., Ouladsine, R., Siniti, M. & Zine-dine, K. 2020, "Performance Assessment of a Hybrid System with Hydrogen Storage and Fuel Cell for Cogeneration in Buildings", Sustainability, vol. 12, no. 12, pp. 4832.	performance efficiency evaluated for a hybrid Cogeneration unit
Cai, M., Yu, Q., Zhou, F. & Liu, W. 2017, "Physicochemistry aspects on frictional interfaces", Friction, vol. 5, no. 4, pp. 361-382.	No mention of HAPS or VOCs or NG or emissions
Calise, F., Costa, M., Wang, Q., Zhang, X. & Duić, N. 2018, "Recent Advances in the Analysis of Sustainable Energy Systems", Energies, vol. 11, no. 10.	No mention of HAPS or VOCs or NG or emissions
Calise, F., Vicidomini, M., Costa, M., Wang, Q., Poul Alberg Østergaard & Duić, N. 2019, "Toward an Efficient and Sustainable Use of Energy in Industries and Cities", Energies, vol. 12, no. 16.	No mention of HAPS or VOCs or NG or emissions
Canter, N. 2010, "What is 'green?'", Tribology & Lubrication Technology, vol. 66, no. 12, pp. 50-58.	No mention of HAPS or VOCs or NG or emissions
CAO, Y., LI, Q., TAN, Y., LI, Y., CHEN, Y., SHAO, X. & ZOU, Y. 2018, "A comprehensive review of Energy Internet: basic concept, operation and planning methods, and research prospects", Journal of Modern Power Systems and Clean Energy, vol. 6, no. 3, pp. 3	basic concept and characteristics of the Energy Internet are summarized, and its basic structural framework is analyzed in detail.
Castellani, B., Morini, E., Nastasi, B., Nicolini, A. & Rossi, F. 2018, "Small-Scale Compressed Air Energy Storage Application for Renewable Energy Integration in a Listed Building", Energies, vol. 11, no. 7, pp. 1921.	prototype system consisting of using the renewable energy from a photovoltaic (PV) array to compress air for a later expansion to produce electricity when needed
Chakraborty, S., Nallapaneni, M.K., Jayakumar, A., Dash, S.K. & Elangovan, D. 2021, "Selected Aspects of Sustainable Mobility Reveals Implementable Approaches and Conceivable Actions", Sustainability, vol. 13, no. 22, pp. 12918.	lit review sustainable mobility, mentions HAPS as hazardous polls,
Chala, G.T., Abd Rashid, A.A. & Hagos, F.Y. 2018, "Natural Gas Engine Technologies: Challenges and Energy Sustainability Issue", Energies, vol. 11, no. 11.	composition of NG, internal combustion, CNG engines
Chang, S.H. 2020, "Utilization of green organic solvents in solvent extraction and liquid membrane for sustainable wastewater treatment and resource recovery—a review", Environmental science and pollution research international, vol. 27, no. 26, pp. 32371	No mention of HAPS or VOCs or NG or emissions
Choudhary, A. & Gokhale, S. 2019, "Evaluation of emission reduction benefits of traffic flow management and technology upgrade in a congested urban traffic corridor", Clean Technologies and Environmental Policy, vol. 21, no. 2, pp. 257-273.	vehicle emission reduction via time management
Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards2013, , Federal Information & News Dispatch, LLC, Washington.	No mention of HAP (only as part of another word (e.g., chap))
Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards2014, , Federal Information & News Dispatch, LLC, Washington.	Two mentions of Hexane (used for dilution). Lots of Methonal citations, but mostly for methanol/oil ratio.
Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder2010, , Federal Information & News Dispatch, LLC, Washington.	nonroad diesel engines O&G regulations, no HAPs, VOCs, NG
Cordtz, R., Mayer, S., Eskildsen, S.S. & Schramm, J. 2018, "Modeling the condensation of sulfuric acid and water on the cylinder liner of a large two-stroke marine diesel engine", Journal of Marine Science and Technology, vol. 23, no. 1, pp. 178-187.	No mention of HAPS or VOCs or NG or emissions
CORPORATE AVERAGE FUEL ECONOMY STANDARDS, PASSENGER CARS AND LIGHT TRUCKS, MODEL YEARS 2012-2016. [Part 3 of 3]2010, .	2010 Standards, no mention HAPS, VOC or NG
Cortez, L., Telma, T.F., Valença, G. & Rosillo-Calle, F. 2021, "Perspective Use of Fast Pyrolysis Bio-Oil (FPBO) in Maritime Transport: The Case of Brazil", Energies, vol. 14, no. 16, pp. 4779.	review of energy alternatives focus on biofuels, no VOC or HAPS, mentions compression engines
Costa, M., Buono, A., Caputo, C., Carotenuto, A., Cirillo, D., Costagliola, M.A., Blasio, G.D., La Villetta, M., Macaluso, A., Martoriello, G., Massarotti, N., Mauro, A., Migliaccio, M., Mulone, V., Murena, F., Piazzullo, D., Prati, M.V., Rocco, V., Stasi	measured emissions from exhaust of 4-cylender,2-stroke IC engine, varied fuel types - no NG
Datta, A. & Mandal, B.K. 2018, "Numerical prediction of the performance, combustion and emission characteristics of a CI engine using different biodiesels", Clean Technologies and Environmental Policy, vol. 20, no. 8, pp. 1773-1790.	Modelling of perfomance and emisison characteristices variables for CI engines.
Demuynck, J., De Paepe, M., Sileghem, L., Vancoillie, J., Verhelst, S. & Chana, K. 2012, "Applying Design of Experiments to Determine the Effect of Gas Properties on In-Cylinder Heat Flux in a Motored SI Engine", SAE International Journal of Engines, vol.	measured heat flux in SI engines
Deng, Y., Wang, X., Li, R., Han, Z., Wu, H., Dong, J., Cui, W. & Guo, Y. 2021, "Study on characteristics of particulate emission of diesel aftertreatment with reciprocating flow", Energy Science & Engineering, vol. 9, no. 4, pp. 535-547.	Characterization of Diesel exhaust gas, CO, PM, NO, NO2
De-Xing, P. 2017, "Effect of unleaded gasoline blended with biofuels on gasoline injector wear and exhaust emissions", Industrial Lubrication and Tribology, vol. 69, no. 2, pp. 208-214.	No mention of HAPS or VOCs or NG or emissions
Dodero, M., Bertagna, S., Alberto Marino' & Bucci, V. 2020, "Performance In-Live of Marine Engines: A Tool for Its Evaluation", Applied Sciences, vol. 10, no. 16, pp. 5707.	No mention of HAPS or VOCs or NG or emissions
Doustdar, O., Wyszynski, M.L., Mahmoudi, H. & Tsolakis, A. 2016, "Enhancing the properties of Fischer-Tropsch fuel produced from syngas over Co/SiO2 catalyst: Lubricity and Calorific Value", IOP Conference Series.Materials Science and Engineering, vol. 14	No mention of HAPS or VOCs or NG or emissions
Dziubak, T. & Dziubak, S.D. 2020, "Experimental Study of Filtration Materials Used in the Car Air Intake", Materials, vol. 13, no. 16, pp. 3498.	car filters for PM
FORT STEWART TRAINING RANGE AND GARRISON SUPPORT FACILITIES CONSTRUCTION AND OPERATION, LIBERTY, LONG, BRYAN, EVANS, AND TATTNALL COUNTIES, GEORGIA. [Part 30 of 32]2010, .	No mention of HAPS or VOCs or NG or emissions
Ftwi, Y.H., Aziz, A.R. & Shaharin, A.S. 2014, "Trends of Syngas as a Fuel in Internal Combustion Engines", Advances in Mechanical Engineering, .	review of fuels used for Internal combustion engines
Fuc, P., Kurczewski, P., Lewandowska, A., Nowak, E., Selech, J. & Ziolkowski, A. 2016, "An environmental life cycle assessment of forklift operation: a well-to-wheel analysis", The International Journal of Life Cycle Assessment, vol. 21, no. 10, pp. 1438-	Life cycle assessment of fork lifts, emissions measured
Gandiglio, M., Lanzini, A., Soto, A., Leone, P. & Santarelli, M. 2017, "Enhancing the Energy Efficiency of Wastewater Treatment Plants through Co-digestion and Fuel Cell Systems", Frontiers in Environmental Science, .	No mention of HAPS or VOCs or NG or emissions
Ghaderi, M., Javadikia, H., Naderloo, L., Mostafaei, M. & Rabbani, H. 2019, "Analysis of noise pollution emitted by stationary MF285 tractor using different mixtures of biodiesel, bioethanol, and diesel through artificial intelligence", Environmental scie	noise pollution measured for engines with different fuel types

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Reference	ERG Review Note
Gheorghe, D., Tutunea, D., Bică, M., Gruia, A. & Calbureanu, M. 2019, "Hydrogen a new fuel for internal combustion engines", IOP Conference Series.Materials Science and Engineering, vol. 595, no. 1.	review of limitations, challenges and perspectives on the combustion technologies such dual fuel engines, homogeneous charge compression ignition (HCCI) and low-temperature combustion (LTC). T
Gil-Lopez, T. & Verdu-Vazquez, A. 2021, "Environmental Analysis of the Use of Liquefied Natural Gas in Maritime Transport within the Port Environment", Sustainability, vol. 13, no. 21, pp. 11989.	Marine engines, analysis of LNG, auxillary engines, EF for NOX, Sox, CO2, PM
Gilmore, E.A., Adams, P.J. & Lave, L.B. 2010, "Using Backup Generators for Meeting Peak Electricity Demand: A Sensitivity Analysis on Emission Controls, Location, and Health Endpoints", Journal of the Air & Waste Management Association, vol. 60, no. 5, pp	emissions from back-up generators before and after controls, modelling
Gimelli, A. & Muccillo, M. 2021, "Development of a 1 kW Micro-Polygeneration System Fueled by Natural Gas for Single-Family Users", Energies, vol. 14, no. 24, pp. 8372.	Measured CO2, Nox, speciated HCs for 2-stroke gas engines at different RPM.
González-Espasandín, Ó., Leo, T.J. & Navarro-Arévalo, E. 2014, "Fuel Cells: A Real Option for Unmanned Aerial Vehicles Propulsion", The Scientific World Journal, vol. 2014.	No mention of HAPS or VOCs or NG or emissions
Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles--Phase 22015, , Federal Information & News Dispatch, LLC, Washington.	all vehicle emissions, No mention of HAPS or VOCs or NG
Grljusic, M., Medica, V. & Racic, N. 2014, "Thermodynamic Analysis of a Ship Power Plant Operating with Waste Heat Recovery through Combined Heat and Power Production", Energies, vol. 7, no. 11, pp. 7368-7394.	heat analysis of cogen plant using low-temp waste
Ireneusz, S., Sozańska, M., Biegańska Jolanta, Cebula, J. & Jacek, N. 2020, "Fluctuations of the elemental composition in the layers of mineral deposits formed on the elements of biogas engines", Scientific Reports (Nature Publisher Group), vol. 10, no. 1	study mineral deposits composition left on engines using syngas
Ismail, A.J., Bhandari, R. & Zerga, A. 2019, "Environmental Life Cycle Assessment of Grid-Integrated Hybrid Renewable Energy Systems in Northern Nigeria", Sustainability, vol. 11, no. 21, pp. 5889.	Mentions of Hexane and Methanol as working fluids.
J.W.G. Turner, Blundell, D.W., Pearson, R.J., Patel, R., Larkman, D.B., Burke, P., Richardson, S., Green, N.M., Brewster, S., Kenny, R.G. & Kee, R.J. 2010, "Project Omnivore: A Variable Compression Ratio ATAC 2-Stroke Engine for Ultra-Wide-Range HCCI Oper	review of new compression engine types
Jagadish, D., Puli, R.K. & Murthy, K.M. 2011, "The effect of supercharging on performance and emission characteristics of C.I. Engine with diesel-ethanol-ester blends", Thermal Science, vol. 15, no. 4, pp. 1165-1174.	measured emissions from a direct injection Diesel engine using ethanol diesel blends with palm stearin methyl ester as additive.
Jamrozik, A., Tutak, W., Gnatowska, R. & Nowak, Ł. 2019, "Comparative Analysis of the Combustion Stability of Diesel-Methanol and Diesel-Ethanol in a Dual Fuel Engine", Energies, vol. 12, no. 6.	combustion stability analysis, dual fuel engine using diesel/alcohol mixtures
Javier, C.G., Guillermo, V.O. & Duarte-Forero, J. 2020, "Regenerative Organic Rankine Cycle as Bottoming Cycle of an Industrial Gas Engine: Traditional and Advanced Exergetic Analysis", Applied Sciences, vol. 10, no. 13, pp. 4411.	No mention of HAPS, VOCs or NG or emissions
Jayaram, V. 2010, Analytical framework to evaluate emission control systems for marine engines, University of California, Riverside.	emission controls on ships
Jia, X.C., Wong, J.F., Petrů, M., Hassan, A., Nirmal, U., Othman, N. & Rushdan, A.I. 2021, "Effect of Nanofillers on Tribological Properties of Polymer Nanocomposites: A Review on Recent Development", Polymers, vol. 13, no. 17, pp. 2867.	No mention of HAPS or VOCs or NG or emissions
Johannes, L.H. & Jacobus, C.E. 2019, "Noise Sources and Control, and Exposure Groups in Chemical Manufacturing Plants", Applied Sciences, vol. 9, no. 17, pp. 3523.	noise pollution
John, J.C., Melgar, A. & Tinaut, F.V. 2021, "Influence of Environmental Changes Due to Altitude on Performance, Fuel Consumption and Emissions of a Naturally Aspirated Diesel Engine", Energies, vol. 14, no. 17, pp. 5346.	variatied the atmospheric temperature, pressure and relative humidity is carried out in AVL BOOST™, showing the effects on mean effective pressure, fuel consumption and specific pollutant emissions (CO_2, NOx, CO and soot
Kagiri, C., Zhang, L. & Xia, X. 2019, "A Hierarchical Optimisation of a Compressed Natural Gas Station for Energy and Fuelling Efficiency under a Demand Response Program", Energies, vol. 12, no. 11, pp. 2165.	No mention of HAPS or VOCs or NG or emissions
Karczewski, M., Chojnowski, J. & Szamrej, G. 2021, "A Review of Low-CO2 Emission Fuels for a Dual-Fuel RCCI Engine", Energies, vol. 14, no. 16, pp. 5067.	measured CO2 emissions from IC engine, fuel with H2 additive tested
Kharazmi, S., Mozafari, A. & Hajilouy-Benisi, A. 2014, "Simulation and experimental investigation of performance and emissions of a turbocharged lean-burn natural gas engine considering thermal boundary layer", Scientia Iranica.Transaction B, Mechanical E	modelled emissions for a lean burn NG SI engine, NO, CO2 and Unburned HC.
Kim, D., Kyung-Tae, K. & Young-Kwon, P. 2020, "A Comparative Study on the Reduction Effect in Greenhouse Gas Emissions between the Combined Heat and Power Plant and Boiler", Sustainability, vol. 12, no. 12, pp. 5144.	life cycle assessment of CHPP plant and boilers, compared lower GHG emissions to performance.
Kim, S., Sim, J., Cho, Y., Back-Sub Sung & Park, J. 2021, "Numerical Study on the Performance and NOx Emission Characteristics of an 800cc MPI Turbocharged SI Engine", Energies, vol. 14, no. 21, pp. 7419.	optimize engine performance and NOX emission characteristics of off-road engines with retarded spark timing compared to MBT by repurposing the existing passenger engine
Kirmse, C.J.W., Oyewunmi, O.A., Haslam, A.J. & Markides, C.N. 2016, "Comparison of a Novel Organic-Fluid Thermofluidic Heat Converter and an Organic Rankine Cycle Heat Engine[dagger]", Energies, vol. 9, no. 7, pp. 479.	No mention of HAPS or VOCs or NG or emissions
Klein-Banai, C. 2010, "RESEARCH ARTICLE: A Greenhouse Gas Inventory as a Measure of Sustainability for an Urban Public Research University", Environmental Practice, vol. 12, no. 1, pp. 35-47.	GHG inventory for a public university
Kolasiński, P. 2020, "Domestic Organic Rankine Cycle-Based Cogeneration Systems as a Way to Reduce Dust Emissions in Municipal Heating", Energies, vol. 13, no. 15, pp. 3983.	No mention of HAPS or VOCs or NG or emissions
Kook, S. & Pickett, L.M. 2012, "Soot Volume Fraction and Morphology of Conventional, Fischer-Tropsch, Coal-Derived, and Surrogate Fuel at Diesel Conditions", SAE International Journal of Fuels and Lubricants, vol. 5, no. 2, pp. 647-664.	investegated soot formation, and oxidation processes for vaious fuels,
Kousheshi, N., Yari, M., Paykani, A., Ali, S.M. & German F de, l.F. 2020, "Effect of Syngas Composition on the Combustion and Emissions Characteristics of a Syngas/Diesel RCCI Engine", Energies, vol. 13, no. 1, pp. 212.	Modelling of emisisons from a Reactivity controlled compression ignition (RCCI)with two different fuels with different reactivities. RCCI provides more control over the combustion process can dramatically lower combustion temperature and NO_X and PM emissions.
Krutilla, K., Good, D.H. & Graham, J.D. 2015, "Uncertainty in the Cost-Effectiveness of Federal Air Quality Regulations", Journal of Benefit-Cost Analysis, vol. 6, no. 1, pp. 66-111.	No mention of HAPS or VOCs or NG or emissions
Kumar, A., Rajakumar, D.G., Mownesh, G.K. & Basavarajappa 2020, "CFD Simulation of Producer Gas Fuelled SI Engine", IOP Conference Series.Materials Science and Engineering, vol. 925, no. 1.	SI internal combustion engin, Modelling varying the fuel burning rate, measured performance efficiency.

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Reference	ERG Review Note
Kumar, A., Tirkey, J. & Shukla, S.K. 2018, "Performance investigation of compression ignition engine using empirical correlation for burning duration", Thermal Science, vol. 22, no. 3, pp. 1311-1323.	modelled CI engine PM output when varying combustion time
Kwonse, K. & Dooseuk, C. 2018, "Thermodynamic kernel, IMEP, and response based on three plasma energies", Journal of Mechanical Science and Technology, vol. 32, no. 8, pp. 3983-3994.	No mention of HAPS or VOCs or NG or emissions
Labeckas, G., Slavinskas, S. & Kanapkienė, I. 2019, "Study of the Effects of Biofuel-Oxygen of Various Origins on a CRDI Diesel Engine Combustion and Emissions", Energies, vol. 12, no. 7, pp. 1241.	hydrotreated renewable diesle fuel blends, fuel-O2 mas changed, NOX, PM, total HC, soot
Lacerda, A., Rodrigues de Souza, G., Jorge, N.B. & Soto, F. 2021, "Numerical Study to Achieve Low Fuel Consumption and Nitrogen Oxides Emissions in a Split-Cycle Engine Adapted from the Conventional Architecture", SAE International Journal of Engines, vol	Numerical Study to Achieve Low Fuel Consumption and Nitrogen Oxides Emissions in a Split-Cycle Engine Adapted from the Conventional Architecture, tbl 3 provides NX emissions for conventional ICE (Silva)
Latiff, Z.A., Aziz, A.A., Perang, M.R.M. & Abdullah, N. 2013, "The Effect of Fuel Additives on Gasoline Heating Value and Spark Ignition Engine Performance: Case Study", Applied Mechanics and Materials, vol. 388, pp. 301.	No mention of HAPS or VOCs or NG or emissions
Lehtovaara, M., Kokkonen, K., Rousku, P. & Kässi, T. 2011, "Firms' Collaboration Within Their Business Networks in Bioenergy Technology: A Case Study", International Journal of Industrial Engineering and Management, vol. 2, no. 3, pp. 87-97.	No mention of HAPS or VOCs or NG or emissions
Li, C., Li, M., Wang, X., Feng, W., Zhang, Q., Wu, B. & Hu, X. 2019, "Novel Carbon Nanoparticles Derived from Biodiesel Soot as Lubricant Additives", Nanomaterials, vol. 9, no. 8.	No mention of HAPS or VOCs or NG or emissions
Li, C.L., Foscoli, B., Mastorakos, E. & Evans, S. 2021, "A Comparison of Alternative Fuels for Shipping in Terms of Lifecycle Energy and Cost", Energies, vol. 14, no. 24, pp. 8502.	energy efficiency and cost of fuels for shipping
Li, M., Luo, N. & Lu, Y. 2017, "Biomass Energy Technological Paradigm (BETP): Trends in This Sector", Sustainability, vol. 9, no. 4, pp. 567.	No mention of HAPS, VOCs or NG or emissions
Li, X., Chen, L., Wu, L., Xu, H. & Dong, J. 2017, "Green Synthesis of Double Long-Chain Diglycerol Diacetal and Its Application as Lubricating Base Oil", JAOCS, Journal of the American Oil Chemists' Society, vol. 94, no. 10, pp. 1301-1311.	lubricant synthesis
Liang, F., Ryvak, M., Sayeed, S. & Zhao, N. 2012, "The role of natural gas as a primary fuel in the near future, including comparisons of acquisition, transmission and waste handling costs of as with competitive alternatives", Chemistry Central Journal, v	One mention of methanol in the references.
Lillo, P.M., Pickett, L.M., Persson, H., Andersson, O. & Kook, S. 2012, "Diesel Spray Ignition Detection and Spatial/Temporal Correction", SAE International Journal of Engines, vol. 5, no. 3, pp. 1330-1346.	spark ignition engines study, no emissions
Lin, R., Liu, Y., Man, Y. & Ren, J. 2019, "Towards a sustainable distributed energy system in China: decision-making for strategies and policy implications", Energy, Sustainability and Society, vol. 9, no. 1, pp. 1-25.	No mention of HAPS, VOCs or NG or emissions
Liso, V., Cui, X., Li, N., Zhu, J., Sahlin, S.L., Jensen, S., Nielsen, M.P. & Søren Knudsen Kær 2020, "A Review of The Methanol Economy: The Fuel Cell Route", Energies, vol. 13, no. 3, pp. 596.	research of methanol use in energy systems for net-zero emission carbon cycle
Liu, B., Liu, J., Chen, T., Yang, B., Jiang, Y., Wei, D. & Chen, F. 2015, "Rapid Characterization of Fatty Acids in Oleaginous Microalgae by Near-Infrared Spectroscopy", International Journal of Molecular Sciences, vol. 16, no. 4, pp. 7045-7056.	analysis of biodiesel for fatty acids
Liu, L., Guo, X., Liu, W. & Lee, C. 2021, "Recent Progress in the Energy Harvesting Technology—From Self-Powered Sensors to Self-Sustained IoT, and New Applications", Nanomaterials, vol. 11, no. 11, pp. 2975.	sensors/IOT
Lopatin, O.P. 2020, "Calculation of the process of nitrogen oxides formation during combustion of methanol in the engine", IOP Conference Series.Materials Science and Engineering, vol. 919, no. 6.	method is based on a two-zone model and allows calculating the pressure and temperature (fresh mixture and combustion products), cycle indicators, as well as the current concentration of nitrogen oxides (NO) in the combustion chamber as a function of the crank angle.
Lu, Q., Zhang, Z., Liao, H., Yang, X. & Dong, C. 2012, "Lubrication Properties of Bio-Oil and Its Emulsions with Diesel Oil", Energies, vol. 5, no. 3, pp. 741-751.	lubricants
Luna, C., Luna, D., Bautista, F.M., Calero, J., Romero, A.A., Posadillo, A., Sancho, E.D. & Estevez, R. 2018, "Evaluation of Lipases from Wild Microbial Strains as Biocatalysts in Biodiesel Production", Separations, vol. 5, no. 4, pp. 53.	No mention of HAPS or VOCs or NG or emissions
Luna, C., Sancho, E., Luna, D., Caballero, V., Calero, J., Posadillo, A., Verdugo, C., Bautista, F.M. & Romero, A.A. 2013, "Biofuel that Keeps Glycerol as Monoglyceride by 1,3-Selective Ethanolysis with Pig Pancreatic Lipase Covalently Immobilized on AlPO	No mention of HAPS or VOCs or NG or emissions
Luna, C., Verdugo, C., Sancho, E.D., Luna, D., Calero, J., Posadillo, A., Bautista, F.M. & Romero, A.A. 2014, "Biocatalytic Behaviour of Immobilized Rhizopus oryzae Lipase in the 1,3-Selective Ethanolysis of Sunflower Oil to Obtain a Biofuel Similar to Bi	No mention of HAPS or VOCs or NG or emissions
Ma, F., Zhao, Z., Zhang, Y., Wang, J., Feng, Y., Su, T., Zhang, Y. & Liu, Y. 2017, "Simulation Modeling Method and Experimental Investigation on the Uniflow Scavenging System of an Opposed-Piston Folded-Cranktrain Diesel Engine", Energies, vol. 10, no. 5,	No mention of HAPS or VOCs or NG or emissions
Mahdisoozani, H., Mohsenizadeh, M., Bahiraei, M., Kasaeian, A., Daneshvar, A., Goodarzi, M. & Safaei, M.R. 2019, "Performance Enhancement of Internal Combustion Engines through Vibration Control: State of the Art and Challenges", Applied Sciences, vol. 9,	No mention of HAPS or VOCs or NG or emissions
Mahmood, H.A., Al-Sulttani, A. & Attia, O.H. 2021, "Simulation of Syngas Addition Effect on Emissions Characteristics, Combustion, and Performance of the Diesel Engine Working under Dual Fuel Mode and Lambda Value of 1.6", IOP Conference Series.Earth and	model of combustion characteristics, dual-fuel diesel/sysgas engine, measured efficiency, emissions no, cO2, CO.
Malingappa, P. & Yarradoddappa, V. 2014, "A Continuous Flow System for the Measurement of Ambient Nitrogen Oxides [NO + NO2] Using Rhodamine B Hydrazide as a Chemosensor", Analytical Chemistry Insights, vol. 9, pp. 67-73.	analysis of NO2, no emissions
Marcantonio, V., Müller, M. & Bocci, E. 2021, "A Review of Hot Gas Cleaning Techniques for Hydrogen Chloride Removal from Biomass-Derived Syngas", Energies, vol. 14, no. 20, pp. 6519.	review scrubbing methods for Cl
Martin, J.M., Matta, C., Bouchet, M.D., Barros, Forest, C., Le Mogne, T., Dubois, T. & Mazarin, M. 2013, "Mechanism of friction reduction of unsaturated fatty acids as additives in diesel fuels", Friction, vol. 1, no. 3, pp. 252-258.	lubricants
Martinez-Nolasco, J., Samano-Ortega, V., Rodriguez-Segura, E., Orozco-Guerrero, R. & Santoyo-Mora, M. 2021, "Implementation of an Embedded Control for the Maximum Power Point Tracker in Photovoltaic systems", Journal of Electrical Systems, vol. 17, no. 4,	No mention of HAPS or VOCs or NG or emissions
Mbamalu, V.C. 2013, Glycerin and the market, The University of Tennessee at Chattanooga.	No mention of HAPS or VOCs or NG or emissions

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Reference	ERG Review Note
Michaelides, E.E. 2021, "Thermodynamics, Energy Dissipation, and Figures of Merit of Energy Storage Systems—A Critical Review", Energies, vol. 14, no. 19, pp. 6121.	No mention of HAPS or VOCs or NG or emissions
Müllerová, D., Landis, M., Schiess, I., Jablonický, J. & Prístavka, M. 2011, "Operating parameters and emission evaluation of tractors running on diesel oil and biofuel", Research in Agricultural Engineering, vol. 57, pp. 35-42.	emission analysis of combusion exhaust from 2 engines and diesel oil
Napoleon, E., Cuartero-Enteria Odinah & Takao, S. 2020, "Review of the advances and applications of variable refrigerant flow heating, ventilating, and air-conditioning systems for improving indoor thermal comfort and air quality", International Journal o	No mention of HAPS or VOCs or NG or emissions
National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers2010, , Federal Information & News Dispatch, LLC, Washington.	standards on Industrial boilers
National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines2010, , Federal Information & News Dispatch, LLC, Washington.	No mention of speciated VOCs emissions factor as a term.
National Emission Standards for Hazardous Air Pollutants From Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial-Institutional, and Small Industrial-Commer	standards HAPS from Coal and Oil fired EGU
Niculescu, R., Clenci, A. & Iorga-Siman, V. 2019, "Review on the Use of Diesel–Biodiesel–Alcohol Blends in Compression Ignition Engines", Energies, vol. 12, no. 7, pp. 1194.	lit review, CI engines, biodiesel/alc mixtures
Nirmala, P., Ramkumar, G., Sahoo, S., Anitha, G., Ramesh, S., Shifani, S.A. & Agegnehu, S.S. 2021, "Artificial Intelligence to Analyze the Performance of the Ceramic-Coated Diesel Engine Using Digital Filter Optimization", Advances in Materials Science an	No mention of HAPS or VOCs or NG or emissions
NO Formation and Autoignition Dynamics during Combustion of H2O-Diluted NH3/H2O2 Mixtures with Air.,Energies 2021, 14(1), 84; https://doi.org/10.3390/en14010084	No mention of HAPS or VOCs or NG or emissions
Nowak, P., Kucharska, K. & Kamiński, M. 2019, "Ecological and Health Effects of Lubricant Oils Emitted into the Environment", International Journal of Environmental Research and Public Health, vol. 16, no. 16.	One mention of Toluene in references. No mention of emissions factors as a term.
Obaid, J., Ramadan, A., Elkamel, A. & Anderson, W. 2017, "Comparing Non-Steady State Emissions under Start-Up and Shut-Down Operating Conditions with Steady State Emissions for Several Industrial Sectors: A Literature Review", Energies, vol. 10, no. 2, pp	One mention of methanol in the references.
Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews2011, , Federal Information & News Dispatch, LLC, Washington.	NSPS HAPS 2011
Olaguer, E.P. 2021, "The Potential Ozone Impacts of Landfills", Atmosphere, vol. 12, no. 7, pp. 877.	No mention of "conc" or "emi"
Orwell, M., Andreas, H., Little, N., Foster, S.N. & Isaac, R. 2021, "Feasibility of hydrogen fuel cell technology for railway intercity services: a case study for the Piedmont in North Carolina", Railway Engineering Science, vol. 29, no. 3, pp. 258-270.	study of use of hydrogen fuel cells for Piedmont railroad
Osigwe, E.O., Gad-Briggs, A. & Nikolaidis, T. 2021, "Feasibility of a Helium Closed-Cycle Gas Turbine for UAV Propulsion", Applied Sciences, vol. 11, no. 1, pp. 28.	experimental turbines
Otremba, Z. 2019, "Detecting the Presence of Different Types of Oil in Seawater Using a Fluorometric Index", Sensors, vol. 19, no. 17, pp. 3774.	No mention of HAPS or VOCs or NG or emissions
Ozbay, G., Jones, M., Gadde, M., Isah, S. & Attarwala, T. 2021, "Design and Operation of Effective Landfills with Minimal Effects on the Environment and Human Health", Journal of Environmental and Public Health, vol. 2021.	landfill management, no emisisons measured
Papagiannakis, R.G., Rakopoulos, D.C. & Rakopoulos, C.D. 2017, "Theoretical Study of the Effects of Spark Timing on the Performance and Emissions of a Light-Duty Spark Ignited Engine Running under Either Gasoline or Ethanol or Butanol Fuel Operating Modes	four-stroke, SI engine running under three different fuel operating mode, NO and CO
Papagiannakis, R.G., Rakopoulos, D.C. & Rakopoulos, C.D. 2018, "Evaluation of the Air Oxygen Enrichment Effects on Combustion and Emissions of Natural Gas/Diesel Dual-Fuel Engines at Various Loads and Pilot Fuel Quantities", Energies, vol. 11, no. 11.	modelled effect of air/O2 mix with NG/Biodiesel blends using a NG/DDF engine
Pastor, J.V., Payri, R., GarciaOliver, J.M. & Briceño, F.,J. 2013, "Schlieren Methodology for the Analysis of Transient Diesel Flame Evolution", SAE International Journal of Engines, vol. 6, no. 3, pp. 1661-1676.	tip penetration analysis of sprays under diesel-like engine conditions.
Patel, A., Mu, L., Shi, Y., Rova, U., Christakopoulos, P. & Matsakas, L. 2021, "Single-Cell Oils from Oleaginous Microorganisms as Green Bio-Lubricants: Studies on Their Tribological Performance", Energies, vol. 14, no. 20, pp. 6685.	lubricants
Payri, F., Pastor, J.V., Nerva, J. & GarciaOliver, J.M. 2011, "Lift-Off Length and KL Extinction Measurements of Biodiesel and Fischer-Tropsch Fuels under Quasi-Steady Diesel Engine Conditions", SAE International Journal of Engines, vol. 4, no. 2, pp. 227	2-stroke diesel engine, tested additives to DIE
Pekney, Natalie J., et al. "Measurement of Atmospheric Pollutants Associated with Oil and Natural Gas Exploration and Production Activity in Pennsylvania's Allegheny National Forest." Journal of the Air & Waste Management Association 64.9 (2014): 1062.	A mobile, autonomous air quality monitoring laboratory was constructed to collect measurements of ambient concentrations of pollutants (NOX, O3, PM, VOC) associated with oil and natural gas E&P activities.
Pellegrini, M., Guzzini, A. & Saccani, C. 2020, "A Preliminary Assessment of the Potential of Low Percentage Green Hydrogen Blending in the Italian Natural Gas Network", Energies, vol. 13, no. 21, pp. 5570.	studied hydrogen blending with diesel,no emissions
Peng, Q. & Du, Q. 2016, "Progress in Heat Pump Air Conditioning Systems for Electric Vehicles-A Review", Energies, vol. 9, no. 4, pp. 240.	No mention of HAPS or VOCs or NG or emissions
Perić, M.,M., Komatina, M.S., Antonijević, D., Bugarski, B.M. & Dželetović, Ž.,S. 2019, "Diesel production by fast pyrolysis of Miscanthus giganteus, well-to-pump analysis using the greet model", Thermal Science, vol. 23, no. 1, pp. 365-378.	tested method for producing diesel
Pielecha, I., Wierzbicki, S., Sidorowicz, M. & Pietras, D. 2021, "Combustion Thermodynamics of Ethanol, n-Heptane, and n-Butanol in a Rapid Compression Machine with a Dual Direct Injection (DDI) Supply System", Energies, vol. 14, no. 9, pp. 2729.	DI duel fuel in test engine (rapid compression machine) varied parameters,
Point Thomson Project, North Slope, Alaska. [Part 18 of 35]2011, .	Fed register proposed rules for O&G leases, 2011
Posen, I.D., Jaramillo, P., Landis, A.E. & Griffin, W.M. 2017, "Greenhouse gas mitigation for U.S. plastics production: energy first, feedstocks later", Environmental Research Letters, vol. 12, no. 3.	No mention of HAPS, focus on plastics
Preißinger, M. & Brüggemann, D. 2017, "Thermoeconomic Evaluation of Modular Organic Rankine Cycles for Waste Heat Recovery over a Broad Range of Heat Source Temperatures and Capacities", Energies, vol. 10, no. 3, pp. 269.	thermoeconomic modelling for an Organic Rankine Cycle to find best fuel sources
PROPOSED ABENGOA BIOREFINERY PROJECT NEAR HUGOTON, STEVENS COUNTY, KANSAS. [Part 2 of 3]2010, .	Federal Register record of decision based for Biorefineray EGU construction.

Appendix B - ProQuest References for Reciprocating Engines

Reference	ERG Review Note
Quang, D.V., Kim, J., Choi, J., Jae-ung, L., Ji-woong, L., Jeon, H., Jung-Ho, N., Yoon, S.H. & Won-Ju, L. 2021, "Study on the Variable Speed Diesel Generator and Effects on Structure Vibration Behavior in the DC Grid", Applied Sciences, vol. 11, no. 24, p	No mention of HAPS or VOCs or NG or emissions
Ragsdale,John W.,,Jr 2013, "To Return from Where We Started: A Re visioning of Property, Land Use, Economy, and Regulation in America", The Urban Lawyer, vol. 45, no. 3, pp. 631-692.	No mention of HAPS or VOCs or NG or emissions
Ramirez, J.A., Brown, R.J. & Rainey, T.J. 2015, "A Review of Hydrothermal Liquefaction Bio-Crude Properties and Prospects for Upgrading to Transportation Fuels", Energies, vol. 8, no. 7, pp. 6765-6794.	Methanol citations are part of "biomethanol"
Rao, P.R. 2017, "USAGE OF ETHANOL BLENDED PETROL: EXPERIMENTAL INVESTIGATIONS OF REDUCTION IN POLLUTION LEVELS IN SI ENGINE", International Journal of Advances in Engineering & Technology, vol. 10, no. 3, pp. 437-448.	IC-engine blending study gas/ethanol lowered emissions CO, CO2, HC, NOX, plots
Riley, D.M., Tian, J., Güngör-Demirci, G., Phelan, P., Villalobos, J.R. & Milcarek, R.J. 2020, "Techno-Economic Assessment of CHP Systems in Wastewater Treatment Plants", Environments, vol. 7, no. 10, pp. 74.	One mention of VOC
Roberts, G., Johnson, B. & Edwards, C. 2014, "Prospects for High-Temperature Combustion, Neat Alcohol-Fueled Diesel Engines", SAE International Journal of Engines, vol. 7, no. 1, pp. 448-457.	No mention of HAPS or VOCs or NG or emissions
Rodionova, M.A., Khrestianovskaia, M.V. & Kukolev, M.I. 2017, "Primary energy sources of cogeneration units", Stroitel'stvo Unikal'nyh Zdanij i Sooruzenij, , no. 4, pp. 50-66.	review of Cogen engery sources
Rodríguez-Fernández, J., Hernández, J.J., Calle-Asensio, A., Ramos, Á. & Barba, J. 2019, "Selection of Blends of Diesel Fuel and Advanced Biofuels Based on Their Physical and Thermochemical Properties", Energies, vol. 12, no. 11, pp. 2034.	No mention of HAPS or VOCs or NG or emissions
Rozzi, E., Minuto, F.D., Lanzini, A. & Leone, P. 2020, "Green Synthetic Fuels: Renewable Routes for the Conversion of Non-Fossil Feedstocks into Gaseous Fuels and Their End Uses", Energies, vol. 13, no. 2, pp. 420.	Methanol mention 3 times (2 times related to methane steam reforming)
Salman, M. & Kim, S.C. 2019, "Effect of Cylinder Air Pressure and Hot Surface Temperature on Ignition Delay of Diesel Spray in a Constant Volume Combustion Chamber", Energies, vol. 12, no. 13, pp. 2565.	DI diesel engines, varied T, P, no emisisons measured
Serra, P. & Fancello, G. 2020, "Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping", Sustainability, vol. 12, no. 8, pp. 3220.	review of IMO's GHG goals concerning decarbonizing International Shipping
Seye, O., Rubem Cesar, R.S., Pereira Silva, R.E. & Robson Leal, d.S. 2020, "Crude palm oil as a complementary fuel for power generation in Amazonia: diesel engine performance, emissions, and economic assessment", Acta Scientiarum.Technology, vol. 42.	4-stroke IC engine diesel with blended diesel/biofuel, emissions were mesured CO, NOX,
Shcheklein, S.E. & Dubinin, A.M. 2018, "Stoichiometric analysis of air oxygen consumption in modern vehicles using natural and synthetic fuels", IOP Conference Series.Earth and Environmental Science, vol. 177, no. 1.	Results obtained for stoichiometric reactions of fuel oxidization in air for various motor fuels and for biomass-converted and coal-based artificial fuels.
Simanjuntak, J.P., Lisyanto, Daryanto, E. & Tambunan, B.H. 2018, "Producer gas production of Indonesian biomass in fixed-bed downdraft gasifier as an alternative fuels for internal combustion engines", Journal of Physics: Conference Series, vol. 970, no.	biogas, no emissions
Singh, P., Gundimeda, H. & Stucki, M. 2014, "Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households", The International Journal of Life Cycle Assessment, vol. 19, no. 5, pp. 1036-1048.	life assessment - cooking oils, biodiesel
Singh, Y., Sharma, A. & Singla, A. 2019, "Non-edible vegetable oil–based feedstocks capable of bio-lubricant production for automotive sector applications—a review", Environmental science and pollution research international, vol. 26, no. 15, pp. 14867-14	lubricants
Solazzo, E., Crippa, M., Guizzardi, D., Muntean, M., Choulga, M. & Janssens-Maenhout, G. 2021, "Uncertainties in the Emissions Database for Global Atmospheric Research (EDGAR) emission inventory of greenhouse gases", Atmospheric Chemistry and Physics, vol	EDGAR emissions by sector, country, sources
Sornek, K. 2020, "Prototypical Biomass-Fired Micro-Cogeneration Systems—Energy and Ecological Analysis", Energies, vol. 13, no. 15, pp. 3909.	mini-Cogen, no emissions
South Unit Oil And Gas Development Project, Duchesne/roosevelt Ranger District, Ashley National Forest, Duchesne County, Utah. [Part 3 of 3]2010, .	EPA Env Impact statement for areas near Unita Basin, UT
Standards of Performance for Greenhouse Gas Emissions From New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units, 2015, , Federal Information & News Dispatch, LLC, Washington., https://www.federalregister.gov/documents/2018/12/20/2018-27052/review-of-standards-of-performance-for-greenhouse-gas-emissions-from-new-modified-and-reconstructed	Reference contains search terms, but does not contain data applicable to developing speciation profiles
Stępień, Z. 2021, "A Comprehensive Overview of Hydrogen-Fueled Internal Combustion Engines: Achievements and Future Challenges", Energies, vol. 14, no. 20, pp. 6504.	overview of recent advances in Hydrogen powered ICE
Stouffs, P. 2011, "Hot Air Engines", Journal of Applied Fluid Mechanics, vol. 4, no. 3, pp. 1-8.	experimental design of a solar engine
Stylianidis, N., Azimov, U. & Birkett, M. 2019, "Investigation of the Effect of Hydrogen and Methane on Combustion of Multicomponent Syngas Mixtures using a Constructed Reduced Chemical Kinetics Mechanism", Energies, vol. 12, no. 12.	modelling of syngas mixtures on combustion
Subramanian, R., et. al., Methane Emissions from Natrual Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Prototcol, Environ. Sci. Technol. 2015, 49, 3252−3261	site-level methane emissions from 45 compressor stations in the transmission and storage (T&S) sector of the US natural gas system
Suprakash, S., Singh, S. & Sahoo, R.R. 2020, "Lubrication of dry sliding metallic contacts by chemically prepared functionalized graphitic nanoparticles", Friction, vol. 8, no. 4, pp. 708-725.	lubrication
Szwaja, S., Gruca, M., Pyrc, M. & Juknelevičius, R. 2021, "Performance and Exhaust Emissions of a Spark Ignition Internal Combustion Engine Fed with Butanol–Glycerol Blend", Energies, vol. 14, no. 20, pp. 6473.	ICE using butanol/glycerol compared with gas
Tan, D., Ran, G., Xie, G., Wang, J., Luo, J., Huang, Y., Cui, S. & Zhang, Z. 2021, "Effect of Different Technologies on Performance Enhancement of the Micro-Combustor for the Micro Thermophotovoltaic Application: A Review", Energies, vol. 14, no. 20, pp.	micro-combuster optimization using technology
Tang, W., Zhang, Z. & Li, Y. 2021, "Applications of carbon quantum dots in lubricant additives: a review", Journal of Materials Science, vol. 56, no. 21, pp. 12061-12092.	lubricants
Tavakkoli, S. 2018, A Systems-level Approach for Integrated Shale Gas Wastewater Management, University of Pittsburgh.	NG compressor station excess heat is used to power fracking water desalinatior
Tchanche, B. 2021, "Dynamics of Greenhouse Gas (GHG) Emissions in the Transportation Sector of Senegal", Earth, vol. 2, no. 1, pp. 1.	mobile source GHG emissions
Thomas, R. 2020, "CLIMATE CHANGE AS A CHALLENGE FOR THE ETHICAL ACTING OF COMPANIES IN THE GLOBAL CONTEXT", Ramon Llull Journal of Applied Ethics, , no. 11, pp. 9-31.	No mention of HAPS or VOCs or NG or emissions

Appendix B - ProQuest References for Reciprocating Engines

Reference	ERG Review Note
Tian, J., Kataoka, H. & Nishida, K. 2012, "Experimental Study on Mixture Formation and Ignition Processes of Spray Injected by Hole-Type Nozzle for DISI Engine", SAE International Journal of Engines, vol. 5, no. 1, pp. 17-24.	No mention of HAPS or VOCs or NG or emissions
Tirkey, J.V. 2018, "Concept development and prediction of VCR engine performance using slider crank pin mechanism based on quasi-dimensional combustion modeling", Thermal Science, vol. 22, no. 3, pp. 1249-1258.	No mention of HAPS or VOCs or NG or emissions
Trivyza, N.L., Rentizelas, A. & Theotokatos, G. 2020, "A Comparative Analysis of EEDI Versus Lifetime CO Emissions", Journal of Marine Science and Engineering, vol. 8, no. 1, pp. 61.	modelling Energy Efficiency Design Index (EEDI)
Tsymbal, V.P., Rybenko, I.A., Olennikov, A.A., Rybushkin, A.A., Kozhemyachenko, V.I. & Sechenov, P.A. 2018, "Fully environmentally closed technology of gasification dusted fractions of coal concentration with restoration of metals and alumosilicates from	No mention of HAPS or VOCs or NG or emissions
Tutak, W. & Grab-Rogaliński, K. 2021, "Combustion Stability, Performance and Emission Characteristics of a CI Engine Fueled with Diesel/n-Butanol Blends", Energies, vol. 14, no. 10, pp. 2817.	stationary compression ignition engine fueled with mixtures of diesel oil and n-butanol compared to a conventional diesel-only engine, THC and CO emissions and a decrease in NOx and PM emissions
Tutak, W. & Jamrozik, A. 2014, "Generator gas as a fuel to power a diesel engine", Thermal Science, vol. 18, no. 1, pp. 205-216.	CI engine, biogas efficiency, no emissions
Ushakov, S., Stenersen, D. & Einang, P.M. 2019, "Methane slip from gas fuelled ships: a comprehensive summary based on measurement data", Journal of Marine Science and Technology, , pp. 1.	tables provide LNG gas composition, suppliers, engines are for marine vessels, measured Nox, CO, CO2, THC, methane in exhaust gas.
Valencia, G., Fontalvo, A., Cárdenas, Y., Duarte, J. & Isaza, C. 2019, "Energy and Exergy Analysis of Different Exhaust Waste Heat Recovery Systems for Natural Gas Engine Based on ORC", Energies, vol. 12, no. 12.	No mention of HAPS or VOCs or NG or emissions
Vernon, D.R. 2010, Hydrogen Enrichment and Thermochemical Recuperation in Internal Combustion Engines: An Investigation of Dilution and Inlet Temperature Effects in the Autothermal Reformation of Ethanol, University of California, Davis.	No mention of HAPS or VOCs or NG or emissions
Vutukuru, S., Carreras-Sospedra, M., Brouwer, J. & Dabdub, D. 2011, "Future Impacts of Distributed Power Generation on Ambient Ozone and Particulate Matter Concentrations in the San Joaquin Valley of California", Journal of the Air & Waste Management Asso	Study of distributed power generation on air quality, decrease in energy consumption overall, computer modelling.
Wądrzyk, M., Plata, M., Zaborowska, K., Janus, R. & Lewandowski, M. 2021, "Py-GC-MS Study on Catalytic Pyrolysis of Biocrude Obtained via HTL of Fruit Pomace", Energies, vol. 14, no. 21, pp. 7288.	analysis of biofuel
Wang, Y. 2018, "Research on Application of Automobile New Energy and Energy Saving Technology", IOP Conference Series.Materials Science and Engineering, vol. 394, no. 4.	No mention of HAPS or VOCs or NG or emissions
Wilson Guillin-Estrada, Maestre-Cambronel, D., Bula-Silvera, A., Gonzalez-Quiroga, A. & Duarte-Forero, J. 2021, "Combustion and Performance Evaluation of a Spark Ignition Engine Operating with Acetone–Butanol–Ethanol and Hydroxy", Applied Sciences, vol. 1	studied Spark Ignition Engine, syngas, no emissions
Wilson, D.G. 2012, "Energy supplies and future engines for land, sea, and air", Journal of the Air & Waste Management Association, vol. 62, no. 6, pp. 607-624.	overview, no emissions
Xingchang, T., Xiangfei, W., Yang, L., Zhang, Z., Junhong, L. & Wang, J. 2020, "Multifunctional nickel nanofiber for effective air purification: PM removal and NO reduction from automobile exhaust", Journal of Materials Science, vol. 55, no. 14, pp. 6161-	No mention of HAPS or VOCs or NG or emissions
Xu, X., Liu, Z., Jiangdong, W., Jiaming, X. & Wang, X. 2019, "Misfire Fault Diagnosis of Range Extender Based on Harmonic Analysis", International Journal of Automotive Technology, vol. 20, no. 1, pp. 99-108.	No mention of HAPS or VOCs or NG or emissions
YERBA BUENA ISLAND RAMPS IMPROVEMENT PROJECT ON INTERSTATE 80 (I-80), CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA. [Part 1 of 14]2011, .	Hwy project in CA in 2018
Ying, Q. & Krishnan, A. 2010, "Source contributions of volatile organic compounds to ozone formation in southeast Texas", Journal of Geophysical Research.Atmospheres, vol. 115, no. 17.	2010 Study, CMAQ modeled using Voc to estimate O3, TCEQ reviewed sources of VOC: in biogenic sources, diesel vehicles, highway gasoline vehicles, off-highway gasoline vehicles, solvent utilization, petroleum industries, other industries and wildfires in SW TX in ME,HR, BI, GV, JE.
Yonggang, M., Xu, J., Jin, Z., Braham, P. & Yuanzhong, H. 2020, "A review of recent advances in tribology", Friction, vol. 8, no. 2, pp. 221-300.	No mention of HAPS or VOCs or NG or emissions
Yu, X., Li, Z., Lu, Y., Huang, R. & Roskilly, A.P. 2018, "Investigation of an Innovative Cascade Cycle Combining a Trilateral Cycle and an Organic Rankine Cycle (TLC-ORC) for Industry or Transport Application", Energies, vol. 11, no. 11.	No mention of HAPS or VOCs or NG or emissions
Yu, X., Luo, X., Jansons, M., Kim, D., Martz, J. & Violi, A. 2015, "A Fuel Surrogate Validation Approach Using a JP-8 Fueled Optically Accessible Compression Ignition Engine", SAE International Journal of Fuels and Lubricants, vol. 8, no. 1, pp. 119-134.	tested 3 jet fuel surrogates in a compression ignited optical engine under a range of start-of-injection temperatures and densities
Yu, X., Venecek, M., Kumar, A., Hu, J., Tanrikulu, S., Su-Tzai Soon, Tran, C., Fairley, D. & Kleeman, M.J. 2019, "Regional sources of airborne ultrafine particle number and mass concentrations in California", Atmospheric Chemistry and Physics, vol. 19, no	used NEI emissiosn for modelling PM sources
Yuan, S., Li, K., Chen, T., Bi, X. & Wang, Q. 2014, "Soil contamination by polycyclic aromatic hydrocarbons at natural recreational areas in Delaware, USA", Environmental Earth Sciences, vol. 72, no. 2, pp. 387-398.	PAH contamination in soil
Zacharia, R. & Rather, S.u. 2015, "Review of Solid State Hydrogen Storage Methods Adopting Different Kinds of Novel Materials", Journal of Nanomaterials, vol. 2015.	lit review on H2 energy storage
Žaglinskis, J., Rapalis, P. & Lazareva, N. 2018, "An overview of Natural Gas Use in Ships: Necessity and Engine Supply", Periodica Polytechnica.Transportation Engineering, vol. 46, no. 4, pp. 185-193.	existing and planned air pollution from ships control and prevention tools, has specifications for engines used
Zahid, R., Masjuki, H.H., Varman, M., Riaz, A.M., Md, A.K. & Gulzar, M. 2015, "Effect of Lubricant Formulations on the Tribological Performance of Self-Mated Doped DLC Contacts: a review", Tribology Letters, vol. 58, no. 2, pp. 1-28.	No mention of HAPS or VOCs or NG or emissions
Zamboni, G. 2019, "Influence of Fuel Injection, Turbocharging and EGR Systems Control on Combustion Parameters in an Automotive Diesel Engine", Applied Sciences, vol. 9, no. 3.	No mention of HAPS or VOCs or NG or emissions
Zdrodowski, R., Gangopadhyay, A., Anderson, J.E., Ruona, W.C., Uy, D. & Simko, S.J. 2010, "Effect of Biodiesel (B20) on Vehicle-Aged Engine Oil Properties", SAE International Journal of Fuels and Lubricants, vol. 3, no. 2, pp. 579-597.	residual diesel fuel found in lubricant oils was analyzed
Zhang, J. & Meng, Y. 2015, "Boundary lubrication by adsorption film", Friction, vol. 3, no. 2, pp. 115-147.	lubrication
Zhao, R., Huang, T. & McGuire, M. 2012, "From a Literature Review to an Alternative Treatment System for Landfill Gas and Leachate", Challenges, vol. 3, no. 2, pp. 278-289.	literature review landfill management, biogases

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Reference	ERG Review Note
Zobel, T., Schürch, C., Boulouchos, K. & Onder, C. 2020, "Reduction of Cold-Start Emissions for a Micro Combined Heat and Power Plant", Energies, vol. 13, no. 8, pp. 1862.	No mention of HAPS or VOCs or NG or emissions
Zöbinger, N., Schweizer, T., Lauer, T., Kubach, H. & Koch, T. 2021, "Experimental and Numerical Analysis on Two-Phase Induced Low-Speed Pre-Ignition", Energies, vol. 14, no. 16, pp. 5063.	No mention of HAPS or VOCs or NG or emissions

APPENDIX C. LIST OF TRADE ASSOCIATIONS FOR THE OIL AND GAS SECTOR

Trade Association Name	Website	State
Alabama Natural Gas Association (ANGA)	https://alnga.org/	Alabama
Alaska Oil & Gas Association (AOGA)	https://www.aoga.org/	Alaska
Arkansas Independent Producers & Royalty Owners Association (AIPRO)	http://aipro.org/	Arkansas
California Independent Petroleum Association (CIPA)	https://www.cipa.org/i4a/pages/index.cfm?pageid=1	California
Western States Petroleum Association (WSPA)	https://www.wspa.org/	California
Independent Oil Producers' Agency	Appears to be same as IPAA	California
Colorado Oil & Gas Association (COGA)	https://www.coga.org/	Colorado
Independent Petroleum Association of Mountain States (IPAMS)	www.westernenergyalliance.org	Colorado
American Exploration & Production Council (AXPC)	https://www.axpc.org/	District of Columbia
American Gas Association (AGA)	https://www.aga.org/	District of Columbia
American Petroleum Institute (API)	https://www.api.org/	District of Columbia
Independent Petroleum Association of America (IPAA)	https://www.ipaa.org/	District of Columbia
Interstate Natural Gas Association of America (INGAA)	https://www.ingaa.org/	District of Columbia
National Association of Energy Service Companies (NAESCO)	https://www.naesco.org/	District of Columbia
National Petroleum Council (NPC)	https://www.npc.org/	District of Columbia
National Propane Gas Association (NPGA)	https://www.npga.org/	District of Columbia
Natural Gas Supply Association (NGSA)	https://www.ngsa.org/	District of Columbia
United States Energy Association (USEA)	https://usea.org/	District of Columbia
US Oil & Gas Association (USOGA)	https://www.usoga.org/	District of Columbia
Florida Independent Petroleum Producers Association, Inc. (FLIPPA)	Appears to be same as IPAA	Florida
Florida Natural Gas Association (FNGA)	https://www.floridagas.org/	Florida
Association of Energy Engineers (AEE)	https://www.aeecenter.org/	Georgia

Trade Association Name	Website	State
Gas Research Institute (GRI) / Gas Technology Institute (GTI)	https://www.gti.energy/	Illinois
Illinois Oil & Gas Association (IOGA)	https://ioga.com/	Illinois
Midwest Cogeneration Association (MCA)	https://cogeneration.org/	Illinois
Indiana Energy Association	https://indianaenergy.org/	Indiana
Indiana Oil & Gas Association (IOGA)	https://www.indianaoga.org/	Indiana
Eastern Kansas Oil & Gas Association (EKOGA)	https://www.ekoga.org/	Kansas
Kansas Independent Oil & Gas Association (KIOGA)	https://kioga.org/	Kansas
Kentucky Oil & Gas Association (KOGA)	https://members.kyoilgas.org/	Kentucky
Louisiana Oil & Gas Association (LOGA)	https://www.loga.la/	Louisiana
Louisiana Mid-Continent Oil and Gas Association	https://www.lmoga.com/	Louisiana
Northeast Gas Association (NGA)	https://www.northeastgas.org/	Massachusetts
Michigan Oil and Gas Association (MOGA)	https://www.michiganoilandgas.org/	Michigan
Mississippi Independent Producers and Royalty Owners (MIPRO)	http://www.mipro.ms/	Mississippi
Montana Petroleum Association (MPA)	https://montanapetroleum.org/	Montana
Independent Petroleum Association of New Mexico (IPANM)	https://ipanm.org/	New Mexico
New Mexico Oil & Gas Association (NMOGA)	https://www.nmoga.org/	New Mexico
Independent Oil and Gas Association of New York (IOGA of NY) (IOGANY)	https://iogany.org/	New York
New York State Oil Producers Association (NYSOPA)	https://newyorkstateoilproducersassociation.com/	New York
Southeastern Gas Association (SEGA)	https://southerngas.org/	North Carolina
North Dakota Petroleum Council	https://www.ndoil.org/	North Dakota
Ohio Oil & Gas Association (OOGA)	https://www.ooga.org/	Ohio
Oklahoma Independent Petroleum Association (OIPA)	https://www.thepetroleumalliance.com/	Oklahoma
Oklahoma Oil & Gas Association	https://www.thepetroleumalliance.com/	Oklahoma
Gas Processors Association (GPA)	https://gpamidstream.org/	Oklahoma
Natural Gas & Energy Association of Oklahoma (NGEAO)	https://www.ngeao.org/	Oklahoma
National Stripper Well Association (NSWA)	https://nswa.us/	Oklahoma
Northwest Gas Association (NWGA)	https://www.nwga.org/	Oregon
Independent Oil & Gas Association of Pennsylvania	https://pioga.org/	Pennsylvania

Trade Association Name	Website	State
Energy Association of Pennsylvania (formerly Pennsylvania Electric Association formerly Pennsylvania Gas Association)	https://www.energypa.org/	Pennsylvania
Pennsylvania Independent Oil and Gas Association (PIOGA)	https://pioga.org/	Pennsylvania
Tennessee Oil and Gas Association (TOGA)	http://www.tennoil.com/	Tennessee
Panhandle Producers & Royalty Owners Association (PPROA)	https://pproa.org/	Texas
Texas Pipeline Association (formerly Association of Texas Intrastate Natural Gas Pipelines)	https://texaspipelines.com/	Texas
Texas Independent Producers & Royalty Owners Association (TIPRO)	https://www.tipro.org/	Texas
Texas Oil & Gas Association (TXOGA)	https://www.txoga.org/	Texas
Southern Gas Association (SGA)	https://southerngas.org/	Texas
National Association of Energy Service Companies (AESC)	https://www.naesco.org/	Texas
East Texas Producers & Royalty Owners Association	See TIPRO	Texas
Natural Gas Society of the Permian Basin (NGSPB)	https://ngspb.com/	Texas
Permian Basin Petroleum Association (PBPA)	https://pbpa.info/	Texas
Natural Gas Society of East Texas (NGSET)	https://www.ngset.org/	Texas
Texas Alliance of Energy Producers	https://texasalliance.org/about/	Texas
Petroleum Marketers Association of America (PMAA)	https://www.pmaa.org	Virginia
American Public Gas Association (APGA)	https://www.apga.org/home	Virginia
Independent Oil & Gas Association of West Virginia (IOGA-WV), Inc.	https://gowv.com/	West Virginia
Petroleum Association of Wyoming (PAW)	https://pawyo.org/	Wyoming

APPENDIX D. FACILITY TYPES CONTAINED IN THE OPEN AIR DATABASE

Facility Type
Asphalt Plant, Portable
Asphalt Plant, Stationary
Bentonite Plant
Beverage Can Manufacturing
Blowdown/Venting/Completions
Cement Plant
Chemical Processing
Chrome Plating
Coal Conversion
Coal Products
Compressor Station
Concrete Plant, Portable
Concrete Plant, Stationary
Crushing and Screening, Portable
Crushing and Screening, Stationary
Dehydration
Engine, Portable
Engine, Stationary
Equipment, Portable
General Manufacturing
General Oil & Gas
Gypsum Board Plant
Heat Plant
Incineration
Landfill
Lime Plant
Liquids Handling Facility
O&G Drill Rigs, Portable
Other (see description)
Pad/Central Gathering
Petroleum Refinery
Pipeline Station
Power Plant
Produced Water Handling
Remediation
Sawmill
Single Well

Facility Type
Single Well Routed to Pad/Central Gathering
Small Mine (Non-Coal)
Sour Gas Plant, Liquid
Storage Tank Battery
Sugar Beet Plant
Surface Coal Mine
Surface Coating
Sweet Gas Plant, Liquid
Transloading Facility
Trona Industry
Uranium Industry
Wood Furniture Industry

APPENDIX E. EMISSIONS FACTORS USED BY EGLE/MAERS

SCC	Pollutant Name	Factor Value (lb/MMscf)	Control Device 1	Control Device 2
20100201	Acetaldehyde	4.08E-02		
	Acrolein	6.528E-03		
	Benzene	1.224E-02		
		9.282E-04	Reducing catalyst	
	Formaldehyde	2.04E-02	Reducing catalyst	
		7.242E-01		
		3.509E-01	Afterburner	
	Toluene	1.326E-01		
	VOC	2.142E+00		
	Xylenes Iso	6.528E-02		
20100202	VOC	1.16E+02		
20200201	Acetaldehyde	4.08E-02		
		4.376E-03	Scrubber	Ammonia injection
		2.173E-02	Afterburner	
	Acrolein	6.528E-03		
	Benzene	1.224E-02		
		9.282E-04	Reducing catalyst	
	Formaldehyde	2.04E-02	Reducing catalyst	
		7.242E-01		
	Toluene	1.326E-01		
	VOC	2.142E+00		
	Xylenes Iso	6.528E-02		
20200202	VOC	1.16E+02		
20200203	Acetaldehyde	4.08E-02		
	Acrolein	6.528E-03		
	Benzene	1.224E-02		
		9.282E-04	Reducing catalyst	
	Formaldehyde	7.242E-01		
		2.04E-02	Reducing catalyst	
	Toluene	1.326E-01		
	VOC	2.142E+00		
	Xylenes Iso	6.528E-02		
20200204	VOC	1.16E+02		
20200252	Acetaldehyde	7.915E+00		
	Acrolein	7.936E+00		
	Benzene	1.979E+00		
	Formaldehyde	5.63E+01		
	Hexane	4.539E-01		
	Methanol	2.53E+00		
	Toluene	9.823E-01		
	VOC	1.224E+02		
	Xylenes Iso	2.734E-01		
20200253	Acetaldehyde	2.846E+00		

SCC	Pollutant Name	Factor Value (lb/mmscf)	Control Device 1	Control Device 2
	Acrolein	2.683E+00		
	Benzene	1.612E+00		
	Formaldehyde	2.091E+01		
	Methanol	3.121E+00		
	Toluene	5.692E-01		
	VOC	3.019E+01		
	Xylenes Iso	1.989E-01		
20200254	Acetaldehyde	8.527E+00		
	Acrolein	5.243E+00		
	Benzene	4.488E-01		
	Formaldehyde	5.386E+01		
	Hexane	1.132E+00		
	Methanol	2.55E+00		
	Toluene	4.162E-01		
	VOC	1.204E+02		
	Xylenes Iso	1.877E-01		
20300201	VOC	1.16E+02		
20300202	Acetaldehyde	4.08E-02		
	Acrolein	6.528E-03		
	Benzene	1.224E-02		
		9.282E-04	Reducing catalyst	
	Formaldehyde	7.242E-01		
		2.04E-02	Reducing catalyst	
	Toluene	1.326E-01		
	VOC	2.142E+00		
	Xylenes Iso	6.528E-02		
20300203	Acetaldehyde	4.08E-02		
	Acrolein	6.528E-03		
	Benzene	1.224E-02		
	Benzene	9.282E-04	Carbon injection	
	Formaldehyde	7.242E-01		
		2.04E-02	Reducing catalyst	
	Toluene	1.326E-01		
	VOC	2.142E+00		
	Xylenes Iso	6.528E-02		

APPENDIX F. HAP SPECIATION PROFILES FOR NATURAL GAS-FIRED TURBINES AND RECIPROCATING ENGINES

SCC	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Control Status	Usage Note	Basis[a]	Data Source
20100201	0.44%	0.08%	0.13%	1.74%	1.71%	Uncontrolled	All load conditions	TOC	WebFIRE
20200201	0.46%	0.09%	0.15%	1.25%	2.06%	Uncontrolled	All load conditions	TOC	WebFIRE
20200203	0.46%	0.09%	0.15%	1.25%	2.06%	Uncontrolled	All load conditions	TOC	WebFIRE
20300202	0.77%	0.15%	0.25%	2.11%	3.46%	Uncontrolled	All load conditions	TOC	WebFIRE
20300203	0.50%	0.09%	0.16%	1.37%	2.26%	Uncontrolled	All load conditions	TOC	WebFIRE
20100201	0.44%	0.08%	0.13%	1.71%	1.71%	Uncontrolled	High load conditions (≥80%)	TOC	WebFIRE
20200201	0.46%	0.09%	0.15%	1.35%	2.06%	Uncontrolled	High load conditions (≥80%)	TOC	WebFIRE
20200203	0.46%	0.09%	0.15%	1.35%	2.06%	Uncontrolled	High load conditions (≥80%)	TOC	WebFIRE
20300202	0.77%	0.15%	0.25%	2.28%	3.46%	Uncontrolled	High load conditions (≥80%)	TOC	WebFIRE
20300203	0.50%	0.09%	0.16%	1.48%	2.26%	Uncontrolled	High load conditions (≥80%)	TOC	WebFIRE
20100201	0.36%	0.06%	0.11%	6.45%	1.18%	Uncontrolled	High load conditions (≥80%)	TOC	AP-42
20200201	0.36%	0.06%	0.11%	6.45%	1.18%	Uncontrolled	High load conditions (≥80%)	TOC	AP-42

SCC	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Control Status	Usage Note	Basis[a]	Data Source
20200203	0.36%	0.06%	0.11%	6.45%	1.18%	Uncontrolled	High load conditions (≥80%)	TOC	AP-42
20300202	0.36%	0.06%	0.11%	6.45%	1.18%	Uncontrolled	High load conditions (≥80%)	TOC	AP-42
20300203	0.36%	0.06%	0.11%	6.45%	1.18%	Uncontrolled	High load conditions (≥80%)	TOC	AP-42
20100201	1.90%	0.30%	0.57%	33.81%	6.19%	Uncontrolled	High load conditions (≥80%)	VOC	AP-42
20200201	1.90%	0.30%	0.57%	33.81%	6.19%	Uncontrolled	High load conditions (≥80%)	VOC	AP-42
20200203	1.90%	0.30%	0.57%	33.81%	6.19%	Uncontrolled	High load conditions (≥80%)	VOC	AP-42
20300202	1.90%	0.30%	0.57%	33.81%	6.19%	Uncontrolled	High load conditions (≥80%)	VOC	AP-42
20300203	1.90%	0.30%	0.57%	33.81%	6.19%	Uncontrolled	High load conditions (≥80%)	VOC	AP-42
20200252	0.47%	0.47%	0.12%	3.37%	0.06%	Uncontrolled	All load conditions	TOC	AP-42
20200253	0.78%	0.73%	0.44%	5.73%	0.16%	Uncontrolled	All load conditions	TOC	AP-42
20200254	0.57%	0.35%	0.03%	3.59%	0.03%	Uncontrolled	All load conditions	TOC	AP-42
20200252	6.47%	6.48%	1.62%	46.00%	0.80%	Uncontrolled	All load conditions	VOC	AP-42
20200253	9.43%	8.89%	5.34%	69.26%	1.89%	Uncontrolled	All load conditions	VOC	AP-42
20200254	7.08%	4.36%	0.37%	44.75%	0.35%	Uncontrolled	All load conditions	VOC	AP-42

SCC	Acetaldehyde	Acrolein	Benzene	Formaldehyde	Toluene	Control Status	Usage Note	Basis[a]	Data Source
20200201	Not available (NA)	NA	NA	24.8%	NA	Dry low emissions combustion for NO_x control	None	VOC	Wyoming DEQ
20200253	NA	NA	NA	6.6%	NA	Catalytic oxidation	None	VOC	TCEQ
20200254	NA	NA	NA	42.9%	NA	Uncontrolled	None	VOC	TCEQ
20200254	NA	NA	NA	46.4%	NA	Oxidation catalyst	None	VOC	TCEQ
20200253	NA	NA	NA	17.9%	NA	NSCR	None	VOC	Wyoming DEQ
20200254	NA	NA	NA	19.7%	NA	Oxidation catalyst	None	VOC	Wyoming DEQ

[a] HAP speciation profiles expressed as a percent of lb TOC or VOC/MMBtu heat input.

APPENDIX G. HAP SPECIATION PROFILE CALCULATIONS USING WEBFIRE DATA

Electronic files only. Available from TCEQ upon request.

APPENDIX H. HAP SPECIATION PROFILE CALCULATIONS USING TCEQ DATA

Electronic files only. Available from TCEQ upon request.

APPENDIX I. HAP SPECIATION PROFILE CALCULATIONS USING WYOMING DEQ DATA

Electronic files only. Available from TCEQ upon request.