Updated Human Health Risk Assessment (HHRA) for Exelon's Proposed West Medway Project

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Abbreviations

AAL	Allowable Ambient Limit
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic Substances and Disease Registry
CalEPA	California Environmental Protection Agency
CASAC	Clean Air Scientific Advisory Committee
CHNA	Community Health Network Area
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CTG	Combustion Turbine Generator
EFSB	Energy Facilities Siting Board
ELCR	Excess Lifetime Cancer Risk
EPC	Exposure Point Concentration
EPHT	Environmental Public Health Tracking
HI	Hazard Index
HQ	Hazard Quotient
HHRA	Human Health Risk Assessment
IRIS	Integrated Risk Information System
LOAEL	Lowest-observed-adverse-effect-level
MassCHIP	Massachusetts Community Health Information Profile
MADEP	Massachusetts Department of Environmental Protection
MADPH	Massachusetts Department of Public Health
MRL	Minimal Risk Level
NAAQS	National Ambient Air Quality Standards
NO_2	Nitrogen Dioxide
NOAEL	No-observed-adverse-effect-level
OAQPS	Office of Air Quality Planning and Standards
OEHHA	Office of Environmental Health Hazard Assessment
OSW	Office of Solid Waste
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter
$PM_{2.5}$	Particles Less than 2.5 Micrometers in Diameter
PM_{10}	Particles Less than 10 Micrometers in Diameter
RAGS	Risk Assessment Guidance for Superfund
REL	Reference Exposure Level
RfC	Reference Concentration
SCR	Selective Catalytic Reduction
SIL	Significant Impact Level
SIR	Standardized Incidence Ratio
SO_2	Sulfur Dioxide
TEL	Threshold Effects Exposure Limit
ULSD	Ultra-low Sulfur Distillate
UF	Uncertainty Factor

UR	Unit Risk
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

Executive Summary

Exelon's Proposed West Medway Project will involve construction and operation of a simple cycle, peaking power generating facility consisting of two combustion turbine generators (CTGs), in addition to ancillary equipment, for a total output of ~200 MW in Medway, Massachusetts. Detailed descriptions and specifications for the Project are described in several reports and regulatory filings, including a petition prepared by Epsilon Associates, Inc. (Epsilon) for submittal to the Massachusetts Energy Facilities Siting Board (EFSB) (Epsilon Associates, 2015a) and a comprehensive air plan approval application prepared by Epsilon for submittal to the Massachusetts Department of Environmental Protection (MADEP) (Epsilon Associates, 2015b).

As described in the comprehensive air plan approval application (Epsilon Associates, 2015b), Epsilon conducted air dispersion modeling of stack air emissions from the proposed Project, predicting short-term and annual average impacts for United States Environmental Protection Agency (US EPA) criteria air pollutants (*e.g.*, $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO)[1] and for 22 air toxics. Epsilon determined maximum modeled Project-related concentrations as well as modeled Project-related concentrations at the location of a day care center nearby to the Project site. Epsilon Associates (2015b) compared these model-predicted air concentrations to health-protective ambient air quality standards (*e.g.,* the US EPA National Ambient Air Quality Standards [NAAQS]) and air toxics guidelines (*e.g.*, the MADEP annual Allowable Ambient Limits [AALs] and 24-hour Threshold Effects Exposure Limits [TELs]) to assess the potential for health impacts from the Project stack air emissions.

In order to support and confirm Epsilon's air quality impacts analysis, Gradient prepared this human health risk assessment (HHRA) evaluating the likelihood of acute non-cancer health risks and chronic non-cancer and cancer health risks that may result from people's inhalation of Project-related airborne pollutants, as predicted by Epsilon for the Project stack air emissions. As an update to the prior HHRA report dated July 22, 2015 (Gradient, 2015; previously submitted to the Massachusetts EFSB as Attachment EFSB-H-2(1)), this HHRA relies upon revised air modeling results provided in the comprehensive air plan approval application (Epsilon Associates, 2015b), as well as additional air modeling results provided by Epsilon. Gradient also collected relevant information on background health status for Medway and surrounding communities to compare local disease prevalence (*e.g.*, cancer, asthma) to Massachusetts as a whole.

Overall, our HHRA for the Project has demonstrated that maximum modeled air concentrations and modeled air concentrations at a nearby day care center for specific substances associated with the Project stack air emissions would not be expected to contribute to significant health risks among potentially affected populations. Several separate lines of evidence from our health-risk analysis support the conclusion that the Project stack air emissions are not expected to create public health risks of concern in the Medway area:

1. With regard to Project stack emissions of criteria air pollutants, total air concentrations corresponding to maximum modeled Project impacts plus existing background remain below the health-protective NAAQS for the criteria air pollutants of concern, which include SO_2, CO, NO_2, and PM (Tables 2.1 and 2.2). Therefore, Project stack emissions of criteria air pollutants are not

[1] PM = particulate matter (less than 2.5 µm in size [$PM_{2.5}$]; less than 10 µm in size [PM_{10}]); NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; CO = carbon monoxide.

expected to cause adverse health impacts (*e.g.*, asthma, cardiovascular, and respiratory diseases) in nearby communities. Furthermore, as a matter of perspective, it is important to recognize that the total inhaled dose from one year of cumulative exposure to maximum modeled $PM_{2.5}$ and NO_2 concentrations associated with Project stack emissions is equivalent to the dose received from short durations of everyday exposures that are routinely received during common indoor and outdoor activities such as cooking, doing yard work, or driving in a car (Table 2.4).

2. With regard to Project stack emissions of non-criteria pollutants (*i.e.*, air toxics), both the maximum modeled air concentrations and modeled air concentrations at the nearby day care center location are below both the MADEP 24-hour TELs and the annual-average AALs, indicating that these concentrations cannot be expected to cause adverse health effects, even in sensitive populations and for children attending the day care center (Table 1.1 and Table 1.2).

3. As a matter of perspective with regard to Project air toxics emissions, measurements from the closest Boston-area air toxics monitor show that maximum modeled Project impacts for metals are between about 18-fold to 639-fold below measured ambient background levels in the Boston area, while for volatile organic compounds (VOCs), maximum modeled Project impacts are between 80-fold and >6,400-fold below measured ambient background levels (Table 2.6). At the day care center location, the amounts by which modeled Project impacts remain below measured background air toxics levels are even greater (Table 2.7).

4. Our quantitative HHRA showed that all hazard quotients (HQs) calculated for a hypothetical off-site resident exposed to maximum modeled incremental Project stack air toxics impacts are well below unity (HQ = 1),[2] with none being higher than HQ = 0.023. The overall summed hazard index (HI) for Project stack air toxics emissions, which makes the health-protective assumption that all chemicals act via the same toxic-effect pathway, is also well below 1.0 (HI = 0.04). These results help assure that non-cancer health effects from chronic exposures are not to be expected from Project stack air toxics emissions (Table 2.9). As shown in Table 2.9 and Figure 2.1, the non-cancer health risks posed by background levels of several of the air toxics of interest with available air monitoring data from the closest Boston-area air toxics monitor are well below levels of potential health concern, yet are in fact greater than HIs calculated for the maximum modeled incremental Project stack air toxics impacts.

5. The HQs calculated for a child attending the nearby day care center near the site of the Project are also well below 1, with the highest HQ = 0.004. The overall summed HI for a child attending the day care center is also well below 1 (HI = 0.008). These results assure that a child attending the day care center near the Project would not be expected to experience any non-cancer health effects from chronic exposures associated with Project air toxics emissions (Table 2.11).

6. The quantitative HHRA shows that conservatively projected lifetime cancer risks for maximum modeled incremental Project stack air toxics impacts are well below the 1 in 1,000,000 to 1 in 10,000 range considered to be acceptable by US EPA.[3] The overall summed cancer risk is about 8 in 100,000,000, which is well below US EPA's *de minimis* 1-in-1,000,000 risk. The individual pollutant cancer risks are each even lower than the acceptable range, between about 1 in 10,000,000,000 to about 3 in 100,000,000. These results support an absence of any significant cancer risk from worst-case chronic exposures to maximum modeled Project stack air impacts (Table 2.10). As shown in Table 2.10 and Figure 2.2, the cancer risks posed by background levels of several of the air toxics of interest with available air monitoring data from the closest Boston air toxics monitor are well below levels of potential health concern, yet are in fact greater

[2] HQ = 1 is a screening criterion meaning that exposure below this level, *i.e.*, HQ<1, cannot be expected to lead to adverse health effects.

[3] It should be noted that the likelihood of developing cancer over a lifetime (*i.e.*, the background risk) is approximately 400,000 in 1,000,000. That is, the chance of developing cancer sometime during a lifetime is about 40%.

than the projected lifetime cancer risks for the maximum modeled incremental Project stack air toxics impacts.

7. The cancer risks calculated based on modeled Project-related ambient air concentrations at the day care center are even lower than those calculated based on the maximum modeled Project impacts, and are also well below the range considered acceptable by US EPA. The overall summed cancer risk is about 2 in 1,000,000,000, which is well below US EPA's *de minimis* risk. The individual pollutant cancer risks are far below the acceptable range, between about 1 in 1,000,000,000,000 to about 9 in 10,000,000,000 (Table 2.12).

8. To evaluate the possibility of Project stack air emissions causing short-term respiratory irritation in sensitive populations such as asthmatics, maximum modeled 1-hr concentrations of NO_2, SO_2 acetaldehyde, acrolein, and formaldehyde were further examined. The Project maximum modeled air concentrations and the modeled air concentrations at the day care center were compared to short-term exposure guidelines and standards, including the short-term NAAQS for SO_2 and NO_2 that are specifically designed to protect against asthma exacerbation and respiratory irritation. The results show that both the maximum modeled 1-hour NO_2 and SO_2 concentrations, as well as estimates of total impacts corresponding to the sum of maximum modeled 1-hr concentrations and ambient background, are below the 1-hour health-protective NAAQS and other short-term exposure guideline levels. The 1-hour SO_2 and NO_2 modeled concentrations at the day care center are also well below the NAAQS (Table 2.13). Moreover, maximum modeled 1-hour concentrations and modeled 1-hour concentrations for the day care center are well below relevant short-term exposure guideline levels for each of the other air toxics (acetaldehyde, acrolein, formaldehyde) considered in the acute (short-term) exposure evaluation for respiratory irritants.

9. The review of community health data for Medway and nearby communities indicates that the Medway area generally has similar asthma, cardiovascular, and cancer rates compared with the state of Massachusetts. In combination with the HHRA results, there's no expectation that cancer rates will be affected by operation of the peaking-plant Project.

1 Introduction

1.1 Brief Overview of Exelon's Proposed West Medway Project

As described in the petition prepared by Epsilon and submitted by Exelon to the Massachusetts EFSB (Epsilon Associates, 2015a), the proposed West Medway Project will be located at the 94-acre site of an existing power plant in the town of Medway, Massachusetts. The existing peaking power plant is made up of six combustion turbines (each of which vents through its own 65 foot stack), three electric generators each rated at approximately 45 MW, and ancillary equipment.

Briefly, the Project consists of a simple cycle peaking power generation facility utilizing two combustion turbine generators (CTGs), in addition to ancillary equipment, for a total output of ~200 MW (Epsilon Associates, 2015b). It is to be constructed in an area that is approximately 10 acres of currently open field. The proposed facility will burn primarily pipeline natural gas with ultra-low sulfur distillate (ULSD) oil as a back-up fuel supply for up to 60 days/year. The facility is proposed to operate at up to a 60% capacity factor in any single year (5,256 full load hours per year). In accordance with the new New Source Performance Standards (NSPS) at 40 CFR 60, Subpart TTTT, each turbine will be limited to a three year average capacity factor of 43%. The two new turbines will each be vented through a dedicated 160 foot stack after passing through an emissions control unit with selective catalytic reduction (SCR) and oxidation catalyst.

As discussed in more detail in the sections that follow, the analyses below address two potential exposure scenarios for stack air emissions from the Project. We assessed non-cancer and cancer risks for a hypothetical off-site resident at the location of maximum project impacts and for a hypothetical child attending the day care center abutting the Project. As noted in the petition to the Massachusetts EFSB (Epsilon Associates, 2015a), there is a children's day care center located approximately 600 feet to the southeast of the Project. Although the risk assessment calculations for the hypothetical off-site resident are highly conservative and will be protective of other potential receptors (*e.g.*, day care children and workers) nearby to the Project, we supplemented our analysis of human health risks associated with the maximum modeled Project impacts with a separate analysis that is specific to a hypothetical child attending (11 hours/day, 5 days/week, 52 weeks/year, for 4.25 years) the day care center, where the modeled concentrations of Project stack air emissions are lower than the maximum modeled concentrations. As an update to the prior HHRA report dated July 22, 2015 (Gradient, 2015; previously submitted to the Massachusetts EFSB as Attachment EFSB-H-2(1)), this HHRA relies upon revised air modeling results provided in the comprehensive air plan approval application (Epsilon Associates, 2015b), as well as additional air modeling results provided by Epsilon.

1.2 Epsilon's Air Dispersion Modeling Analysis for Proposed West Medway Project Stack Air Emissions

The comprehensive air plan approval application (Epsilon Associates, 2015b) submitted to MADEP describes the air dispersion modeling that was conducted by Epsilon for air pollutant emissions from the Project's stacks to predict short-term and annual average impacts for United States Environmental

Protection Agency (US EPA) criteria air pollutants (*e.g.*, $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO)[4] and 22 air toxics. The modeled concentrations are based on impacts from two turbines, one diesel engine emergency generator, and one diesel engine fire pump. In its air quality modeling and impact analysis, Epsilon compared maximum modeled Project air impacts to health-protective ambient air quality standards (*e.g.*, the US EPA National Ambient Air Quality Standards [NAAQS] and air toxics guidelines (*e.g.*, the Massachusetts Department of Environmental Protection [MADEP] Allowable Ambient Limits [AALs] and 24-hour Threshold Effects Exposure Limits [TELs]) to assess the potential health impacts of Project stack air emissions. Both the US EPA NAAQS and MADEP ambient air limits are intended to be protective of adverse health effects among members of the general population, including potentially susceptible individuals.

To evaluate potential public health impacts from the Project criteria air pollutant emissions, we also relied on an approach in this human health risk assessment (HHRA) that compared maximum modeled total concentrations, as well as total concentrations at the day care center location, to the health-protective NAAQS (Section 2.1). For non-criteria air pollutants (*i.e.*, air toxics), we conducted an inhalation risk assessment to assess the likelihood of chronic non-cancer and cancer health risks (Section 2.2). These risk assessment calculations supplement, rather than replace, Epsilon's comparison of the air modeling results to the MADEP ambient air toxic guidelines. Because of the health-protective nature of the AALs and TELs,[5] comparison to these limits is an appropriate methodology for determining whether there is a potential risk to public health due to stack emissions of air toxics from the Project. As such, we have verified the Epsilon analyses of air toxics, which are reproduced in Table 1.1 and Table 1.2 below.

[4] PM = particulate matter (less than 2.5 μm in size [$PM_{2.5}$]; less than 10 μm in size [PM_{10}]); NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; CO = carbon monoxide.

[5]As stated by MADEP (MADEP, 2015), both the TELs and AALs are intended to be protective of adverse health effects among members of the general population, including potentially susceptible individuals such as children.

Table 1.1 Comparison of Maximum Modeled Ambient Air Impacts of Air Toxics from Project Stack Emissions to MADEP Air Pollutant Guidelines

Pollutant	24- hour Concentrations (µg/m^3)			Annual Concentrations (µg/m^3)		
	Total Impact	TEL	% of TEL	Total Impact	AAL	% of AAL
1,3-Butadiene	0.0047	1.2	0.4%	0.0000090	0.003	0.3%
Acetaldehyde	0.033	30	0.1%	0.0020	0.4	0.5%
Acrolein	0.0046	0.07	6.6%	0.00028	0.07	0.4%
Benzene	0.058	0.6	9.7%	0.0070	0.1	7.0%
Naphthalene	0.016	14.25	0.1%	0.0010	14.25	0.0%
Ethylbenzene	0.011	300	0.0%	0.00011	300	0.0%
Formaldehyde	0.16	2	7.9%	0.0045	0.08	5.7%
Propylene Oxide	0.010	6	0.2%	0.000099	0.3	0.0%
Toluene	0.063	80	0.1%	0.0031	20	0.0%
Xylenes	0.034	11.8	0.3%	0.0021	11.8	0.0%
Arsenic	0.0012	0.003	39.7%	0.0000019	0.0003	0.6%
Beryllium	0.000092	0.001	9.2%	0.00000015	0.0004	0.0%
Cadmium	0.0014	0.002	71.0%	0.0000023	0.0002	1.1%
Chromium (total)	0.0033	1.36	0.2%	0.0000052	0.68	0.0%
Lead	0.0042	0.14	3.0%	0.0000066	0.07	0.0%
Mercury	0.00036	0.14	0.3%	0.00000057	0.07	0.0%
Nickel	0.0014	0.27	0.5%	0.0000022	0.01	0.0%
Selenium	0.0074	0.54	1.4%	0.000012	0.54	0.0%
Ammonia	2.4	100	2.4%	0.026	100	0.0%
Total PAH	0.021	--		0.00173	--	
Manganese	0.23	--		0.00037	--	
Sulfuric acid	0.93	2.72	34%	0.023	2.72	0.8%

Notes:
TEL – Threshold Effects Exposure Limit; AAL – Allowable Ambient Limit; PAH – Polycyclic Aromatic Hydrocarbon.

Table 1.2 Comparison of Modeled Ambient Air Impacts of Air Toxics from Project Stack Emissions at the Day Care Center to MADEP Air Pollutant Guidelines

Pollutant	24- hour Concentrations (µg/m^3)			Annual Concentrations (µg/m^3)		
	Total Impact	TEL	% of TEL	Total Impact	AAL	% of AAL
1,3-Butadiene	0.0028	1.2	0.2%	0.0000016	0.003	0.1%
Acetaldehyde	0.017	30	0.1%	0.0015	0.4	0.4%
Acrolein	0.0026	0.07	3.7%	0.0002	0.07	0.3%
Benzene	0.035	0.6	5.9%	0.0057	0.1	5.7%
Naphthalene	0.0097	14.25	0.1%	0.0008	14.25	0.0%
Ethylbenzene	0.0072	300	0.0%	0.000023	300	0.0%
Formaldehyde	0.095	2	4.7%	0.0027	0.08	3.4%
Propylene Oxide	0.0065	6	0.1%	0.000021	0.3	0.0%
Toluene	0.039	80	0.0%	0.0023	20	0.0%
Xylenes	0.021	11.8	0.2%	0.0016	11.8	0.0%
Arsenic	0.00070	0.003	23.3%	0.00000033	0.0003	0.1%
Beryllium	0.000054	0.001	5.4%	0.000000025	0.0004	0.0%
Cadmium	0.00084	0.002	41.9%	0.00000039	0.0002	0.2%
Chromium (total)	0.0019	1.36	0.1%	0.00000090	0.68	0.0%
Lead	0.0024	0.14	1.7%	0.0000011	0.07	0.0%
Mercury	0.00021	0.14	0.1%	0.000000098	0.07	0.0%
Nickel	0.0008	0.27	0.3%	0.00000038	0.01	0.0%
Selenium	0.0044	0.54	0.8%	0.0000020	0.54	0.0%
Ammonia	1.5	100	1.5%	0.0054	100	0.0%
Total PAH	0.013	--		0.00142	--	
Manganese	0.14	--		0.000064	--	
Sulfuric acid	0.59	2.72	21.5%	0.013	2.72	0.5%

Notes:
TEL – Threshold Effects Exposure Limit; AAL – Allowable Ambient Limit; PAH – Polycyclic Aromatic Hydrocarbon.

Tables 1.1 and 1.2 show that modeled air quality impacts of Project stack air toxics emissions at both the location of maximum project impact and at the day care center are well below the 24-hour TELs and annual-average AALs, indicating an absence of potential public health risk from Project stack emissions of non-criteria air pollutants. Importantly, safety factors are incorporated into the TELs and AALs to protect sensitive populations and children, and to account for other pathways of exposure to these compounds. In order to further verify that the Project emissions would not increase non-cancer and cancer risks to nearby communities, Gradient calculated Hazard Quotients (HQs) and Excess Lifetime Cancer Risks (ELCRs) according to well-established HHRA protocols to quantify non-cancer and cancer health risks, respectively (Section 2.2).

In the tables above, and throughout HHRA, the Project contributions to ground-level air concentrations in nearby communities are given in units of micrograms per cubic meter (µg/m^3). It is helpful to consider the size of this measurement unit to appreciate that a microgram represents an extremely tiny concentration. A cubic meter of air (1 m^3) is a volume of about a yard by a yard by a yard, and the air in this volume weighs 1.2 kg or 1,200 grams (about 2⅔ pounds). A gram is about 1/28th of an ounce (*i.e.*, about 28 grams in an ounce), and a microgram is one-millionth of a gram, or one-billionth of a kilogram. Thus, a concentration of 1 µg/m^3 corresponds to a weight of a substance floating in the air that is about one-billionth of the weight of the air surrounding it – a concentration of 1 part in one billion (ppb). One ppb is a very tiny amount of material; it is approximately the weight of a single (6") human hair (0.0001 oz) relative to the weight of a 3-ton SUV (100,000 oz), or the lapse of one second in a time span of 32 years. Finding an impurity present at the level of 1 ppb would be more difficult than finding one specific individual among the United States population of approximately 320 million people. That is, at 1 ppb you would have to examine about 999,999,999 chunks of clean air before you could be assured of finding the impurity at the 1 ppb concentration level. Another helpful comparison might be that of carbon dioxide (CO_2), which is a trace-gas constituent of the outside air, and which we all breathe in at an ambient concentration of 714,000 $\mu g/m^3$. In comparison, typical background annual-average levels of airborne particulate ($PM_{2.5}$) in the Worcester area are about 8.3 $\mu g/m^3$ (See Table 2.1 below).

1.3 HHRA Organization

Our HHRA includes two main components. These two components are an evaluation of the potential for human health risks of Project stack air quality impacts (Section 2) and an evaluation of baseline health status in the Medway area (Section 3). Importantly, our evaluation of potential human health risks of the Project stack air quality impacts contains multiple components for two hypothetical exposure scenarios (an off-site resident and a child attending the nearby day care center), including:

- a public health evaluation of Project criteria air pollutant stack emissions (Section 2.1);
- an assessment of chronic inhalation non-cancer and cancer health risks from the Project air toxics stack emissions (Section 2.2); and
- an acute (short-term) exposure evaluation for respiratory irritants (Section 2.3).

For each of these HHRA components, we made determinations regarding the acceptability of the Project impacts by relying upon two standard types of acceptability criteria, namely: 1) comparison with health-based benchmarks (*e.g.*, the primary health-based NAAQS, the US EPA regulatory lifetime-cancer-risk range of 10^{-6} to 10^{-4}, HQ calculation, *etc.*), and 2) the comparison of incremental Project ambient air impacts with ubiquitous, background levels of these pollutants in ambient air. Implicit in our determinations is the fundamental toxicology principle that, although elevated doses of any compound can be harmful, sufficiently low, yet non-zero levels of exposure can be considered innocuous and protective of public health, or of sufficiently low risk so as to be acceptable.

The societal acceptability of a non-zero level of risk is consistent with the fact that risk to health and life accompanies all parts of our everyday existence. To live and breathe is to be at risk for disease, injury, and death. Regardless of what we do, or do not do, we encounter risk. A short drive to the grocery store entails some risk. Walking or bicycling the same distance poses different risks. You may jog or exercise to improve your health, but these activities may also endanger it in unanticipated ways. Most accidental injuries and deaths occur in our homes. All of our activities entail risk, and when we act to eliminate or reduce one risk, we likely increase or create another risk. Most of the risks we face are (or seem) very small, and when we are asked to make judgments about how to avoid risks by changing our behavior, expending effort, or spending our money, we must ask ourselves whether our actions are reducing our overall risk. Would the time, effort, and expense be better spent on addressing some other potential danger? Health risk assessment is a quantitative process that helps answer this question.

Health risk assessment is a formalized, quantitative process for numerically estimating the probability of whether certain exposure levels to specific "chemicals of concern" might lead to an adverse health outcome, such as cancer. As noted by the Presidential/Congressional Commission on Risk Assessment and Risk Management, risk assessment relies on scientific observations regarding the relationship between exposure and effects, as well as inferences and assumptions, in order to determine what levels of exposure carry acceptable risks (CRARM, 1997). For cancer, the result of a risk assessment is an upper bound estimate on the probability of getting cancer, given the concentrations measured or estimated to be present, the toxicity of the chemicals, and the degree of exposure assumed, often accompanied by a description of the uncertainty in the overall assessment and in each of its components (US EPA, 1995, 2000a). Although uncertainty is inherent in every risk assessment, conservative assumptions are commonly used, *i.e.*, assumptions are made so that calculated risks represent overestimates of potential risks. Given these conservative assumptions and their associated safety factors, it is important to recognize that calculated risks are upper-bound and hypothetical in nature. Hypothetical risks are risks that are not known to actually occur, but that are estimated from assumptions regarding exposure and toxicity. Known risks, sometimes referred to as "actuarial risks," have known probabilities based on actual empirical data (*e.g.*, deaths, accident rates, hospitalizations, emergency room visits).

To put calculated hypothetical health risks from ambient or project-specific pollutant exposures into perspective, it is helpful to consider how these risks compare to overall health risks faced by the general public. Of the U.S. population (over 320 million people[6]), about 2.4 million people die every year (CDC, 2010). Of the annual U.S. deaths:

- heart and vascular disease are responsible for about one third of all deaths, and
- cancer deaths are responsible for about one quarter.

Thus, for the population generally, our lifetime risk of dying from cardiovascular disease is about 1 in 3, and for dying from cancer is about 1 in 4. These proportions of deaths from cardiovascular disease and cancer are roughly stable over time and from place to place in the U.S. Only a proportion of the individuals developing cancer die of the disease. In the U.S., the baseline chances of developing invasive cancer (cancer incidence) sometime during one's life are as follows:

- 43% for men, and
- 38% for women (Siegel *et al.*, 2015)

or, 40.5% as an average for both sexes, which can be expressed as a lifetime odds of 1 in 2.5. By comparison, the upper limit of US EPA's acceptable lifetime cancer risk range is 1 in 10,000, about 4,000-fold lower than baseline for all of us. As we describe in Section 2.2, hypothetical lifetime excess cancer risks associated with maximum modeled Project stack air toxics impacts are several orders of magnitude smaller than even US EPA's range – *i.e.*, in the range of about 1 in 10,000,000,000 to 3 in 100,000,000.

For estimating the likelihood of non-cancer effects from intake of chemicals, exposure concentrations are compared to reference concentrations (RfCs). For example, chronic RfCs are concentrations set low enough (through the use of uncertainty factors [UFs] and margins of safety) that lifetime exposure is not anticipated to result in any adverse health effect, even for sensitive subpopulations such as children, the elderly, or individuals with pre-existing disease. RfCs are set to levels many times lower than levels of exposure that have actually been demonstrated to have a potentially adverse health effect.

[6] http://www.census.gov/population/www/popclockus.html.

2 Human Health Risk Evaluation of Project Stack Air Emissions

2.1 Evaluation of Project Stack Criteria Air Pollutant Emissions

Elevated levels of common ambient air pollutants, such as PM, NO_2, SO_2, have been statistically linked with increased risk of cardiorespiratory health outcomes, including asthma symptoms, emergency room visits and hospital admissions for respiratory illnesses, and premature mortality. To address potential health concerns from these and other common ambient air pollutants (termed criteria air pollutants, and including PM, NO_2, SO_2, CO, ozone, and lead), the Clean Air Act directs US EPA to develop NAAQS that "accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in the ambient air" (US Congress, 1970, as cited in US EPA, 2011).

Compliance with the primary NAAQS is designed to assure, with an adequate margin of safety, a lack of significant public health risks. Because the primary NAAQS are solely health-based, they are not adjusted for factors such as technological feasibility, or costs and benefits. By incorporating a margin of safety, the NAAQS are set to address both uncertainties in the state of the science and the possibility of additional harms that might be identified in the future. Furthermore, the NAAQS are intended to be protective of the health of sensitive subpopulations, such as people with pre-existing disease (*e.g.*, cardiovascular diseases or asthma), children, and older adults. Similarly, the NAAQS are established to be protective of both short-term health effects and long-term health effects by defining the averaging time for the standards. These averaging times vary from 1 hour to 1 year, with the 1-hour standards intended to be protective of potential short-term effects, and the annual average standards intended to be protective of potential long-term health effects. In Section 2.3, we focus on potential health impacts of short-term (acute) NO_2 and SO_2 exposures.

The NAAQS reflect the current understanding of the health effects literature because the Clean Air Act requires US EPA to periodically review and, if appropriate, revise existing criteria and standards every five years. The NAAQS review process is extensive and involves several offices within US EPA as well as the external scientific community, various stakeholder groups, and the public. In particular, the Clean Air Scientific Advisory Committee (CASAC) – a congressionally mandated independent panel of non-government scientists and technical experts selected from the medical, academic, and research communities – plays a key role in reviewing the current status of health effects research and recommending whether revisions to criteria and standards are necessary. Although the NAAQS are periodically reviewed and updated, this does not mean that prior NAAQS were not health protective. Instead, changes in standards such as the NAAQS may reflect increased margins of safety rather than an increased expectation of serious, adverse health effects. Judgments on what constitutes an adequate margin of safety can change as the state of the science evolves and the understanding and manner of dealing with uncertainties changes. For example, as part of the last full review of the PM standards that was completed in 2012, US EPA broadened its health analyses to address developmental effects and susceptible populations, such as people with lower socioeconomic status (US EPA, 2011).

We note that several NAAQS have been revised to more stringent levels in recent years. In particular, US EPA completed its review of the NO_2 and SO_2 NAAQS in 2010, adding 1-hour NAAQS for both pollutants (US EPA, 2010a,b). More recently, US EPA (2012a) completed its review of the PM NAAQS, issuing a final rule in December 2012 that changed the $PM_{2.5}$ annual NAAQS from 15 $\mu g/m^3$ to a level of 12 $\mu g/m^3$. US EPA decided to retain the 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$ without any change. These recommendations are based on epidemiological studies that have reported associations between health effects (including cardiovascular disease effects) and PM levels below the prior annual $PM_{2.5}$ NAAQS of 15 $\mu g/m^3$. US EPA also retained the 24-hour PM_{10} standard of 150 $\mu g/m^3$.

For our HHRA, Gradient compared total impacts of the criteria air pollutants that correspond to the sum of modeled Project-related ground-level air concentrations and monitored ambient background levels with the current health-protective NAAQS to assess the likelihood of potential health effects associated with Project criteria air pollutant stack emissions at both the location of maximum modeled Project impacts and at the nearby day care center (Tables 2.1 and 2.2). As indicated in the tables, Project-specific modeled concentrations for each pollutant and averaging time represent either the highest modeled concentrations for the 5-year modeling period at the location of maximum impacts (Table 2.1) or the day care center location (Table 2.2), or averages of the highest modeled concentrations over the 5-year modeling period. All Project-specific modeled concentrations were provided by Epsilon and are based on the modeling analysis described in Epsilon Associates (2015b).

The results, as shown in Table 2.1 and Table 2.2, indicate that total impacts at both locations are well below the health-protective NAAQS for the criteria air pollutants associated with Project stack emissions. In fact, the maximum modeled Project concentrations are generally a small fraction of ambient background concentrations, as measured at the closest criteria air pollutant monitoring site at Summer Street in Worcester, Massachusetts (Epsilon Associates, 2015b). Therefore, Project-related emissions of criteria air pollutants are expected to have no significant impacts on human health risks, including on local community rates of cardiovascular and respiratory diseases.

Table 2.1 Criteria Air Pollutant Levels, Including for Both Maximum Modeled Project-specific Impacts and Total Impacts, Compared to the US EPA NAAQS

Pollutant	Averaging Period	Maximum Modeled ($\mu g/m^3$)[a]	Monitored Background ($\mu g/m^3$)	Total Impact ($\mu g/m^3$)[f]	NAAQS ($\mu g/m^3$)[g]
SO_2	1-hr	1.38[b]	25.2	26.6	196
	3-hr (secondary)	1.54	33.5	35.0	1300
	24 -hr	0.69	21	21.7	365[h]
	Annual	0.04	8.4	8.4	80[h]
PM_{10}	24-hr	9.09	40	49.1	150
	Annual	0.17	17.4	17.6	50[i]
$PM_{2.5}$	24-hr	6.12[c]	20.7	26.8	35
	Ann.	0.13[c]	8.3	8.4	12
NO_2	1-hr	9.01[b, d]	97.2	106.2	188
	Annual	0.33[e]	32.6	32.9	100
CO	1-hr	52.97	2635.8	2688.8	40000
	8-hr	22.35	1948.2	1970.6	10000

Notes:

NAAQS – National Ambient Air Quality Standards; SO_2 – Sulfur Dioxide; PM_{10} – Particles Less than 10 Micrometers in Diameter; $PM_{2.5}$ – Particles Less than 2.5 Micrometers in Diameter; NO_2 – Nitrogen dioxide; CO – Carbon Monoxide.

All data provided by Epsilon for air modeling analyses described in Epsilon Associates (2015b).

(a) Unless indicated otherwise, Project-specific modeled concentrations represent the maximum modeled concentrations for the given averaging time over the 5-year modeling period.

(b) Maximum daily 1-hr concentrations averaged over 5 years.

(c) Maximum 24-hour or annual concentrations averaged over 5 years.

(d) 1-hr NO_2 used Plume Volume Molar Ratio Method (PVMRM) for conversion of NOx to NO_2.

(e) Annual NO_2 used Ambient Ratio Method (ARM) scaling for conversion of NOx to NO_2.

(f) Maximum modeled concentration plus monitored background concentrations.

(g) NAAQS (US EPA, 2014a) available at http://www.epa.gov/air/criteria.html.

(h) The 24-hour and annual SO_2 NAAQS were revoked by US EPA in 2010. http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_history.htm (US EPA, 2014b).

(i) The annual PM_{10} NAAQS was revoked by US EPA in 2006. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_history.html

Table 2.2 Criteria Air Pollutant Levels, Including for Both Modeled Project-specific Impacts and Total Impacts at the Day Care Center, Compared to the US EPA NAAQS

Pollutant	Averaging Period	Day Care Modeled (μg/m³)[a]	Monitored Background (μg/m³)	Total Impact (μg/m³)[f]	NAAQS (μg/m³)[g]
SO_2	1-hr	0.69[b]	25.2	25.9	196
	3-hr (secondary)	1.16	33.5	34.7	1300
	24 -hr	0.45	21	21.5	365[h]
	Annual	0.02	8.4	8.4	80[h]
PM_{10}	24-hr	6.35	40	46.4	150
	Annual	0.11	17.4	17.5	50[i]
$PM_{2.5}$	24-hr	3.02[c]	20.7	23.7	35
	Annual	0.06[d]	8.3	8.4	12
NO_2	1-hr	4.27[b,d]	97.2	101.5	188
	Annual	0.29[e]	32.6	32.9	100
CO	1-hr	23.28	2635.8	2659.1	40000
	8-hr	8.97	1948.2	1957.2	10000

Notes:
NAAQS - National Ambient Air Quality Standards; SO_2 – Sulfur Dioxide; PM_{10} – Particles Less than 10 Micrometers in Diameter; $PM_{2.5}$ – Particles Less than 2.5 Micrometers in Diameter; NO_2 – Nitrogen dioxide; CO – Carbon Monoxide.
All data provided by Epsilon for air modeling analyses described in Epsilon Associates (2015b).
(a) Unless indicated otherwise, Project-specific modeled concentrations represent the maximum modeled concentrations at the day care center location for the given averaging time over the 5-year modeling period.
(b) Maximum daily 1-hr concentrations averaged over 5 years.
(c) Maximum 24-hour or annual concentrations averaged over 5 years.
(d) 1-hr NO_2 used Plume Volume Molar Ratio Method (PVMRM) for conversion of NOx to NO_2.
(e) Annual NO_2 used Ambient Ratio Method (ARM) scaling for conversion of NOx to NO_2.
(f) Maximum modeled concentration plus monitored background concentration.
(g) NAAQS (US EPA, 2014a) available at http://www.epa.gov/air/criteria.html.
(h) The 24-hour and annual SO_2 NAAQS were revoked in 2010 http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_history.htm (US EPA, 2014b).
(i) The annual PM_{10} NAAQS was revoked by US EPA in 2006. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_history.html

Table 2.1 uses maximum modeled Project-related concentrations that represent the highest predicted airborne exposure concentration increments to criteria air pollutants for a single location. As such, these concentrations are not representative of the reduced time- and spatially-averaged exposures to Project-related emissions that would be anticipated as an individual moves among different locations (*e.g.*, home, workplace, stores, *etc.*) within a community. As shown in Table 2.2, modeled Project-specific concentrations and total impact concentrations for each of the criteria air pollutants at the day care center adjacent to the Project site are lower than the corresponding concentrations at the location of maximum modeled Project impacts and thus are also well below the health-protective NAAQS.

To provide additional perspective regarding our conclusion that even the maximum modeled Project impacts are expected to pose insignificant public health risks, it is important to note that, for all of us, exposure to criteria air pollutants comes from multiple sources. These sources include primarily long-distance transport from upwind sources, local stationary sources and mobile sources (*e.g.*, from cars and buses), as well as from indoor sources (*e.g.*, at home or in an office). Because people spend a majority of their time in indoor environments, indoor sources of air pollutants are major contributors to overall daily exposures. Studies have shown that indoor concentrations of air pollutants are often greater than outdoor concentrations because pollutants from indoor sources can remain confined within the home over extended periods of time (Long *et al*., 2000; US EPA, 2009b). Indoor sources of criteria air pollutants include cooking, natural gas combustion, home-heating combustion, candles, cleaning activities, and cigarette smoke. As shown in Table 2.3, cooking and cleaning activities can result in elevated short-term $PM_{2.5}$ impacts ranging from 10 to 100 μg/m^3 (Long *et al*., 2000).

Table 2.3 Average Short-term Peak $PM_{2.5}$ Impacts During Various Cleaning, Cooking, and Other Activities in Boston-area Homes

Activity	$PM_{2.5}$ Concentration (μg/m^3)
Baking (electric)	15
Baking (gas)	101
Toasting	54
Broiling	29
Sautéing	66
Stir-frying	37
Frying	41
Dusting	23
Vacuuming	7
Cleaning with Pine Sol	11
Walking vigorously over carpet indoors	12
Burning candles	28

Note:
$PM_{2.5}$ – Particles Less than 2.5 Micrometers in Diameter.

To help provide perspective on how exposures to the maximum modeled Project impacts compare to everyday incremental (*i.e.*, on top of typical background) exposures associated with common voluntary activities, we calculated equivalent exposures to $PM_{2.5}$ and NO_2 for several typical everyday activities. These comparisons are presented in Table 2.4. The results show that the exposure that would be received from a full year of breathing ambient air with $PM_{2.5}$ and NO_2 concentrations at the levels of the maximum modeled Project stack air emissions impacts is equivalent to short durations of everyday $PM_{2.5}$ and NO_2 exposures from common indoor and outdoor activities (*e.g.*, driving a car, mowing the lawn, cooking).

Table 2.4 Comparison of Equivalent Exposures to Criteria Air Pollutants for Everyday Activities Compared to Maximum Modeled Concentrations from Project Stack Air Emissions

Project-related Concentration	Type of Impact	Approximate Equivalent Exposure
$PM_{2.5}$ µg/m^3		
0.13	Maximum modeled annual impact	4 minutes per day (over a year) in a car[a] 4 times per year lawn mowing for 20 minutes each time[b] 30 minutes per week (over a year) in the kitchen while baking with a gas oven[c]
NO_2 µg/m^3		
0.33	Maximum modeled annual impact	9 minutes per week (over a year) cooking with a gas stove and oven[d] 4 minutes per week (over a year) of oven cleaning[d] 6 minutes per day (over a year) in a car[a]

Notes:

$PM_{2.5}$ – Particles Less than 2.5 Micrometers in Diameter; NO_2 – Nitrogen Dioxide.

(a) Average in-vehicle concentrations ($PM_{2.5}$ = 48 µg/m^3, NO_2 = 78.5 µg/m^3) from Zhu *et al*. (2008) and Riediker *et al.* (2003), respectively.

(b) Average personal $PM_{2.5}$ exposure level (936 µg/m^3) for lawn mowing activities from Baldauf *et al.* (2006).

(c) Average whole-house $PM_{2.5}$ concentrations (50 µg/m^3) for cooking activities with a gas stove or gas oven from Wallace *et al*. (2004).

(d) Average NO_2 concentrations for cooking a full meal using gas (358 µg/m^3) and for gas oven cleaning activities (753 µg/m^3) from ARCADIS (2001).

In conclusion, the predicted maximum modeled impacts from Project stack air emissions are not expected to contribute significantly to the ubiquitous background levels of criteria air pollutants we all experience. Importantly, the total impacts (Project impacts + background) are well below the health-protective NAAQS at both the day care center and the location of maximum impact and are thus not expected to present significant risk to the health of residents in the area, including people with pre-existing cardiovascular or respiratory disease, or children attending the day care. To provide additional perspective, we demonstrated in Table 2.4 that cumulative year-long exposures to maximum modeled Project $PM_{2.5}$ and NO_2 impacts are equivalent to those doses received from short durations of everyday common activities.

2.2 Chronic Non-cancer and Cancer Health Risks from the Project Stack Air Toxics Emissions

To assess the potential for adverse health effects from Project stack air toxics emissions, we calculated chronic inhalation non-cancer and cancer health risks associated with maximum modeled Project air concentrations and modeled air concentrations at the day care center in accordance with standard risk assessment protocols, including guidelines provided in the US EPA Risk Assessment Guidance for Superfund (RAGS) Part F, Supplemental Guidance for Inhalation Risk Assessment (US EPA, 2009a). Project-specific modeled air concentrations were provided by Epsilon and are based on the air modeling analysis conducted in support of the comprehensive air plan approval application (Epsilon Associates, 2015b). These chronic risk calculations are intended to supplement the comparisons of maximum modeled annual average Project impacts and impacts at the day care center with the MADEP AALs, which are themselves health-based ambient air standards intended to be protective of both threshold and non-threshold effects from long-term (annual) exposures. Based on the finding that no Project maximal impacts or impacts at the day care center were above AALs, with most being two or more orders of magnitude less than the corresponding AALs, the Epsilon analysis provided evidence that Project stack air emissions would not be expected to lead to non-cancer or cancer health effects for residents in nearby neighborhoods or children attending the day care center abutting the Project site.

We estimated HQs and ELCRs to further assess the likelihood of potential non-cancer and cancer health effects, respectively, among individuals with hypothetical chronic inhalation exposures to maximum modeled Project-related concentrations or to modeled Project-related concentrations at the day care center. The HQ expresses the result of dividing the Project-related concentration by a health-protective concentration to which a continuous exposure over a lifetime would not be expected to harm health. Importantly, these risk calculations utilize alternative health-based benchmarks for non-cancer and cancer endpoints other than the Massachusetts AALs. Specifically, we relied upon chronic dose-response values recommended for use in inhalation risk assessments of hazardous air pollutants (HAPs) available from the US EPA Office of Air Quality Planning and Standards (OAQPS).[7] As stated on the OAQPS Air Toxics Website (US EPA, 2014c), OAQPS developed a priority scheme for selecting the recommended chronic dose-response values, with US EPA RfCs and Unit Risks (URs) from US EPA's Integrated Risk Information System (IRIS) being the preferred values for assessing non-cancer and cancer health outcomes, respectively. As defined by US EPA, an RfC is "an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (US EPA, 2012b). US EPA defines a UR as "the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/L in water, or 1 $\mu g/m^3$ in air." Inhalation URs are upper bound values and US EPA acknowledges that actual cancer risk is likely to be lower, and could be as low as zero, in particular for the numerous air toxics (*e.g.*, acetaldehyde, naphthalene) included in the cancer risk assessment based on their classification as probable or possible carcinogens, but that lack sufficient data to establish them as proven human carcinogens (US EPA, 2014d).

For substances lacking current IRIS assessments, OAQPS selected alternative dose-response values from the following sources (in ranked order of preference): 1) Agency for Toxic Substances and Disease Registry (ATSDR) chronic inhalation Minimal Risk Levels (MRLs)[8] (ATSDR, 2014; available only for non-cancer effects); 2) California Environmental Protection Agency [CalEPA] Chronic Reference Exposure Levels (RELs)[9] and URs[10] (CalOEHHA, 2014); and 3) toxicity factors from the US EPA Health Effects Assessment Summary Tables (US EPA, 1997).[11] No toxicity factors were available for total chromium, although it is not expected to contribute significantly to health risks due to the very low predicted concentrations. We did, however, calculate the potential non-cancer and cancer risks from chromium (VI), or hexavalent chromium, the form of chromium associated with potential cancer risk (US EPA, 2000b). We conservatively assumed that 20 percent of the modeled concentrations of total chromium were made up of chromium (VI). Appendix A summarizes the toxicity factors that were used in our risk calculations.

In general, each of the dose-response values used in our risk assessment was developed by US EPA or other regulatory agencies (*e.g.*, CalEPA, ATSDR) following a comprehensive process that considered the weight of the toxicological evidence and that typically utilized multiple safety and UFs. For example, in deriving RfCs from Lowest-Observed-Adverse-Effect-Levels (LOAELs) and/or No-Observed-Adverse-Effect-Levels (NOAELs) from either human epidemiology or laboratory animal toxicology studies, US EPA typically divides these concentrations by multiple UFs to account for potential uncertainties (including inter- and intra-species differences in sensitivity, insufficient study durations, use of a LOAEL

[7] http://www2.epa.gov/fera/dose-response-assessment-assessing-health-risks-associated-exposure-hazardous-air-pollutants.
[8] http://www.atsdr.cdc.gov/mrls/index.html.
[9] http://oehha.ca.gov/air/allrels.html.
[10] http://www.oehha.ca.gov/air/hot_spots/pdf/CPFs042909.pdf.
[11] http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2877.

instead of a NOAEL, and data deficiencies) to arrive at a final RfC. Such health-based benchmarks are set low enough to assure safety, rather than to represent a threshold above which an adverse effect might be expected. That is, the levels are derived to over predict rather than under predict potential health effects, and are thus considered to contribute to the "conservative" (*i.e.*, health-protective) nature of the risk assessment process.

Consistent with US EPA inhalation risk assessment guidance (US EPA, 2009a), we calculated time-adjusted exposure concentrations for each pollutant at both the day care center and location of maximum Project impacts as follows:

$$\text{Time-adjusted exposure} = \frac{(EPC * ET * EF * ED)}{AT}$$

Where:

EPC	=	Exposure point concentration (modeled Project impacts, μg/m^3)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
AT	=	Averaging time (hours)

For non-cancer risks, the averaging time (or total period of interest) is equivalent to the exposure duration expressed as hours. For cancer risks, the standard averaging time is a lifetime, or 613,200 hours to represent a 70-year lifetime.

Table 2.5 below summarizes the exposure assumptions used for the highly conservative hypothetical exposure scenarios considered in our health risk calculations, namely that of an off-site resident present continuously (24/7) at the location of maximum modeled annual average Project impacts and a child attending the nearby day care center. As shown in Table 2.5, we assumed that a hypothetical resident was present 24 hours a day, 365 days a year, for the standard assumed residential duration of 30 years, at the location of maximum modeled annual average Project impacts. This continuous-resident scenario has a higher exposure frequency and duration than other potential receptors (*e.g.*, schoolchildren, day care center children and workers), meaning that this hypothetical scenario is designed to yield risk estimates that are highly conservative (*i.e.*, that would be overestimates for other potential receptors).

The exposure assumptions for a hypothetical child attending the day care center are based on information provided on the center's website (Country Cottage Children's Center, 2015). With weekday business hours of 7 AM to 6 PM, the day care center provides day care, preschool, and after-school care for children ages 2 years and 9 months through age 6. The exposure duration of 4.25 years includes the entire period that children are eligible for services at the day care, while the exposure time of 11 hours a day assumes that the hypothetical child attends a full-day of programs at the day care each weekday. Conservatively assuming that a child spends every week day in a year at the day care center results in an exposure frequency of 261 days/year.

In addition, our health-protective scenarios assume that indoor pollutant concentrations due to the Project air emissions are identical to ambient (outdoor) predicted pollutant concentrations; this is a highly conservative assumption for the particulate phase pollutants (*e.g.*, metals) and reactive pollutants (formaldehyde, acetaldehyde), where indoor concentrations of outdoor-derived contributions of these pollutants can be substantially reduced compared to the corresponding outdoor concentrations (US EPA, 2009b; Seaman *et al*., 2007; Salthammer *et al*., 2010).

We calculated health risks for both an off-site resident and a child at the nearby day care center to illustrate the differences in potential health risks between these two receptors that arise due to the differences in model-predicted air concentrations at the location of maximum project impacts *versus* the location of the day care center, as well as differences in the exposure frequency and exposure duration for these two hypothetical receptors. Regardless of the differences in model-predicted air concentrations at the two locations, inhalation health risks for a resident with continuous exposure over a 30-year duration of exposure will be greater than the risks for a day care center child (or day care center worker) with non-continuous exposure over a shorter time period. The age difference between the two receptors does not contribute to the differences in risks because health risks for the inhalation pathway are calculated in a similar fashion for both adults and children. For exposure pathways other than inhalation, child and adult health risks are typically evaluated separately in risk assessments because these exposure pathways have child-specific exposure factors (such as body weight, soil ingestion rates, dermal surface areas, and so on) that lead to differential risks in children compared to adults. Previously, US EPA endorsed the conversion of inhalation exposures to an internal dose, which would contribute to differential inhalation risks for children *vs*. adults due to differences in factors such as inhalation rates and body weights. However, a US EPA working group recommended abandoning this approach, and instead advocated comparison of individual exposure concentrations directly to the RfC (US EPA, 2009a). The consensus among the working group was that this approach was health-protective without the incorporation of any additional adjustments for child-specific factors, given that the RfC is developed to protective sensitive population groups such as children (US EPA, 2003, 2009a).

Table 2.5 Exposure Assumptions for the Hypothetical Off-Site Resident and Day Care Child Scenarios

Exposure Factor	Off-Site Resident Scenario	Day Care Child Scenario
For Non-cancer Hazard Quotients:		
ET (hours/day)	24	11
EF (days/year)	365	261
ED (years)	30	4.25
Averaging Time (hours)	262,800	37,230
For Cancer Risks:		
ET (hours/day)	24	11
EF (days/year)	365	261
ED (years)	30	4.25
Averaging Time (hours)	613,200	613,200

Notes:
ET – Exposure Time; EF – Exposure Frequency; ED – Exposure Duration.

Table 2.6 summarizes Epsilon's maximum modeled annual average concentrations for the Project stack air toxics emissions, while Table 2.7 summarizes the modeled annual average concentrations for the Project stack air toxics emissions at the location of the nearby day care center. We used these model-predicted concentrations as the exposure point concentrations (EPCs) in our inhalation risk calculations for the hypothetical off-site resident and day care center child, respectively. Tables 2.6 and 2.7 also contain measured ambient air background concentrations for a limited subset of air toxics measured at the air toxics monitor at Harrison Avenue in Boston (approximately 25 miles from the proposed Project site). This is the closest ambient air toxics monitoring site to the Project site and thus is used to represent background air toxics levels at the Project site. As shown in Table 2.6, measured annual average ambient background levels of metals in Boston are between about 18 times (manganese) and 639 times (nickel) higher than the corresponding maximum modeled Project-specific concentrations. All measured annual average ambient background concentrations of volatile organic compounds (VOCs) for the Boston air toxics monitor are also substantially higher than the corresponding maximum modeled Project-specific concentrations; ambient background concentrations are from about 80 times (benzene) to 6,400 times (1,3-butadiene) higher for the Boston air toxics monitoring data. As shown in Table 2.7, the differences between the modeled Project concentrations at the day care center and the ambient background concentrations measured at the Boston air toxics monitor are even greater than those for the maximum modeled Project concentrations.

Table 2.6 Maximum Modeled Annual Average Project Stack Air Toxics Concentrations and Ambient Background Air Toxics Concentrations

Pollutant	Annual Average Project Impact (μg/m^3)	Annual Average Measured Background Concentration (Maximum Measured Background) (μg/m^3)
1,3-Butadiene	0.000009	0.058 (0.241)
Acetaldehyde	0.002040	--
Acrolein	0.000281	--
Benzene	0.007040	0.575 (1.473)
Naphthalene	0.001030	--
Ethylbenzene	0.000109	0.234 (0.755)
Formaldehyde	0.004530	--
Propylene Oxide	0.000099	--
Toluene	0.003130	1.681(6.388)
Xylenes	0.002070	0.851 (3.148)
Arsenic	0.000002	0.00048 (0.00153)
Beryllium	0.0000001	0.00001 (0.00003)
Cadmium	0.000002	0.00009 (0.00019)
Chromium (total)	0.000005	0.00325 (0.00914)
Lead	0.000007	0.00341 (0.00730)
Mercury	0.0000006	0.00002 (0.00004)
Nickel	0.000002	0.00139 (0.00527)
Selenium	0.000012	0.00022 (0.00113)
Ammonia	0.026300	--
Total PAH	0.001733	--
Manganese	0.000373	0.00663 (0.01790)
Sulfuric acid	0.022533	

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
Project modeled concentrations provided by Epsilon for air modeling analyses described in Epsilon Associates (2015b).
Background concentrations from 2013 as measured at the ambient air monitor on Harrison Avenue in Boston, MA (MADEP, 2014).

Table 2.7 Modeled Annual Average Project Stack Air Toxics Concentrations at the Day Care Center and Ambient Background Air Toxics Concentrations

Pollutant	Annual Average Project Impact (µg/m^3)	Annual Average Measured Background Concentration (Maximum Measured Background) (µg/m^3)
1,3-Butadiene	0.000002	0.058 (0.241)
Acetaldehyde	0.001470	--
Acrolein	0.000204	--
Benzene	0.005725	0.575 (1.473)
Naphthalene	0.000839	--
Ethylbenzene	0.000023	0.234 (0.755)
Formaldehyde	0.002711	--
Propylene Oxide	0.000021	--
Toluene	0.002283	1.681(6.388)
Xylenes	0.001557	0.851 (3.148)
Arsenic	0.0000003	0.00048 (0.00153)
Beryllium	0.00000003	0.00001 (0.00003)
Cadmium	0.0000004	0.00009 (0.00019)
Chromium (total)	0.0000009	0.00325 (0.00914)
Lead	0.000001	0.00341 (0.00730)
Mercury	0.0000001	0.00002 (0.00004)
Nickel	0.0000004	0.00139 (0.00527)
Selenium	0.000002	0.00022 (0.00113)
Ammonia	0.005402	--
Total PAH	0.001417	--
Manganese	0.000064	0.00663 (0.01790)
Sulfuric acid	0.012969	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
Project modeled concentrations provided by Epsilon for air modeling analyses described in Epsilon Associates (2015b).
Background concentrations from 2013 as measured at the ambient air monitor on Harrison Avenue in Boston, MA (MADEP, 2014).

Table 2.8 Estimated Time-adjusted Exposure Concentrations for Assessing Non-cancer and Cancer Risks, Using Modeled Maximum Project Stack Air Impacts, Modeled Day Care Impacts, and Monitored Background Air Toxics Concentrations in Boston, MA

Pollutant	For Calculating Hazard Quotients				For Assessing Cancer Risks			
	Maximum Modeled Impact (µg/m³)	Max Impact Background (µg/m³)	Day Care Center (µg/m³)	Day Care Background (µg/m³)	Maximum Modeled Impact (µg/m³)	Max Impact Background (µg/m³)	Day Care Center (µg/m³)	Day Care Background (µg/m³)
1,3-Butadiene	9.03E-06	5.75E-02	5.29E-07	1.89E-02	3.87E-06	2.47E-02	3.21E-08	1.14E-03
Acetaldehyde	2.04E-03	--	4.82E-04	--	8.73E-04	--	2.92E-05	--
Acrolein	2.81E-04	--	6.69E-05	--	1.21E-04	--	4.06E-06	--
Benzene	7.04E-03	5.75E-01	1.88E-03	1.88E-01	3.02E-03	2.46E-01	1.14E-04	1.14E-02
Naphthalene	1.03E-03	--	2.75E-04	--	4.40E-04	--	1.67E-05	--
Ethylbenzene	1.09E-04	2.34E-01	7.51E-06	7.67E-02	4.66E-05	1.00E-01	4.56E-07	4.66E-03
Formaldehyde	4.53E-03	--	8.88E-04	--	1.94E-03	--	5.39E-05	--
Propylene Oxide	9.86E-05	--	6.81E-06	--	4.23E-05	--	4.13E-07	--
Toluene	3.13E-03	1.68E+00	7.48E-04	5.51E-01	1.34E-03	7.20E-01	4.54E-05	3.34E-02
Xylenes	2.07E-03	8.51E-01	5.10E-04	2.79E-01	8.88E-04	3.65E-01	3.10E-05	1.69E-02
Arsenic	1.89E-06	4.80E-04	1.07E-07	1.57E-04	8.10E-07	2.06E-04	6.50E-09	9.55E-06
Beryllium	1.47E-07	1.00E-05	8.29E-09	3.28E-06	6.28E-08	4.29E-06	5.03E-10	1.99E-07
Cadmium	2.27E-06	9.00E-05	1.28E-07	2.95E-05	9.72E-07	3.86E-05	7.80E-09	1.79E-06
Chromium (total)	5.20E-06	3.25E-03	2.94E-07	1.07E-03	2.23E-06	1.39E-03	1.79E-08	6.47E-05
Chromium (VI)[a]	1.04E-06	--	5.88E-08	--	4.46E-07	--	3.57E-09	--
Lead	6.62E-06	3.41E-03	3.74E-07	1.12E-03	2.84E-06	1.46E-03	2.27E-08	6.79E-05
Mercury	5.67E-07	2.00E-05	3.21E-08	6.55E-06	2.43E-07	8.57E-06	1.95E-09	3.98E-07
Nickel	2.17E-06	1.39E-03	1.23E-07	4.56E-04	9.32E-07	5.96E-04	7.47E-09	2.77E-05
Selenium	1.18E-05	2.20E-04	6.69E-07	7.21E-05	5.06E-06	9.43E-05	4.06E-08	4.38E-06
Ammonia	2.63E-02	--	1.77E-03	--	1.13E-02	--	1.07E-04	--
Total PAH	1.73E-03	--	4.64E-04	--	7.43E-04	--	2.82E-05	--
Manganese	3.73E-04	6.63E-03	2.11E-05	2.17E-03	1.60E-04	2.84E-03	1.28E-06	1.32E-04
Sulfuric acid	2.25E-02	--	4.25E-03	--	9.66E-03	--	2.58E-04	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
(a) Based on assumption that 20% of chromium is emitted in hexavalent form.
-- = Data not available.

Using the time-adjusted exposure concentrations in Table 2.8, we estimated chronic inhalation non-cancer health risks by calculating HQs according to the following equation (US EPA, 2009a):

$$Hazard\ Quotient = \frac{Exposure\ Concentration\ (\frac{\mu g}{m^3})}{RfC\ (\frac{\mu g}{m^3})}$$

For cancer risks, we estimated theoretical incremental ELCRs by combining time-adjusted exposure concentrations and URs according to the following equation (US EPA, 2009a):

$$Cancer\ Risk = Exposure\ Concentration\ \left(\frac{\mu g}{m^3}\right) x\ Unit\ Risk\ [\ \left(\frac{\mu g}{m^3}\right)^{-1}]$$

For the off-site resident exposure scenario, the calculated HQs and ELCRs are summarized in Tables 2.9 and 2.10, respectively. As shown in Table 2.9, all Project-specific HQs calculated for a hypothetical off-site resident exposed to maximum modeled Project stack air impacts are far below an HQ of 1,[12] ranging from 1.09×10^{-7} for ethylbenzene to 0.023 for sulfuric acid. The overall summed hazard index (HI) of 0.04 is also well below 1, indicating that estimated chronic exposures to maximum modeled Project stack air impacts are not expected to result in non-cancer health risks. In addition, Table 2.10 shows that all estimated Project-specific ELCRs are well below the regulatory cancer risk range of 10^{-6} to 10^{-4} that is considered to be acceptable by US EPA (US EPA, 1990), with ELCRs ranging from 1.16×10^{-10} for ethylbenzene to 2.5×10^{-8} for formaldehyde. The overall summed cancer risk for an off-site resident of 7.7×10^{-8} is also below the US EPA regulatory *de minimis* level, further supporting an absence of significant cancer risk from worst-case chronic exposures to maximum modeled Project stack air impacts.

For the day care child exposure scenario, the calculated HQs and ELCRs are summarized in Tables 2.11 and 2.12, respectively. Due to both the lower model-predicted concentrations of all air toxics at the day care center versus the location of maximum modeled Project impacts, as well as the non-continuous exposure for a child attending the day care, the Project-specific non-cancer and cancer risks calculated for a child attending the day care center are lower than the risks calculated for the hypothetical off-site resident. As shown in Table 2.11, all HQs calculated for a child attending the day care center are far below an HQ of 1, ranging from 7.5×10^{-9} for ethylbenzene to 0.0043 for sulfuric acid. The overall summed HI of 0.008 is also well below 1, indicating that estimated chronic exposures to the modeled concentrations from Project stack air toxics emissions at the day care center are not expected to result in non-cancer health risks. In addition, Table 2.12 shows that all estimated Project-specific ELCRs for a child attending the day care are well below the regulatory cancer risk range of 10^{-6} to 10^{-4} that is considered to be acceptable by US EPA (US EPA, 1990), with ELCRs ranging from 9.6×10^{-13} for ethylbenzene to 8.9×10^{-10} for benzene. The overall summed cancer risk of 2.3×10^{-9} is also below the US EPA regulatory *de minimis* level, further supporting an absence of significant cancer risk from exposure to Project impacts at the day care center.

[12] US EPA (2006) states that HQs of less than one indicate that an estimated exposure for an individual is considered to be without significant non-cancer health risk. However, because RfCs are not direct estimators of risk but are instead reference points for gauging potential effects that incorporate protective assumptions in the face of uncertainty, US EPA documents (US EPA, 2006) state that exceedances of the RfC (*i.e.*, HQs exceeding one) do not necessarily suggest a likelihood of adverse health effects. In other words, the HQ is not a measure of the probability that adverse effects will occur and is not likely to be proportional to risk. An HQ greater than one is interpreted as an indication that there is the potential for adverse health effects and that additional evaluation of chronic non-cancer risks is warranted.

Table 2.9 Non-cancer Hazard Quotients (HQs) With and Without the Project for a Hypothetical Off-Site Resident

Pollutant	Maximum Annual Average Impacts		
	Project-specific HQs	HQs w/o Project (*i.e.*, Background)	HQs with Project (*i.e.*, Background Plus Maximum Project Impact)
1,3-Butadiene	4.5E-06	2.9E-02	2.9E-02
Acetaldehyde	2.3E-04	--	--
Acrolein	1.4E-02	--	--
Benzene	2.3E-04	1.9E-02	1.9E-02
Naphthalene	3.4E-04	--	--
Ethylbenzene	1.1E-07	2.3E-04	2.3E-04
Formaldehyde	4.6E-04	--	--
Propylene Oxide	3.3E-06	--	--
Toluene	6.3E-07	3.4E-04	3.4E-04
Xylenes	2.1E-05	8.5E-03	8.5E-03
Arsenic	1.3E-04	3.2E-02	3.2E-02
Beryllium	7.3E-06	5.0E-04	5.1E-04
Cadmium	2.3E-04	9.0E-03	9.2E-03
Chromium (total)	--	--	--
Chromium (VI)[a]	1.0E-05	--	--
Lead	4.4E-05	2.3E-02	2.3E-02
Mercury	1.9E-06	6.7E-05	6.9E-05
Nickel	2.4E-05	1.5E-02	1.5E-02
Selenium	5.9E-07	1.1E-05	1.2E-05
Ammonia	2.6E-04	--	--
Total PAH	--	--	--
Manganese	1.2E-03	2.2E-02	2.3E-02
Sulfuric acid	2.3E-02	--	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
(a) Based on assumption that 20% of chromium is emitted in hexavalent form.
-- = Not calculated.

Table 2.10 Estimated Excess Lifetime Cancer Risks (ELCRs) With and Without the Project for a Hypothetical Off-Site Resident

Pollutant	Maximum Annual Average Impacts		
	Project-specific Cancer Risks	Cancer Risks w/o Project (*i.e.*, Background)	Cancer Risks with Project (*i.e.*, Background plus Maximum Project Impact)
1,3-Butadiene	1.2E-10	7.4E-07	7.4E-07
Acetaldehyde	1.9E-09	--	--
Acrolein	--	--	--
Benzene	2.4E-08	1.9E-06	1.9E-06
Naphthalene	1.5E-08	--	--
Ethylbenzene	1.2E-10	2.5E-07	2.5E-07
Formaldehyde	2.5E-08	--	--
Propylene Oxide	1.6E-10	--	--
Toluene	--	--	--
Xylenes	--	--	--
Arsenic	3.5E-09	8.8E-07	8.9E-07
Beryllium	1.5E-10	1.0E-08	1.0E-08
Cadmium	1.8E-09	6.9E-08	7.1E-08
Chromium (total)	--	--	--
Chromium (VI)[a]	5.3E-09	--	--
Lead	--	--	--
Mercury	--	--	--
Nickel	--	--	--
Selenium	--	--	--
Ammonia	--	--	--
Total PAH		--	--
Manganese	--	--	--
Sulfuric acid	--	--	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
(a) Based on assumption that 20% of chromium is emitted in hexavalent form.
-- = Not calculated.

Table 2.11 Non-cancer Hazard Quotients (HQs) With and Without the Project for a Hypothetical Child Attending the Day Care Center

Pollutant	Day Care Average Annual Impacts		
	Project-specific HQs	HQs w/o Project (*i.e.*, Background)	HQs with Project (*i.e.*, Background plus Project Impact)
1,3-Butadiene	2.6E-07	9.4E-03	9.4E-03
Acetaldehyde	5.4E-05	--	--
Acrolein	3.3E-03	--	--
Benzene	6.3E-05	6.3E-03	6.3E-03
Naphthalene	9.2E-05	--	--
Ethylbenzene	7.5E-09	7.7E-05	7.7E-05
Formaldehyde	9.1E-05	--	--
Propylene Oxide	2.3E-07	--	--
Toluene	1.5E-07	1.1E-04	1.1E-04
Xylenes	5.1E-06	2.8E-03	2.8E-03
Arsenic	7.1E-06	1.0E-02	1.0E-02
Beryllium	4.1E-07	1.6E-04	1.6E-04
Cadmium	1.3E-05	2.9E-03	3.0E-03
Chromium (total)	--	--	--
Chromium (VI)[a]	5.9E-07	--	--
Lead	2.5E-06	7.5E-03	7.5E-03
Mercury	1.1E-07	2.2E-05	2.2E-05
Nickel	1.4E-06	5.1E-03	5.1E-03
Selenium	3.3E-08	3.6E-06	3.6E-06
Ammonia	1.8E-05	--	--
Total PAH	--	--	--
Manganese	7.0E-05	7.2E-03	7.3E-03
Sulfuric acid	4.3E-03	--	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
(a) Based on assumption that 20% of chromium is emitted in hexavalent form.
-- = Not calculated.

Table 2.12 Estimated Excess Lifetime Cancer Risks (ELCRs) With and Without the Project for a Hypothetical Child Attending the Day Care Center

Pollutant	Day Care Annual Average Impacts		
	Project-specific Cancer Risks	Cancer Risks w/o Project (*i.e.*, Background)	Cancer Risks with Project (*i.e.*, Background plus Project Impact)
1,3-Butadiene	9.6E-13	3.4E-08	3.4E-08
Acetaldehyde	6.4E-11	--	--
Acrolein	--	--	--
Benzene	8.9E-10	8.9E-08	9.0E-08
Naphthalene	5.7E-10	--	--
Ethylbenzene	1.1E-12	1.2E-08	1.2E-08
Formaldehyde	7.0E-10	--	--
Propylene Oxide	1.5E-12	--	--
Toluene	--	--	--
Xylenes	--	--	--
Arsenic	2.8E-11	4.1E-08	4.1E-08
Beryllium	1.2E-12	4.8E-10	4.8E-10
Cadmium	1.4E-11	3.2E-09	3.2E-09
Chromium (total)	--	--	--
Chromium (VI)[a]	4.3E-11	--	--
Lead	--	--	--
Mercury	--	--	--
Nickel	--	--	--
Selenium	--	--	--
Ammonia	--	--	--
Total PAH		--	--
Manganese	--	--	--
Sulfuric acid	--	--	--

Notes:
PAH – Polycyclic Aromatic Hydrocarbon.
(a) Based on assumption that 20% of chromium is emitted in hexavalent form.
-- = Not calculated.

Although some polycyclic aromatic hydrocarbons (PAHs) have been classified by US EPA as probable human carcinogens, we did not include total PAHs, which were modeled by Epsilon as the summed emissions of acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(j,k)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3,c,d)pyrene, perylene, phenanthrene, and pyrene, in our risk calculations given the lack of modeled concentrations for individual PAH compounds. Since not all PAHs are considered to be carcinogenic and those that are considered to be carcinogenic differ in their cancer potency, modeled concentrations for individual PAH compounds are needed to assess their potential cancer risks. However, even if we conservatively apply the inhalation UR for benzo(a)pyrene to estimate cancer risks for modeled concentrations of total PAHs, the total ELCRs for both the hypothetical off-site resident and day care center child scenarios remain below the cancer risks considered acceptable by the US EPA.

For those air toxics measured at the Boston air toxics monitor, we also calculated non-cancer and cancer risks using estimates of existing background air toxics levels based on the monitoring data (*i.e.*, background only), and for the sum of the maximum modeled Project stack air impacts and existing background air toxics levels (*i.e.*, background with Project). We calculated and compared these risks for both the hypothetical off-site resident and day care scenarios. As shown in Tables 2.9 and 2.10 and below in Figures 2.1 and 2.2, HQs and ELCRs estimated for an off-site resident from background levels alone are almost identical to those calculated for both background and Project impacts combined. This is particularly well illustrated by Figures 2.1 and 2.2, which show no discernible differences between the "Background with Project" and "Background Only" calculated risks. In other words, it is expected that even maximum modeled Project stack air quality impacts will have only a negligible impact on chronic inhalation non-cancer and cancer health risks in nearby communities. As illustrated by Figures 2.3 and 2.4, the same is true for the day care center child exposure scenario where there is no discernible difference between the "Background with Project" and "Background Only" calculated risks. In other words, the calculated risks with the Project are nearly identical to those calculated using only the measured background concentrations, further supporting the lack of any significant impacts of Project stack air toxics emissions on non-cancer and cancer risks. Note that ELCRs for both the "Background with Project" and "Background Only" cases are significantly lower for the hypothetical day care child scenario than for the hypothetical off-site resident scenario due primarily to the small exposure duration of 4.25 years for this exposure scenario and the non-continuous nature of the exposures (*e.g.*, 11 hours per day and 261 days per year) as compared to the exposure duration of 30 years and continuous exposures for the off-site resident scenario. While Project-specific ELCRs are also lower for the hypothetical day care child scenario due to reductions in model-predicted Project impacts at the location of the day care center as compared to the maximal Project impacts, these reductions in Project-specific ELCRs have only a minimal impact on the ELCRs for the "Background with Project" case because they are dominated by the cancer risks from background air toxics levels.

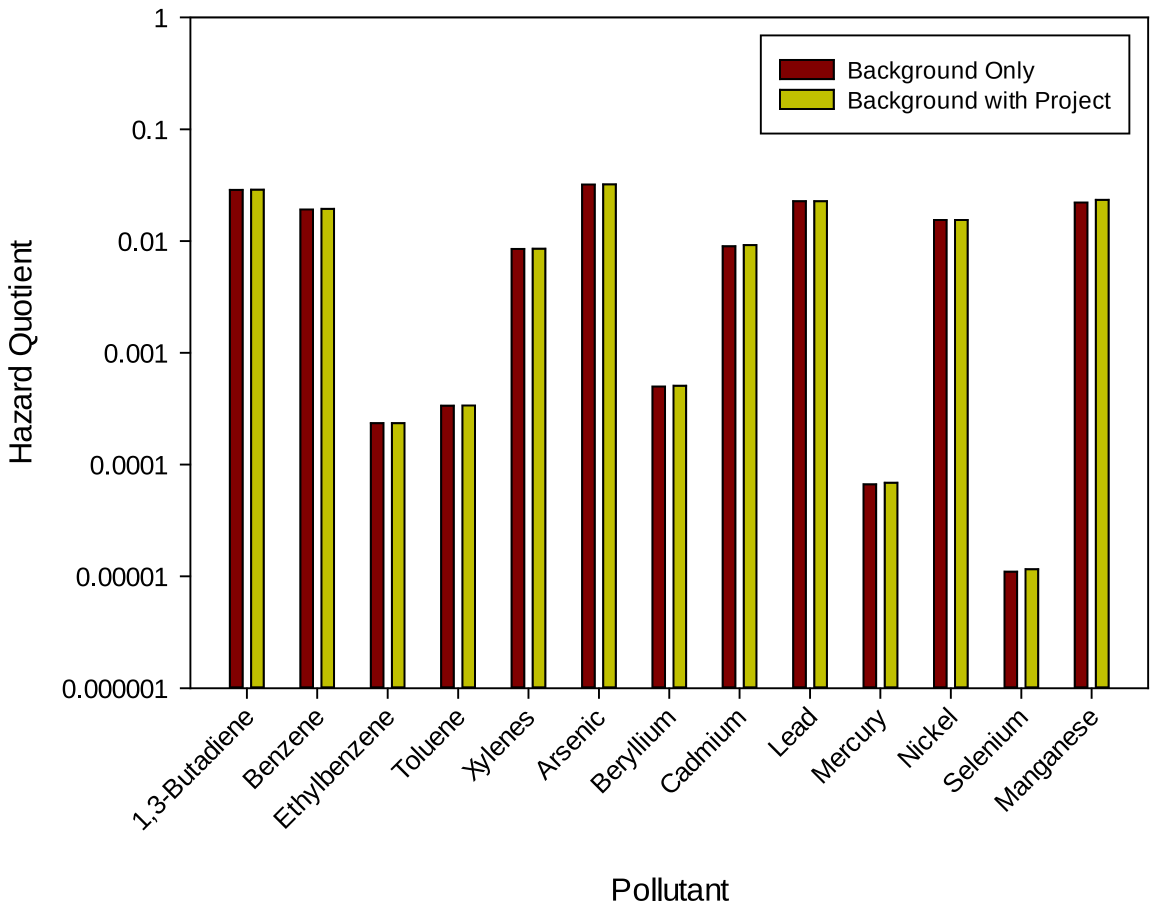

Figure 2.1 Non-cancer Hazard Quotients (HQs) With and Without the Project Maximum Modeled Stack Air Impacts for a Hypothetical Off-Site Resident

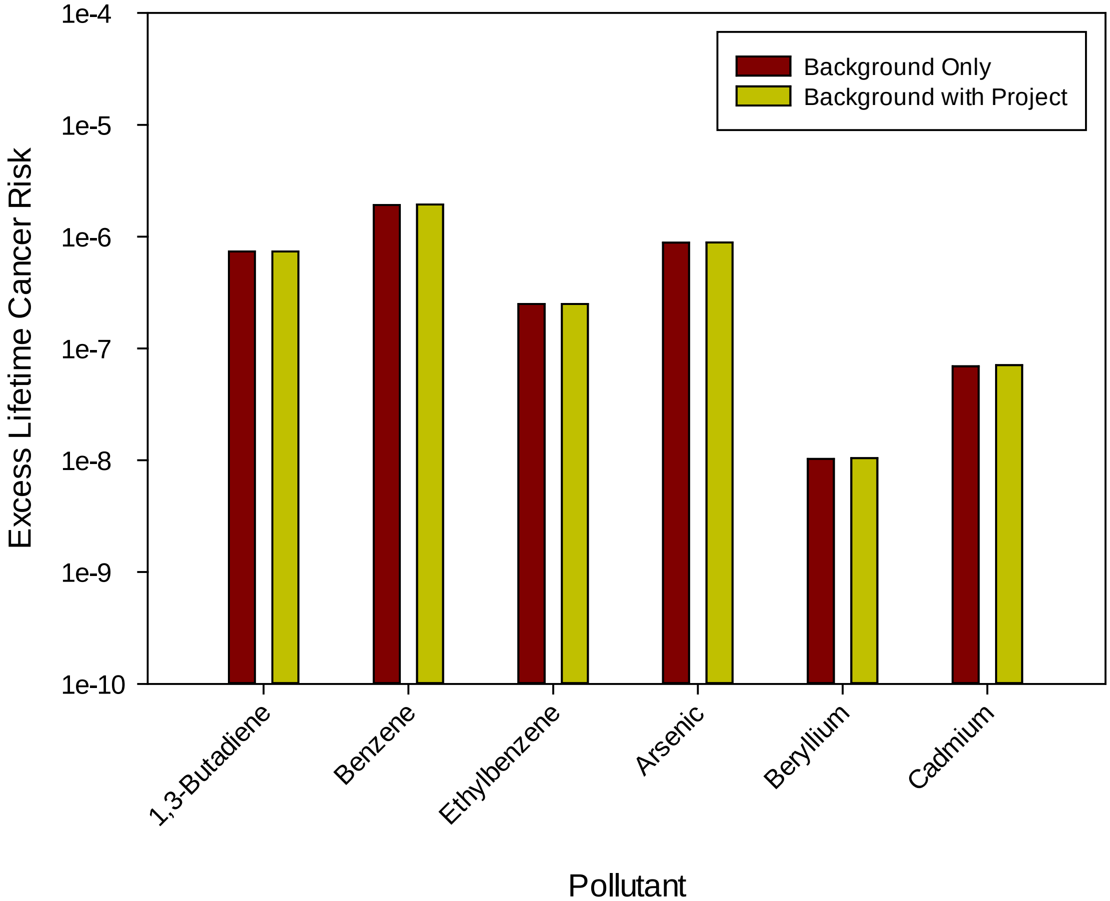

Figure 2.2 Excess Lifetime Cancer Risks (ELCRs) With and Without the Project Maximum Modeled Stack Air Impacts for a Hypothetical Off-Site Resident

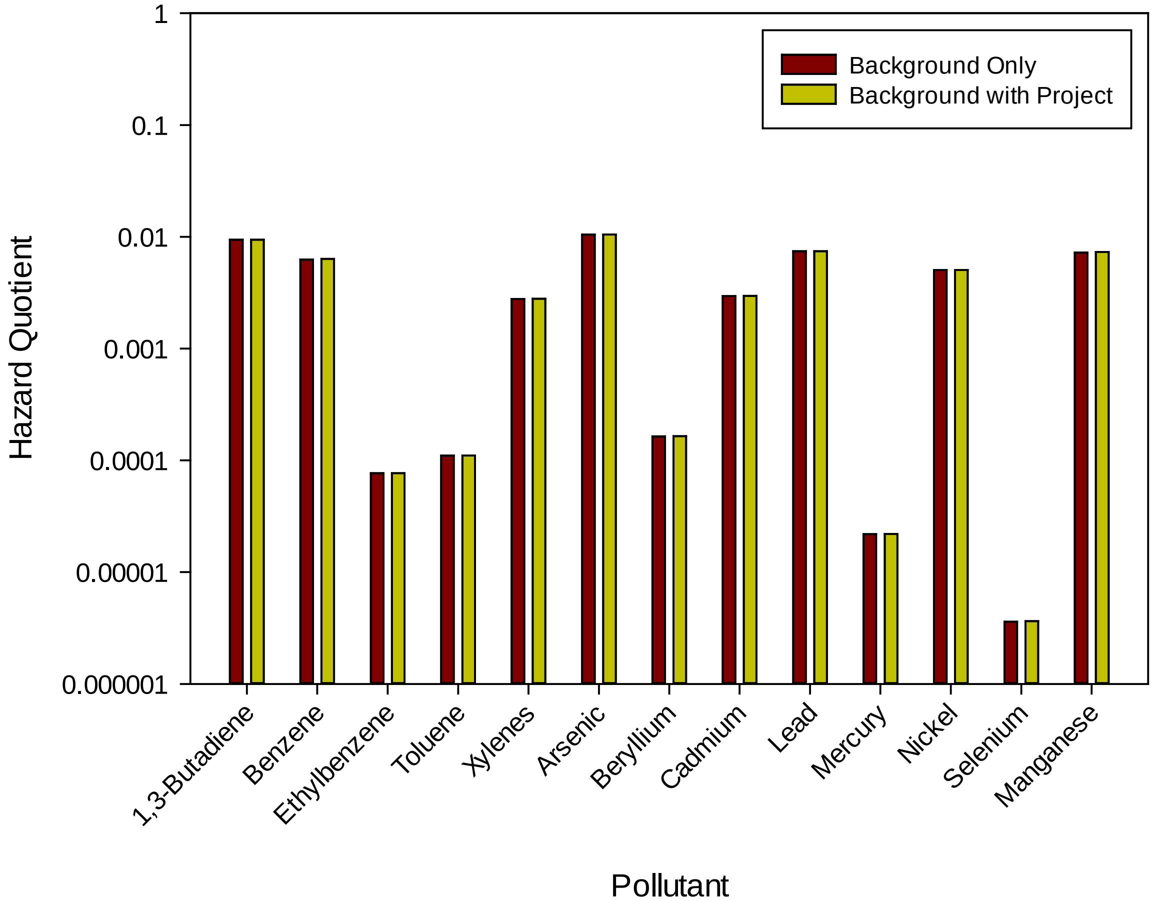

Figure 2.3 Non-cancer Hazard Quotients (HQs) With and Without the Project Maximum Modeled Stack Air Impacts for a Hypothetical Child at the Day Care Center

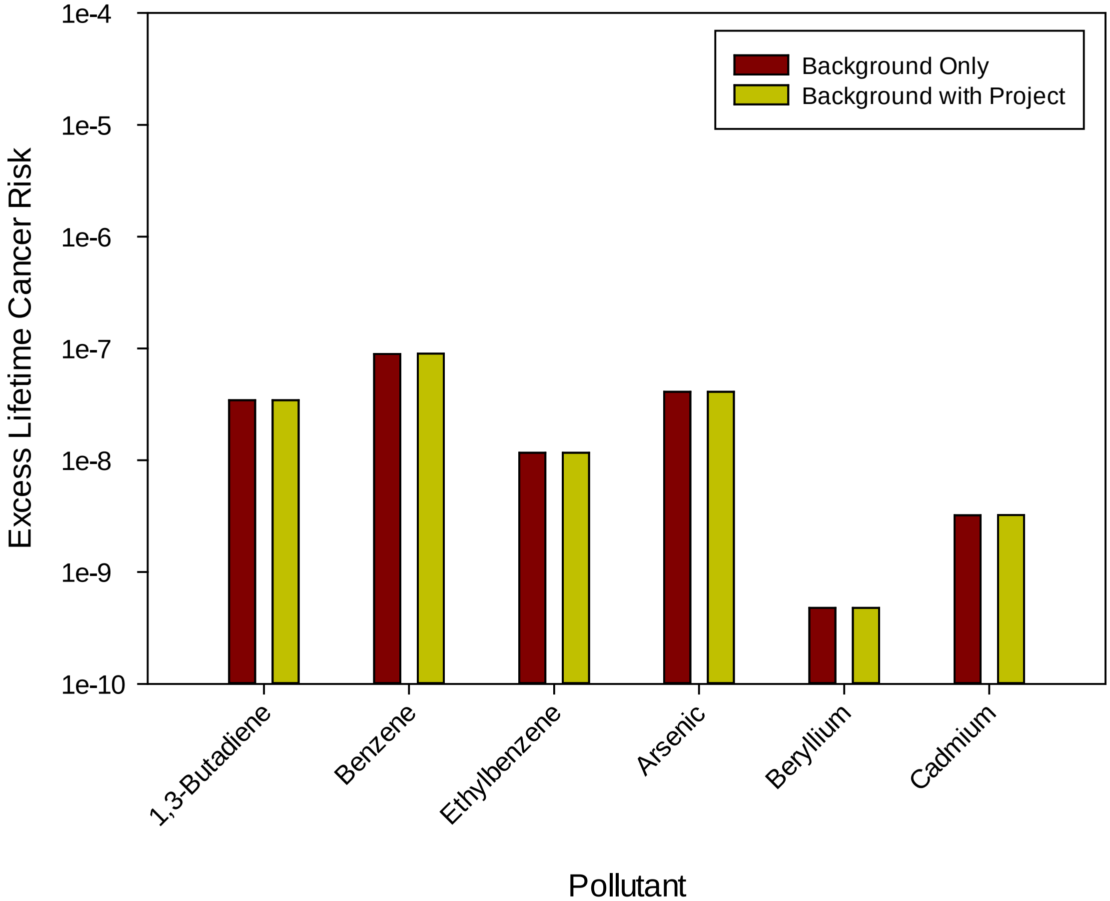

Figure 2.4 Excess Lifetime Cancer Risks (ELCRs) With and Without the Project Modeled Stack Air Impacts for a Hypothetical Child at the Day Care Center

2.3 Acute (Short-term) Exposure Evaluation for Respiratory Irritants

Two of the criteria air pollutants (NO_2 and SO_2) and three of the additional modeled air toxics (acetaldehyde, acrolein, and formaldehyde) are known to be respiratory irritants at sufficiently high exposure levels and therefore may be associated with increased risk of acute respiratory effects among asthmatics. To supplement the chronic risk estimates calculated in Section 2.2, we conducted an acute exposure evaluation for these respiratory irritants. For the criteria air pollutants, we principally relied upon the 1-hour NAAQS that incorporate the current evidence for acute effects to short-term NO_2 and SO_2 exposures (US EPA, 2010a,b). Regarding NO_2, US EPA indicates that "current scientific evidence links short-term NO_2 exposures, ranging from 30 minutes to 24 hours, with an array of adverse respiratory effects including increased asthma symptoms, more difficulty controlling asthma, and an increase in respiratory illnesses and symptoms."[13] Regarding SO_2, US EPA states that "current scientific evidence links short-term exposure to SO_2, ranging from five minutes to 24 hours, with a range of adverse respiratory effects including narrowing of the airways that can cause difficulty breathing (bronchoconstriction) and increased asthma symptoms. These effects may be important for asthmatics at elevated ventilation rates (*e.g.*, while exercising or playing)."[14] Furthermore, US EPA has concluded that "studies also show a connection between short-term exposure to [both pollutants] and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at risk populations including children, the elderly, and asthmatics." Therefore, in 2010, US EPA set a 1-hour average NO_2 standard at the level of 100 ppb (equivalent to 188 $\mu g/m^3$). Similarly, US EPA revised the primary SO_2 standard to a 1-hour average level of 75 ppb (equivalent to 196 $\mu g/m^3$). These 1-hour US EPA standards are intended to protect against the adverse health effects associated with short-term NO_2 and SO_2 exposures, including respiratory effects in sensitive populations such as asthmatics.

We also compared the maximum modeled Project 1-hour concentrations and modeled Project 1-hour concentrations at the day care center with Acute Exposure Guideline Levels (AEGLs). The US EPA Office of Solid Waste (OSW) recommends a hierarchal approach for establishing acute inhalation exposure criteria that are protective of the general public from short-term discomfort or mild adverse health effects (US EPA, 2005), and AEGLs are the preferred values in the OSW hierarchal approach based on: 1) their applicability to a 1-hour exposure period for protection of the general public, and 2) the high level of documentation and associated review.

The AEGLs are developed by the National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances (AEGL Committee) to represent threshold exposure limits for the general public, including sensitive subpopulations (NRC, 2001). Members of the AEGL Committee include US EPA scientists as well as scientists from other governmental and regulatory agencies. AEGLs are subjected to a comprehensive review process that includes both public and peer review components.[15] AEGLs are typically developed for three levels of severity (AEGL-1, AEGL-2, and AEGL-3) for exposure periods ranging from 10 minutes up to 8 hours (for 10-minute, 30-minute, 1-hour, 4-hour, and 8-hour exposure periods) to be protective of toxic effects of varying degrees of severity, including both non-cancer and cancer health effects.

The AEGL-1 values are used in this assessment, as they represent the lowest exposure thresholds that are protective of mild health effects such as discomfort and irritation.

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[13] From the US EPA NO_2 Fact Sheet available at: http://www.epa.gov/airquality/nitrogenoxides/pdfs/20100122fs.pdf.
[14] From the US EPA SO_2 Fact Sheet available at: http://www.epa.gov/airquality/sulfurdioxide/pdfs/20100602fs.pdf.
[15] The current listing of finalized, interim, and proposed AEGLs is available on the US EPA website at: http://www.epa.gov/oppt/aegl/ (US EPA, 2012c).

As defined on the US EPA AEGLs web page (US EPA, 2012c), the AEGL-1 is:

> the airborne concentration (expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

US EPA (2012c) additionally states that airborne concentrations below the AEGL-1 may "produce mild and progressively increasing but transient and non-disabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects." The AEGL-1 is intended to be protective of the general population including infants and children, the elderly, asthmatics, and other susceptible individuals. This assessment utilizes AEGL-1 values in either final, interim, or proposed form for the airborne chemicals of interest.

In addition to the 1-hr AEGL-1 acute reference values, we also compared modeled 1-hour concentrations to acute toxicity factors developed by the CalEPA Office of Environmental Health Hazard Assessment (OEHHA). An acute REL[16] is defined as "an exposure that is not likely to cause adverse health effects in a human population, including sensitive subgroups, exposed to that concentration (in units of micrograms per cubic meter or µg/m^3) for the specified exposure duration on an intermittent basis." Acute RELs are developed for potential non-cancer health impacts associated with routine, short-term exposures and are based on the most sensitive, relevant adverse health effect reported in the toxicological literature. They are specifically developed to protect the most sensitive individuals in the population through use of margins of safety. Thus, acute RELs are typically based on very mild health effects that include eye, nose, or throat irritation.

As shown in Table 2.13, maximum modeled Project 1-hour concentrations and modeled 1-hour concentrations at the day care center, as well as estimates of total impact levels (maximum modeled 1-hour + ambient background), are well below relevant acute reference values for each of the respiratory irritants included in the acute exposure evaluation. Relevant acute reference values include the 1-hour health-protective NAAQS that were specifically designed to address asthma and respiratory diseases, as well as the AEGL-1 values and the RELs established by the CalEPA.

[16] http://www.oehha.ca.gov/air/hot_spots/pdf/6dranoncdf.pdf.

Table 2.13 Comparison of Modeled Project Acute (1-Hour) Concentrations for Potential Respiratory Irritants Relative to Acute Reference Values

Pollutant	Maximum Project Impact		Day Care Center		Acute (1-Hour) Reference Values (μg/m^3)		
	Maximum Modeled 1-Hour Project Impact (μg/m^3)[a]	Estimated 1-Hour Total Impact (μg/m^3)[b]	Maximum Modeled 1-Hour Project Impact (μg/m^3)[a]	Estimated 1-Hour Total Impact (μg/m^3)[b]	NAAQS[c]	REL[d]	AEGL-1[e]
Nitrogen dioxide	9.01	106.2	4.27	101.5	188	470	940
Sulfur dioxide	1.38	26.6	0.69	25.9	196	660	520
Acetaldehyde	0.0686	--	0.0588	--	--	470	81000
Acrolein	0.0097	--	0.0083	--	--	2.5	70
Formaldehyde	0.3349	--	0.2572	--	--	55	11

Notes:
NAAQS – National Ambient Air Quality Standards; REL – Reference Exposure Level.
(a) Modeled Project 1-hour concentrations provided by Epsilon.
(b) From Tables 2.1 and 2.2.
(c) NAAQS (US EPA, 2014a) available at http://www.epa.gov/air/criteria.html.
(d) Acute (1-hour) Reference Exposure Levels from CalEPA OEHHA (US EPA, 2014 available at: http://oehha.ca.gov/air/allrels.html.
(e) AEGLs (US EPA, 2014e) available at http://www.epa.gov/oppt/aegl/.

3 Evaluation of Community Baseline Health Status

As a supplement to the health risk calculations in Section 2, Gradient compiled and evaluated existing baseline health data for Medway. Where available, we also considered baseline health data for several neighboring communities, including Milford, Holliston, Bellingham, Franklin, Millis, and Norfolk. Baseline health data include cancer statistics available from the Massachusetts Cancer Registry; pediatric asthma surveillance data, asthma emergency department visit and hospital admission data, and myocardial infarction hospital admission data available from the MADPH Environmental Public Health Tracking website; and asthma and cardiovascular hospitalization data available from the Massachusetts Community Health Information Profile (MassCHIP) website. We review these baseline health data in the following sections, and comment on whether Project air emissions could be expected to augment risks for these diseases.

3.1 General Description of the Town of Medway

Incorporated in 1713, the Town of Medway is a residential community of approximately 13,000 located on the western edge of Norfolk County, 25 miles southwest of Boston and bordered by the towns of Holliston on the north; Millis on the east; Norfolk, Franklin, and Bellingham on the south; and Milford on the west. Medway has a total area of 11.54 square miles and a land area of 11.45 square miles (MADHCD, undated; Medway, MA, Undated). Based on 2010 population data, the majority of the population of Medway is white (95.0%); 1.0% are Black, 2.0% Hispanic or Latino, and 2.2% are Asian (US Census Bureau, 2010). State highway Route 109 runs the length of Medway from east to west and Route 495 is close by in the neighboring communities of Bellingham and Milford (MADHCD, undated).

Most of the top employers in Medway are healthcare and education related, but the town still hosts a few manufacturing businesses (MALWD, 2014a). In the town of Holliston to the north, the top four employers are either industrial or bioscience-related while other top employers are education related (MALWD, 2014b). Millis, to the east of Medway, has a construction company and a sand and gravel company; other employers are education-related or retail stores and restaurants (MALWD, 2014c). To the south, Norfolk has a correctional facility and education-related jobs as well as a few manufacturing facilities, while Bellingham's biggest employer is Whirlpool, with some additional manufacturing as well as jobs in education and retail (MALWD, 2014d). In Franklin, also to the south of Medway, Garelick Farms is the largest employer, followed by Dean College as well as a number of manufacturing companies (MALWD, 2014e). In Milford to the west, healthcare is a large employer (*e.g.*, Milford Regional Medical Center), in addition to biotech and retail (MALWD, 2014f).

3.2 Cancer Incidence

The Massachusetts Cancer Registry (which is part of MADPH) provides estimates of cancer incidence for each of the 351 cities and towns of Massachusetts (http://www.mass.gov/dph/mcr). The report "Cancer Incidence in Massachusetts, 2006-2010" (MADPH, 2014) provides the most recent available data for the five-year time period 2006-2010 for 23 types of cancer, for all cancer types combined, and for both males and females. The "all cancers combined" category includes the 23 main types presented in this report and other malignant neoplasms in order to provide a summary of the total cancer experience in a community. City and town rates are compared to the statewide-average annual age-specific incidence rates for each cancer, each sex, and each city and town (*i.e.*, a total of about 14,391 possible calculations based on data for 351 cities and towns x 41 gender cancer categories). Note that gender/cancer categories with less than 5 observed cases are not evaluated for statistical significance, so the actual number of tests is slightly lower than 14,391. When multiple significance tests are performed, some will result in a significant finding due to chance alone. Because of the large number of comparisons, "statistically significantly greater" or "statistically significantly lower" cancer incidence rates can occur by random chance alone.

Medway is part of the Massachusetts Cancer Registry, and the most recent data can be found in the 2014 MADPH report (MADPH, 2014). The observed number of cases, the expected number of cases, the standardized incidence ratios (SIRs), and 95% confidence intervals are presented for twenty-three main types of cancer and for all cancer types combined. MADPH reports that, within statistical confidence limits, Medway incidence rates for most cancers are about average. Medway rates are not statistically significantly above the state average for any cancer types, while the Medway rate for all site/types among females (SIR = 83.3) is statistically significantly <u>below</u> the state average. All other specific cancer types are comparable to the state incidence rates, including the rate for all site/types among males (SIR = 97.1).

Milford cancer rates are similar to Massachusetts as a whole, with the exception of rates that were statistically significantly increased among males for all sites/types (SIR = 123.5) and two specific cancer types: bladder and urinary (SIR = 208.4) and prostate (SIR = 144.5). Female breast (SIR = 74.4) and the combined rate for all types of cancer among females (SIR = 88.2) were statistically significantly decreased from the statewide rates.

For Bellingham, Holliston, and Millis, there were no statistically significantly increased rates of cancer in males or females. For these three towns, the only statistically significant difference with state rates was a decreased rate of lung and bronchus cancer in Holliston (SIR = 55.1). Overall rates in males and females for all types of cancer are not significantly different than the state incidence rate (male SIR = 104.2 and female SIR = 108.1 in Bellingham; male SIR = 119.5 and female SIR = 108.9 in Millis; and male SIR = 100.0 and female SIR = 97.7 in Holliston).

In Franklin, only prostate cancer rates (SIR = 141.6) were statistically significantly increased, while lung and bronchus cancer rates (SIR = 69.4) were statistically significantly decreased. Overall rates in males and females for all types of cancer are not significantly different than the state incidence rate (male SIR = 108.7; female SIR = 102.9).

In Norfolk, there were statistically significantly increased rates of cancer in females for breast cancer (SIR = 153.1) and all sites/types of cancer (SIR = 129.5). The incidence rate for all site/types for males was 102.1, which was consistent with statewide incidence.

In summary, based on the above, and based on the negligible ELCRs calculated for maximum modeled Project impacts (Section 2.2), it is not expected that Project air emissions will have any impact on Medway cancer incidence rates, which in general are comparable to statewide average rates. This same conclusion also applies to neighboring communities such as Milford, Millis, Franklin, Bellingham, Norfolk, and Holliston, which also have average incidence rates for most cancers that are comparable to statewide averages.

3.3 Asthma

3.3.1 Asthma Prevalence Among Schoolchildren

MADPH provides pediatric asthma prevalence data for Massachusetts school populations on its Environmental Public Health Tracking (EPHT) Program website.[17] Data for five school years between 2007 and 2012 are currently available on the EPHT Program website: 2007-2008, 2008-2009, 2009-2010, 2010-2011, and 2011-2012. Data are available for many Massachusetts cities and towns, including Medway. Findings for Medway for each of the five available school years include the following:

- For the 2007-2008 school year, the statewide average school asthma prevalence was 10.9%, with Medway at 10.8% and "not statistically significantly different" than the statewide average (MADPH, 2015a).
- For the 2008-2009 school year, the statewide average school asthma prevalence was 11.0%, with Medway at 7.4% and "statistically significantly lower" than the statewide average (MADPH, 2015a).
- For the 2009-2010 school year, the statewide average school asthma prevalence was 11.6%, with Medway at 8.8% and "statistically significantly lower" than the statewide average (MADPH, 2015a).
- For the 2010-2011 school year, the statewide average school asthma prevalence was 11.7%, with Medway at 11.8% and "not statistically significantly different" than the statewide average (MADPH, 2015a).
- For the 2011-2012 school year (the most recent date range for which asthma prevalence is available), the statewide average school asthma prevalence was 11.9%, with Medway at 14.2% and "statistically significantly higher" than the statewide average (MADPH, 2015a).

Pediatric asthma data were formerly summarized in MADPH reports, which provided some insights on MADPH's interpretation of these school-by-school pediatric asthma statistics. For example, the last available 2012 report (MADPH, 2012a), which covered the 2008-2009 school year, stated:

> [Asthma] continues to affect more than 9.1% of Americans under the age of 18…and…[w]hile there was notable variation in reported asthma prevalence between schools (range of 0-75.0%), caution should be used when comparing school prevalence estimates. It is possible that some schools with either very high or very low prevalence may be impacted by methodological differences in reporting.

MADPH (2012a) further identifies a number of separate factors that may play a role in asthma:

> It is also important to note that a higher prevalence of asthma at one school compared with another does not necessarily indicate environmental problems within that particular school. Pediatric respiratory symptoms have been associated with a number of factors including exposures in the outdoor environment, exposures in the home environment, genetic factors, and lifestyle factors.

[17] https://matracking.ehs.state.ma.us/welcome.html.

Given these statements by MADPH, it is more appropriate to consider the five-year record of pediatric asthma data, which do not indicate that pediatric asthma rates are elevated in Medway as compared to the state, than just the 2011-2012 school year data. The 2011-2012 school year data are very different than the data for prior years and may indicate methodological problems. Interestingly, the EPHT website also provides pediatric asthma prevalence data by grade for grades between kindergarten and grade 8, and for Medway in 2011-2012, all grades but grade 7 had pediatric asthma prevalences that were not statistically significantly different from the statewide average – *i.e.*, grade 7 was the only grade with a pediatric asthma prevalence that was statistically significantly increased compared to the statewide average.

Findings from a February 19, 2008, report by the MADPH on "Air Pollution and Pediatric Asthma in the Merrimack Valley" also have bearing on the possible role of industrial emission sources such as power plants and incinerators on asthma rates. In this study, MADPH analyzed whether asthma in children was associated with major stationary (point) sources of air pollution. The main finding was that the prevalence of asthma was not associated with air pollution levels from stationary sources (MADPH, 2008). In fact, the geographic areas which received the highest fraction of air pollutants from stationary sources had the lowest asthma prevalence. The close proximity of high volumes of vehicle traffic was found to be associated with increased asthma.

Moreover, MADPH asthma prevalence findings for cities with power plants do not show increased pediatric asthma (Table 3.1). Three cities in Massachusetts with large power plants, namely Salem, Sandwich, and Somerset, were found to have 2007-2012 average pediatric asthma prevalence rates of 11.5%, 8.6%, and 11.9%, respectively. The MADPH data show that these "power-plant" towns in fact have lower pediatric asthma rates than many rural, non-industrial Massachusetts communities, where the pediatric asthma rates are often higher (average for 2007-2012: Athol = 15.2%; Brimfield = 16.2%; Erving = 15.7%; Monson = 19.8%). The pediatric asthma rates for Medway, Milford, Millis, Franklin, Bellingham, Norfolk, and Holliston also fall well below the rates found in these rural communities.

Table 3.1 Reported Asthma Prevalence (%) in Schools by Community Comparison of Communities with Large Electric-Power Generating Plants to Rural Communities

	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	Average
Power-plants Communities:						
Salem	11.8	11.7	10.9	11.7	11.4	
Sandwich	9.0	8.8	9.0	8.5	7.8	
Somerset	11.5	9.5	12.1	13.6	12.9	
AVERAGE						**10.7**
Other Subject Cities:						
Milford	9.7	9.4	9.9	9.5	9.0	
Millis	7.6	7.9	8.6	11.2	7.7	
Franklin	9.9	9.9	9.4	11.0	10.7	
Bellingham	4.2	6.2	6.4	5.4	5.8	
Norfolk	8.9	8.7	9.8	9.6	7.7	
Holliston	9.9	9.4	10.0	10.4	10.9	
AVERAGE						**8.8**
Rural:						
Athol	14.4	15.9	14.7	16.6	14.5	
Brimfield	13.8	14.7	16.1	19.3	16.9	
Erving	14.9	17.3	16.3	14.5	15.5	
Monson	20.3	20.6	19.5	20.0	18.4	
AVERAGE						**2.2**

Note:
Data from Environmental Public Health Tracking (EPHT) Program website (MADPH, 2015a).

3.3.2 Asthma Prevalence and Hospitalization Rates Among Adults

The latest Massachusetts adult health statistics are provided in "A Profile of Health Among Massachusetts Adults, 2012: Results from the Behavioral Risk Factor Surveillance System," which summarizes several chronic health conditions including asthma (MADPH, 2012b). Medway is in Region 2, the Central Region, but borders Region 4, the Metro West, and is two towns away from Region 5, the South East Region. Generally, the "Western" and "Boston" sections of Massachusetts have the highest adult asthma prevalence (18.7% and 16.1%, respectively, for people reporting that they "ever had asthma"). The Central, Metro West, and South East Regions had overall prevalence rates of 15.8, 14.0, and 14.6%, respectively, for those reporting that they "ever had asthma" (MADPH, 2012b).[18] Another relevant report is "Burden of Asthma in Massachusetts" (MADPH, 2009). In the most current version of this report, the five-year (2003-2007) average annual prevalence of current asthma among adults by Community Health Network Area (CHNA) of Residence Massachusetts respondents Ages 18+ Years indicates that CHNAs 6 and 7, the regions encompassing Medway and the surrounding towns, had an adult asthma prevalence of 8.2-9.5% for the years 2003-2007, which is lower than the statewide five-year average annual prevalence of current asthma among adults of 9.8% (MADPH, 2009).

Data obtained from the Massachusetts Community Health Information Profile (MassCHIP) database (http://www.mass.gov/dph/masschip) indicate that Medway's hospitalization rate for asthma (*i.e.*, "hospital discharges for primary care manageable conditions") was 161.4 per 100,000 persons as an area age-adjusted rate for the 2009 calendar year, which is comparable to the age-adjusted rate for the State of

[18] http://www.mass.gov/eohhs/docs/dph/behavioral-risk/report-2012.pdf.

160.2 (MADPH, 2013a). In the Metrowest area (which consists of 22 communities including Holliston, Millis, and Norfolk), the rates of asthma inpatient hospitalizations were lower than in the state as a whole for males and females, all races, and all age groups, including children and people 65 and older (MADPH, 2013b). Similarly, for asthma emergency room visits and asthma hospital observation stays, the rates in Metrowest were lower than for the State for males and females, all races, and all age groups, except that people 65 and older had slightly higher rates of asthma emergency visits (170.5 as compared to 160.3 per 100,000 for the state) and slightly higher rates of asthma hospital observation stays (16.9 as compared to 15.1 per 100,000 for the state; MADPH, 2013b).

Similar to the data in the MassCHIP database, age-adjusted rates of asthma hospital admissions and emergency department visits for males and females combined available from the MADPH EPHT Program website for Medway are either not statistically significantly different or statistically significantly lower than statewide rates (MADPH, 2015b, 2015c). For example, for the latest year (2011) with available data, the age-adjusted rate of asthma hospital admissions for males and females combined in Medway was 12.4 per 10,000, which was not statistically significantly different from the statewide average rate of 15.1 per 10,000. For age-adjusted rates of asthma-related emergency department visits for males and females combined, Medway's rate of 45.5 per 10,000 was statistically significantly lower than the statewide rate of 72.0 per 10,000.

3.3.3 Conclusions for Asthma

Overall, there is no expectation that operation of Exelon's Proposed West Medway Project will affect asthma prevalence or hospitalizations among either schoolchildren or adults. This conclusion is supported by the results of our public health evaluation of criteria air pollutants from Project stack emissions (Section 2.1), our assessment of chronic inhalation non-cancer and cancer health risks from Project air toxics stack emissions (Section 2.2), and our acute (short-term) exposure evaluation for respiratory irritants (Section 2.3), all of which support the negligible impacts of Project stack air emissions to both local air quality and potential health risks. In particular, maximum modeled Project 1-hour concentrations of several respiratory irritants (NO_2, SO_2, acetaldehyde, acrolein, formaldehyde) were shown to be far below health-based acute reference values that are developed to be protective of sensitive subpopulations including asthmatics.

3.4 Cardiovascular Disease

Epidemiologic studies of ambient air pollution have reported statistical associations between levels of various criteria air pollutants, and $PM_{2.5}$ in particular, measured at centrally located monitors and cardiovascular-related mortality and morbidity (*e.g.*, hospitalizations, emergency room visits). Although these statistical associations cannot establish that a "causal link" exists, it is important to examine cardiovascular health statistics for Medway, which can be obtained from both the MADPH MassCHIP database and the EPHT Program website. Table 4.2 below provides cardiovascular hospitalization and cardiovascular mortality data for Medway available from the MADPH MassCHIP database, showing somewhat higher age-adjusted rates of cardiovascular hospitalizations and mortality in Medway as compared to statewide average rates (MADPH, 2013c). Age-adjusted rates of hospital admissions for myocardial infarction among age 35+ males and females combined for Medway are available from the MADPH EPHT Program website, and are either not statistically significantly different or statistically significantly lower than statewide rates (MADPH, 2015d). For example, for 2012, the Medway rate of 25.4 per 10,000 was not statistically significantly different than the statewide rate of 29.5 per 10,000.

Table 3.2 Cardiovascular Mortality and Hospitalizations Statistics for Medway[a,b]

CV Health Outcome	CV Mortality (2008-2010)		CV Hospitalization (2007-2009)	
	Medway 3-yr Age-adjusted Rate	State 3-yr Age-adjusted Rate	Medway 3-yr Age-adjusted Rate	State 3-yr Age-adjusted Rate
Coronary Heart Disease	105.9	101.5	479.0	379.8
Acute Myocardial Infarction	46.6	29.7	232.6	184.7
Cerebrovascular Disease	31.3	32.0	269.9	234.7
All Circulatory System Diseases	208.4	201.6	1889.4	1536.8

Notes:
CV – Cardiovascular.
(a) All data obtained from MADPH MassCHIP website: http://www.mass.gov/dph/masschip (MADPH, 2013c).
(b) As explained on the MassCHIP website, age-adjusted rates expressed per 100,000 persons, with standardization using the 2000 US population as the standard population.

Despite the somewhat higher age-adjusted rates of cardiovascular hospitalizations and mortality in Medway as compared to statewide average rates, it is not expected that Project $PM_{2.5}$ emissions will contribute significantly to cardiovascular health risks in Medway due to the small incremental impacts of even the maximum modeled Project impacts on area $PM_{2.5}$ levels. For example, the maximum modeled Project annual average $PM_{2.5}$ impacts of 0.13 $\mu g/m^3$ are approximately three percent of area background $PM_{2.5}$ levels, and approximately two percent of the revised health-protective annual average $PM_{2.5}$ NAAQS (12 $\mu g/m^3$).

4 Conclusions

Overall, similar to the prior HHRA (Gradient, 2015), our updated HHRA for the Project has demonstrated that maximum modeled air concentrations and modeled air concentrations at a nearby day care center for specific substances associated with the Project stack air emissions would not be expected to contribute to significant health risks among potentially affected populations. Several separate lines of evidence from our health-risk analysis support the conclusion that the Project stack air emissions are not expected to create public health risks of concern in the Medway area:

1. With regard to Project stack emissions of criteria air pollutants, total air concentrations corresponding to maximum modeled Project impacts plus existing background remain below the health-protective NAAQS for the criteria air pollutants of concern, which include SO_2, CO, NO_2, and PM (Tables 2.1 and 2.2). Therefore, Project stack emissions of criteria air pollutants are not expected to cause adverse health impacts (*e.g.*, asthma, cardiovascular, and respiratory diseases) in nearby communities. Furthermore, as a matter of perspective, it is important to recognize that the total inhaled dose from one year of cumulative exposure to maximum modeled $PM_{2.5}$ and NO_2 concentrations associated with Project stack emissions is equivalent to the dose received from short durations of everyday exposures that are routinely received during common indoor and outdoor activities such as cooking, doing yard work, or driving in a car (Table 2.4).
2. With regard to Project stack emissions of non-criteria pollutants (*i.e.*, air toxics), both the maximum modeled air concentrations and modeled air concentrations at the nearby day care center location are below both the MADEP 24-hour TELs and the annual-average AALs, indicating that these concentrations cannot be expected to cause adverse health effects, even in sensitive populations and for children attending the day care center (Table 1.1 and Table 1.2).
3. As a matter of perspective with regard to Project air toxics emissions, measurements from the closest Boston-area air toxics monitor show that maximum modeled Project impacts for metals are between about 18-fold to 639-fold below measured ambient background levels in the Boston area, while for volatile organic compounds (VOCs), maximum modeled Project impacts are between 80-fold and >6,400-fold below measured ambient background levels (Table 2.6). At the day care center location, the amounts by which modeled Project impacts remain below measured background air toxics levels are even greater (Table 2.7).
4. Our quantitative HHRA showed that all hazard quotients (HQs) calculated for a hypothetical off-site resident exposed to maximum modeled incremental Project stack air toxics impacts are well below unity (HQ = 1),[19] with none being higher than HQ = 0.023. The overall summed hazard index (HI) for Project stack air toxics emissions, which makes the health-protective assumption that all chemicals act via the same toxic-effect pathway, is also well below 1.0 (HI = 0.04). These results help assure that non-cancer health effects from chronic exposures are not to be expected from Project stack air toxics emissions (Table 2.9). As shown in Table 2.9 and Figure 2.1, the non-cancer health risks posed by background levels of several of the air toxics of interest with available air monitoring data from the closest Boston-area air toxics monitor are well below levels of potential health concern, yet are in fact greater than HIs calculated for the maximum modeled incremental Project stack air toxics impacts.

[19] HQ = 1 is a screening criterion meaning that exposure below this level, *i.e.*, HQ<1, cannot be expected to lead to adverse health effects.

5. The HQs calculated for a child attending the nearby day care center near the site of the Project are also well below 1, with the highest HQ = 0.004. The overall summed HI for a child attending the day care center is also well below 1 (HI = 0.008). These results assure that a child attending the day care center near the Project would not be expected to experience any non-cancer health effects from chronic exposures associated with Project air toxics emissions (Table 2.11).

6. The quantitative HHRA shows that conservatively projected lifetime cancer risks for maximum modeled incremental Project stack air toxics impacts are well below the 1 in 1,000,000 to 1 in 10,000 range considered to be acceptable by US EPA.[20] The overall summed cancer risk is about 8 in 100,000,000, which is well below US EPA's *de minimis* 1-in-1,000,000 risk. The individual pollutant cancer risks are each even lower than the acceptable range, between about 1 in 10,000,000,000 to about 3 in 100,000,000. These results support an absence of any significant cancer risk from worst-case chronic exposures to maximum modeled Project stack air impacts (Table 2.10). As shown in Table 2.10 and Figure 2.2, the cancer risks posed by background levels of several of the air toxics of interest with available air monitoring data from the closest Boston air toxics monitor are well below levels of potential health concern, yet are in fact greater than the projected lifetime cancer risks for the maximum modeled incremental Project stack air toxics impacts.

7. The cancer risks calculated based on modeled Project-related ambient air concentrations at the day care center are even lower than those calculated based on the maximum modeled Project impacts, and are also well below the range considered acceptable by US EPA. The overall summed cancer risk is about 2 in 1,000,000,000, which is well below US EPA's *de minimis* risk. The individual pollutant cancer risks are far below the acceptable range, between about 1 in 1,000,000,000,000 to about 9 in 10,000,000,000 (Table 2.12).

8. To evaluate the possibility of Project stack air emissions causing short-term respiratory irritation in sensitive populations such as asthmatics, maximum modeled 1-hr concentrations of NO_2, SO_2 acetaldehyde, acrolein, and formaldehyde were further examined. The Project maximum modeled air concentrations and the modeled air concentrations at the day care center were compared to short-term exposure guidelines and standards, including the short-term NAAQS for SO_2 and NO_2 that are specifically designed to protect against asthma exacerbation and respiratory irritation. The results show that both the maximum modeled 1-hour NO_2 and SO_2 concentrations, as well as estimates of total impacts corresponding to the sum of maximum modeled 1-hr concentrations and ambient background, are below the 1-hour health-protective NAAQS and other short-term exposure guideline levels. The 1-hour SO_2 and NO_2 modeled concentrations at the day care center are also well below the NAAQS (Table 2.13). Moreover, maximum modeled 1-hour concentrations and modeled 1-hour concentrations for the day care center are well below relevant short-term exposure guideline levels for each of the other air toxics (acetaldehyde, acrolein, formaldehyde) considered in the acute (short-term) exposure evaluation for respiratory irritants.

9. The review of community health data for Medway and nearby communities indicates that the Medway area generally has similar asthma, cardiovascular, and cancer rates compared with the state of Massachusetts. In combination with the HHRA results, there's no expectation that cancer rates will be affected by operation of the peaking-plant Project.

[20] It should be noted that the likelihood of developing cancer over a lifetime (*i.e.*, the background risk) is approximately 400,000 in 1,000,000. That is, the chance of developing cancer sometime during a lifetime is about 40%.

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Appendix A

Chronic Non-cancer and Cancer Inhalation Toxicity Factors

Table A.1 Chronic Non-cancer Inhalation Toxicity Factors and Cancer Inhalation Unit Risk Factors Used in the Exelon Proposed West Medway Project Assessment

Pollutant	Chronic Non-cancer Inhalation Toxicity Factors		Chronic Cancer Unit Risk Factor	
	Value ($\mu g/m^3$)	Source	Value ($(\mu g/m^3)^{-1}$)	Source
1,3-Butadiene	2	IRIS	0.00003	IRIS
Acetaldehyde	9	IRIS	0.0000022	IRIS
Acrolein	0.02	IRIS	--	--
Benzene	30	IRIS	0.0000078	IRIS
Naphthalene	3	IRIS	0.000034	CAL
Ethylbenzene	1000	IRIS	0.0000025	CAL
Formaldehyde	9.8	IRIS	0.000013	IRIS
Propylene oxide	30	IRIS	0.0000037	IRIS
Toluene	5000	IRIS	--	--
Xylenes	100	IRIS	--	--
Arsenic	0.015	CalEPA	0.0043	IRIS
Beryllium	0.02	IRIS	0.0024	IRIS
Cadmium	0.01	ATSDR	0.0018	IRIS
Chromium (total)	--	--	--	--
Chromium (VI)	0.1	IRIS	0.012	IRIS
Lead	0.15	EPA OAQPS	--	--
Mercury	0.3	IRIS	--	--
Nickel	0.09	ATSDR	--	--
Selenium	20	CalEPA	--	--
Ammonia	100	IRIS	--	--
Total PAH	--	--	--	--
Manganese	0.3	ATSDR	--	--
Sulfuric acid	1	CalEPA	--	--

Notes:
IRIS = Integrated Risk Information System; ATSDR = US Agency for Toxic Substances and Disease Registry; CalEPA = California Environmental Protection Agency; EPA OAPQS = Environmental Protection Agency, Office of Air Quality Planning and Standards.
-- Tox value is not available.