Human Health Risk Assessment of the Riverside Energy Center in Beloit, WI

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Executive Summary:

This risk assessment was prepared to examine if inhalation of the pollutants from the Riverside Energy Center natural gas power plant poses a significant health risk to the surrounding residents in Beloit, Wisconsin. Beloit, identified as an environmental justice community, has concerns regarding respiratory issues due to its high asthma rates. To do this assessment, we gathered emissions data of hazardous and criteria air pollutants for the power plant from the National Emissions Inventory and applied a Gaussian Plume Model to estimate the exposure concentration for the surrounding community and identify chemicals of potential concern. From this, we identified four chemicals of concern to perform further assessment on and calculated the Hazard Index and Excess Lifetime Cancer Risk for non-carcinogenic and carcinogenic chemicals, respectively. The findings show that exposure levels of $PM_{2.5}$ exceed a Hazard Index of 1 for both adults and children, indicating that there may be an increased risk of adverse health outcomes to the surrounding community from $PM_{2.5}$ exposure. This assessment recommends continued monitoring of this site, as well as providing resources to the local community to support improving respiratory health conditions. It is also important that policymakers continue to create stricter emissions standards for power plants, particularly when they are upwind of surrounding communities.

Introduction:

The Riverside Energy Center is a natural gas power plant located north of the town of Beloit, Wisconsin. The city of Beloit has a population of over 36,000 people and is a known environmental justice community with approximately 90% of the community considered low income.[1] Demographically, Beloit is approximately 59.1% non-Hispanic White, 21.5% Hispanic, and 13.1% non-Hispanic Black or African American. Compared to state averages, the race and ethnicity of Beloit's population are fairly similar, as Wisconsin's population identified as 61.6% White alone, 18.7% Hispanic, and 12.4% Black alone in the 2020 census.[2] In terms of health, the community has some of the highest asthma-related hospitalizations in Wisconsin but does not currently have access to data on their local air quality. The community has expressed concern about the emissions coming from the Riverside Energy Center, as the emissions from these power plants are suspected to contribute to asthma and related health conditions in Beloit. The objective of this report is to perform a risk assessment for the fence line communities surrounding the local natural gas plants to determine the risk of exposure to power plant emissions and their associated health impacts.

Hazard Identification:

Natural gas power plants are a necessary component of modern cities, providing electricity to homes and other critical infrastructure. However, their operation emits a wide range of air pollutants that can negatively impact the health of nearby communities. These pollutants have been attributed to a variety of diseases and disorders, most often including cancer and asthma.[3–5] This paper aims to conduct a risk assessment of chemical air pollutants emitted by the Riverside Energy Center power plant in Beloit, Wisconsin. Chemicals of potential concern (COPCs) from the plant were sourced from the EPA National Emissions Inventory from 2020 along with their annual emission rates in tons per year.[6] These rates were converted to grams per second and fed into a Gaussian Plume model to calculate annual concentrations at 2 kilometers away from the power plant. This distance was selected due to visual observations using Google Earth, which placed the town center and most residential buildings within that distance, as shown in Figure 1. Annual concentrations were then compared against EPA standards to determine which air pollutants were chemicals of concern (COCs). Hazardous air pollutants (HAPs) and criteria air pollutants (CAPs) were compared against EPA screening levels and EPA ambient air quality standards (AAQS), respectively. COCs were identified as chemicals that had annual concentrations similar to or greater than their EPA standards or were carcinogenic while approaching EPA standard values. Table 1 identifies said COCs and their corresponding concentrations, as well as the EPA values used for determination.

The identified COCs (formaldehyde, acrolein, chromium compounds, cadmium compounds, nitrogen oxides (NO_x), and $PM_{2.5}$) share a variety of adverse health effects, which may impact Beloit residents living near the power plant. Other common properties include critical effects such as respiratory (lung disease, asthma, bronchitis, upper respiratory tract irritation), cardiovascular (heart disease, heart attacks, strokes), nervous (headaches, dizziness, brain damage), and developmental (birth defects, disrupted childhood development).[7] Many of these effects pose a serious threat to health, making it worthwhile to conduct a risk assessment on the identified COCs. Doing so will provide the necessary information and understanding to make health-protective recommendations to help residents mitigate the impact of airborne hazards emitted by the Riverside Energy Center.

Exposure Assessment

The exposure pathway for residents is shown in Figure 2. For this assessment, the receptors chosen were adults and children, given that Beloit's population is fairly young, with 24.7% of the population aged 18 years or younger and only 13.5% of the population aged 65 years and over.[1] We modeled exposures at 2km directly downwind, approximating the neighborhood near the intersection of Town Line Road and I-39 Alt, just south of Blackhawk Technical College. To model exposures, we used a Gaussian Plume model. Children are considered separately in this assessment given their physiological susceptibility in the forms of puberty, neurological development, and bone growth.[8] For this risk assessment, children considered are those aged 3, 6, 9, 12, 15, and 18, corresponding to the ages given in the EPA Exposure Factors Handbook Chapter 16 Table 109.[9] For this assessment, the 95th percentile of the residential occupancy period years was calculated to represent a conservative estimate of years lived in a residence across these ages. While the conceptual model in Figure 2 also shows ingestion and dermal pathways, for this risk assessment, air pollution (and thus inhalation) will be prioritized given the high asthma rates in Beloit.

Before determining the estimated exposure for both vulnerable groups, the exposure point concentration (EPC) for each contaminant was calculated, providing an estimate of each contaminant's concentration in the air. These calculations were performed using annual emissions data from the National Emissions Inventory for 2020 and input into a Gaussian Plume Model that integrates data points like distance downwind from the site, stack height, emissions rate, and wind speed, among others.[6] The calculated EPCs for each COC are shown in Table 2 (Non-Carcinogens) and Table 3 (Carcinogens).

The remaining variables needed to calculate the Average Daily Exposure (ADE, for non-carcinogens) and Lifetime Average Daily Exposure (LADE, for carcinogens) values for each receptor group are shown in Table 4 and Table 5. For both the ADE (non-carcinogenic) and LADE (carcinogenic) calculations, the Exposure Time (ET) and Exposure Frequency (EF) were assumed to be chronic, meaning that residents and workers were exposed to the COCs in the air for 24 hours a day, 365 days of the year. These values were chosen based on the assumption that emissions were constant over this period and that outdoor air is an ever-present environmental media for residents and workers alike.

For the non-carcinogenic COCs, the Exposure Duration (ED) for children is 9.25 years. This value is the calculated 95th percentile of the average residence years for children aged 3, 6, 9, 12, 15, and 18 from Chapter 16 Table 109 in the EPA Exposure Factors Handbook.[9] The average number of years living at a particular residence (ED) for all adults is 12.[9] Finally, the Averaging Time (AT) is calculated for the ADE to be the ED weighted by the chronic exposure time of 24 hours per day and exposure frequency of 365 days per year.

For the carcinogenic COCs, the difference between the ADE and LADE calculation is determined by the AT, which for carcinogens weighs the *lifetime in years* by the same ET and EF. For both children and adults, the AT is based on a lifespan of 78 years, which is based on the EPA Exposure Factors Handbook, Chapter 18 Table 1.[10] All ADE and LADE calculations for each COC are shown in Table 2 and Table 3.

Dose-Response Assessment:

The dose-response assessment aims to evaluate the relationship between exposure to each chemical of concern and the associated toxicological outcomes. As shown in the Hazard Assessment, pollutants emitted from the natural gas plant have been linked to both carcinogenic and non-carcinogenic health outcomes. For each outcome, the dose-response relationship was evaluated by deriving the Reference Concentration and Inhalation Unit Risk. The Reference Concentration (RfC) and Inhalation Unit Risk (IUR) values for each chemical of concern are found in Table 6.

Non-Cancer Dose-Response:

The RfC is a chemical's toxicity value in which exposure to that quantity or below over a person's lifetime will not cause an increased risk of non-cancerous health outcomes. If exposure to a chemical exceeds the threshold level, a person may experience an increased risk of non-cancerous health effects. For inhalation exposure, a reference concentration is defined based on the current toxicological literature, and factors in multiple uncertainty values to ensure it is protective for sensitive and vulnerable populations. This section will define the reference concentrations for all non-carcinogenic pollutants used in this risk assessment.

The RfC for acrolein was found in the EPA Integrated Risk Information System (IRIS).[4] The RfC was determined from a collection of toxicological studies performed on rodents and rabbits that were repeatedly exposed to varying levels of acrolein and monitored for nasal lesion development. The approach to deriving the RfC involved using the Lowest Observed Adverse Effect Level (LOAEL) as the point of departure. A LOAEL of 0.02 mg/m3 was calculated, and an uncertainty factor of 1000 was used. Uncertainty factors were calculated by assuming a factor of 3 for animal-to-human extrapolation, a value of 10 for intraspecies variation, a value of 10 for adjusting from sub-chronic to chronic exposure durations, and a value of 10 for using a LOAEL when a NOAEL (No Observed Adverse Effect Level) was not available. With these values, a RfC of 2×10^{-5} μg/m^3 for acrolein was used.[11]

Criteria air pollutants, such as NO_x and $PM_{2.5}$, do not have RfCs. Because of this, a substituted value is required. The National Ambient Air Quality Standards (NAAQS) are standards established by the EPA under the Clean Air Act to regulate levels of specific criteria air pollutants that are known to cause harmful health effects. These standards are based on multiple studies in the literature, where they are designed to protect the most vulnerable populations and are periodically reviewed and revised as new literature comes out. As there is no RfC for NO_x or $PM_{2.5}$, the NAAQS annual exposure limit of 9 μg/m^3 for $PM_{2.5}$ and 64.998 μg/m^3 for NO_x were used.[12]

Cancer Dose-Response:

For chemical exposures that are carcinogenic, it is assumed that there are no safe levels of exposure, and any exposure will increase the risk of a person developing a cancerous health outcome. To estimate the inhalation exposure for carcinogenic compounds, Inhalation Unit Risks (IURs) are calculated. The IUR is an estimate of the increased cancer risk from inhalation exposure to a concentration of 1 μg/m^3 of the chemical of concern for a lifetime.[13] The IURs for all carcinogenic compounds in this risk assessment were gathered from the EPA IRIS.

The IUR for formaldehyde is an upper-bound estimate of the increased lifetime risk of cancer from inhaling 1 μg/m^3 of formaldehyde for 70 years (this unit translates to the 78-year lifetime estimate used in later calculations given the interchangeability of the 70 and 78-year estimates).[14] This is based on the increased risk of nasopharyngeal cancer (NPC), which can be caused by formaldehyde inhalation. The risk rate is calculated based on models of the association from exposure for a cohort study followed by the National Cancer Institute.

The IUR for chromium compounds was obtained from the datasheet for chromium VI.[15] chromium VI is a known carcinogenic compound based on consistent evidence that inhalation causes lung cancer in humans and supporting evidence of carcinogenicity in animals. The IUR is based on an occupational cohort study.

The IUR for cadmium compounds was found from the datasheet for cadmium. Inhalation of cadmium is currently classified as a probable human carcinogen, with sufficient evidence of carcinogenicity from inhalation in rats and mice. The risk factor was calculated through a combination of human and animal studies.

Risk Characterization:

The risk characterization assesses the potential cancer and non-cancerous health effects associated with exposure to Chemicals of Concern (COCs) emitted from the natural gas power plant in Beloit. The risk was quantified individually for non-carcinogenic and carcinogenic effects using two main metrics: the Hazard Index (HQ) for non-carcinogenic chemicals and the Excess Lifetime Cancer Risk (ELCR) for carcinogens. The use of these metrics provides a quantitative measure that helps to objectively determine the levels of risk, allowing us to make informed decisions about potential health impacts.

Non-Cancer Risk Assessment

The *Hazard Quotient (HQ)* was calculated to quantify the risk of non-cancer health effects associated with exposure to non-carcinogenic contaminants, i.e., acrolein, $PM_{2.5}$.and NO_x. The HQ is determined by dividing the Average Daily Exposure (ADE) by the Reference Concentration (RfC) for each chemical, as taken from the EPA IRIS Guidelines. An HQ value of less than 1 indicates a low or acceptable level of risk, while an HQ greater than 1 suggests that adverse health effects are possible. The calculated HQs are found in Table 6.

Using this approach, the HQ for acrolein in adults would be:

Hazard Quotient (HQ)= Average Daily Dose (ADE) / Reference Concentration (RfC)
$= 4.46 \times 10^{-2}\ \mu g/m^3 / 2.00 \times 10^{-5}\ mg/m^3 * 1000 = 7.35 \times 10^{-1}$

The calculated HQ for acrolein was 2.23 for adults and children. Both values fall below the threshold of 1, indicating that adverse health outcomes are not expected because of inhalation exposure to acrolein. However, for $PM_{2.5}$, an HQ of 4.31 for adults and children was obtained. As these values exceed the threshold of 1, it indicates a potential risk for non-cancer health effects. For NO_x, an HQ of 9.22×10^{-4} for both adults and children were calculated, suggesting that there is a relatively low risk of adverse health effects from $NO_{x.}$ alone.

To evaluate the cumulative effect of exposure across multiple pollutants a *Hazard Index (HI)* was calculated, which is the sum of one or more HQs across multiple COCs. An HI with values greater than 1, indicates that an adverse health effect is possible and may warrant further analysis, and a HI <1 indicates no adverse health effects are expected. For the COCs, the cumulative HI for acrolein, NO_x, and $PM_{2.5}$ was calculated as 6.54 for adults and for children. These values exceed the threshold of 1, suggesting there may be overall adverse health outcomes from inhalation exposure for both adults and children, warranting further attention to mitigate potential health impacts.

Cancer Risk Assessment

For carcinogenic chemicals, the Excess Lifetime Cancer Risk (ELCR) was used to estimate the probability of an individual developing cancer over a lifetime due to exposure to each carcinogenic chemical. The ELCR is calculated by multiplying the (L)ADE - Lifetime Average Daily Exposure by the Inhalation Unit Risk (IUR) for the chemical. The calculated ELCRs are found in Table 6.

For formaldehyde, the Inhalation Unit Risk (IUR) is 1.10×10^{-5}, as taken from the IRIS EPA database. Therefore, using the rationale above, the ELCR value calculated for formaldehyde in adults through the equation would be:

Excess Lifetime Cancer Risk (ELCR) = Lifetime Average Daily Exposure (L)ADE x Inhalation

Unit Risk (IUR) = 1.04×10^{-1} x 1.10×10^{-5} (μg/m³) = 3.76×10^{-7}

The ECLR value of 1.14×10^{-6} indicates the probability of an adult developing cancer over a lifetime because of exposure to formaldehyde through inhalation. Using the same rationale, the ELCR for children was 8.79×10^{-7}. For chromium compounds, ELCR values were 8.77×10^{-8} for adults and 6.76×10^{-8} for children. Finally, for cadmium compounds, ECLR values were 1.82×10^{-7} for adults and 1.41×10^{-7} for children. The EPA considers an ELCR range of 1×10^{-6} (one-in-a-million) to 1×10^{-4} (one-in-ten thousand) as acceptable for regulatory decision-making. As the values for both formaldehyde and chromium compounds fall below these levels, the carcinogenic risk posed by these chemicals is considered insignificant.

The risk characterization identified chemicals with HQ > 1 or ELCR exceeding acceptable thresholds that may pose potential health risks at the current exposure levels. For these chemicals, further monitoring or risk management actions are recommended. Chemicals with HQ values less than 1 and ELCR values within acceptable limits are considered to pose minimal risk based on the assumptions and data used in this assessment.

Uncertainty Analysis:

Uncertainty is an inherent part of risk assessment, with the potential to impact the reliability of the risk characterization results. In this assessment of air pollution exposures, uncertainties arose from several key areas:

- The Gaussian Plume Model provided pollutant concentration estimates based on several assumptions, including steady wind speeds, constant emission rates, and flat terrain. These assumptions may not have accurately always reflected real-world conditions, introducing uncertainty into the exposure estimates. For example, if the actual wind speed was lower than the assumed 3.2 m/s, pollutant concentrations could have been higher than estimated, leading to an underestimation of risk. Conversely, higher wind speeds would have resulted in more dispersion, potentially overestimating risk at longer distances.

- The assumptions made for dose-response calculations assumed a constant exposure over time, which may not have represented real-world variability, e.g., some individuals may have had shorter or intermittent exposure periods, leading to different levels of cumulative risk. Emissions rates from the power plant could vary over time, along with meteorological conditions, which can affect exposures downwind. Similarly, the inhalation rates, exposure durations, and body weights used in the ADE and L(ADE) calculations were based on standard EPA values which provided mean estimates and may not have always represented the actual population near the power plants.

- The Reference Concentrations (RfC) and Inhalation Unit Risk (IUR) values used for estimating excess hazards, through Hazard Quotients and Excess Lifetime Cancer Risk (ELCR), were often derived from experimental studies and epidemiological data. These occasionally involved extrapolations from animal data to humans. While these reference concentrations provided guidelines for safe exposure levels, they may have sometimes either underestimated or overestimated actual risk for specific populations, leading to variability and uncertainty.

Conclusion:

This risk assessment evaluated the exposure and health risks associated with air pollutants emitted from the Riverside Energy Center in Beloit, Wisconsin. The assessment shows that $PM_{2.5}$ levels emitted from the power plant exceed a Hazard Index of 1 for both adults and children. This indicates that the surrounding area may be at a higher risk for potential adverse health effects from $PM_{2.5}$ exposure, such as respiratory and cardiovascular conditions which is of particular interest because of the high rates of asthma experienced in this community. While the risk associated with carcinogenic chemicals of concern, such as formaldehyde and chromium compounds, remained within acceptable limits based on EPA's guidelines, continued monitoring for emissions is crucial to ensure the health and safety of the community. These results also reaffirm the disproportionate burden placed on environmental justice communities like Beloit, where existing health disparities are exacerbated by proximity to plants. To help mitigate these risks, we recommend continued monitoring of this site, as well as providing resources to the local community to support improving respiratory health conditions. It is also important that policymakers continue to create stricter emissions standards for power plants, particularly when they are upwind of surrounding communities.

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Figures and Tables:

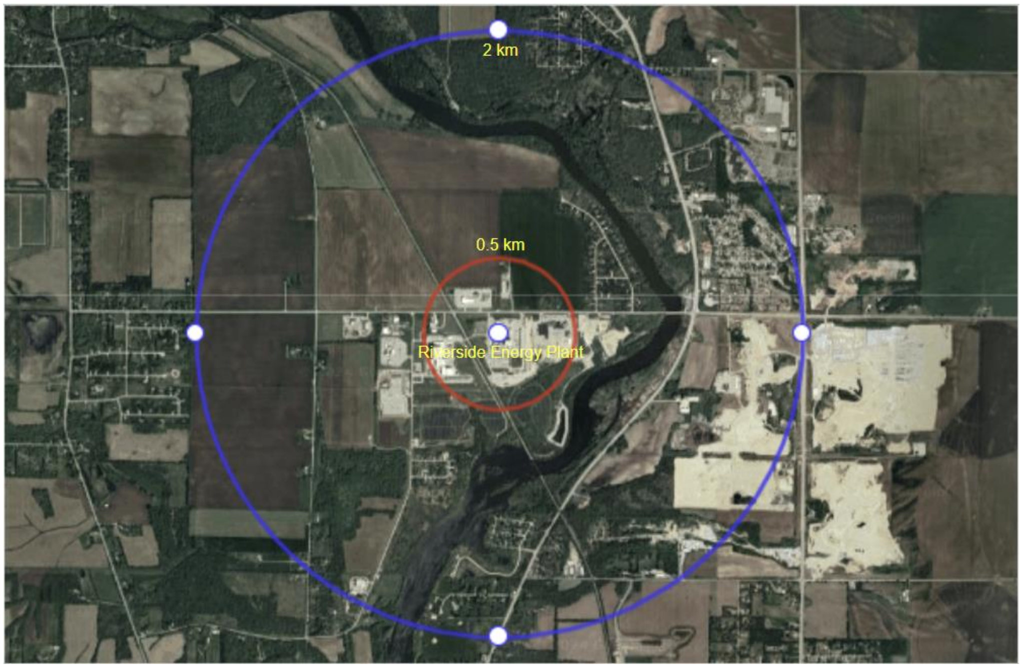

Figure 1. Google Earth view of the Riverside Energy Plant with rings indicating 0.5 and 2 km radiuses from the facility center. Most residences appear to fall within the 2 km ring.

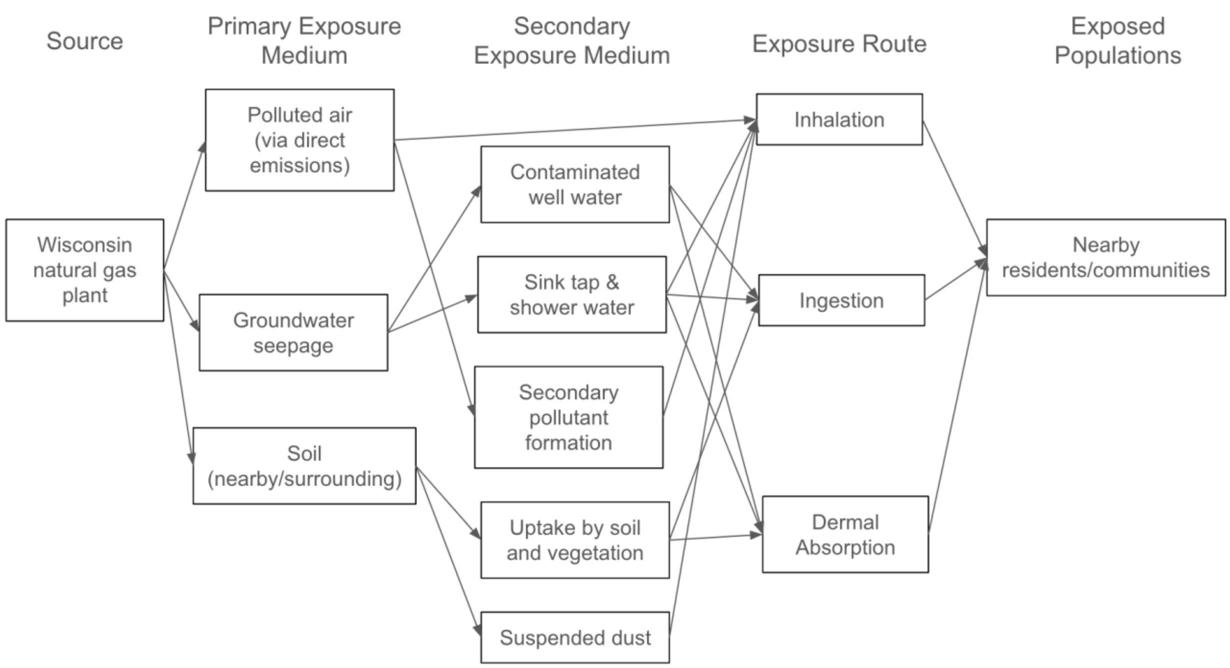

Figure 2. Conceptual Model of Exposure to Emissions from Natural Gas Power Plants in Beloit, Wisconsin.

Hazardous Air Pollutant (HAP) Chemical	CAS Number	Annual Concentration µg/m3 (2km)	US EPA Regional Screening Levels (µg/m3)	Carcinogenic	Chemical of Potential Concern (COC) (Y/N)
Toluene	108-88-3	9.06E-01	5.20E+03	nc	N
Formaldehyde	50-00-0	6.74E-01	2.20E-01	c	Y
Hexane	110-54-3	5.54E-01	7.30E+02	nc	N
Xylenes	1330-20-7	4.46E-01	1.00E+02	nc	N
Acetaldehyde	75-07-0	2.82E-01	1.30E+00	c	N
Ethylbenzene	100-41-4	2.23E-01	1.10E+00	c	N
Propylene Oxide	75-56-9	1.94E-01	7.60E-01	c	N
Acrolein	0107-02-08	4.46E-02	2.10E-02	nc	Y
Benzene	71-43-2	3.37E-02	3.60E-01	c	N
Naphthalene	91-20-3	9.06E-03	8.30E-02	c	N
1,3-Butadiene	106-99-0	2.98E-03	9.40E-02	c	N
Nickel Compounds	-	1.23E-03	1.10E-02	c	N
Cadmium Compounds	-	6.59E-04	1.60E-03	c	Y
Arsenic Compounds	-	7.60E-05	6.50E-04	c	N
Mercury Compounds	-	5.07E-05	3.10E-01	nc	N
Chromium Compounds	-	3.17E-05	1.20E-05	c	Y
Manganese Compounds	-	6.34E-06	5.20E-02	nc	N
Lead Compounds	-	6.34E-06	1.50E-01	c	N
CAP Chemical	**CAS Number**	**Annual Concentration µg/m3 (2km)**	**US EPA NAAQS Standards (µg/m3)**	**US EPA Regional Screening Levels (µg/m3)**	**COC (Y/N)**
Volatile Organic Compounds	-	60.4715373	-	-	N
Nitrogen Oxides	-	59.89615778	64.998	-	Y
PM_{10} Primary (Filt + Cond)	-	40.77589874	150	-	N
$PM_{2.5}$ Primary (Filt + Cond)	-	38.76228905	9	-	Y
Carbon Monoxide	630-08-0	20.91880083	10350	-	N
Ammonia	7664-41-7	11.10201558	-	520	N
Sulfur Dioxide	-	5.753117124	27.594	-	N

Table 1: Air pollutants emitted by the Riverside Energy Center according to the EPA National Emissions Inventory, with chemicals of concern highlighted. Ammonia concentrations were compared against EPA regional screening levels due to the EPA NAAQS standard for it being unavailable.

Non-carcinogenic: ADE = EPC * ((ET*EF*ED)/AT)							
COC Name	**Concentration (EPC)**	**Exposure Time (ET)**	**Exposure Frequency (EF)**	**Exposure Duration (ED)**	**Averaging Time (AT)**	**Average Daily Exposure (ADE)**	**Receptor Type**
Acrolein	4.46E-02	24	365	9.25	81,030	4.46E-02	**Children** (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	105,120	4.46E-02	**Adults** (Overall Residential Occupancy Period value for adults older than 18 years)
$PM_{2.5}$ Primary (Filt + Cond)	3.88E+01	24	365	9.25	81,030	3.88E+01	**Children** (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	105,120	3.88E+01	**Adults** (Overall Residential Occupancy Period value for adults older than 18 years)
Nitrogen Oxides	5.99E+01	24	365	9.25	81,030	5.99E+01	**Children** (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	105,120	5.99E+01	**Adults** (Overall Residential Occupancy Period value for adults older than 18 years)

Table 2: Average Daily Exposure Calculations for non-carcinogenic pollutants

Carcinogenic: (L)ADE = EPC * ((ET*EF*ED)/AT)							
COC Name	**Exposure Point Concentration (EPC)**	**Exposure Time (ET)**	**Exposure Frequency (EF)**	**Exposure Duration (ED)**	**Averaging Time (AT)**	**Lifetime Average Daily Exposure ((L)ADE)**	**Receptor**
Formaldehyde	6.74E-01	24	365	9.25	683,280	8.00E-02	**Children** (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	683,280	1.04E-01	**Adults** (Overall Residential Occupancy Period value for adults older than 18 years)
Chromium Compounds	3.17E-05	24	365	9.25	683,280	3.76E-06	**Children** (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	683,280	4.87E-06	**Adults** (Overall Residential Occupancy Period value for adults older than 18 years)
Cadmium Compounds	6.59E-04	24	365	9.25	683,280	7.82E-05	Children (95th percentile of ages 3, 6, 9, 12, 15, 18)
				12	683,280	1.01E-04	Adults (Overall Residential Occupancy Period value for adults older than 18 years)

Table 3: Lifetime Average Daily Exposure calculations for carcinogenic pollutants

Non-carcinogenic: ADE = EPC * ((ET*EF*ED)/AT)					
Name	**Units**	**Receptor**	**Value**	**Source**	**Notes/Comments**
EPC (Exposure Point Concentration	$\mu g/m^3$	Both	Varies for each COC	Modeled NEI Emissions data	Calculated using the Gaussian plume model and annual emissions data for each COC at 2 km distance
ET (Exposure Time)	hr/day	Both	24	N/A	
EF (Exposure Frequency)	days/year	Both	365	N/A	This assumes that people have contact with outdoor air every day in some capacity, whether that be going outdoors or opening windows in the home, etc.
ED (Exposure Duration)	Years	Children	9.25	EPA Exposure Factors Handbook Ch. 16 Table 109	95th percentile of the mean residential occupancy period for ages 3, 6, 9, 12, 15, and 18.
		Adults	12	EPA Exposure Factors Handbook Ch. 16 Table 5	Overall Residential Occupancy Period value
AT (Averaging Time)	Hours	Children	81,030		ED in years * 365 days/year * 24 hours/day
		Adults	105,120		

Table 4: Variables used to calculate Average Daily Exposure (ADE)

Carcinogenic: (L)ADE = EPC * ((ET*EF*ED)/AT)					
Name	**Units**	**Receptor**	**Value**	**Source**	**Notes/Comments**
EPC (Exposure Point Concentration)	µg/m^3	Both	Varies for each COC	Modeled NEI Emissions data	Calculated using the Gaussian plume model and annual emissions data for each COC at 2 km distance
ET (Exposure Time)	hr/day	Both	24	N/A	
EF (Exposure Frequency)	days/yr	Both	365	N/A	This assumes that people have contact with outdoor air every day in some capacity, whether that be going outdoors or opening windows in the home, etc.
ED (Exposure Duration)	Years	Children	9.25	EPA Exposure Factors Handbook Ch. 16 Table 109	95th percentile of the mean residential occupancy period for ages 3, 6, 9, 12, 15, and 18.
		Adults	12	EPA Exposure Factors Handbook Ch. 16 Table 5	Overall Residential Occupancy Period value
AT (Averaging Time)	Hours	Both	683,280		Lifetime in years * 365 days/year * 24 hours/day

Table 5: Variables used to calculate Lifetime Average Daily Exposure (LADE)

Non-Carcinogenic COCs: Hazard Quotient = ADE (ug/m^3) / RfC (ug/m^3)						
Chemical Name	**CAS No.**	**RfC (mg/m^3)**	**Data Source**	**ADE (µg/m^3)**	**Hazard Quotient (HQ)**	**Receptor**
Acrolein	0107-02-08	2.00E-05	IRIS	4.46E-02	2.23E+00	Adults
				1.30E-024.46E-02	2.23E+00	Children
$PM_{2.5}$	-	0.009	EPA NAAQS	3.88E+01	4.31E+00	Adults
				3.88E+01	4.31E+00	Children
Nitrogen Oxides	-	64.998	EPA NAAQS	5.99E+01	9.22E-04	Adults
				5.99E+01	9.22E-04	Children
Carcinogenic COCs: Excess Lifetime Cancer Risk (ELCR) = (L)ADE X (IUR) (ug/m^3)						
Chemical Name	**CAS No.**	**Inhalation Unit Risk (IUR) (µg/m3)**	**Data Source**	**(L)ADE (ug/m^3)**	**Excess Lifetime Cancer Risk (ELCR)**	**Receptor**
Formaldehyde	50-00-0	1.10E-05	IRIS/EPA	1.04E-01	1.14E-06	Adults
				8.00E-02	8.79E-07	Children
Chromium Compounds	18540-29-9	1.80E-02	IRIS/EPA	4.87E-06	8.77E-08	Adults
				3.76E-06	6.76E-08	Children
Cadmium Compounds	7440-43-9	1.80E-03	IRIS/EPA	1.01E-04	1.82E-07	Adults
				7.82E-05	1.41E-07	Children

Table 6: Hazard Quotient and Excess Lifetime Cancer Risk Calculations for Chemicals of Concern for Adult and Children Exposure