

Technical Review of TransAlta Corporation Keephills 1 Repowering Units Project Air Quality Assessment

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Authors Role and Responsibility: *The authors acknowledge that they have been engaged to be independent witnesses to give evidence-based opinion on issues within our areas of expertise and acknowledge that we have a duty to provide evidence and opinion to the Alberta Utilities Commission that is fair, objective, and non-partisan.*

CONTEXT

This document provides an expert review and opinion on the air quality assessment prepared for the proposed TransAlta Keephills 1 Repowering Unit Project (the Project); a large natural gas electricity generation facility to be located near Wabamun Lake, Alberta. The assessment evaluates the impact of emissions of pollutants associated with routine operation of the facility. This opinion is written by nationally and internationally recognized air pollution scientists with more than 50 years of combined experience in air pollution modelling.

The air quality assessment for the Project relies on CALPUFF air dispersion model in accordance with Alberta's Air Quality Model Guideline (AQMG). The modelling uses a 45×45 km study domain centred on the Project. This expert opinion examines the modelling approach, key assumptions, and broader impacts of atmospheric release of pollutants and greenhouse gases (GHGs) to assess whether the assessment adequately characterizes the Project's potential effects on air quality, climate, environment, and nearby communities.

The opinion is divided into three sections. In the first section, the air quality assessment conducted by the applicant is reviewed for the approach, assumptions, and inputs used, based on Alberta's AQMG. The review in the second section examines the adequacy of the approaches and methods/models suggested in the AQMG. The last section briefly discusses and evaluates the climate impact of the proposed project which is related to the atmospheric release of the pollutants resulting from the operation of the proposed plant, as well as the impact on Edmonton which is directly downwind of the Project.

EXECUTIVE SUMMARY

This expert opinion examines the assessment of the air quality and environmental impacts of the proposed TransAlta Keephills 1 repowering project. In our evaluation, we find a number of deficiencies and inaccuracies. With regards to the execution of air quality assessment, we find the following practices to be unjustified and/or against guidelines:

- Various inaccuracies or errors exist in estimating emissions for the Project. Some emissions are estimated based on emission standards/guidelines while estimation of others is based on operational emission factors. Different sources are used for different

pollutants. Emission factors from AP-42 are lower than those reported. For the estimation of emissions based on AP-42, energy output, rather than energy input is used as the activity measure, implying 100% thermal efficiency. No emissions are reported for ammonia as no control technology is specified, even though the Project documents indicate that ammonia emissions would occur.

- Exclusion of wildfire cases/years is unjustified as the AQMG already allow for screening of exceptional events, which was done in the assessment of the Project.
- The size of the domain is too small to adequately capture the dynamics of transport across longer distances.
- While the assessment finds no exceedances of the Alberta Ambient Air Quality Objectives and Guidelines (AAAQOG), estimated PM_{2.5} concentrations are close to the AAAQG despite underestimation of background concentrations, and exclusion of secondary PM_{2.5}. NO₂ concentrations are in exceedance of federal standards.
- The Project is directly upwind of Edmonton and at a distance that is likely to make its impact on ozone exposure in the city and its surrounding area which warrants additional analysis and evaluations.

Beyond procedural issues and study design, and yet as importantly, we find that the choice of models recommended in provincial guidelines are not adequate for addressing air pollution challenges that a plant such as the Project would pose. Most importantly, the recommended dispersion models do not account for ozone and secondary inorganic (sulfate, nitrate, ammonium) and organic PM_{2.5} which constitute a large portion of particle mass in the Prairies. Therefore, these provincial guidelines in their current form are neither adequate nor responsive to provincial and federal air quality objectives/standards. In particular, it is our opinion that:

- Dispersion models are incapable of simulating secondary pollutants and therefore, are not proper tools for evaluating the impact of large sources on PM_{2.5} and ozone, the two main pollutants (from a public health perspective) in Alberta.
- Dispersion models are generally limited in their ability to characterize the impact on distant sources, an issue that can be important for larger sources.
- Individual assessment of sources belies the cumulative impact, particularly for rapid expansion of sources for an industry such as data centres.

Finally, we note that the Project may have a significant climate footprint and constitute a sizeable share of Alberta's current greenhouse gas emissions, with a valuated climate impact in hundreds of millions of dollars annually. If unmitigated, the Project can affect provincial and federal climate mitigation targets.

To address these issues, we recommend the following:

1. In its current form, Alberta's AQMG is not fully responsive to objectives foreseen in the AAAQOG as it does not address ozone and secondary (inorganic and organic) PM_{2.5}. Assessment of a large source such as the Project should be conducted using a state-of-

the-art photochemical model so that the impact on ozone and secondary PM_{2.5}, and the potential for long-range pollution transport and impact can be properly assessed.

2. Any type of modelling should not exclude wildfires or other exceptional episodes, as the AQMG already allows for these events to be generously screened out.
3. As the Project is directly upwind of Edmonton, additional assessment to evaluate the impact on population exposure is recommended. In particular, the impact of the Project on ozone exposure should be assessed.
4. Estimation of Project emissions should be performed in a consistent manner, and an assessment of all emissions and their impact should be conducted. This includes clear definition of control technologies and quantification of ammonia emissions.
5. In a setting where extensive and rapid expansion/addition of sources is expected, the cumulative impact of these sources should be evaluated using a state-of-the-art air quality model as individual assessments will be inaccurate and inadequate to reproduce realistic impacts.
6. It is recommended that the overall assessment of the Project, and any other new source of the same size, include an integrated evaluation of impacts on air quality, environment, population exposure, climate, and distributional effects (i.e., environmental justice).

1. EVALUATION OF THE ASSESSMENT BASED ON AQMG

The Keephills repowering Air Quality Assessment relies on the CALPUFF plume dispersion model to estimate ground-level concentrations of NO₂, CO, and PM_{2.5}. CALPUFF is a widely used dispersion model accepted by Alberta Environment and Protected Areas' (AEPA) Air Quality Modelling Guidelines (AQMG-AEPA 2021). The AQMG is issued by the Government of Alberta to ensure that air quality assessments can safeguard achieving the Alberta Ambient Air Quality Objectives and Guidelines (AAAQOG). Before examining the air quality assessment, two points pertaining to air pollution impacts and dispersion modelling are worth emphasizing.

A. Air pollution health impacts: While the air quality assessment follows the AQMG, the primary purpose and the spirit of the AQMG is the protection of public health and the environment. Air pollution is associated with a wide range of adverse health outcomes, including both mortality (premature death) and morbidity (non-fatal outcomes such as asthma attacks, emergency room visits, dementia, or prenatal effects). Health effects may arise from acute (short-term) or chronic (long-term) exposure, with chronic exposure responsible for more than 80% of air-pollution-related mortality in Canada (Health Canada, 2019). These impacts may be monetized to facilitate benefit-cost assessment of pollution control measures. In Canada, valuation/monetization of these outcomes is often based on cost-of-illness (COI) measures for morbidity, and based on governmental estimates of the value of statistical life (VSL). From a societal perspective, mortality accounts for the vast majority of the economic burden of air pollution in Canada (Hubbel et al., 2005; Health Canada, 2019). These impacts are quantified using concentration-response functions derived from epidemiological studies, which describe how changes in pollutant concentrations translate into changes in health outcomes. This

framework underlies governmental impact assessment tools such as Health Canada's Air Quality Benefits Assessment Tool (AQBAT) (Judek et al., 2012).

B. Dispersion models: The use of CALPUFF or other dispersion models comes with several inherent simplifications and assumptions. These simplifications are applied to make regulatory modeling feasible, but they influence the accuracy and reliability of the predicted concentrations. The Project is also a large-emitting facility, which increases the importance of accurately representing atmospheric processes in the assessment. These limitations will be discussed in more details in a subsequent section, but an overview of them is important in evaluating the submitted assessment. CALPUFF is a Lagrangian air quality model (i.e., a model where parcels of air are tracked based on wind patterns) that relies on Gaussian puff formulation to produce time-dependent concentrations of pollutants. While CALPUFF is more advanced than some other dispersion models (e.g., AERMOD), it is still limited in its ability to reproduce a realistic range of processes in the atmosphere. Most importantly, CALPUFF often includes no or very simplistic chemistry to represent transformation of pollutants.

An important limitation of CALPUFF is in its treatment of atmospheric stability and mixing height. CALPUFF calculates concentrations for every hour (3600 sec as indicated in the control file, Appendix A3) of the year, and for each of those hours it uses a single set of boundary-layer parameters supplied by its meteorological processor (CALMET), including one stability class (a measure of mixing in the atmosphere) and one mixing height. The model assumes that turbulence intensity, vertical mixing, and boundary-layer structure remain constant throughout that hour. The stability classes used by CALMET describe the level of atmospheric turbulence, ranging from very unstable conditions with strong vertical mixing to very stable conditions with limited mixing. In real atmospheric conditions, however, the lower boundary layer (the layer in contact with the surface) often changes more rapidly than this hourly framework allows. Stability can shift within short periods during evening inversion formation or boundary-layer breakup in the morning, and mixing heights frequently decrease quickly after sunset as surface cooling develops. These transitions are precisely the periods when pollutant concentrations tend to peak, because emissions become trapped within a shallow, stable layer with limited vertical dilution. Because CALPUFF dispersion modeling relies on a simplified, hourly stability category, it is limited in representing the rapid atmospheric changes that occur within an hour, and this smooths out the very conditions that produce the highest ground level concentrations. As a result, the model can show a systematic tendency to underestimate peak ground-level concentrations, limiting its ability to identify worst-case conditions for estimated concentrations.

CALPUFF also suffers from some of the inherent limitations of Lagrangian models. As it treats the plume as one or more parcels of air, it often predicts unrealistically large concentration gradients between the plume and its surrounding. In reality, plumes from large sources will expand significantly over large distances, and as such the concentration gradient that the centre of the plume experiences is often less than that predicted in a Lagrangian model such as CALPUFF. This mischaracterization of concentration gradients, in turn, results in enhanced dispersion and dilution of the plume, leading to underestimated concentrations. As a result, the model can show a systematic tendency to underestimate peak ground-level concentrations, limiting its ability to identify worst-case conditions for estimated concentrations. *As a result,*

dispersion modelling for air quality assessment should always seek the worst possible conditions as a mechanism to compensate for these inherent underestimations.

CALPUFF does not have some of the limitations of simpler dispersion models such as AERMOD, in that it does not assume steady state and relies on more detailed meteorology. Also, because it follows individual parcels of air, it can include limited forms of chemical and thermodynamic transformations without too much computational cost. However, in most applications of CALPUFF, either no chemistry or very simplified chemistry is considered, which significantly limits the model's ability to produce realistic concentrations.

CALPUFF is able to follow parcels of air over longer distances, and therefore unlike AERMOD, can in principle model long-range transport. Consideration of long-range transport for larger emission sources is essential as, depending on the atmospheric conditions, plumes from these sources can travel long distances before mixing within the boundary layer and touching the surface and causing air pollution impacts. This phenomenon can occur frequently when emissions are injected above the shallow nocturnal mixed layer and are transported aloft. These plumes can then travel hundreds of kilometres before daytime mixing brings them to surface resulting in higher concentrations at a distant location.

1.1. Size of the modelling domain

The air quality assessment indicates that the study domain is 45×45 km, centered around the Project location. This provides a source-impact radius of 23-32 km (i.e., distance from the plant to the sides or corners of the study area, respectively) – depending on the wind direction – for the conducted assessment (see Figure 1). This is a very small study area that does not take advantage of CALPUFF's ability to evaluate long-range impacts.

As noted earlier, the mixing height and boundary-layer structure play a central role in determining the dispersion of emitted pollutants, and these effects become even more important when considering the size of the modelling domain. Alberta's AQMG requires that the domain be sufficiently large to include nearby sources that substantially influence concentrations at the receptors; however, large emitters such as power plants can also produce regional-scale impacts that extend well beyond the study area. Transitions in boundary-layer depth influence how emissions disperse when the stack height remains within the boundary layer, as shallow and stable conditions limit vertical dilution and can lead to higher ground-level concentrations. When the stack height extends above the boundary layer or the nocturnal inversion layer, the dispersion behaviour differs as emissions

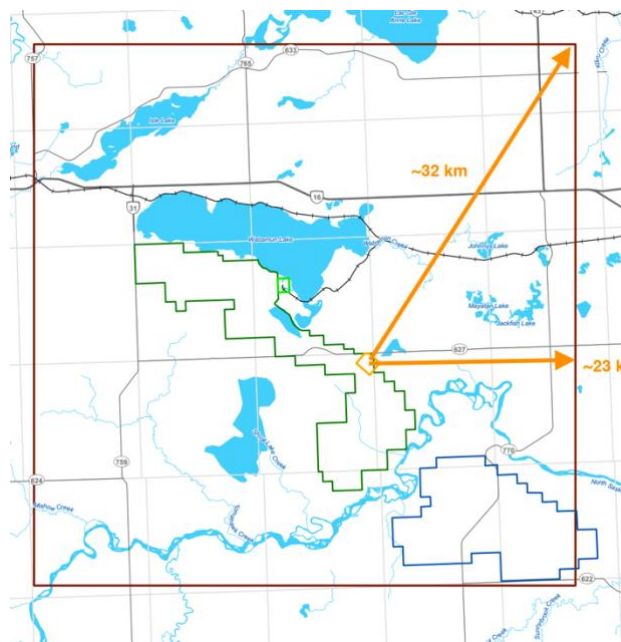


Figure 1: Range of distance between Keephills plant and the study area boundary.

may remain aloft for extended periods, undergo longer transport, and re-enter the boundary layer under more mixed conditions. A modelling domain that is too small cannot capture these processes, and truncating the domain removes downwind impacts that would occur under real atmospheric conditions.

The assessment claims that the study area covers all locations where the Project contribution to ambient concentrations is at 10% of the AAAQOG or more. However, the assessment document provides no further information about this analysis. It is not clear how the modelers have determined contributions for averaging periods prescribed by the AAAQOG at longer distances without conducting CALPUFF modelling over a larger domain and for the 3-year analysis period. As mentioned before, injection of plume above the mixed layer and its re-entry into the surface layer after long-range transport is a common occurrence, and the use of a small domain precludes capturing these instances. This is particularly important as Edmonton is 60 km downwind of the Project and the City's suburbs are just outside of the study area. Cutting the study area short removes the modellers' ability to evaluate increased exposure in a densely populated area that is downwind of the Project.

The work by Oztaner et al. (2024) provides a basis for estimating the impact of long-range transport for primary pollutants. They used an advanced methodology to estimate location-specific emission source impacts by coupling a photochemical model with reverse influence modelling to link chronic PM_{2.5} exposure to emissions from coal-fired and natural gas power plants across Canada. In their analysis, they distinguished between monetized *in-province* health impacts, defined as the portion of the PM_{2.5}-related health burden occurring within the same province as the emitting facility and *out-of-province* impacts, which represent the contribution of those emissions to PM_{2.5} related health burden occurring outside of the province and across Canada. They found that for power plants in proximity to the Project, more than 10% of the impact from PM_{2.5} emissions occurs outside of province, i.e., hundreds of kilometres away. While the exact distribution in space in the work of Oztaner et al. (2024) is not known, it does demonstrate that the impact on public health occurs over large distances and that the 23-32 km radii will not be adequate for capturing the dispersive impact of a facility with significant emissions.

1.2. Exclusion of wildfires

The assessment excludes the year 2023 from background concentration calculations due to unusual wildfire activity. The assessment document does not provide any rationale for this practice which appears arbitrary and outside of recommended guidelines in the AQMG.

The AQMG suggests the following for estimating the background concentrations used in dispersion models:

“Screening assessments for all averaging periods should be based on average of the reduced hourly data set for each year, i.e., the top hourly values above the 99.9th percentile non-blank ambient baseline data are removed. Do not include blank data as zero values when determining the 99.9th percentile. For all averaging periods greater than one hour, the maximum calculated

average for each averaging period, to be used as the baseline value for modelling purposes, must then be based on the reduced hourly ambient data sets. No further removal of maximum values for other averaging time periods is allowed.

*Refined and advanced assessments should be calculated in a similar manner as the screening assessment but now based on a 90% percentile. **This allows for some variability in the baseline due to anthropogenic or unusual local sources.**” [emphasis added]*

Removal of wildfire episodes is not discussed or suggested in the AQMG. As the regulator suggests, the use of percentiles in preparing monitoring datasets and calculating a background concentration is meant to address variability and unusual/exceptional conditions (such as wildfires) that lead to extreme concentrations. The assessment follows the guidelines in removing the worst 10% hourly values. This is more than 5 weeks’ worth of hourly data in a year and is meant to cover episodes of extreme concentrations such as wildfires. Also, the assessment of exceedance is based on a 3-year average of yearly estimates, which would further dilute the impact of an anomalous year. Note that unless there were wildfires inside the study area (which was not the case), the impact of wildfires on the study area is only felt through background concentrations. If the worst 10% of hours are already removed, then exclusion of wildfires is not appropriate. Given the existing provision in the guidelines, further removal of wildfire episodes, or exclusion of an entire year – which is also the most recent year as required by the AQMG – is simply unjustified. While the concept of transboundary flows/exceptional events is recognized by the government of Alberta through the recommendation of the Canadian Council of the Ministers of Environment (CCME), applying it on top of a percentile approach appears redundant and against the spirit of the AAAQOG and the Canada Ambient Air Quality Standards (CAAQS). We also note that the 90th percentile recommended by the AQMG is already substantially less stringent than what is envisioned in the AAAQOG as the 9th highest concentration (i.e., 97.5th percentile, on a daily basis, and 99.9th percentile on an hourly basis), making such exclusions even more problematic.

1.3. Project emissions

The revised air quality assessment in response to information requests (IRs) from the Commission states the following (AQA; WSP, 2026):

“NO_x Emissions associated with the Project are based on information provided by TransAlta in conjunction with the applicable federal regulatory emission limit for NO_x. CO and PM_{2.5} emissions were estimated based on emission factors from Canadian Energy Partnership for Environmental Innovation (CEPEI; 2012) and United States Environmental Protection Agency (US EPA) AP-42 (US EPA 1998 and 2000), respectively.”

The assessment uses a different source for the emissions factor for each pollutant, rather than using a consistent source (e.g., AP-42) and methodology for all pollutants. The reason for using three different sources for emission factors remains unclear in the assessment, as such practice may lead to inconsistencies and the appearance of looking for the best emission factors. Also, the statement suggests that AP-42 is the source for PM_{2.5} emissions; however, PM_{2.5} emission factors

we retrieve from USEPA's AP-42 for natural gas engines/turbines are significantly (5-10 times, for gas turbines vs. gas engines) larger than those used in the assessment. From USEPA's AP-42 database (USEPA's WebFire online interface), we retrieve a value of $2.8 \times 10^{-3} \text{ kg/GJ}$ for a gas turbine rather than $2.4 \times 10^{-4} \text{ kg/GJ}$ used in the assessment (Section B2, Appendix B).

Additionally, regardless of the emission factors used, calculations provided in section B2 of appendix B appear to be incorrect. Calculation of emission rates require multiplication of emission factors and the activity level, with appropriate unit conversions. For activity measure, sample calculations shown appear (the exact calculations and assumptions about natural gas energy content are not shown) to use the hourly energy output for all three pollutants. However, the emission factor used for NO_x is based on the energy output of the unit (i.e. kg/GJ-output), while AP-42 emission factors are expressed per energy input to the unit (kg/GJ-input), i.e., the fuel energy delivered to the plant. As shown, the assessment assumes that all the input energy is converted to output electricity. In other words, it assumes 100% thermal efficiency, which is very far from reality. These calculations need to be corrected and explained in a clear manner such that the final results can be trusted.

TransAlta's response to LSAMCA's IRs also includes the following statements:

"The emissions weren't estimated based on specific emission control technology but rather the maximum emissions allowed under current regulation (e.g., Federal Guidelines for Reduction of Nitrogen Oxide Emissions from Natural gas-fueled Stationary Combustion Turbine (ECCC 2017 for NO_x) as explained in the 2025 and 2026 AQA reports, Attachment B, Section B2. For CO and PM_{2.5}, emissions were estimated based on published emission factors."

"Based on the current design, the Keephills 1 Repowering Project is not expected to emit NH₃ emissions."

Merely stating that emissions are based on standards is not sufficient. As a design document, the Project's proposal should include technical information about the control technologies used for pollution reduction. From the statement, it appears that no control technology is used for reducing PM_{2.5} (which is not ideal, but a fairly common practice for natural gas plants). However, the NO_x emission limits stipulated in the assessment are not possible without post-combustion treatment. Such post-combustion treatment almost always relies on chemical reduction of NO_x, often catalytically – using selective catalytic reduction (SCR) – and through the addition of reducing agents in ammonia or urea. Both types of reducing agents, and in both catalytic and non-catalytic configurations, would lead to emissions of ammonia, which is contrary to the second statement (i.e., that the Project is not expected to emit NH₃ emissions). Emissions of ammonia are very important in assessing the impact of the Project on the formation of secondary inorganic particles, and as such its omission is not justified.

1.4. Exceedance of AAAQOG and CAAQS

The assessment does not find any exceedances within the study area. However, we note the following with regards to this conclusion:

- Background concentrations are likely to be underestimated due to the exclusion of the year 2023 from calculations, which in our opinion is unjustified based on the AQMG.
- As the modelling exercise only considers primary PM_{2.5}, contributions from sources to secondary PM_{2.5} is likely to increase the estimated concentrations.

We also note that both Power and Genesee stations were in exceedance of the AAAQG for hourly and daily PM_{2.5} for every year except 2022 (ECCC, 2026). All of these suggest that the estimated daily PM_{2.5} maximum for the domain (26.2 µg/m³) is likely to be an underestimation due to methodological choices. As the estimated maximum value is already very close to the AAAQG, it does not provide a safety factor that would ensure protection of the environment and public health. Finally, we note that while simulated NO₂ concentrations do not exceed AAAQO values under the Ozone Limited Method (OLM) method, they exceed the CAAQS for NO₂ for both 1-hr and 24-hr averaging periods. Finally, the assessment does not provide any rationale for using the OLM values from among the range of options provided.

1.5. Section summary

We find numerous problems with the air quality assessment done for the Project. In summary, we find that:

- Various inaccuracies or errors exist in estimating emissions for the Project. Some emissions are estimated based on emission standards/guidelines while estimation of others is based on operational emission factors. Different sources are used for different pollutants. Emission factors from AP-42 are lower than those reported. For the estimation of emissions based on AP-42, energy output, rather than energy input is used as the activity measure, implying 100% thermal efficiency. No emissions are reported for ammonia as no control technology is specified, even though the need for NO_x control is likely to result in ammonia emissions.
- Exclusion of wildfire cases/years is unjustified as the AQMG already allow for screening of exceptional events, which was done in the assessment of the Project.
- The size of the domain is too small to adequately capture the dynamics of transport across longer distances.
- While the assessment finds no exceedances, estimated PM_{2.5} concentrations are close to the AAAQG despite underestimation of background concentrations, and exclusion of secondary PM_{2.5}. NO₂ concentrations are in exceedance of federal standards.

2. ADEQUACY OF ALBERTA AQMG

The AQMG document issued by the Government of Alberta provides guidelines for model-based assessment of air quality from industrial sources. The previous section evaluated the Project's air quality assessment against these guidelines. While the AQMG provides guidelines for dispersion modelling, we find the document deficient in important aspects. In this section, we briefly discuss why the AQMG may not be sufficient in protecting the public health and providing guidance towards maintaining the AAAQOGs. To better understand these limitations and to provide clarity for the technical language, we first define two key concepts used in our opinion.

A. Primary/secondary pollutants: From an air quality perspective, atmospheric pollutants can be divided into two categories of primary and secondary pollutants. Primary pollutants are those that are directly emitted into the atmosphere from emission sources. Conversely, secondary pollutants are not directly emitted, but are formed through chemical reactions or thermodynamic transformations of other emitted pollutants (i.e., primary pollutants) after their release into the atmosphere. For instance, carbon monoxide (CO) is mainly a primary pollutant, while ozone (O₃) is an entirely secondary pollutant. Other pollutants, such as fine particulate matter (or particles with an aerodynamic diameter less than 2.5 micrometer; PM_{2.5}) can contain both primary and secondary components formed from reactions involving nitrogen oxides (NO_x), sulfur dioxide (SO₂), ammonia (NH₃), and volatile organic compounds (VOCs). Although nitrogen dioxide (NO₂) can be directly emitted as a minor fraction of NO_x, most atmospheric NO₂ is produced secondarily through oxidation of NO. The processes that lead to the formation of secondary pollutants are central to understanding regional air quality impacts because secondary pollutants often contribute significantly to the population exposure and their formation can span over timescales and distances that extend well beyond the immediate vicinity of the emission source.

B. Dispersion models vs. photochemical models: Two main groups of models that provide estimates of pollutant concentrations are grid-based photochemical models and dispersion models. Dispersion models mainly simulate the transport of pollutants emitted directly from sources. These models often treat pollutants as inert, and therefore do not account for chemical or physical transformations that can happen in the atmosphere. Some versions of dispersion models (i.e., CALPUFF) account for simplified chemistry and can produce rudimentary estimates of deposition into sensitive environments (e.g. lakes). As a result, dispersion models are only appropriate for the assessment of primary pollutants. On the other hand, photochemical models simulate a range of atmospheric processes that include chemistry in the gas or aqueous phases, particle partitioning and growth, physical transformations (e.g., condensation/evaporation, coagulation, interaction with clouds, etc) and therefore can simulate secondary pollutants such as ozone and secondary PM_{2.5}, and over any spatial distances and temporal scales.

2.1. Exclusive reliance on dispersion models

As mentioned earlier, dispersion models suffer from inherent limitations. Due to their simplicity and ease of use, these models are invaluable as screening tools and for the assessment of small to moderate size emission sources. For these smaller sources, the limitation of dispersion models in adequately representing long-range transport of pollution (across hundreds of kilometres) is likely to be unimportant. However, regional and long-range transport can become a significant consideration for larger projects. For larger projects, the use of more detailed, gridded photochemical models that can account for transport over longer distances, as well as transformation of pollutants (see below) is the more appropriate methodology and considered as state-of-the-art. Currently, these models are not included in the AQMG even on an optional basis, and even large facilities will only have to undergo simple dispersion modelling for air quality assessment.

The most important deficiency in the AQMG's reliance on dispersion models is the inability of these models to simulate secondary pollutants. From a public health standpoint, the most important pollutants in Alberta, Canada, and worldwide are ozone and PM_{2.5}. Over the past few years, Alberta has had frequent AAAQOG exceedances for both pollutants. Ozone is an entirely secondary pollutant, while secondary inorganic and organic components often constitute much of PM_{2.5} in Alberta. Analysis of National Air Pollution Surveillance (NAPS) data from seven urban and two rural sites across Canada (2010–2016) shows that secondary inorganic components typically account for about half of total PM_{2.5} mass, with sulfate contributing 10.8–18.1%, nitrate 3.7–16.7%, and ammonium 4.7–7.4% (Wang et al., 2021). At the Edmonton urban site, sulfate, nitrate, and ammonium account for approximately 10.8%, 16.7%, and 7.0% of PM_{2.5}, respectively, while organic carbon and elemental carbon contribute about 18.8% and 7.8%. Another study attributes 24% of PM_{2.5} to secondary organic aerosol and an additional 23% to secondary inorganic PM_{2.5} species (sulfate ~13%, nitrate ~10%), indicating the significance of secondary processes in PM_{2.5} composition in Calgary, similar to Edmonton (Anastasopoulos et al., 2022). These findings indicate that PM_{2.5} in Alberta is strongly shaped by atmospheric chemical transformation of precursor gases (NO_x, SO₂, NH₃), underscoring the need to consider secondary formation pathways. Dispersion models ignore these pollutants altogether, and as such, the AQMG, in its current model recommendations, is not responsive to the aspirations of the AAAQOGs.

For the assessment of this facility, consideration of secondary pollutants is essential, as the Project has large NO_x emissions, as well as likely ammonia slippage due to the use of catalytic or non-catalytic reduction for NO_x control. Neither of these impacts are considered in the assessment. Furthermore, as secondary pollutants may take a longer time to form in the atmosphere, long-range transport will play a more prominent role in a proper assessment. For instance, Oztaner et al. (2024) found significant health burdens associated with the emissions of ammonia from power plants in Alberta and Canada, with most of those health impacts occurring outside the province due to long-range transport.

It is important to note that CALPUFF has some limited built-in ability to model simplified gas-phase and aqueous-phase chemistry leading to the formation of secondary PM_{2.5}. However, these options were not utilized in the air quality assessment for the Project, presumably as they are not required by the AQMG. Furthermore, activating these more sophisticated options would also require conducting the assessment over a much larger study area to allow for long-range transport and the time required for the formation of secondary particles. Even with those options activated, CALPUFF's ability to adequately reproduce concentrations of secondary pollutants remains very limited.

2.2. Cumulative impact of sources

The importance of secondary pollutant formation becomes even more relevant in the context of all existing and approved industrial facilities included in the current assessment and elsewhere in the region and province, as well as those that may be planned for future. These facilities emit substantial quantities of NO_x, SO₂, and NH₃, all of which influence the atmospheric chemical regime and the availability of precursors for secondary PM_{2.5} formation. When an additional source is introduced into an already emissions-dense region, the chemical environment can shift

in ways that increase the efficiency of secondary pollutant formation, particularly for ammonium nitrate and/or ammonium sulfate. Although the current assessment includes other facilities in its emission inventory, the modelling framework cannot represent the chemical interactions that occur when multiple sources contribute precursors simultaneously. As a result, the cumulative modelling scenarios may underestimate PM_{2.5} concentrations by neglecting secondary PM_{2.5} formation and downwind impacts, even though these processes are central to understanding regional air quality in Alberta.

The assessment conducted here considers some of the planned facilities within the very small study domain. For a rapidly growing industry such as data centres, estimating the cumulative impact of energy requirements should extend beyond individual assessment in small domains. Even if the impact from one data centre facility is within limits, aggregate impacts from many facilities across Alberta's airshed and beyond may be significantly larger. As such, a more thorough and integrated assessment for such industry sources using an appropriate model that accounts for secondary pollutant formation and long-range transport is essential.

2.3. Section Summary

We find that the choice of models in the AQMG for air quality assessment is not state-of-the-art and is inadequate for properly evaluating the impact of new sources on population health and environment. In particular, it is our opinion that:

- Dispersion models are incapable of simulating secondary pollutants and therefore, are not proper tools for evaluating the impact of large sources on PM_{2.5} and ozone, the two main pollutants (from a public health perspective) in Alberta.
- Dispersion models are generally limited in their ability to characterize the impact on distant sources, an issue that can be important for larger sources.
- Individual assessment of sources belies the cumulative impact, particularly for rapid expansion of sources for an industry such as data centres.

3. OTHER IMPACTS

The previous sections focused on air quality impacts as related to the AAAQOGs. Atmospheric release of pollutants from the Project can have other impacts as well. In this section we briefly discuss climate impacts of the Project due to its use of natural gas. Apart from emissions of carbon dioxide (CO₂) from combustion, operation of a natural gas plant will include emissions of methane (CH₄) due to incomplete combustion and fugitive emissions, as well as emissions of nitrous oxide (N₂O). Both CH₄ and N₂O are greenhouse gases (GHGs) that are significantly more potent than CO₂.

The impact of GHG emissions is often valued in monetary terms (e.g., a carbon price) to facilitate benefit-cost assessment of mitigation options. The social cost of GHG (SC-GHG) represents the monetized damages associated with emitting one additional tonne of a greenhouse gas into the atmosphere that occurs due to the warming of the climate. These damages include

impacts on human health, agricultural productivity, infrastructure, and climate-related extreme events. The Social Cost of Carbon (SCC) is the most commonly used form of SC-GHG and quantifies the long-term (over a certain period) global damages from one tonne of CO₂ emissions. Social Cost of Methane (SCM) and Social Cost of Nitrous Oxide (SCN) reflect the substantially higher warming potential of CH₄ and N₂O. An alternative (but more subjective) approach to estimating the social cost of other greenhouse gases is the common practice of presenting them as CO₂-equivalent (CO₂-eq) through an equivalency metric such as the global warming potential (GWP). GWP, estimated for a certain long-term period, provides a measure of the relative potency of a GHG compared to that of CO₂. SCC and GWP, as adopted by the Government of Canada, provides a consistent framework for evaluating the climate impacts of industrial projects and for comparing the societal impact of releasing greenhouse gases on a common monetary basis. Note that SCC is different from the carbon price set by the federal or provincial governments. While the former is a measure of the cost to the society, the latter is an economic instrument set by the regulator to partially account for those societal costs. As a result, while the two are related, the carbon price will be always lower than the SCC estimate.

3.1. Climate Impacts

The proposed repowering of Keephills will emit large quantities of CO₂ and CH₄ from routine and upstream operations. These emissions would constitute a sizeable increase in Alberta and Canada's GHG emissions. The Project documents do not specify the expected GHG emissions; however, based on the Greenhouse Gas Reporting Program (GHGRP) of Canada, as of 2024, Keephills Electric Generating Plant's existing units emit 2.7 million tonnes of CO₂ emissions. Emissions reporting from similar natural gas plants in the United States suggests that a plant similar to the Project would emit on average an additional 3 million tonnes of CO₂ every year (see Table 1), expanding the facility's overall climate impact and increasing its contribution to provincial and national GHG inventories. At that level of CO₂ emission, the Project (only the proposed repowered unit) would constitute more than 1% of Alberta's GHG emissions and together with the existing units at Keephills would account for nearly 2% of Alberta's emissions. The Social Costs of Carbon (SCC) provides a monetary estimate of the long-term damages associated with each ton of GHG emitted, including impacts in human health, agricultural productivity, climate-related extreme events such as floods, heat waves, droughts, sea-level rise. The current values of SCC are set by the government of Canada at \$275/tonne of CO₂ (2021 CAD). Applying the SCC to the proposed project's estimated CO₂ emissions (i.e., the approximated 3 million tonnes) amounts to annual climate-related impact of more than \$800 million. This does not account for emissions of methane or nitrous oxide at the plant or upstream methane loss during the transportation of natural gas.

Table 1: CO₂ emissions from U.S. plants similar to the Project for the year 2020.

Facility ID	Facility Name	Generation (MWh)	CO ₂ emissions (t/yr)
55298	Fairless Energy Center	7,847,977	3,227,571
7873	Bayside Power Station	7,573,447	3,196,641
60589	CPV Fairview, LLC	7,396,747	2,769,720
55464	Deer Park Energy Center	7,385,212	2,645,038
1378	Paradise	7,365,156	3,316,502
55481	Mesquite Generating Station	7,276,336	3,128,883
55131	Kendall Energy Facility	7,271,182	3,354,899
55297	New Covert Generating Project	7,200,741	3,076,431
55097	Lamar Power Plant	7,022,063	2,952,070

Source: USEPA National Emission Inventory (NEI) database and Emission and Generation Resource Integrated Database (eGRID)

On a valuated basis, the Project has significant climate impact, even if Government of Canada agrees to a lower level of SCC with the Government of Alberta. Given the size of the Project and its potential impact on undermining Alberta's and Canada's commitments to GHG emission reductions, consideration of a Carbon Capture and Storage (CCS) option for the plant seems prudent. While CCS is less cost-effective for natural gas plants compared to coal, rapid expansion of data centres as an industry may necessitate their use to ensure that climate targets remain within reach. It is important to note that CCS would only address the climate impact of the Project, and may impose additional air quality considerations due to higher fossil fuel consumption that should be properly assessed.

3.2. Population exposure

As mentioned before, the Keephills plant is upwind of Edmonton, and as such its emissions will impact the city. Due to the choice of the model and the size of the study area, evaluating the impact on the population exposure and health risks is not possible with the current modelling setup. This impact is likely to be most important for exposure to ozone, which is not considered in this assessment. As a secondary pollutant, ozone is generated from reactions between NO_x and organic compounds. However, due to its nonlinear chemistry and titration with NO_x, the highest ozone concentrations from a major NO_x source such as a power plant or dense urban area are always experienced downwind of the source, as the plume is given enough time to reach optimal conditions for the formation of ozone. This distance for the ozone maximum is variable and depends on the plume, meteorological conditions, and atmospheric composition of the surroundings, but it is typically 30 – 100 km downwind of the source. Therefore, Edmonton is likely to be the location of maximum ozone impact from the Keephills plant on some days during regular operations. While not considered in the AQMG, given the location of the plant, an assessment of the impact on population exposure and subsequent health risks seems necessary for the protection of public health.

3.3. Section Summary

GHG emissions and climate impacts, as well as population exposure and public health impacts, are important considerations that are not accounted for in the air quality assessment for the Project. Consideration of these impacts underline the spirit of the AAAQOG in protecting the

public health and the environment. The Project will have a relatively large carbon/GHG footprint and valuated climate impact in hundreds of millions of dollars per year and can hinder provincial and national climate targets. Furthermore, as the Project includes significant NO_x emissions directly upwind of Edmonton, a sizeable impact on ozone concentrations in the city is likely and should be assessed.

CONCLUSIONS AND RECOMMENDATION

In evaluating the air quality assessment conducted for the repowering of Keephills Unit 1, we find deficiencies, inaccuracies, and instances where the approach can be improved. In its current form, the assessment does not adequately safeguard public health, environment, and climate. We find the following deficiencies in the assessment.

- The dispersion model used cannot adequately assess important pollutants in ozone and secondary (organic and inorganic) PM_{2.5}.
- The exclusion of wildfire events in their entirety, when provincial guidelines provide procedural instructions for their screening, is not justified.
- The size of the domain used does not allow for proper evaluation of longer-range impacts.
- Emissions from Project are not adequately characterized, as different methodologies and sources are used for various pollutants. Specification of NO_x control technologies is missing from the assessment. No emissions are assigned to ammonia, which are likely to occur in order to achieve NO_x emission targets. Emissions calculations appear to contain errors/mistakes. PM_{2.5} emissions factors used do not match those cited from EPA's AP-42.
- The assessment finds simulated concentrations to be below AAAQOG values. However, PM_{2.5} estimates are close to the AAAQOG, despite methodological choices that are likely to cause underestimations. Simulated NO₂ concentrations are in excess of federal air quality standards.
- The Project is directly upwind of Edmonton and at a distance that is likely to make an impact on ozone exposure in the city and its surrounding area, which warrants additional analysis and evaluations.
- The project will carry a significant carbon footprint which should be considered.

To improve this assessment and provide for public health and environmental protection, we recommend the following:

1. In its current form, Alberta's AQMG is not fully responsive to objectives foreseen in the AAAQOG, as it does not address ozone and secondary (inorganic and organic) PM_{2.5}. Assessment of a large source such as the Project should be conducted using a state-of-the-art photochemical model so that the impact on ozone and secondary PM_{2.5}, and the potential for long-range transport and impact can be properly assessed.

2. Any type of modelling should not exclude wildfires or other exceptional episodes, as the AQMG already allows for these events to be generously screened out.
3. As the Project is directly upwind of Edmonton, additional assessment to evaluate the impact on population exposure is recommended. In particular, the impact of the Project on ozone exposure should be assessed.
4. Estimation of Project emissions should be performed in a more consistent manner, and an accounting for all emissions and their impact should be conducted. This includes clear definition of control technologies and quantification of ammonia emissions.
5. In a setting where extensive and rapid expansion/addition of sources is expected, the cumulative impact of these sources should be evaluated using a state-of-the-art air quality model as individual assessments will be inaccurate and inadequate to reproduce realistic impacts.
6. It is recommended that the overall assessment of the Project, and any other new source of the same size, include integrated evaluation of impact on air quality, environment, population exposure, climate, and distributional effects (i.e., environmental justice).

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