EXH. RJR-31r2
DOCKETS UE-220066/UG-220067 and UG-210918 (Consolidated)
2022 PSE GENERAL RATE CASE
WITNESS: RONALD J. ROBERTS

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**DOCKETS UE-220066/UG-220067 and UG-210918 (Consolidated)**
In the Matter of the Petition of **PUGET SOUND ENERGY** **For an Order Authorizing Deferred Accounting Treatment for Puget Sound Energy's Share of Costs Associated with the Tacoma LNG Facility**	

FIRST EXHIBIT (NONCONFIDENTIAL) TO THE PREFILED TESTIMONY OF

RONALD J. ROBERTS

ON BEHALF OF PUGET SOUND ENERGY IN SUPPORT OF THE MULTIPARTY SETTLEMENT FOR TACOMA LNG

REVISED VERSION
NOVEMBER 14, 2022

AUGUST 26, 2022

BEFORE THE POLLUTION CONTROL HEARINGS BOARD
STATE OF WASHINGTON

ADVOCATES FOR A CLEANER TACOMA; SIERRA CLUB; WASHINGTON ENVIRONMENTAL COUNCIL; WASHINGTON PHYSICIANS FOR SOCIAL RESPONSIBILITY; STAND.EARTH, and THE PUYALLUP TRIBE OF INDIANS, a federally recognized Indian Tribe, Appellants, v. PUGET SOUND CLEAN AIR AGENCY; PUGET SOUND ENERGY, INC., Respondents.	**PCHB No. P19-087c** **PREPARED DIRECT TESTIMONY OF DR. SHARI BETH LIBICKI ON BEHALF OF PUGET SOUND ENERGY, INC.** [AMENDED WITH EXHIBIT NUMBERS]

INTRODUCTION

Q: PLEASE STATE YOUR NAME, OCCUPATION, AND BUSINESS ADDRESS.

A: My name is Dr. Shari Beth Libicki. I am a Principal at Ramboll US Corporation where I am a senior member of the company's air quality practice. I also serve as an Adjunct Professor in the Department of Chemical Engineering at Stanford University. My business address is 2200 Powell St Suite 700, Emeryville, CA 94608.

Q: FOR WHOM ARE YOU TESTIFYING IN THIS CASE?

A: I am testifying on behalf of Puget Sound Energy, Inc. ("PSE"), but the expert opinions that I express herein are my own.

Q: PLEASE DESCRIBE YOUR EDUCATIONAL EXPERIENCE.

A: I earned my BSE in Chemical Engineering from the University of Michigan (1979), my MS in Chemical Engineering from Stanford University (1981), and my PhD in Chemical Engineering from Stanford University (1985).

Q: PLEASE DESCRIBE YOUR BACKGROUND AND PROFESSIONAL EXPERIENCE.

A: I have over 30 years of environmental and air quality experience, drawing on my chemical engineering background, with particular expertise in estimating air emissions and dispersion from refineries and other heavy industries. I have conducted extensive air quality regulatory assessments for New Source Review ("NSR")/Prevention of Significant Deterioration ("PSD") permitting, as well as state minor source permitting, including evaluations of emissions impacts and the application and assessment of Best Available Control Technology ("BACT"). For state programs, I have extensive experience in estimating the impacts of toxic air pollutants. I have conducted and managed air dispersion modeling studies for the past 30 years, and my modeling experience has ranged from simple air dispersion models, such as SCREEN, intermediate complexity models such as the AERMOD modeling suite, all the way to using the results of regional air quality models, such

as Comprehensive Air Model with Extensions ("CAMx"). I have conducted air studies using computational fluid dynamics ("CFD"), and I have evaluated the impact of buildings and obstructions on air dispersion using CFD models. I have worked with meteorologists to understand the different types of meteorological data sets that are available and broadly evaluated the applicability of meteorological data sets to air dispersion modeling, including understanding how different meteorological data sets impact results.

Since 1989, I have been employed at Ramboll (and its predecessor company, ENVIRON), in positions of increasing responsibility applying scientific theories and chemical engineering principles of mass transport to air emissions and dispersion estimation. Ramboll is an international scientific and engineering consultancy. While at Ramboll, I have conducted numerous studies on the generation (*i.e.*, where is it coming from?), fate (*i.e.*, does it transform?) and transport (*i.e.*, how does it get there?) of environmental contaminants, with an emphasis on airborne contaminants. I have designed and operated ambient air monitoring systems and analyzed data from those monitoring systems. I have conducted air dispersion modeling studies for numerous purposes, including PSD permits, minor source permitting, and air toxics assessments.

I have prepared dozens of air permit applications for a wide variety of industrial sources, including steel mills, refineries, waste disposal and treatment systems, aluminum smelters, container glass manufacturing plants, and power generation

systems. In my permitting work, I have estimated emissions from, addressed BACT for, and conducted dispersion modeling from many of the same components that exist at Tacoma LNG, including process components that emit fugitive VOCs, enclosed ground level flares, and process heaters. I have prepared major and minor source applications, including PSD permit applications.

I have done permitting work in a number of states, including Washington, where I have done minor and major source permitting. I have extensive permitting experience in California, which has some of the strictest permitting regimes in the nation. I have done permitting work within the Puget Sound Clean Air Agency's (the "Agency") jurisdiction.

In addition to my consulting work, I am an Adjunct Professor at Stanford University, where I have taught courses for over 20 years. I currently teach a course on the science and engineering that support environmental rules and regulation.

I was appointed to the Regional Targets Advisory Committee ("RTAC") by the Executive Director of the Air Resources Board ("ARB"). The RTAC was charged with providing recommendations on factors to be considered and methodologies to be used in the ARB vehicle emissions greenhouse gas target setting process, as required under California's SB 375.

I was appointed to the Department of Defense's Science Advisory Board ("SAB") of the Strategic Environmental Research and Development ("SERDP"). The SAB has the authority to make recommendations to the SERDP Council regarding technologies, research, projects, programs, activities, and funding. The SAB is composed of between six and fourteen members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the United States Environmental Protection Agency (EPA).

I have provided consulting services to various government entities, including the California Air Resources Board, the South Coast Air Quality Management District, the Bay Area Air Quality Management District, the Sacramento Metropolitan Air Quality Management District, the California Air Pollution Control Officers Association, and other semi-governmental authorities, such as the Bay Area Rapid Transit authority, and several Ports, including the Port of Los Angeles and the Port of San Francisco. The single largest project that I have ever had was for the City of Richmond evaluating a modernization project at the Chevron Refinery. I have also consulted for non-governmental organizations such as the Environmental Defense Fund.

I have testified as an expert witness in the area of air quality in state and federal courts and before the Pollution Control Hearings Board.

My full curriculum vitae is included as Attachment A.[1]

Q: WHAT WAS THE SCOPE OF YOUR RETENTION FOR THIS LITIGATION?

A: I was retained by Baker Botts L.L.P. on behalf of PSE to perform work in connection with this litigation regarding the Notice of Construction ("NOC") Order of Approval (*i.e.*, the air permit) for PSE's Tacoma Liquefied Natural Gas project ("Tacoma LNG"), PSE's application for the air permit, and related air emissions issues pertaining to Tacoma LNG.

Q: WHAT ARE YOUR PRIMARY OPINIONS IN THIS CASE?

A: My primary opinions in this case are as follows:

1. The alleged deficiencies in the permitting process lack analytical support.
2. Tacoma LNG's key design parameters that impact emissions were final prior to the issuance of the permit.
3. Emissions factors were used appropriately in the permit application.
4. Fugitive emissions of volatile organic compounds ("VOCs") from the process components were estimated using conservative assumptions.

[1] PSE-0063, Curriculum Vitae of Shari Libicki (attached hereto as Attachment A).

5. Dr. Sahu's classification of Tacoma LNG as a fuel conversion plant is inconsistent with prior EPA determinations; Tacoma LNG is subject to the 250-ton major source threshold.

6. Tacoma LNG is not a major source of criteria air pollutant emissions under the PSD program, nor under the Title V program.

7. It is appropriate to use the sum of background data and modeled concentrations for comparison to the ambient air quality standards.

8. The NOC application appropriately used representative meteorological data in the air dispersion modeling.

9. Tacoma LNG will not cause or contribute to a violation of any ambient air quality standard;

10. Toxic Air Pollutant ("TAP") emissions from Tacoma LNG will not exceed the relevant standards.

11. The BACT and tBACT limits for the flare are reasonable.

12. Dr. Sahu's proposed approach for calculating sulfur emissions would have resulted in a less stringent sulfur dioxide ("SO_2") limit.

13. The small amount of additional nitrogen in the purge gas will not discernibly change nitrous oxide ("N_2O") emissions.

OPINION 1: THE ALLEGED DEFICIENCIES IN THE PERMITTING PROCESS LACK ANALYTICAL SUPPORT.

Q: HAVE YOU REVIEWED THE PREFILED TESTIMONY OF THE TRIBE'S EXPERT DR. SAHU?

A: Yes.

Q: WHAT ARE YOUR OVERALL CONCLUSIONS FROM READING DR. SAHU'S TESTIMONY?

A: Dr. Sahu has identified many concerns he has with the Tacoma LNG permitting process and underlying calculations but, in most cases, has undertaken no analysis to support his conclusions. In particular, he has not made a measured attempt to evaluate whether any of those concerns could materially impact the permit calculations or the permitting decisions that were made. Rather, Dr. Sahu largely *assumes* that the concerns are significant, without doing the work to back up his opinions. I have evaluated many of Dr. Sahu's concerns, some in great detail, and in each instance, the issue he raises is immaterial. Additionally, Dr. Sahu has advocated for regulatory approaches that not applicable to minor sources of air pollution like Tacoma LNG and, often, his proposed approaches are outside of the regulatory mainstream. Importantly, his regulatory approaches are not consistent with the approaches undertaken by the Puget Sound Clean Air Agency (the "Agency").

Q: CAN YOU GIVE SOME EXAMPLES OF WHERE DR. SAHU FAILS TO UNDERTAKE ANALYSIS TO BACK UP HIS OPINIONS?

A: Yes, I can provide several.

(1) Dr. Sahu claims that Tacoma LNG is a major source of volatile organic compound ("VOC") emissions, but undertakes little analysis of the emissions from Tacoma LNG. Rather, he builds a house of cards from several assumptions. First, he hypothesizes that there will be higher emissions because Tacoma LNG will violate its permit by (a) bypassing the flare and emitting uncontrolled waste gases and (b) failing to achieve the 99% destruction efficiency required by the permit. Second, he states that fugitive emissions of VOCs are undercalculated, but undertakes no quantitative analysis of fugitive emissions. Finally, he states that the Agency failed to account for emissions from two pretreatment heaters, which is incorrect as a factual matter, but he has undertaken no analysis of the emissions from those heaters. It should be noted that even Dr. Sahu states that these are "small heaters." If fact, they are so small, they are not required to be permitted.

(2) Dr. Sahu claims that Tacoma LNG's emissions impacts exceed regulatory thresholds for SO_2 and fine particulate matter ("$PM_{2.5}$") but has undertaken no analysis to support this conclusion. He claims that air dispersion modeling was done incorrectly, but he has undertaken no air dispersion

modeling, and has no basis to suppose that "corrected" air dispersion modeling would result in higher results as opposed to lower results. Dr. Sahu merely assumes that the results of any corrections that he has not evaluated would be higher.

(3) Dr. Sahu claims that the Agency erroneously concluded that Tacoma LNG's emissions of toxic air pollutants ("TAPs") will not exceed acceptable source impact levels ("ASILs") and small quantity emission rates ("SQERs"). But Dr. Sahu has undertaken limited analysis and emissions calculations to support his conclusions regarding the SQERs (cherry picking emission factors for acrolein and formaldehyde that he says are more accurate, and comparing to the SQER). And he has not undertaken any dispersion modeling to compare the results to the ASILs.

(4) Dr. Sahu claims that the permit for Tacoma LNG utilized incorrect emissions factors, but fails to provide what he views as corrected emissions factors (save the cursory discussion mentioned above) or to determine whether any such "correct" emissions factors would have materially impacted the results of the permit analysis.

(5) Dr. Sahu claims that the SEIS materially underestimates Tacoma LNG's N_2O emissions but he undertakes no analysis of these emissions whatsoever, resting his conclusion of materiality on nothing more than assumption.

There are many other such examples throughout Dr. Sahu's testimony.

Q: CAN YOU ALSO PROVIDE SOME EXAMPLES OF WHERE DR. SAHU ASSUMES ISSUES ARE SIGNIFICANT WHEN THEY ARE IMMATERIAL?

A: Yes, I can provide several.

(1) In his major source opinions, Dr. Sahu opines that because the flare manufacturer (in his view) states that one of its flare operating cases would only achieve a 95% destruction efficiency, that Tacoma LNG would therefore emit 225 tons of VOCs per year from the flare.[2] Dr. Sahu misapplied this value. In the operating case that Dr. Sahu is referring to, the flare would be fed a small amount of nitrogen and methane from purging lines after truck or ship loading, so the flare is burning only trace amounts of incoming VOCs, because methane and nitrogen are not VOCs.[3] The annual emissions estimate from this case was 0.00015 tons per year of VOCs (at a 99% destruction rate).[4] Even if Dr. Sahu were correct and the flare only achieved a 95% destruction rate in this operating case, the annual emissions would be 0.00074 tons of VOCs per year, not 225 tons per year.

[2] Pre-filed Direct Testimony of Dr. Ranajit Sahu, ¶ 29 (March 22, 2021) (hereinafter "Sahu Testimony").
[3] RA-68, Final Notice of Construction Worksheet for NOC No. 11386 at 32-35 (December 10, 2019) (hereinafter "Final NOC Worksheet").
[4] PSE-0333, Tacoma LNG Facility Heat Emission Data (Revised), April 10, 2018.

(2) Also in his major source opinions, Dr. Sahu states that emissions from the pretreatment heaters should have been included, as if that would push Tacoma LNG above the major source threshold.[5] As reported in Attachment A to the permit application, however, VOC emissions from the two heaters were calculated at 0.20 and 0.035 tons per year respectively, and immaterial to the major source analysis, regardless of whether the 100 or 250 ton threshold applies.[6]

(3) With respect to alleged exceedances of ambient air regulatory thresholds of SO_2 and $PM_{2.5}$, I performed a dispersion modeling analysis to evaluate impacts of emissions on ambient air. I found that even in hypothetical worst-case modeling scenarios, emissions of those criteria air pollutants, even when adding background, do not come anywhere close to the ambient air quality standards.[7] Thus, Tacoma LNG will not cause or contribute to any exceedance of applicable regulatory standards.

(4) With respect to TAPs, I again evaluated hypothetical worst-case scenarios, and none of the TAPs reaches more than a small percentage of the applicable ASIL, and most are orders of magnitude (thousands or even millions) of times under the applicable ASIL.[8]

[5] Sahu Testimony ¶ 59.
[6] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017).
[7] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).
[8] *See id.*

Had Dr. Sahu done the analysis, he would have seen that his core opinions are simply incorrect. I cannot speculate why Dr. Sahu chose to not conduct these analyses himself.

Q: FINALLY, CAN YOU PROVIDE SOME EXAMPLES OF WHERE DR. SAHU TAKES REGULATORY POSITIONS THAT ARE CONTRARY TO GUIDANCE OR OUTSIDE OF THE MAINSTREAM?

A: Yes. Again, there are many examples of Dr. Sahu taking extreme regulatory positions.

(1) Dr. Sahu concludes that Tacoma LNG is a "fuel conversion plant," and thus subject to a 100-ton major source threshold (as opposed to a 250-ton threshold). This conclusion is directly contrary to EPA's 2017 applicability determination for a similar liquefaction plant (Jordan Cove in Oregon) finding that it is not a fuel conversion plant.[9]

(2) Dr. Sahu opines that emissions from hypothetical future permit violations (*e.g.*, bypassing the flare or exceeding the 99% destruction efficiency requirement) are to be included in potential to emit. In my experience, this is contrary to how air agencies across Washington (including the Puget Sound Clean Air Agency) and the entire country determine potential to

[9] RA-127, Letter from Donald Dossett, U.S. EPA to Claudia Davis, ODEQ re: Jordan Cove LNG Terminal (Sept. 26, 2017) (hereinafter "Jordan Cove Letter").

emit. Potential to emit covers normal operations, not emissions from emergency conditions or from hypothetical permit violations.

(3) Dr. Sahu opines that the use of temperature as a surrogate for VOC destruction efficiency in the flare is improper. However, the use of temperature for continuous parametric monitoring of destruction efficiency is common and accepted by permitting agencies across the country (including the Agency). It also is written into various federal environmental regulations (*i.e.*, the New Source Performance Standards and the National Emissions Standards for Hazardous Air Pollutants). Dr. Sahu's opinion, if followed, would invalidate permits and regulations across the country that rely on such parametric monitoring.

(4) Dr. Sahu opines that exceedances of screening thresholds in WAC 173-400-113 require "full NAAQS and PSD increment ambient air quality analysis."[10] While in some circumstances this type of analysis is required for *major* sources of air pollution, it is not required for *minor* sources of air pollution like Tacoma LNG. In my experience, Dr. Sahu's opinion is contrary to how air agencies across Washington (including the Agency) evaluate exceedances of screening thresholds. As the Agency did here, for minor sources, exceedances of screening thresholds are evaluated by adding background concentrations to the source's contribution and

[10] Sahu Testimony at 5 (Opinion 4).

comparing the result to the ambient air quality standards. Dr. Sahu takes this even further in his opinion, with the nonsensical statements that "Tacoma LNG's emissions violate WAC 173-400-113's requirements for SO_2 (1-hour and 24-hour and also for 3-hour and annual averaging times), $PM_{2.5}$ (24-hour), and NO_2 (1-hour)"[11] and "WAC 173-400-113's threshold for $PM_{2.5}$ is violated…"[12] The Section 113 thresholds are not themselves ambient air quality standards, nor are they standards or limits that can be "violated." Rather, they are screening levels that are used to determine the next step in an emissions analysis for a permit application.

(5) Dr. Sahu opines that it is improper to rely on average emission factors and that the Agency should have looked to the underlying data and selected higher emission factors than those that are published in EPA literature intended for use by permitting agencies.[13] Dr. Sahu points to no guidance supporting his approach and this approach is contrary to the approach of permitting authorities across the country, including PSCAA.

(6) Dr. Sahu opines that the fugitive component emissions calculations were incorrect because they use average emissions factors. However, EPA has endorsed the average emission factor approach. EPA has clearly stated that

[11] Sahu Testimony at ¶ 85.
[12] Sahu Testimony at ¶ 98.
[13] *See e.g.*, Sahu Testimony ¶ 112–13.

the use of average emissions factors is appropriate because among hundreds or thousands of components at a facility, there is a span of possible leak rates. Thus, EPA and other state agencies have adopted the average emission factors approach to address the potential for leaks across a large population of equipment.

I will discuss these and other issues in detail during my testimony.

OPINION 2: TACOMA LNG'S KEY DESIGN PARAMETERS THAT IMPACT EMISSIONS WERE FINAL PRIOR TO THE ISSUANCE OF THE PERMIT.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE STATUS OF TACOMA LNG'S DESIGN WHEN THE PERMIT WAS ISSUED.

A: A facility design does not need to be final at a detailed level prior to the issuance of an air permit. Rather, the key design parameters that impact facility emissions must be sufficiently mature to allow the Agency to estimate emissions. It is my opinion that the design criteria that impact Tacoma LNG's emissions were sufficiently final when PSE submitted its emissions information and air dispersion modeling results.

Q: AT WHAT STAGE IN THE DESIGN OF AN EMITTING FACILITY DOES ITS OWNER/OPERATOR APPLY FOR AN NOC PERMIT?

A: Air permits, such as a NOC Order of Approval, are typically based on early engineering designs. There are several stages of engineering design for a project like Tacoma LNG. The first stage is a conceptual design, where drawings are used to allow the project team to gain a better understanding of the project. In the case of Tacoma LNG, a conceptual design might include a general description of all of the process components, including docks and pipeline offtakes. The next stage is call Front End Engineering Design ("FEED"). The FEED focuses on the technical requirements and also provides a rough investment cost for the project. The FEED package is used as the basis for bidding the construction. The next step in engineering design is detailed design. Detailed design is the phase where the design is refined and plans, specifications, and estimates are created, and also where the full cost of the project is identified in most cases. The near-final number of process components is typically identified in the detailed design phase.

Air permits are typically based on the conceptual design or the FEED, which is a "time where sufficient design detail is defined that a serious critique of the

environmental and safety issues, technical issues and operating/capital costs can and should be performed."[14]

Q: WOULD A FACILITY APPLY FOR AN NOC PERMIT AFTER THE DESIGN IS COMPLETE?

A: Generally, no. Because the permitting process is intended to ensure that the source operates in compliance with state and federal regulations, design changes may be a part of the process. Basing the permitting on either conceptual design or FEED is necessary, in part, so that regulatory agencies can ensure that the final design includes necessary air pollution controls. As part of the permitting process, it is quite common for air pollution controls, such as burners and collection devices, to be modified as a result of the agency's permitting review. The facility design must remain flexible during the permitting process to accommodate permit requirements. Permits are therefore *necessarily* based on interim designs. If facility designs were finalized prior to engaging with the permitting authority and the public, the whole application process and public comment process would not be able to accomplish the intended goals. In my permitting experience, it is common to change some aspects of the facility design in response to agency and public comment. The potential for evolution as the facility moves through the

[14] *See* PSE-0123, Mody, D. and D. Strong, An Overview of Chemical Process Design Engineering: Proceedings of the Canadian Design Engineering Network ("CDEN") Conference, Toronto, Canada (July 24–26, 2006).

permitting process is typical and could render moot any final design submitted with an application.

Q: WHAT DOES IT MEAN FOR THE AGENCY TO DEEM AN NOC APPLICATION "COMPLETE"?

A: The Agency deems an NOC application complete after concluding that the necessary components of the application are present.[15] Once the application is deemed complete, the permitting authority reviews the application to determine if it complies with all regulations, including the requirement for BACT. Accordingly, deeming an application complete is the beginning of the permitting process, not the end.

Q: IS A FACILITY REQUIRED TO SUBMIT FINAL DESIGNS BEFORE THE NOC ORDER OF APPROVAL IS ISSUED?

A: No. A NOC Order of Approval may be issued before final designs are complete. However, the Agency must have enough information to submit a permit application that provides information on the nature and amounts of emissions to be

[15] WAC 173-400-111(1)(b) (PSE-0306) defines a complete application as follows:
A complete application contains all the information necessary for processing the application. At a minimum, the application must provide information on the nature and amounts of emissions to be emitted by the proposed new source or increased as part of a modification, as well as the location, design, construction, and operation of the new source as needed to enable the permitting authority to determine that the construction or modification will meet the requirements of WAC 173-400-113. Designating an application complete for purposes of permit processing does not preclude the reviewing authority from requesting or accepting any additional information.

emitted. This information is used by the Agency to develop the permit conditions. The facility's final design must then be consistent with the permit's requirements.

Q: HOW DEVELOPED WAS TACOMA LNG'S DESIGN WHEN THE AGENCY ISSUED THE PERMIT?

A: The key design criteria for Tacoma LNG's emitting equipment subject to NOC permitting requirements, and the expected flows of gases to them, were final by the time the Agency issued the permit. PSE included in its permit application information on the nature and amounts of expected emissions. Specifically, the permit application and subsequent submittals reflected the final height and diameter of the stacks, and the location of both the flare and the vaporizer.[16] The flare was determined to contain the four burners that have been built: a large warm low-NOx burner, a large cold low-NOx burner, a small warm burner, and a small cold burner. Further, CB&I had determined the range of the flare's operating scenarios, as well as the range of composition of waste gas going to the flare.[17] Although detailed engineering was not complete at the time of the application, the key design parameters were set. Nothing changed in the design of the point sources of emissions that would impact emissions of pollutants.

[16] *See* RA-29, Letter from Keith Faretra, PSE to Ralph Munoz, Agency re: Supplemental Information for Tacoma LNG Notice of Construction Application with Attachment A attached (September 15, 2017).
[17] *See* Exhibit RA-31, PSE Submittal on Flare Scenario Summary (September 27, 2017).

Q: DR. SAHU HAS ASSERTED THAT "THE UNDERLYING PROCESS DESIGN WAS NOT SUFFICIENTLY MATURE NOR STABLE WHEN PSE SUBMITTED EMISSIONS CALCULATIONS . . . AND AIR DISPERSION MODELING RESULTS."[18] DO YOU AGREE WITH THIS ASSERTION?

A: No, I do not agree with Dr. Sahu's assertion. Dr. Sahu appears to be claiming that the process design is not final because the composition of incoming natural gas fluctuates over time. Taken to its logical conclusion, you could never permit any process for which incoming feedstock varies over time, which would include renewable oil refineries, landfills, wastewater treatment plants, etc. Variation in the incoming feedstock has no bearing on whether the physical and operational design of the facility itself is final. It is further my opinion that the physical and operational design criteria that impact facility emissions from the flare and the vaporizer at Tacoma LNG were sufficiently final when PSE submitted its emissions information and air dispersion modeling results. As I explained in my previous answer, these design criteria include the range of the flare's operating scenarios, as well as the range of composition of waste gas going to the flare. As discussed further in Opinion 6 at page 70-71, the information on the flare's operating scenarios and the range of waste gas composition is intended to bracket the operation of the flare as well as the range of possible composition of the

[18] *See* Sahu Testimony ¶ 118.

natural gas incoming to the plant, which allowed Landau to calculate the range of potential emissions from the flare.

I understand that Dr. Sahu believes Landau used the wrong flare exhaust temperature and exhaust velocity in its air dispersion modeling, which he believes could result in modeling results that understate ambient air quality impacts.[19] Dr. Sahu has done no analysis to support his theory that different temperature or velocity values would result in modeled exceedances of the ambient air quality standards. Unlike Dr. Sahu, I have performed two analyses to assess the impact of temperature, and also stack velocity, on the air dispersion modeling and concluded that different exhaust temperature and velocity values would not yield meaningfully different results.

First, I conducted a "sensitivity analysis,"[20] which looked at the impact of unrealistic[21] lower-bound exit temperatures and exhaust velocities for the flare on the modeling results, leaving everything else the same.[22] As I explain in more detail on pages 112-18 and 129-30, the results are consistent with the results presented by Landau to the Agency. Specifically, the results demonstrate that

[19] Sahu Testimony ¶ 78.
[20] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).
[21] Dr. Sahu misunderstands the sensitivity analysis. It is not an analysis of "other plausible values for stack temperature and velocity." Sahu Testimony ¶ 102. The analysis uses worst case values that are not expected to occur, for the purpose of bounding the analysis.
[22] I also conducted a refined sensitivity analysis using Dr. Smith's temperature and exit velocity values. These results similarly show that Tacoma LNG is not predicted to exceed ambient air quality standards or the ASILs. *See* PSE-0138, XQ Modeling Assessment Results – Updated XQ parameters Flare Expert (March 5, 2021).

Tacoma LNG is not predicted to emit criteria air pollutants that would contribute to ambient air quality levels that exceed the ambient air quality standards, nor is it predicted to emit TAPs in excess of the ASILs.[23] Dr. Sahu misunderstands the sensitivity analysis. It is not an analysis of "other plausible values for stack temperature and velocity."[24] The analysis uses worst case values that are not expected to occur for the purpose of bounding the analysis.[25]

Second, I re-ran Landau's model using the temperatures and exit velocities calculated by Dr. Joseph Smith, leaving all other parameters the same.[26] As explained in Dr. Smith's testimony, these temperatures and exit velocities are calculated by a computational fluid dynamics (CFD) model that has been built to reflect the Tacoma LNG flare dimensions and design. The model predicts the temperature and exit velocities for the range of the flare's operations. Unlike the temperatures and stack velocities used in the sensitivity analysis, these are more "plausible" (as Dr. Sahu would call them) values for the flare. When these temperatures and velocities are input into the air dispersion model directly, the results demonstrate that Tacoma LNG is not predicted to emit criteria air pollutants that would contribute to ambient air quality levels that exceed the

[23] *Id.*
[24] Sahu Testimony at ¶ 102.
[25] In addition to scaling up the emissions from the flare, the analysis also scales up vaporizer emissions by the same ratio as the flare.
[26] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final (March 19, 2021).

ambient air quality standards, nor is it predicted to emit TAPs in excess of the ASILs.

I address Dr. Sahu's claims about SO_2 emissions in Opinion 12, the flare DRE in Opinion 6, and the BTEX concentrations in Opinion 10. As I will explain, Dr. Sahu has not done any credible analysis to determine what, if any, implications these issues have on Tacoma LNG's emissions. I have analyzed these issues and determined that they do not change any of the regulatory determinations made in the permit. In fact, Dr. Sahu appears to argue that the permit limit on SO_2 is too stringent, and that Tacoma LNG should be permitted to emit higher levels of SO_2.

Q: WAS THE DESIGN SUFFICIENTLY MATURE TO ACCOUNT FOR FUGITIVE EMISSIONS?

A: Yes. It is standard accepted practice to rely on vendor estimates for component counts when calculating fugitive emissions from a facility. As is common practice, PSE's permit application contains calculations for fugitive emissions using the number of expected components at the facility (like piping valves and flanges), assuming a certain leak rate for those components, and assuming a certain level of leak control from a Leak Detection And Repair (LDAR) program. After a facility is built, a final component count is conducted and any necessary reconciliation with the original count can be addressed with the agency at that time. In this case, Landau made many conservative assumptions designed to over-estimate fugitive emissions when performing its calculations, as explained in

Opinion 4. Thus, even with a final component count that differs from the count estimated in the permit, there are contingencies included in the emissions calculation to address that potential.

OPINION 3: EMISSIONS FACTORS WERE USED APPROPRIATELY IN THE PERMIT APPLICATION.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE USE OF EMISSIONS FACTORS IN THE NOC APPLICATION.

A: It is my opinion that the use of emissions factors in the permit application was appropriate. It is standard practice to use emissions factors to estimate emissions in permit applications for facilities that have not yet been built, yet Dr. Sahu insists that it was inappropriate for Landau to rely on average emission factors when calculating a facility's "potential to emit" ("PTE"). This is an extreme position outside the regulatory norm. Further, I disagree with Dr. Sahu's specific criticism of the use of the $PM_{2.5}$ emission factor from EPA's "AP-42" compilation, as that factor is particularly conservative.

Q: WHAT IS AN EMISSIONS FACTOR AND WHAT IS IT USED FOR IN THE AIR PERMITTING PROCESS?

A: Emissions factors are numeric values used to estimate emissions from sources that have not yet been built and therefore cannot be tested. An emissions factor is a

ratio of emissions of a pollutant to the activity releasing that pollutant. For example, emissions factors for combustion processes are typically displayed as units of pollutant mass per heat released.

It is a standard engineering practice for air permit applications to rely upon emissions factors. Because permit applications must be submitted before a source may begin construction, site-specific test data regarding emissions will not be available before an air permit is issued. As a result, many permit applicants rely on emissions factors to predict the planned facility's emissions. This reliance is recommended by many air permitting agencies, such as the South Coast Air Quality Management District ("SCAQMD"). SCAQMD—which regulates the Los Angeles area, one of the most heavily regulated areas of the country—requires emissions calculations as part of a submittal for a permit to construct. Because these calculations must be performed before the emissions units are installed and brought online, no data yet exist from emission source tests or continuous emission monitoring systems ("CEMS") unless the source being installed is a copy of another source, such as an emergency engine. SCAQMD therefore recommends the use of emissions factors or mass balances to estimate emissions. SCAQMD points specifically to the factors maintained by EPA in its "AP-42" compilation as an appropriate source from which to obtain emissions factors. Although SCAQMD acknowledges that using emission factors to estimate emissions is less accurate than using data measured directly at the facility, such as

via a CEMS or a performance test, the agency states that using emission factors "often results in highly conservative estimates of emissions."[27]

Q: CAN YOU BRIEFLY EXPLAIN HOW LANDAU USED EMISSIONS FACTORS IN THE PERMIT APPLICATION?

A: Landau used emissions factors to calculate the emissions of certain air pollutants at Tacoma LNG. These calculations were performed to calculate the facility's potential emissions (*i.e.*, PTE), emissions of TAPs, as well as in the air dispersion modeling.

Q: WHERE DID LANDAU GET THE EMISSIONS FACTORS THAT IT USED IN THE APPLICATION?

A: Among others, Landau used emission factors from EPA's compilation called "AP-42" to calculate PTE for PM and lead emissions from gas combustion in the flare and the vaporizer. Landau also used AP-42 emission factors to calculate PTE VOCs from the vaporizer. Landau used the natural gas combustion emission factors presented in AP-42 Section 1.4.[28]

[27] PSE-0116, SCAQMD, Certified Permitting Professional Program Reference Manual: Engineering and Compliance (2011).

[28] *See* RA-72, EPA, AP-42 – Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1, Chapter 1, Section 1.4: Natural Gas Combustion (July 1998), https://www.epa.gov/sites/production/files/2020-09/documents/1.4_natural_gas_combustion.pdf. EPA also published an associated report: PSE-0296, EPA, Emission Factor Documentation for AP-42 Section 1.4 Natural Gas Combustion (Mar. 1998), https://www3.epa.gov/ttn/chief/ap42/ch01/bgdocs/b01s04.pdf ("Natural Gas Combustion EFD").

Landau used emission factors from AP-42 and other sources for calculating most of the hazardous air pollutants ("HAPs") and TAPs from the combustion of natural gas in the vaporizer and from the combustion of compounds in the flare.[29] These emissions factors came from established regulatory agency compilations of emissions factors. These are: AP-42, EPA's WebFIRE online database, California's Air Toxic Emission Factors online database (CATEF), AB2588 Combustion Emissions Factors inventory, and San Diego's Air Pollution Control District (SDAPCD) emissions inventory tables.

For the remaining types of emissions, Landau used manufacturer emissions data for the specific equipment to be installed at the facility.[30]

Q: PLEASE PROVIDE MORE BACKROUND ON AP-42.

A: AP-42 is EPA's Compilation of Air Pollutant Emissions Factors.[31] It is an online document containing emission factors prepared by EPA based on emissions test data from a variety of industrial facilities and sources. EPA continually updates sections of AP-42, and the emissions factors undergo extensive public review and comment prior to being incorporated into the compilation. Under Section 130 of

[29] Landau did not use emission factors to calculate emissions of benzene, toluene, ethylbenzene, and xylene ("BTEX"), or hydrogen sulfide.

[30] Landau used manufacturer emission data to develop emissions factors for CO, NOx, PM and total VOCs for the vaporizer. RA-68, Final NOC Worksheet at 37. For the flare, Landau used manufacturer emissions information for CO and NOx. *See* PSE-0011, Flaring cases emissions summary ("Schiller spreadsheet") (June 20, 2017).

[31] AP-42 is published online at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors#5thed.

the Clean Air Act, EPA is required to maintain and update emission factors for carbon monoxide ("CO"), NOx, and VOCs—AP-42 is EPA's repository of those emission factors, as well as factors for many additional pollutants.

Q: HOW IS AP-42 TYPICALLY USED?

A: AP-42 is commonly relied upon by both industry and regulatory agencies to help prepare and review emission inventories for permitting purposes, as well as for general emissions inventories. It is regarded as an authoritative source and its use has been standard practice in air permitting for decades. I have personally used AP-42 factors for both state and federal permits in many states, including Washington, California, Maryland, and Arizona. In addition, in my experience, the AP-42 emission factors for natural gas combustion that were used in this NOC application are generally accepted and used nationwide.

Q: IS IT STANDARD PRACTICE IN THE STATE OF WASHINGTON AND IN THE AGENCY'S JURISDICTION TO USE AP-42 IN AIR PERMITTING?

A: Yes. The Agency recommends the use of AP-42 emission factors when completing a NOC application. In its response to comments on the draft NOC for Tacoma LNG, the Agency disagreed with comments expressing concerns or disapproval on the use of AP-42 emission factors in the NOC analysis. The Agency stated that AP-42 is an acceptable source of emission factors for

estimating potential to emit ("PTE") for preconstruction permitting purposes and that it is standard engineering practice to use these data for this purpose.[32] The Washington State Department of Ecology ("Ecology") similarly recommends the use of AP-42 for NOC applications.[33]

Q: DR. SAHU CRITICIZES THE USE OF AVERAGE EMISSION FACTORS, AND ASSERTS THAT PTE MUST BE BASED OFF OF "THE VERY UPPER TAIL" OF THE DISTRIBUTION OF A FACILITY'S ESTIMATED EMISSIONS.[34] DO YOU AGREE WITH THIS OPINION OF DR. SAHU?

A: I disagree with Dr. Sahu's opinion. It does not reflect the realities of preconstruction air permitting in the United States. Applicants for air permits for new stationary sources routinely rely on average emission factors, from AP-42 and other sources, to calculate a facility's PTE when source-specific emissions data from the facility is necessarily not yet available (due to the fact that the facility has not yet been constructed or put into operation). Permitting agencies routinely accept applicants' calculations of a facility's PTE based on the use of average emission factors, and consequentially routinely use these calculations as a basis for establishing permit limits for the facility, yet he insists that it was inappropriate for Landau to rely on average emission factors when calculating PTE for the NOC

[32] *See* R-68(a), PSCAA, Notice of Construction Order of Approval No. 11386, Comments and Responses: Appendix A at 21 (December 10, 2019).
[33] *See* PSE-0064, Department of Ecology, Emission Estimations (February 2013), https://apps.ecology.wa.gov/publications/documents/ecy070410b.pdf.
[34] *See* Deposition of Dr. Ranajit Sahu, March 5, 2021, at 394:8–25.

application. Dr. Sahu's opinion is inconsistent with the Agency's permitting practice, and if adopted would invalidate numerous air permits across the country. It is an extreme and untenable position.

Q: DR. SAHU CLAIMS THAT A RECENT ENFORCEMENT ALERT CAUTIONS THAT USING AP-42 IN PERMITTING WOULD UNDERESTIMATE PTE EMISSIONS. IS DR. SAHU CORRECT?

A: No, Dr. Sahu is incorrect. Dr. Sahu states, "Respondents' use of average emission factors in calculating PTE is incorrect. This is made clear in EPA's recent enforcement alert which cautions that average emission factors should not be misused in permitting because doing so would underestimate PTE emissions."[35] This is not what the enforcement alert states. The enforcement alert never mentions "potential to emit" or PTE as Dr. Sahu states. Instead, the enforcement alert focuses on the idea that AP-42 emission factors should not be used as limits unless testing/monitoring data from that source or a similar facility is not available.[36] The document is focused on facilities that have the capacity to be tested or continuously monitored, *i.e.*, existing sources. The document states that AP-42 can be used if facility-specific data is not available, but implicitly urges that such reliance be verified through subsequent testing. That is precisely how the

[35] Sahu Testimony at ¶ 52.

[36] A-PTI0423, EPA, AP-42 Enforcement Alert (Nov. 2020). ("The Environmental Protection Agency (EPA) is concerned that some permitting agencies, consultants, and regulated entities may incorrectly be using AP-42 emission factors in place of more representative source-specific emission values . . . .") (emphasis added).

Agency has structured the Tacoma LNG permit. Stack testing is required upon startup and periodically thereafter for particulates—the only criteria pollutant for which an AP-42 emission factor was used and that is expected to be emitted by Tacoma LNG in material amounts. To suggest that AP-42 cannot be used in new source permitting would make it virtually impossible to permit new sources and would destroy the whole basis for EPA developing the AP-42 emission factor resource.

Q: **DOES THIS ENFORCEMENT ALERT ADDRESS ALL EMISSION FACTORS SUCH AS THOSE USED FOR FUGITIVE EMISSIONS?**

A. No. The enforcement alert addresses only AP-42 emission factors. It does not address emissions factors in general, and certainly doesn't address emissions factors used for fugitive components.

Q: **WHY ARE EMISSIONS FACTORS FOR FUGITIVE COMPONENTS DIFFERENT?**

A. First, emissions factors for fugitive components are not AP-42 emission factors. While the emissions factors for fugitive emissions from process components are average emission rates for each individual valve or flange, the sheer number of components make the use of an average factor critical. Some process components may have higher emissions and some may have lower emissions. The average

emission factor will characterize the emissions from hundreds or thousands of individual components accurately.

Q: DR. SAHU CRITICIZES THE USE OF AP-42 TO CALCULATE $PM_{2.5}$ EMISSIONS FROM THE FLARE.[37] DO YOU AGREE?

A: I do not agree with Dr. Sahu. It was reasonable for Landau to rely on the AP-42 emission factors. The AP-42 emission factor that Landau used for $PM_{2.5}$, which is the sum of the emission factors for two different forms of PM, is inherently conservative.

Q: WHAT ARE THE TWO FORMS OF PM?

A: PM consists of solid particles and liquid droplets found in the air. Filterable PM includes any particulate matter that may be physically captured on a filter during sampling. Filterable PM fall into three classes: total suspended particulate matter (30 microns or less); respirable particulate matter, or PM_{10} (10 microns or less); and fine particulate matter, or $PM_{2.5}$ (2.5 microns or less). These particulate fractions are not additive: $PM_{2.5}$ is a subset of PM_{10}, which is itself a subset of total suspended particulate. Condensable PM is the PM that passes through the filter and is subsequently captured by a condenser from the gas phase. A condenser condenses PM into sub-micron particles upon cooling. Condensable PM is

[37] Sahu Testimony at ¶ 96.

typically smaller than 2.5 microns.[38] Depending on the emissions source, a significant portion of $PM_{2.5}$ can be condensable PM.

Q: HOW DOES THE AP-42 EMISSION FACTOR THAT LANDAU USED FOR $PM_{2.5}$ ACCOUNT FOR FILTERABLE AND CONDENSIBLE PM?

A: To develop the PM emission factors for natural gas combustion, EPA conducted PM measurements that included both condensable and filterable PM.[39] EPA found that there was no correlation between specific natural gas combustion source types and their PM emission levels, therefore the PM emission factors in Section AP-42 Section 1.4 are intended to represent all natural gas combustion sources.[40] In addition, because natural gas does not contain ash and the nucleation[41] of PM from combustion products does not typically yield particles larger than 1 micron, EPA assumes that all PM from natural gas combustion is less than 1 micron in diameter.[42] Accordingly, AP-42 provides that the emission factors for condensable PM (5.7 lb/MMscf), filterable PM (1.9 lb/MMscf), and total PM (the sum of the two, which is 7.6 lb/MMscf) may be used to estimate emissions of

[38] *See* PSE-0117, Corio, L.A. & J. Sherwell, In-Stack Condensable Particulate Matter Measurements and Issues, J. Air and Waste Management Association 50:207–18 (2000).
[39] *See* PSE-0296, Natural Gas Combustion EFD at 3.8.
[40] See *id.*
[41] Nucleation is the beginning of the process by which gases are converted to particles.
[42] *See* PSE-0296, Natural Gas Combustion EFD at 3.8.

PM_{10}, $PM_{2.5}$, or PM_1.[43] Landau used the AP-42 emission factor for total PM to estimate Tacoma LNG's PTE $PM_{2.5}$.

Q: WHY WAS LANDAU'S USE OF THE AP-42 $PM_{2.5}$ EMISSION FACTOR A CONSERVATIVE CHOICE?

A: The AP-42 emission factors for PM are likely biased high, which means that they significantly overstate PM emissions from gas-fired sources. This is because the AP-42 emission factors were published in 1998 and are based on tests conducted between 1990 and 1995. At that time, test methods and practices were not designed to measure accurately or precisely the concentration of PM from typical natural gas combustion sources, which requires more advanced testing techniques due to the low concentration of PM in natural gas emissions. These tests earlier were designed for combustion sources with much greater PM emissions. More recent testing has shown that the AP-42 PM emission factors significantly overstate emissions from natural gas combustion due to the sensitivity limitations and comparatively archaic measurement practices used for the tests that serve as the basis for those factors.[44] For example, the Canadian Energy Partnership for Environmental Innovation ("CEPEI") provides a natural gas combustion emissions calculator. Based on 2019 airborne contaminant emissions, the CEPEI calculator

[43] *See* RA-72, AP-42, Volume 1, Chapter 1, Section 1.4 at Table 1.4-2 note c.
[44] *See* PSE-0309, Wien, S., England, G. C., Loos, K., & Ritter, K., Investigation of Artifacts in Condensable Particulate Measurements from Stationary Combustion Sources, In Proceedings of the Air & Waste Management Association 94th Annual Meeting (June 25, 2001).

produces a $PM_{2.5}$ emission factor of 0.237 lb/MMscf.[45] This is much lower than the AP-42 emission factors for PM—particularly the emission factor that Landau used for Tacoma LNG (7.6 lb/MMscf).

Q: WHAT DOES THE USE OF THE CONSERVATIVE PM EMISSION FACTOR MEAN FOR TACOMA LNG'S $PM_{2.5}$ EMISSIONS?

A: It means that the facility's actual emissions of $PM_{2.5}$ are likely to be lower than what Landau calculated as Tacoma LNG's PTE, and the facility's potential to emit PM is already very small. PM emissions will result from two combustion sources at Tacoma LNG: the vaporizer and the enclosed ground flare. The flare will be responsible for 95% of the PM emissions from the facility. Even using the conservative AP-42 PM emission factor, the flare's PTE $PM_{2.5}$ is only 1.2 tons per year.[46] The vaporizer is responsible for the other 5% of total PM emissions from the facility, despite the fact that it will have hourly emission rates twice that of the flare.[47] Condition 4 in the NOC Order of Approval limits the vaporizer to 240 hours of operation per operating year, which will further limit the facility's total

[45] *See* PSE-0314, Canadian Energy Partnership for Environmental Innovation, 2019 Airborne Contaminant Emissions from Natural Gas Combustion Emissions Calculator (July 7, 2020), https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/sector-specific-tools-calculate-emissions/request-natural-gas-combustion-calculator.html.

[46] RA-68, Final NOC Worksheet at 45.

[47] *Id.* at 39.

emissions of PM.[48] Because of these permit conditions, and because of the conservative emission factor, Tacoma LNG is expected to emit much less $PM_{2.5}$ than what Landau calculated as the facility's PTE.

Q: DO YOU AGREE WITH THE DR. SAHU'S ASSERTION THAT THE AP-42 NATURAL GAS COMBUSTION EMISSION FACTORS SHOULD NOT BE USED IN PERMITTING?

A: No, I do not. As explained above, it is appropriate and standard practice to rely on emissions factors when permitting new sources of emissions, including the AP-42 natural gas combustion emissions factors.

OPINION 4: FUGITIVE VOC EMISSIONS FROM THE PROCESS COMPONENTS WERE ESTIMATED USING CONSERVATIVE EMISSIONS ASSUMPTIONS.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE CALCULATION OF FUGITIVE EMISSIONS.

A: Landau calculated fugitive emissions based on CB&I's estimated number of process components that may be a source of fugitive emissions and emissions factors. This is the standard method of estimating fugitive emissions before a new

[48] RA-132, Notice of Construction Order of Approval No. 11386 (December 10, 2019) (hereinafter "NOC Order of Approval").

facility is constructed. Additionally, Landau's calculations included several conservative assumptions which provided some margin in the emissions calculations. These conservative assumptions are able to offset some uncertainty about the pre-construction component count.

Q: WHAT ARE FUGITIVE EMISSIONS?

A: Fugitive emissions are emissions from a source that cannot be reasonably collected and routed to a vent, stack, or functionally equivalent opening.[49] This is typically because they are small emissions over a large area. For example, roadway dust is a fugitive emission. The small leaks that come from hundreds of components in a pipe rack, like valves and flanges, are also fugitive emissions.

Q: HOW ARE FUGITIVE EMISSIONS CALCULATED?

A: Fugitive emissions are difficult to quantify by nature, so they typically are estimated using standardized average emission factors developed by EPA and other air agencies. These emissions factors are typically based on expansive studies of these fugitive emissions sources that attempt to collect emissions and measure them. For example, in the case of leaks from process components (*e.g.*, valves), the emission factor studies undertaken by the agencies consisted of bagging hundreds of similar process components and measuring the mass of VOCs

[49] PSE-0308, WAC 173-400-0030(41).

over time. These data are then used to develop average leak rates for that type of component.

The use of emission factors to calculate potential fugitive emissions is widely accepted by regulatory bodies. EPA's Protocol for Equipment Leak Emission Estimates ("EPA Fugitives Guidance") states that "one accepted approach for estimating emissions allows use of average emission factors developed by EPA in combination with unit-specific data that are relatively simple to obtain."[50] The data that are "relatively simple to obtain" relate to information about the type and number of components, which is the process Landau followed here. Similarly, the SCAQMD Guidelines for Fugitive Emissions Calculations ("SCAQMD Fugitives Guidance") lists the use of average emission factors as the agency's "Method 1" for estimating fugitive emissions when an inspection and maintenance program (*e.g.*, LDAR) is not in place at the facility and reliable site-specific screening data are not available.[51] Here, the Agency accepted the use of SCAQMD's Method 1 for estimating fugitives in this scenario.

[50] RA-79, EPA, Protocol for Equipment Leak Emission Estimates at 2–10 (1995).
[51] *See* RA-93, SCAQMD, Guidelines for Fugitive Emissions Calculations at 5 (June 2003).

Q: WHAT WAS THE BASIS OF THE ESTIMATED NUMBER OF SOURCES OF FUGITIVE VOC EMISSIONS IN THE TACOMA LNG NOC APPLICATION?

A: The number of process components that may be sources of VOC leaks and fugitive emissions were provided by the Tacoma LNG project's engineering contractor, CB&I (*i.e.*, the component count was estimated by the engineers responsible for designing the facility).[52]

Q: WAS IT STANDARD PRACTICE FOR LANDAU TO RELY ON CB&I'S ESTIMATES OF PROCESS COMPONENTS TO ESTIMATE FUGITIVE VOC EMISSIONS?

A: Yes, Landau employed standard practices. Prior to construction, it is common air permitting practice to rely on the design engineer's estimate of the number of process components that may be a source of fugitive emissions. This is often based on process and instrumentation diagrams ("P&IDs"), but can be based on other engineering estimates. This is the standard method of estimating components and can be done by an experienced engineer. The final engineering design including individual process components is typically not completed prior to permitting.

[52] PSE-0014, CB&I Information for Air Permitting (May 5, 2017); PSE-0164, Tacoma LNG Fugitive Emissions Valve List (spreadsheet) (May 4, 2017).

Q: HOW DID LANDAU CALCULATE FUGITIVE VOC EMISSIONS FROM COMPONENT LEAKS?

A: Landau used fugitive VOC emission factors derived from SCAQMD Fugitives Guidance developed for existing facilities to use when preparing emissions inventories that must be submitted annually to that agency.[53] There are no specific emission factors available for LNG facilities. Thus, Landau reasonably relied on emissions factors for Terminals/Depots, as opposed to those for refineries or for oil/gas production and chemical plants. (The SCAQMD emissions factors for oil/gas production and chemical plants are essentially identical to those used for Terminals/Depots.) The SCAQMD emission factors for marketing terminals are generally higher—and sometimes much higher—than the comparable factors for marketing terminals provided by EPA. This means that they *overestimate* anticipated fugitive emissions as compared to the most commonly used factors, and are therefore conservative. Landau took other actions which had the effect of increasing the fugitive emissions from process components.

Q: WHAT CONSERVATIVE APPROACHES DID LANDAU USE IN ESTIMATING FUGITIVE EMISSIONS?

A: First, Landau used SCAQMD emission factors which, as shown in the table and figure below, are 3.2 to 21 times higher than the average marketing terminal

[53] RA-68, Final NOC Worksheet at 46.

emission factors from Table 2-3 of EPA's Protocol for Equipment Leak Emission Estimates.

Second, Landau used LDAR control factors reflective of an LDAR program far less vigorous that what the permit requires. The LDAR control factors vary depending on how stringent a facility's LDAR program is.[54] The control factors used by Landau are consistent with an LDAR program that tolerates leaks 20 times greater than what the permit allows (10,000 ppmv v. 500 ppmv).[55] Landau employed these lower LDAR control factors because the permit terms were not known at the time the application was prepared.

Third, Landau assumed that the fluids in contact with the components were 100% VOC when in reality the vast majority of the components are in contact with fluids containing less than 10% VOC and some as low as 0.00099% VOC.[56]

Finally, the SCAQMD guidance from which Landau derived its emissions factors states that it is based, in turn, on the 1995 EPA Fugitives Guidance. The EPA Fugitives Guidance states that the emission factors for Marketing Terminals include ethane and methane. Neither ethane nor methane is a VOC; they are not photochemically reactive. Both methane and ethane will be substantial—if not

[54] *See* Declaration of Eri Ottersburg, attached hereto as Attachment B ("Ottersburg Declaration") ¶ 9.
[55] Ottersburg Declaration ¶ 8.
[56] Ottersburg Declaration ¶¶ 5 & 10.

major—constituents of many of the gas and liquid streams at Tacoma LNG; however, they are not VOCs.

For all of these reasons, Landau's estimates of fugitive VOC emissions for each process component are inherently overestimated.

Comparison of SCAQMD Guidelines Emission Factors used by PSE to EPA Leak Emission Factors

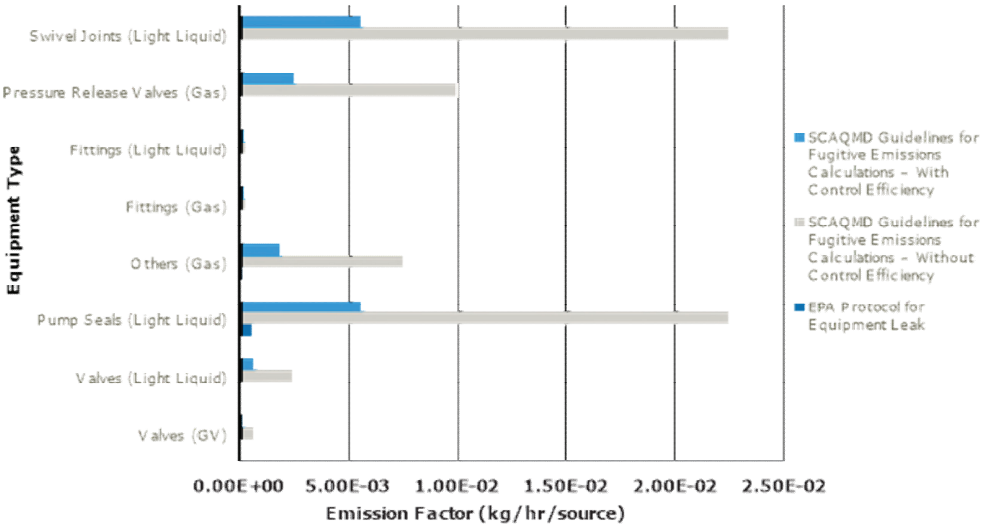
Equipment Type	Service	EPA Protocol for Equipment Leak Emission Factor (kg/hr/source)[a]	SCAQMD Guidelines for Fugitive Emissions Calculations – Without Control Efficiency (kg/hr/source)	SCAQMD Guidelines for Fugitive Emissions Calculations – With Control Efficiency (kg/hr/source)	Ratio of SCAQMD Guidelines with Control Efficiency vs. EPA Protocol[d]
Valves	Gas / Vapor	1.30E-05	6.21E-04	1.55E-04	11.92
	Light Liquid	4.30E-05	2.43E-03	6.08E-04	14.14
Pump Seals	Light Liquid	5.40E-04	2.24E-02	5.59E-03	10.35
Others (compressors and others)[b]	Gas	1.20E-04	7.51E-03	1.88E-03	15.67
Fittings (connectors and flanges)[c]	Gas	4.20E-05	2.54E-04	1.78E-04	4.24
	Light Liquid	8.00E-06	2.54E-04	1.78E-04	22.25
Pressure Release Valves	Gas	NA	9.90E-03	2.50E-03	NA
Swivel Joints	Light Liquid	5.40E-05	2.24E-02	5.59E-03	103.52

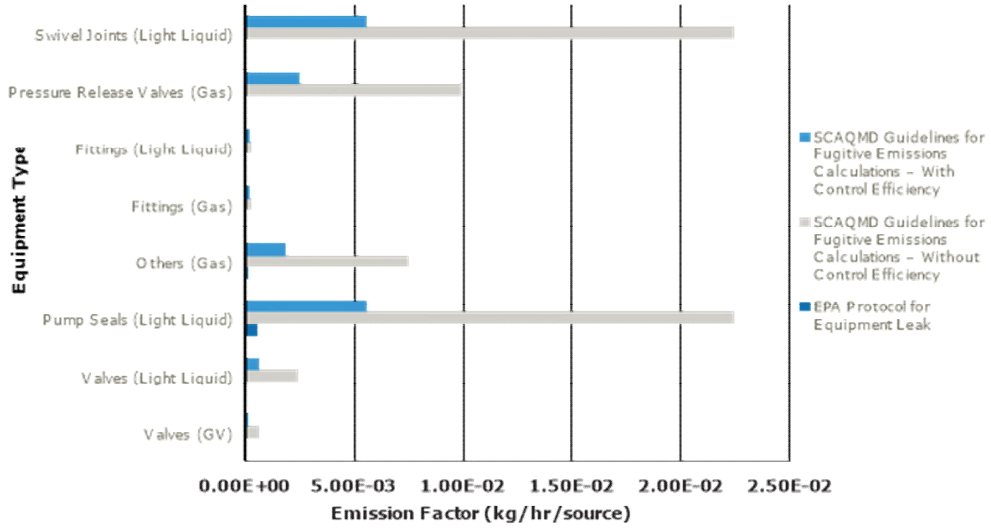
[a] These factors are for total organic compound emission rates (including non-VOCs such as methane and ethane).

[b] The "other" equipment type should be applied for any equipment type other than fittings, pumps, or valves.

[c] "Fittings" were not identified as flanges or non-flanged connectors; therefore, the fitting emissions were estimated by averaging the estimates from the connector and the flange correlation equations.

[d] This represents the percent by which SCAQMD guidelines emission factors are higher than EPA Protocol for Equipment Leak Emission Factors


Swivel Joints (Light Liquid)
Pressure Release Valves (Gas)
Fittings (Light Liquid)
Fittings (Gas)
Others (Gas)
Pump Seals (Light Liquid)
Valves (Light Liquid)
Valves (GV)
Equipment Type
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
Emission Factor (kg/hr/source)
SCAQMD Guidelines for Fugitive Emissions Calculations – With Control Efficiency
SCAQMD Guidelines for Fugitive Emissions Calculations – Without Control Efficiency
EPA Protocol for Equipment Leak


Swivel Joints (Light Liquid)
Pressure Release Valves (Gas)
Fittings (Light Liquid)
Fittings (Gas)
Others (Gas)
Pump Seals (Light Liquid)
Valves (Light Liquid)
Valves (GV)
Equipment Type
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
Emission Factor (kg/hr/source)
SCAQMD Guidelines for Fugitive Emissions Calculations – With Control Efficiency
SCAQMD Guidelines for Fugitive Emissions Calculations – Without Control Efficiency
EPA Protocol for Equipment Leak

Q: IN REFERENCE TO THE PROCESS COMPONENT EMISSION FACTORS, THE TRIBE HAS ASSERTED THAT "BECAUSE THESE FACTORS ARE NOT MAXIMUM VALUES, THEY ARE NOT SUITABLE FOR ASCERTAINING THE FACILITY'S PTE FOR FUGITIVE EMISSIONS OF VOCS."[57] DO YOU AGREE WITH THIS ASSERTION?

A: No, I do not agree. Using maximum emissions rates would be contrary to EPA's Fugitives Guidance, which recommends using average emission factors to estimate process component leaks.[58] For example, in its guidance, EPA states that "the average emission factors are more appropriately applied to the estimation of emissions from populations of equipment. Data indicate that the range of possible leak rate from individual pieces of equipment spans several orders of magnitude. As a result, the majority of total emissions from a population of equipment at any given time will normally occur from a small percentage of total equipment. The average emission factors account for the span of possible leak rates . . . ."[59] Thus, the concept of using a maximum emissions rate (as Dr. Sahu suggests) where there are over one thousand process components considered as sources of VOC leaks is contrary to good science. Even if some process components emitted at the high

[57] PSE-0182, Comments of the Puyallup Tribe of Indians on Proposed NOC Order of Approval, Appendix B to NOC Order of Approval No. 11386 at 36 (September 5, 2019).
[58] *See* PSE-0297, EPA Office of Air Quality Planning and Standards, Potential to Emit: A Guide for Small Businesses, EPA-456/B-98-003 (October 1998), https://www3.epa.gov/airtoxics/1998sbapptebroc.pdf; RA-79, EPA, Protocol for Equipment Leak Emission Estimates, EPA-453/R-95-017 (1995).
[59] RA-79 at 2-17–2-18.

end of the range, it is equally likely that some process components would emit at the low end of the range. Consistent with the EPA Fugitives Guidance and good science, the PTE for process component emissions was established by applying average emissions factors across the span of process components, not by using the highest possible emission rate for each and every process component.

Q: WHAT IS YOUR BASIS FOR REJECTING THE USE OF THE HIGHEST POSSIBLE EMISSION RATE FOR EACH PROCESS COMPONENT?

A: At any given time, not all process equipment will be leaking at the same rate. Screening value datasets from operating facilities show that the majority of sources are non-emitters (*i.e.*, they do not have measurable screening values). This is not surprising since components are designed to not leak. Analysis of screening value datasets from the American Petroleum Institute ("API") illustrates this as shown in the table below. Based on these datasets, components are designated as non-emitters, non-pegged emitters, or pegged emitters. Non-emitters are components with no measurable screening value; non-pegged emitters have measurable screening values; and pegged emitters are the biggest emitters, with screening values above instrument scale, which is typically either 10,000 or 100,000 parts per million ("ppm").[60]

[60] *See* PSE-0315, Epperson et al., AWMA, Equivalent Leak Detections for Smart LDAR (Leak Detection and Repair) When Using Optical Imaging Technology (September 2007).

Distribution of components by leak level, two datasets.				
Category	Dataset 1 (OAG)		Dataset 2 (REF)	
	Count	Percentage	Count	Percentage
Non-emitters	75,104	96.5%	6597835	99.62%
Non-pegged Emitters	1,538	2.0%	23854	0.36%
Pegged Emitters	1,207	1.6%	1458	0.02%
Total	77,849	100.0%	6623147	100.0%

At any point in time, process equipment at a facility will have a range of leak levels. As shown above, the majority of components will have negligible VOC concentrations at sources and are considered non-emitters. The total fugitive emissions are dependent on the distribution of leaking components. Fugitive emissions are dynamic—the leaking components change over time as new equipment leaks occur and other are found and repaired. Assuming every single component is leaking at elevated levels is an unrealistic scenario that does not occur, nor is even approached, in practice. A leak detection and repair program is one way to ensure that this does not happen.

Datasets used in the development of these correlations have been extensively analyzed. These data suggest that the majority of the fugitive emissions from leaking process equipment often result from relatively few sources that are larger leakers (*i.e.*, the "pegged emitters"). API's analyses concluded that over 90 percent of controllable fugitive emissions resulted from only 0.13 percent of

piping components.[61] The use of average emission factors published by EPA and SCAQMD appropriately accounts for this variability in leaking rates.

As noted above, process equipment is designed to not leak. This is because leaks result in product loss, which has negative impacts on a facility's business. This practical consideration cannot be ignored when discussing the likelihood of fugitive emissions. At facilities with thousands of potential leak sources, a certain percentage of the process components will be leaking at a given time. If all components were large leakers, product loss would be significant; accordingly, it is simply economically unrealistic to assume that a facility would have maximum leak rates from all process components at once.

Q: DID LANDAU APPLY A CONTROL FACTOR TO THE FUGITIVE EMISSIONS CALCULATED FROM THE USE OF THE EMISSIONS FACTORS?

A: Yes. Landau applied control factors to the fugitive emissions calculated with the emissions factors.[62] Control factors account for the fact that Tacoma LNG will implement a leak detection and repair ("LDAR") program to further reduce emissions from leaks.

[61] *See id.*

[62] Ottersburg Declaration ¶ 6.

Q: WHICH CONTROL FACTORS DID LANDAU APPLY?

A: Landau applied control factors developed by the Texas Commission on Environmental Quality ("TCEQ").[63] I understand that these control factors were used because TCEQ matches control factors to the specific LDAR requirements at a facility. Landau utilized TCEQ's 28M control factors because Landau did not know the stringency of the LDAR program that the Tacoma LNG permit would ultimately require and so assumed the less restrictive of the LDAR programs.[64]

Q: DO YOU THINK IT WAS REASONABLE FOR LANDAU TO APPLY A CONTROL FACTOR TO THE EMISSIONS?

A: Yes, it is reasonable to apply a control factor if an LDAR program will be used. The EPA Fugitive Guidance supports the use of control factors. As noted above, the emissions calculations here rely on SCAQMD "Method 1" for estimating fugitive emissions. The guidance states that Method 1 can be used only when an inspection and maintenance program (*e.g.*, LDAR) is not in place at the facility and reliable site-specific screening data are not available.[65] As such, these emissions factors are permitted when no LDAR program is in place, which supports the use of control factors if an LDAR program is in place.

---

[63] *Id*.
[64] *Id.*
[65] *See* PSE-0297, EPA Office of Air Quality Planning and Standards, Potential to Emit: A Guide for Small Businesses, EPA-456/B-98-003 (October 1998), https://www3.epa.gov/airtoxics/1998sbapptebroc.pdf; RA-79, EPA, Protocol for Equipment Leak Emission Estimates, EPA-453/R-95-017 (1995).

Q: DR. SAHU STATES THAT A CONTROL FACTOR IS NOT APPROPRIATE BECAUSE "SOUTHERN CALIFORNIA MARINE TERMINALS AND DEPOTS ARE ALREADY SUBJECT TO STRINGENT LDAR PROGRAMS." DO YOU AGREE?

A: No. Dr. Sahu does not provide any evidence that the data for emissions factors already includes LDAR control. To the contrary, as I just indicated, SCAQMD says that these factors are to be used when there is no LDAR program in place.

Q: DR. SAHU STATES THAT LANDAU TOOK CREDIT FOR LDAR FOR ALL COMPONENTS BUT THAT THE LDAR PROGRAM ONLY APPLIES TO A FRACTION OF THE COMPONENTS. DO YOU AGREE?

A: No. Condition 32 of the permit requires that PSE operate in compliance with an LDAR Plan for fugitive emissions submitted to the Agency.[66] Condition 32 does not distinguish between different types of fugitive emissions and so all are covered. On March 11, 2021, PSE submitted its LDAR Plan to the Agency.[67] That LDAR Plan applies to all components in contact with any type of fluid (gas or liquid) that contains any amount of VOC.[68] The VOC content of the fluids covered by the LDAR Plan ranges from a low of 0.00099% (boil-off gas) to a high

[66] RA-132, NOC Order of Approval.
[67] PSE-0009, PSE-0010.
[68] Ottersburg Declaration ¶ 12.

of essentially 100% (*e.g.*, hydrocarbon liquids).[69] The requirements vary depending on whether the fluids contain 10% or more VOC as opposed to less than 10% VOC.[70] For example, a valve in contact with ethylene (100% VOC) is subject to monthly instrument monitoring and a valve in contact with boil-off gas (0.00099% VOC) is subject to a weekly Audible, Visual or Olfactory inspection.[71]

Q: BASED ON THE CB&I ESTIMATES, ARE FUGITIVE VOC EMISSIONS FROM PROCESS COMPONENTS EXPECTED TO BE A LARGE SOURCE OF EMISSIONS AT TACOMA LNG?

A: No. Based on the estimated component count in the permit, the process components will contribute a maximum of 4.2 tons per year of VOCs, which is less than 10 percent of the facility total.[72] As described earlier in my testimony, it is standard practice to conduct a final component count after the facility is constructed. Any discrepancies between the original and final counts are addressed with the permitting agency, as necessary. PSE recently completed the component count at Tacoma LNG and provided the Agency with a final count.[73] As part of that process under the permit, I understand that Landau is in the process of recalculating its fugitive emission calculations. I will review this calculation if available prior to hearing.

[69] Ottersburg Declaration ¶ 5.
[70] *Id.*
[71] *Id.* ¶ 12.
[72] RA-68, Final NOC Worksheet.
[73] PSE-0010, Tacoma LNG – Final LDAR Plan, March 11, 2021.

OPINION 5: DR. SAHU'S CLASSIFICATION OF TACOMA LNG AS A FUEL CONVERSION PLANT IS INCONSISTENT WITH PRIOR EPA DETERMINATIONS; TACOMA LNG IS SUBJECT TO THE 250-TON PSD MAJOR SOURCE THRESHOLD.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE APPROPRIATE PSD MAJOR SOURCE THRESHOLD APPLICABLE TO TACOMA LNG.

A: The appropriate PSD major source threshold for Tacoma LNG is 250 tons, based on a recent EPA determination for a similar facility. According to that determination, Tacoma LNG is not in one of the 28 listed PSD source categories to which the 100-ton threshold applies. I disagree with Dr. Sahu's rationale for stating that Tacoma LNG is a fuel conversion plant (which is one of the listed source categories). Tacoma LNG is extremely similar to another LNG facility, Jordan Cove, that EPA has recently determined is not a fuel conversion plant.[74]

Q: WHAT IS POTENTIAL TO EMIT?

A: Under both the EPA and Washington regulations, PTE is "the maximum capacity of a stationary source to emit a pollutant under its physical and operational design."[75] This definition is used in the Agency's air permitting regulations.[76]

[74] *See* RA-127, Jordan Cove Letter.

[75] 40 C.F.R. §52.21(b)(4); WAC 173-400-030(76) and -710(1).

The regulations further explain that any physical or operational limitation of the source to emit a pollutant—including air pollution control equipment; restrictions on the number of hours the source may operate; or restrictions on the amount of material combusted, stored, or processed—is to be treated as part of the source's design if the limitation on the source is federally enforceable by EPA. Accordingly, PTE is typically determined by assessing the amount of air pollutants emitted by a facility when it operates at its maximum allowable operating rate and for its maximum number of operating hours. These maxima are established by an enforceable permit limitation or by design limitations on the source.

Q: WHAT DOES IT MEAN FOR A STATIONARY SOURCE TO BE A "MAJOR SOURCE" OF AIR EMISSIONS?

A: A major source is one that exceeds the annual emissions levels under one of two Clean Air Act programs. Under the PSD program, a source is major if (1) it is in one of the 28 PSD source categories (shown in the table below) and has the potential to emit pollutants other than GHGs in amounts greater than or equal to 100 tons per year ("tpy"); or (2) it is not in one of the listed source categories and has a PTE of greater than or equal to 250 tpy.

[76] PSCAA Reg. I, Art. 6.01(a)

PSD Source Categories	
Coal cleaning plants with thermal dryers	Charcoal production plants
Portland cement plants	Kraft pulp mills
Iron and steel mills	Primary zinc smelters
Primary copper smelters	Primary aluminum ore reduction plants
Hydrofluoric acid plants	Municipal incinerator capable of charging more than 250 tons of refuse per day
Nitric acid plants	Sulfuric acid plants
Lime plants	Petroleum refineries
Coke oven batteries	Phosphate rock processing plants
Carbon black plants (furnace process)	Sulfur recovery plants
Fuel conversion plants	Primary lead smelters
Secondary metal production plants	Sintering plants
Fossil fuel boilers (or combination thereof) totaling more than 250 MMBtu/hr heat input	Chemical process plants (does not include ethanol production facilities that produce ethanol by natural fermentation, included in NAICS codes 325193 or 312140)
Fossil fuel fired steam electric plants of more than 250 MMBtu/hr heat input	Petroleum storage transfer units, total storage capacity over 300,000 barrels
Taconite ore processing plants	Glass fiber processing plants

Under the Title V program, a source is major if (1) it emits 100 tpy or more of any criteria pollutant; or (2) it emits any individual HAP in amounts greater than or equal to 10 tpy, or any combination of HAPs in an amount greater than or equal to 25 tpy.

Q: DR. SAHU ASSERTS THAT TACOMA LNG IS A FUEL CONVERSION PLANT, WHICH IS ONE OF THE 28 PSD SOURCE CATEGORIES. DO YOU AGREE WITH THIS OPINION?

A: No. First and foremost, Tacoma LNG's potential to emit any criterial pollutants is below 100 tons per year, the lower of the two PSD thresholds. Accordingly, regardless of whether Tacoma LNG is a fuel conversion plant, Tacoma LNG is not

a PSD major source of emissions. But based on the most recent applicable guidance on this issue from EPA, Dr. Sahu's argument that Tacoma LNG is a fuel conversion plant is simply not correct, and thus the 250-ton PSD threshold applies.

Q: WHAT HAS EPA SAID ABOUT FUEL CONVERSION PLANTS?

A: According to EPA,[77] "[t]here is no definition of the terms 'fuel conversion plants' … in the statute and the statute does not otherwise contain a description of such types of facilities or plants." Accordingly, the only source for a definition of whether a facility is a "fuel conversion plant" comes from EPA guidance on the matter.

Q: HAS EPA ADDRESSED THE DEFINITION OF A FUEL CONVERSION PLANT WITH SIMILAR FACILITIES?

A: Yes. In 2017, EPA wrote an applicability letter stating that the Jordon Cove liquified natural gas facility was not a "fuel conversion" plant. The letter states that although a fuel conversion plant involves a change of state of fuel (*i.e.*, from gas to liquid, or from solid to liquid), past EPA guidance states that there must be more than a "simple change in the state of a given fuel" to constitute a fuel conversion plant.[78] The 2017 letter goes on to state that EPA's earliest guidance on defining the source category includes coal gasification; coal liquefaction; and

[77] RA-127, Jordan Cove Letter.

[78] *Id.*

oil shale processing. EPA points out that these examples "involve more than a simple change in state of a given fuel" and that these examples all "irreversibly produce a new type of fuel as an end product."[79]

The 2017 letter identifies a 2006 EPA determination concluding that two LNG facilities were not fuel conversion plants for PSD permitting purposes and one 2007 EPA determination where an LNG facility was determined to be a fuel conversion plant, although not in the PSD permitting context. In the 2017 letter, EPA explicitly concluded that its 2007 determination was wrong, stating "After a closer examination of EPA's historical approach, our view is that a change in state is a possible characteristic of a fuel conversion plant but not the sole characteristic - *i.e.*, not everything that accomplishes a change in state is a fuel conversion plant. Where a change of state occurs only for transportation needs, the fuel remains natural gas throughout the process, and the process is necessarily reversible."[80]

Q: IS DR. SAHU CORRECT IN HIS ASSERTION THAT TACOMA LNG IS A FUEL CONVERSION PLANT?

A: No. Dr. Sahu bases his assertions that Tacoma LNG is a fuel conversion plant on the fact that the facility removes "components in pipeline natural gas such as carbon dioxide, moisture, propane, and higher hydrocarbons…as well as contaminants such as sulfur compounds." Dr. Sahu then states, as a part of his

[79] *Id.*
[80] *Id.*

rationale, that Tacoma LNG then "utilizes a cooling and compression process to change the newly cleaned and composed gas to a liquid." He then states, "for these reasons," the Tacoma LNG facility is a fuel conversion plant.[81]

Yet, the Jordon Cove LNG plant that was the subject of the 2017 applicability letter from EPA stating that it is not a fuel conversion plant also removes compounds from the gas before liquefaction.

According to the process description in the application for the proposed project, the Jordan Cove system includes "mercury removal via sulfur impregnated activated carbon, carbon dioxide ("CO_2") and acid gas removal via an amine system, and dehydration via a molecular sieve adsorbent system," very similar to the treatment of the gas in the Tacoma LNG system.[82] In addition, there are co-adsorbed contaminants in the CO_2 treatment system including benzene, toluene, ethylbenzene and xylenes, which are then combusted. Finally, Jordan Cove also includes a "heavies removal" system followed by a cooling and compression system to liquify the natural gas.[83] In other words, Jordan Cove performs the equivalent processes using the equivalent equipment as Tacoma LNG.

[81] Sahu Testimony ¶ 25.

[82] PSE-0365, Jordan Cove Energy Project, L.P. LNG Terminal, Type B State New Source Review Application (Sept. 2017), also available at https://www.oregon.gov/deq/Programs/Documents/JCEPAQPermitAppl2017.pdf.

[83] *Id.*

Based on EPA's statements in the 2017 guidance, which was issued during the permitting process for Tacoma LNG, the most reasonable conclusion is that Tacoma LNG is not a fuel conversion facility. Tacoma LNG liquefies natural gas, which is a change of state, but not an irreversible chemical change like coal gasification, coal liquefaction, and oil shale processing (*i.e.*, once coal is gasified, it cannot be turned back into coal). Rather, the Tacoma LNG liquefaction process is reversible, as EPA found for the similar Jordan Cove facility. Indeed, during periods when Tacoma LNG is used for peak shaving, LNG from Tacoma LNG will be vaporized and reinjected into the distribution system as natural gas.

In his pre-filed direct testimony, Dr. Sahu cites no authority for his opinion that Tacoma LNG is a fuel conversion plant and fails to even mention the 2017 EPA determination for Jordan Cove. By contrast, during his deposition his basis for concluding Tacoma LNG is a fuel conversion plant was simply "I – I just think that EPA is wrong."[84] I believe that this statement by Dr. Sahu acknowledges that EPA clearly concluded that LNG liquefaction facilities such as Jordan Cove and, by extension, Tacoma LNG are not fuel conversion plants.

[84] Deposition of Dr. Ranajit Sahu, March 5, 2021, at 88:1.

OPINION 6: TACOMA LNG IS NOT A MAJOR SOURCE OF CRITERIA POLLUTANT EMISSIONS UNDER THE PSD PROGRAM, NOR UNDER THE TITLE V PROGRAM.

Q: PLEASE SUMMARIZE YOUR OPINION ABOUT WHETHER TACOMA LNG IS A MAJOR SOURCE.

A: Tacoma LNG is not a major source under the PSD program or the Title V program, regardless of whether the 100-ton or 250-ton threshold applies. The largest PTE of any criteria air pollutant emitted by Tacoma LNG is 49 tpy of VOC emissions. Given the constraints on PTE (*i.e.*, the permit's requirement for 99% destruction of VOCs and the flare's 34 MMBtu/hr (LHV) maximum capacity), Tacoma LNG cannot be a major source of VOCs regardless of how feed gas changes in the future. Even if wildly unrealistically high assumptions are made about the VOC content of the waste gas input into the flare, the VOC emissions from the flare would still be below the 100 tpy threshold. Dr. Sahu has not done any work to calculate PTE, nor to demonstrate how emissions could be high enough to exceed either major source threshold. Finally, I disagree with Dr. Sahu's claims that additional emissions should have been included in the PTE calculations. PTE does not account for emissions from emergency conditions or presumed future violations of permit conditions.

Q: IS TACOMA LNG A MAJOR SOURCE OF EMISSIONS?

A: No, Tacoma LNG is not a major source under the PSD program, nor under the Title V program. As I just noted, I do not believe Tacoma LNG is a fuel conversion plant under the applicable EPA guidance. The Agency has similarly stated that it does not believe Tacoma LNG fits the definition of a fuel conversion plant under PSD.[85] If Tacoma LNG is not a fuel conversion plant, then the facility does not fall into one of the 28 PSD source categories listed in the table above, and it would have to have a PTE greater than or equal to 250 tpy for one or more individual non-GHG criteria pollutants or their respective precursors to qualify as a PSD major source.

However, the question of whether Tacoma LNG is a fuel conversion facility is immaterial to its source determination under the PSD program: the facility's emissions, as calculated in the NOC permitting process, are well below the 100 tpy level that applies to the 28 designated source categories. As shown in the table and graph below, the largest PTE of any criteria air pollutant emitted by Tacoma LNG is 49 tpy of VOC emissions, which is only one fifth of the general PSD permitting emissions level of 250 tpy and less than half of the 100 tpy level that would apply if Tacoma LNG was in one of the 28 designated source categories.[86]

[85] *See* Deposition of Steve Van Slyke, December 7, 2020, at 86:13–20.

[86] For perspective, these emissions are half that of a commercial bakery. The Franz Bakery on Weller Street in Seattle emits 94.17 tons of VOCs per year. PSE-0113 (comparing emissions data from 2017 National Emissions Inventory).

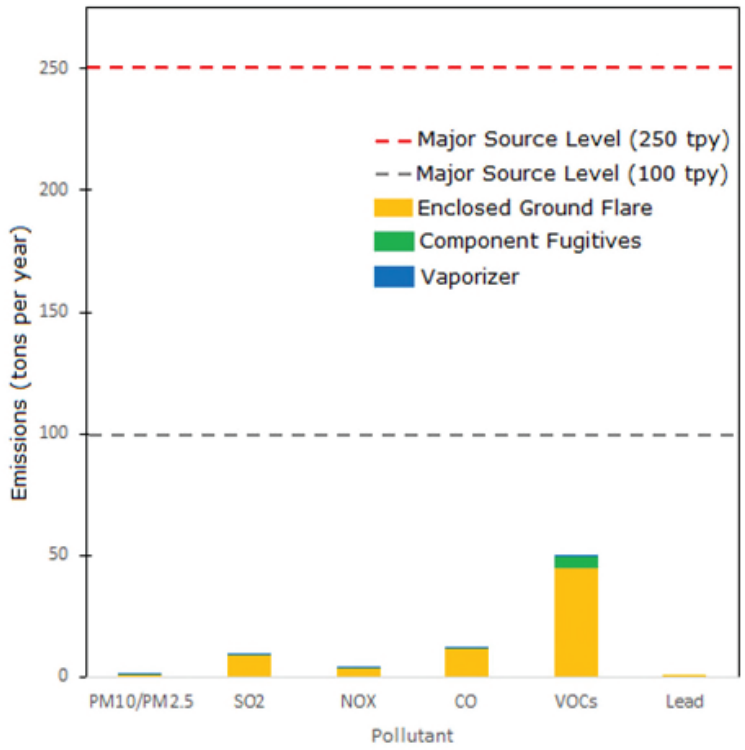
Assuming that Tacoma LNG is not a designated source, the 49 tpy of VOC is actually an overstatement in this context because fugitive emissions are excluded from the PTE calculation for purposes of comparison to the general PSD major source level for sources subject to the 250-ton threshold level.[87]

Because Tacoma LNG's PTE is below 100 tpy for each criteria pollutant, the facility is not a major source of criteria pollutants under Title V or PSD. Additionally, Tacoma LNG's PTE for the sum of HAPs is 0.37 tpy, which is well below the Title V major source levels of 10 tpy for any individual HAP or 25 tpy for any combination of HAP.

Tacoma LNG Criteria Air Pollutant Estimated Emissions[88]				
Pollutant	**Vaporizer (TPY)**	**Enclosed-Ground Flare (TPY)**	**Component Fugitive Emissions (TPY)**	**Total (TPY)**
$PM_{10}/PM_{2.5}$	0.055	1.2	0	1.2
SO_2	0.017	9.1	0	9.1
NO_X	0.086	3.7	0	3.8
CO	0.290	12	0	12
VOCs	0.040	45	4.2	49
Lead	3.6E-6	8.0E-5	0	8.2E-05
Total TAPs/HAPs	0.014	0.30	3.4E-5	1.03/0.37

[87] PSE-0307, WAC 173-400-720(4)(a)(vi) (adopting definitions in 40 C.F.R. 52.21(b) which, in the definition of "major source" states: "The fugitive emissions of a stationary source shall not be included in determining for any of the purposes of this section whether it is a major stationary source, unless the source belongs to one of the following categories of stationary sources…").
[88] RA-68, Final NOC Worksheet.

Tacoma LNG Criteria Air Pollutant Emissions Compared to PSD Major Source Level



Q: HOW RELIABLE ARE THESE EMISSIONS CALCULATIONS?

A: These calculations are appropriately conservative. Tacoma LNG's actual emissions will likely be even further below the major source levels than calculated because the emissions reported in the NOC Worksheet represent the worst-case facility-wide emissions. Landau calculated worst case by calculating emissions for each pollutant under various facility operating scenarios and then selecting the highest

emissions for each pollutant across all scenarios. Thus, for example, Landau calculated emissions of each pollutant conservatively assuming that each of the liquefying cases would occur for every hour of the year (*i.e.*, 8,760 operating hours). Landau also calculated emissions of each pollutant assuming that vaporization would occur for the maximum amount of permitted hours (*i.e.*, 24 hours per day for 10 days, or 240 hours) and that the flare would be operating at the highest rate for the remaining hours of the year (*i.e.*, 8,520 hours). Landau then selected the highest emissions for each pollutant, even if the highest emissions for different pollutants occurred under different operating scenarios. This is conservative. Landau used the highest emitting scenario (*i.e.*, either maximum liquefying or maximum vaporizing + liquefying) for its PTE calculations. It then added the emissions from the small cold burner to address the maximum purge gas combustion that can occur throughout the year from ship and truck loading.[89] This methodology ensured that emissions estimates submitted to the Agency would encompass or accommodate the upper bound of Tacoma LNG's emissions.

[89] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017).

Q: IN ARGUING THAT TACOMA LNG IS A MAJOR SOURCE OF VOCS, DOES DR. SAHU ASSUME THAT THE FLARE WILL EXCEED ITS PERMIT LIMITS?

A: Yes. Dr. Sahu assumes that the flare will not achieve the 99% VOC destruction efficiency required by the permit. Instead, he makes various assumptions about reduced VOC destruction efficiency and then generates artificially high potential emissions by applying lower destruction efficiencies to the highest flow flaring cases. For example, on page 15 of his pre-filed testimony, Dr. Sahu points to CB&I "heat emissions data sheets" that have information on each flaring case. He says that "LFG does not use 99% [destruction efficiency] in all of the cases it analyzed. It used 98% for numerous cases and 95% for one case." On page 12 of his pre-filed testimony, Dr. Sahu takes this one step further, and says that "uncontrolled VOC emissions from the flare are 4,500 tons per year" and "[i]f the DE were to be 95%, as I have noted was the case for at least one case by LFG itself, the PTE would be 4,500*(1-0.95) = 225 tons per year just from the flare alone." He does a similar calculation on the same page assuming a hypothetical 97% destruction efficiency to come up with 135 tons per year. He uses these higher numbers to argue that Tacoma LNG's VOC emissions are above the major source thresholds. Dr. Sahu's calculations appear to be based on a poor understanding of the underlying data.

Q: CAN YOU EXPLAIN WHY DR. SAHU'S ARGUMENT IS BASED ON A POOR UNDERSTANDING OF THE UNDERLYING DATA?

A: Yes. First some background is necessary. The various flaring cases represent different operations of the facility. There are liquefying cases, which are the cases with highest emissions (Cases 1, 3, 4 and 5) due to having much higher hydrocarbon flows to the flare while liquefying at full capacity. Then there are other cases that have much lower emissions due to much lower hydrocarbon flows to the flare. There is a turn-down case where the plant is liquefying at a reduced level (Case 2); a holding case, where the plant is not liquefying at all (Holding Case); and cases that represent purging of equipment with nitrogen after loading a ship or truck (Cases 9A1, 9A2 and 9B), all of which would only happen when the unit is either liquefying or holding.[90]

Attachment A to the permit application calculates VOC emissions for each scenario assuming operation for maximum permitted hours throughout the year and based on the 99% destruction required by the permit.[91] These total annual emissions were reported as follows:

[90] RA-68, Final NOC Worksheet at 32-34.
[91] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017); RA-132, NOC Order of (December 10, 2019).

	VOC TPY From Attachment A
Case 1	13.1
Case 2	3.3
Case 3	40.6
Case 4	41.7
Case 5	44.6
Holding	0.31
9A1	0.00015
9A2	0.0006
9B	0.00015

	VOC TPY From Attachment A
Case 1	13.1
Case 2	3.3
Case 3	40.6
Case 4	41.7
Case 5	44.6
Holding	0.31
9A1	0.00015
9A2	0.0006
9B	0.00015

As can be seen, emissions from the non-liquefying cases are very small, which represents the fact that the flows to the flare in those cases are very low (and that the hours of operation are limited for truck and ship loading activities).

The CB&I heat emissions data sheet lists destruction efficiency for the cases, but Dr. Sahu appears to misunderstand critical information about which cases are listed as 98% and 95% and fails to note that the key liquefying cases are listed as 99.5%. Cases 1, 3, 4, and 5 are listed as 99.5% destruction; Case 2, Holding Case,

and Cases 9A1 and 9A2 are listed as 98%; and case 9B is listed as 95%.[92] Thus, the highest emissions cases (including Case 5, which is the basis for potential to emit) all are listed as 99.5% destruction efficiency.[93]

Dr. Sahu applies the lowest destruction efficiency in the heat emissions data (for Case 9B) to the highest hydrocarbon flows to the flare (Case 5) to create an artificially high emission estimate. In other words, he takes the highest hydrocarbon flow to the flare, which would be the case where the flare would be expected to have the highest destruction efficiency, and applies the lowest destruction efficiency. Dr. Sahu appears to not understand the context of these destruction efficiencies, as he used them incorrectly.

First off, the permit requires 99% destruction efficiency, which will be determined by testing, and then will be maintained by continuous parametric monitoring for temperature.[94] It is not appropriate to measure potential to emit by assuming the plant will violate a permit limit. Thus, Dr. Sahu's calculations are not the appropriate measure to begin with. However, even using Dr. Sahu's approach, it is possible as a thought experiment to use Attachment A to recalculate VOC emissions using the destruction efficiencies for each case on the heat data sheet instead of the 99% required by the permit. This eliminates the apparent poor

[92] It is also important to also note that the composition of Cases 9A1, 9A2 and 9B are only methane and nitrogen. So, there are no VOCs to destroy in those cases, and the destruction efficiency concept is not even relevant.
[93] PSE-0018, CB&I Heat Emission Data (April 5, 2018).
[94] RA-132, NOC Order of Approval, Conditions 12, 15, 21, 28.

understanding of the data that Dr. Sahu had in his generation of artificially high emissions. The results of my calculations are set forth in the table below.[95] I should note that I am not recalculating PTE based on this calculation, but rather, am correctly applying the DRE's that were incorrectly used by Dr. Sahu.

	DRE from CBI/LFG Heat Emissions Data Sheet	VOC TPY From Attachment A (at 99%)	VOC TPY recalculated at DRE from Heat Emission Sheet
Case 1	99.5%	13.1	6.6
Case 2	98%	3.3	6.6
Case 3	99.5%	40.6	20.3
Case 4	99.5%	41.7	20.8
Case 5	99.5%	44.6	22.3
Holding	98%	0.31	0.62
9A1	98%	0.00015	0.00003
9A2	98%	0.0006	0.0012
9B	95%	0.00015	0.00074

	DRE from CBI/LFG Heat Emissions Data Sheet	VOC TPY From Attachment A (at 99%)	VOC TPY recalculated at DRE from Heat Emission Sheet
Case 1	99.5%	13.1	6.6
Case 2	98%	3.3	6.6
Case 3	99.5%	40.6	20.3
Case 4	99.5%	41.7	20.8
Case 5	99.5%	44.6	22.3
Holding	98%	0.31	0.62
9A1	98%	0.00015	0.00003
9A2	98%	0.0006	0.0012
9B	95%	0.00015	0.00074

[95] PSE-0137, VOC Emission Estimates from Flare for Various Fuels, March 5, 2021.

Q: WHAT CONCLUSION HAVE YOU DRAWN FROM THIS ANALYSIS?

A: Even if Dr. Sahu were correct, and the destruction efficiencies from the heat emissions analyses were used to calculate potential to emit, the potential to emit from the flare (based on Case 5) would go *down* from 44.6 tons to 22.3 tons. The other annual emissions depicted are not relevant to potential to emit because they are lower than Case 5. In his example, Dr. Sahu focused on the 95% destruction, which was listed for Case 9B. For Case 9B, reducing the destruction efficiency from 99% to 95% destruction would increase emissions from 0.00015 to 0.00074 tons per year. These tiny fractions of a ton per year are immaterial to the potential to emit calculations. As noted above, Dr. Sahu instead applies 95% destruction to Case 5 to arrive at his 225 tons. This appears to be the result of his misunderstanding the source information. As I describe below, given the constraints on Tacoma LNG, it is not possible for the plant to be a major source of VOC emissions.

Q: IS IT POSSIBLE FOR TACOMA LNG TO BE A MAJOR SOURCE OF VOCS?

A: No.

Q: PLEASE EXPLAIN.

A: Tacoma LNG is subject to certain operational and emissions constraints that make it essentially impossible for Tacoma LNG to be a major source of VOCs.

Q: WHAT ARE THOSE CONSTRAINTS?

A: First, the flare has a maximum design capacity of 34 million BTU per hour (on a lower heating value basis).[96] This is set forth in the NOC application materials,[97] as well as the final specs for the flare,[98] and the deposition of the flare manufacturer.[99] As such, the flare is not designed to operate above that level. I understand that this was a representation during the permitting process and is therefore an enforceable condition pursuant to Condition 1 of the permit. This means that there is only so much heat content, and as a result, a limited mass of VOCs, that can be sent to the flare every hour, and as a result, for the entire year.

Q: WHAT OTHER CONSTRAINTS?

A: Second, the flare is required to achieve a 99% destruction of VOCs going to the flare.[100] This is an enforceable permit condition, so it also constrains potential to emit of the flare.

Q: ARE THERE FURTHER CONSTRAINTS?

A: Yes, the final key constraint is that operationally, only so much of the waste stream going to the flare can be made up of VOCs. During the liquefaction

[96] Note that the permit used the equivalent higher heating value (HHV) of 37.2 MMBtu/hr.
[97] *See* RA-21, Attachment A to Tacoma LNG NOC Application at Tab 8 Flare5 (Case 5 – Potential Emissions from Enclosed Ground Flare Burners).
[98] *See* A-PTI0255, LFG/APTIM Final Flare Proposal and Pricing at 2 (Dec. 6, 2017).
[99] *See* Deposition of Louis Kalani, January 20, 2021, at 99:8–19.
[100] RA-132, NOC Order of Approval, Condition 15.

process, to concentrate methane in the LNG, and to avoid freezing heavier hydrocarbons in the liquefaction process, non-methane hydrocarbons are removed from the incoming natural gas and either sent to the flare or to the heavies storage vessel. However, when pulling non-methane hydrocarbons from the incoming natural gas, methane is also removed and sent to the flare. As such, the flare gas cases always include methane and ethane, as well as heavier hydrocarbons. It is impossible, using the methods employed at Tacoma LNG, to pull heavier hydrocarbons from the incoming feed gas and not pull a substantial amount of methane and ethane in the process. It is akin to skimming fat from soup and trying to leave all of the soup behind in the pot. Some soup will come with the fat.

Thus, the waste gas sent to the flare includes methane and ethane, as well as heavier hydrocarbons. In fact, in every liquefying case, methane is the most prevalent single hydrocarbon in the stream. Neither methane nor ethane are VOCs by definition, so it is just the other hydrocarbons that are VOCs counted toward the major source threshold.

In the maximum flaring case evaluated by Landau (Case 5), VOCs made up approximately 58 percent of the waste stream by weight.[101] The remainder of the stream was predominantly methane and ethane, as well as some non-VOCs like CO_2.

[101] RA-21, Attachment A to Tacoma LNG NOC Application at Gas Data Tab (Liquefying Case 5).

Q: CAN VOCS IN THE WASTE GAS STREAM TO THE FLARE EXCEED THE 58% VOC BY WEIGHT ESTIMATED BY LANDAU?

A: According to CB&I, flaring Case 5 was developed to have a higher percentage of hydrocarbons, and a higher percentage of heavier hydrocarbons than is ever expected to be seen. In fact, Mr. Stobart has indicated that Case 5 was purposefully developed to overestimate the amount of heavy hydrocarbons that could be sent to the flare by assuming an incoming gas composition with a decreased level of methane and increased concentrations of heavier hydrocarbons, some of which would be VOCs. The case was also developed assuming 275,000 gallons of LNG per day, notwithstanding that the permit limits LNG production to 250,000 per day, thus providing an additional 10 percent contingency. And CB&I layered an additional 10 percent flow contingency on top of that. As a result, Case 5 already was designed to overstate heavier hydrocarbons (and thus, VOCs) to the flare, which makes Case 5 conservative for use in potential to emit. Thus, 58 percent VOC by weight, at the maximum heat input, appears to be a very conservative estimate (overstatement) of emissions for purposes of potential to emit.[102]

[102] Declaration of Matthew Stobart, ¶¶ 16-22 (March 29, 2021) (Attached hereto as Attachment C).

Q: IF CB&I WERE WRONG, AND THE WASTE GAS SENT TO THE FLARE COULD BE 100% VOCS, COULD TACOMA LNG BE A MAJOR SOURCE OF VOCS?

A: No. But it is important to remember that CB&I has indicated that it is impossible to send 100% VOCs to the flare because methane and ethane will always be pulled off into the flare gas along with heavier hydrocarbons. In addition, according to Mr. Stobart, there will always be some non-VOCs, such as CO_2 in the gas.

Q: PLEASE EXPLAIN WHY YOU BELIEVE THAT TACOMA LNG CANNOT BE A MAJOR SOURCE OF VOCS.

A: It is possible to consider a thought experiment to show that Tacoma LNG's emissions cannot exceed the major source threshold given the constraints I have just discussed. Accordingly, as a thought experiment, I evaluated how many tons of VOCs would be emitted if the flare combusted 100 percent VOCs at the maximum design capacity at the large warm burner[103] of 34 MMBtu/hr (LHV), and the 99% VOC destruction required by the permit. In other words, I evaluated the facility's PTE if the inlet gas was comprised of 100 percent VOCs—which, as explained, is simply not possible given that heavier hydrocarbons cannot be

[103] I have focused on flare emissions because worst case potential to emit for VOCs is based on full-time operation of the flare. Further, I have focused on the large warm burner of the flare because emissions from the large warm burner represent the potential to emit on the warm side, and emissions from the small cold burner are negligible (a small fraction of a ton).

removed from feed gas without pulling out methane and ethane—hence why this is purely a thought experiment.

For the thought experiment, I evaluated this possibility by looking at the major VOC components of the gas stream (*e.g.*, propane, butane, pentane, etc.) and calculated the mass of VOCs of each component that would be emitted by the flare if the stream were made up of 100 percent of that component, and still subject to the maximum heat input capacity of the flare. For example, I calculated how much propane would go to the flare if the entire stream were made of propane and the flare reached its maximum capacity of 34 MMbtu/hr. Undertaking this calculation is simple because each component, like propane, has a certain heating value per pound. Propane has a heat content of 19,919 btu/lb. So, it would take burning 1,707 lb/hr of propane to get to 34 MMbtu/hr. With 99% destruction in the flare required by permit, this equates to 75 tons of VOC emissions per year, if the flare operates this way all 8,760 hours of the year. Thus, even in this thought experiment, VOC emissions would be well less than the 250-ton major source threshold (and would still be below the 100-ton threshold if it applied, even accounting for fugitive emissions). But, it is important to note that this is strictly a thought experiment. There is no possible way for the operations of Tacoma LNG to yield this level of VOCs to the flare.

Similarly, if the entire gas stream going to the flare was butane (another VOC), emissions from the flare would be 76 tons per year of VOCs, which also is below

the major source threshold. I have undertaken the same evaluation for each VOC between propane (C3) and decane (C10), including the branched alkanes and created a table of the results (PSE-0137). While none of these VOCs outside of the first few could possibly be present in significant quantities, the result relative to the major source threshold would be the same for all of them, or any combination of them. No single VOC or combination of VOCs could exceed 85 tons per year under this impossible scenario, where the stream contains no methane and ethane, and still maxes out the heat capacity of the flare. Thus, in the thought experiment, which could not happen in reality, it is simply not possible for Tacoma LNG to emit more than 250 tons per year of VOCs. And, even if Tacoma LNG were subject to the 100-ton threshold, the thought experiment demonstrates that Tacoma LNG cannot practically be a major source given that that Landau calculated fugitive emissions were 4.2 tons per year.

Given that (1) Case 5 is made up of 58% VOCs, which is likely to be an overstatement given how CB&I created Case 5, and (2) Case 5 assumes 34 MMBtu/hr of heat input, even though this too overstates the likely maximum heat input that will operationally be sent to the flare given how CB&I created Case 5, the 44.8 tons of VOC emissions calculated for the permit PTE is a very conservative potential to emit. Based on the information I have about Tacoma LNG and the calculations I performed in this thought experiment, I am confident

that this facility's PTE does not exceed 100 tpy under any feed gas composition scenario.

Q: IS THE RESULT THE SAME IF CONSIDERING FUTURE POTENTIAL FEED GAS CHANGES?

A: Yes, given the constraints on potential to emit (99% destruction of VOCs and 34 MMBtu/hr maximum flaring capacity), Tacoma LNG cannot be a major source of VOCs regardless of how feed gas changes in the future.

Q: THE TRIBE HAS ALLEGED ERRORS WITH THE ESTIMATION FUGITIVE OF VOCS FROM TACOMA LNG. IF LANDAU HAD MADE THE ALLEGED ERRORS, WOULD TACOMA LNG BE A MAJOR SOURCE OF VOCS?

A: As a threshold matter, the estimation of the quantity of fugitive emissions is irrelevant to determining whether Tacoma LNG is a major source, because—as discussed earlier—fugitive emissions are properly excluded from this calculation for a source subject to the 250-ton major source threshold. Additionally, Dr. Sahu's criticisms of the fugitive emission methodology utilized by Landau is without merit. First, as noted earlier, for fugitive component emissions, it was proper for a control factor to be applied to account for the inspection and maintenance program (*i.e.*, LDAR). This practice is accepted by permitting

agencies,[104] and was accepted by the Agency.[105] Second, and as discussed earlier, the emission factors for fugitive emissions from process components used to estimate VOC emissions were highly conservative as applied to Tacoma LNG because the facility's gases and liquids contain substantial amounts of methane and ethane. These are not VOCs but were counted as VOCs for the purposes of Landau's fugitive emissions calculations in the NOC. However, hypothetically, if fugitive emissions at Tacoma LNG were to even quadruple, the total VOC emissions would still be far below the PSD major source level of 100 tpy (if they were to count toward the calculation of emissions for this purpose).

Q: THE TRIBE ALSO ALLEGES THAT THE FLARE'S DESTRUCTION EFFICIENCY IS LOWER THAN 99 PERCENT. IF THAT IS CORRECT, WOULD TACOMA LNG BE A MAJOR SOURCE OF VOCS?

A: What the Tribe thinks the flare can do is not relevant here. Condition 15 of the NOC Order of Approval requires that Tacoma LNG's flare achieve a minimum destruction efficiency of 99% for VOCs. As discussed earlier, PTE includes enforceable permit limits, of which the 99% destruction efficiency is one. The flare's VOC destruction efficiency will be verified by source testing and must continue to operate at or above the temperature for which it is verified to have a

[104] *See* RA-98, TCEQ Air Permit Technical Guidance for Chemical Sources: Fugitive Guidance, APDG 6422 (June 2018). https://www.tceq.texas.gov/assets/public/permitting/air/Guidance/NewSourceReview/fugitive-guidance.pdf; RA-79, EPA, Protocol for Equipment Leak Emission Estimates (1995).
[105] RA-68, Final NOC Worksheet.

99% destruction efficiency, as required by Conditions 21 and 28 of the permit. This is a standard method to ensure consistent destruction of thermal devices. Therefore, the enforceability of the 99% destruction efficiency of VOCs is inherent in Tacoma LNG's PTE VOCs, regardless of the Tribe's unfounded allegations about the flare's destruction efficiency.

Q: DR. SAHU BELIEVES THAT EMISSIONS FROM THE FLARE BYPASS SHOULD HAVE BEEN INCLUDED IN TACOMA LNG'S PTE CALCULATIONS. DO YOU AGREE?

A: No. The Agency appropriately calculated Tacoma LNG's PTE. Regulatory agencies do not include in PTE emissions prohibited by a permit that arise as the result of a malfunction that is not reasonably foreseeable. Emissions from the flare bypass are both prohibited by the permit and would result only from a malfunction that I understand is not reasonably foreseeable.

Waste gases from the Tacoma LNG process are not permitted to bypass the flare. Condition 10 and 11 of the permit require that waste gases be routed to the enclosed ground flare and that the flare be continuously operating at all times. Condition 11 further requires that all processes routed to the flare must be shut down if the flare is not in service. There is no provision that allows the waste gases to be sent to the bypass vent. Condition 46i requires that all gases vented to the

bypass be recorded.[106] These are enforceable permit conditions, subject to penalties. Accordingly, it is appropriate to exclude flare bypass venting, which would result in unpermitted emissions, when calculating the facility's PTE, consistent with EPA guidance[107] and with the definition of "potential to emit" in Washington State regulations.

The flare bypass vent was installed as a safety precaution at the facility but is not ever planned to be used. In his deposition, Mr. Stobart states regarding the vent: "[i]t's a safety device, that vent, and it will never be used for anything other than that."[108] He later notes that the flare vent would be used in a "shutdown mode" where the entire system will be shut down.[109] It is analogous to the installation of fire prevention systems. A facility may install these systems as a safety measure, but a regulatory agency would not require a calculation of emissions resulting from a fire in a facility's PTE.

[106] Under Condition 46(i), Tacoma LNG is required to keep a written log showing any instance of flare bypass, which must include the date, time, duration, and estimated amount of waste gases released to the atmosphere. The Agency will have full information about Tacoma LNG's bypass events, if any actually occur, and can enforce violations of the permit against Tacoma LNG.
[107] U.S. EPA Memorandum. "State Implementation Plans: Policy Regarding Excess Emissions During Malfunctions, Startup, and Shutdown." September 20, 1999, https://www3.epa.gov/ttn/naaqs/aqmguide/collection/t5/excesem2.pdf; U.S. EPA Letter to Mr. William O'Sullivan, Director, Division of Air Quality, New Jersey Department of Environmental Protection. February 14, 2006.
[108] Deposition of Matthew Stobart, 131:15-16 (Feb. 16, 2021).
[109] Deposition of Matthew Stobart, 383:6-12 (Feb. 18, 2021).

Q: DR. SAHU BELIEVES THAT EMISSIONS FROM THE PROCESS HEATERS WERE IGNORED IN TACOMA LNG'S PTE CALCULATIONS. DO YOU AGREE?

A: No. As part of the permit process, Landau calculated emissions from the two process heaters. These calculations are included within Attachment A to the permit application.[110] The emissions from the water propylene glycol heater were calculated to be 0.20 tons per year of VOCs and the emissions from the regeneration pretreatment heater were calculated to be 0.035 tons per year of VOCs.[111] Thus, Dr. Sahu is incorrect that the permit did not calculate potential to emit from these heaters. Furthermore, the emissions are immaterial to the PTE calculation.

OPINION 7: IT IS APPROPRIATE TO USE THE SUM OF BACKGROUND DATA AND MODELED CONCENTRATIONS FOR COMPARISON TO THE NAAQS/WAAQS.

[110] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017).
[111] *Id.*

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE COMPARISON OF MODELED CONCENTRATIONS TO THE NAAQS/WAAQS.

A: In my experience, when permitting minor sources it is common for permitting agencies to compare modeled concentrations of pollutants to the ambient air quality standards by adding the modeled concentrations to background levels. The Agency's approach in the Tacoma LNG permit analysis was consistent with this practice.

Q: HOW DID THE AGENCY COMPARE MODELED CONCENTRATIONS FROM TACOMA LNG TO THE NAAQS/WAAQS?

A: In this case, the Agency assessed background concentrations of $PM_{2.5}$, which was the pollutant modeled to be at or above the threshold in WAC 173-400-113. Background concentrations reflect emissions from other sources. The Agency added the modeled ambient concentrations from Tacoma LNG to the background level to determine whether the source's contribution in combination with background would cause or contribute to an exceedance of ambient air quality standards.[112]

[112] RA-68, Final NOC Worksheet at 57.

Q: SPECIFICALLY, HOW DOES PSCAA ASSESS THE IMPACT OF EMISSIONS FROM A MINOR SOURCE ON THE AMBIENT AIR QUALITY STANDARDS?

A: For minor sources, the Agency does not require a dispersion modeling analysis to evaluate the ambient air quality impacts of minor sources applying for a permit, but has the discretion to require air dispersion modeling in an overabundance of caution to ensure that the source does not cause or contribute to a violation of the WAAQS and NAAQS. If PSCAA does choose to model or require modeling of emissions from minor sources, PSCAA first uses a screening method to determine whether the emissions from that source have the potential to cause or contribute to a violation of an air quality standard. That screening method is provided in WAC 173-400-113. Briefly, PSCAA compares the maximum modeled estimated impacts from a proposed source to the Threshold Values contained in Table 4a of WAC 173-400-113. If the estimated impacts from a proposed source are less than the Threshold Values contained in Table 4a of WAC 173-400-113 then that evaluation confirms that the emissions from a permitted source do not cause or contribute to a violation of a WAAQS or NAAQS, and the modeling is complete and no further work is needed. In that sense, being below the Threshold Values is a safe harbor. But being at or above the threshold does not mean that a source causes or contributes to a violation of the ambient standard. Rather, it means additional analysis must be undertaken. Specifically, the Agency adds the

background values to the source's contribution and compares the sum to the relevant ambient air quality standard. If the sum is below the NAAQS/WAAQS, then the source does not cause or contribute to a violation of an ambient air quality standard.

Q: WHAT ARE BACKGROUND AIR QUALITY CONCENTRATIONS?

A: The background air quality concentrations are those concentrations that are caused by sources of pollution other than the one that is being considered for permitting. Sources of pollution that contribute to background concentration include vehicles, pollution transported from other states or nations, such as China, other permitted sources of pollution, and other small sources of pollution, such as emissions from natural gas combustion in peoples' homes. The impact of each pollutant that is emitted from a source can be estimated using air dispersion modeling, and the total impact, including background sources, can be estimated using dispersion modeling and background air quality data.

Q: WHERE DOES PSCAA OBTAIN THE BACKGROUND AIR QUALITY CONCENTRATIONS?

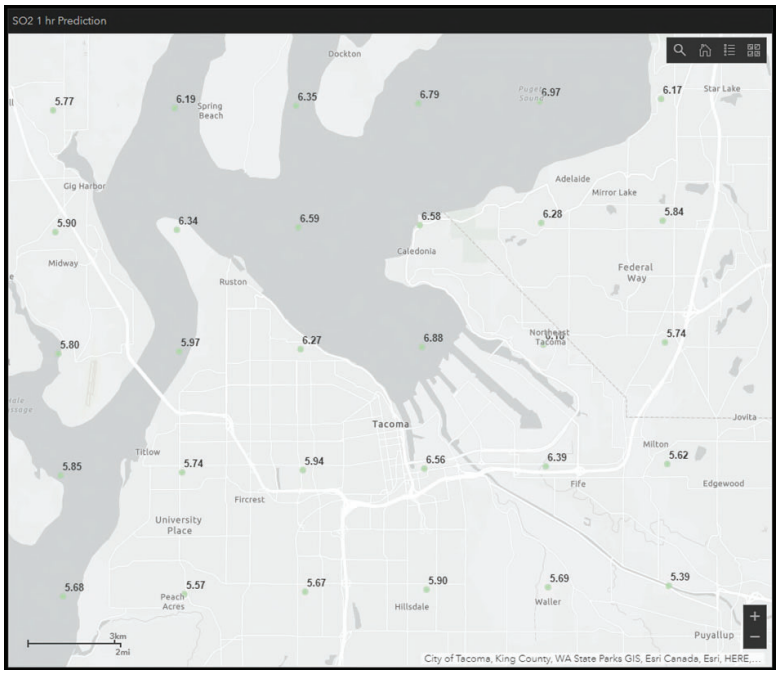
A: There are two sources for background air quality concentrations. The first source is local monitoring data. In this case, the Agency relied on the Tideflats $PM_{2.5}$

monitor that is owned by Ecology and maintained by the Agency,[113] which is located within one kilometer of the Tacoma LNG site. This monitor will represent local air concentrations of $PM_{2.5}$.

When local monitor data is not available, agencies use data from a collaboration between Idaho DEQ, Washington Department of Ecology, and Oregon DEQ. This collaboration yields background air quality concentrations for PM_{10} (24-hour) $PM_{2.5}$ (24-hour and annual), CO (1- and 8-hour), SO_2 (1-, 3- and 8-hour), ozone (8-hour) and NO_2 (annal and 1-hour). These are available on a website supported by the Idaho DEQ. The background data is available online at https://arcg.is/1jXmHH.

The data is provided to the public on a 4 x 4 kilometer grid. The furthest that any location can be from an estimated background concentration is midway on the diagonal between two points, or less than 3 km. As a practical matter, the state agencies typically pick the highest background concentration of the four points surrounding the location of interest. A screenshot showing 1-hour SO_2 background concentrations (in parts per billion) around Tacoma LNG is below.

[113] PSE-0360, PSCAA 2017 Air Quality Data Summary (July 2018).



Q: WHAT IS THE SOURCE OF THE BACKGROUND DATA PROVIDED BY THE AGENCY COLLABORATION?

A: These data are a combination of model and monitoring data from July 2014 through June 2017. The monitored data are used along with land use data (the location of roads, forests, lakes, etc.) to tune the model results to ensure that as much information as possible is taken into account, in order to get the most accurate background concentrations.

Q: ARE THESE BACKGROUND CONCENTRATION DATA BASED ON AN EPA MODEL?

A: Yes. The overall modeling system is called AIRPACT. AIRPACT comprises an emissions inventory, meteorological data, and a regional air quality model. The regional model used in AIRPACT is the Community Multiscale Air Quality (CMAQ) model, a regional model developed by EPA. CMAQ is used by states and EPA to plan for compliance with NAAQS.

Q: IS THE METEOROLOGY USED IN ESTIMATING THE BACKGROUND CONCENTRATION DATA RELIABLE?

A: Yes. The meteorology comes from the Weather Research and Forecasting (WRF) model. The effort to develop WRF began in the late 1990's and was a collaborative partnership of the United States National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration, the U.S. Air Force, the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). Here, the University of Washington ran the WRF model to develop the meteorology used in the AIRPACT modeling system.

Q: DOES THE MODEL USED TO ESTIMATE BACKGROUND CONCENTRATION DATA TAKE INTO ACCOUNT ALL SOURCES OF EMISSIONS?

A: Yes. The emissions that are included in the model come from industry, traffic, and even the small emissions that come from housing and offices.

Q: WHAT MONITORED DATA ARE CONSIDERED IN THE MODELING DATA THAT IS USED TO TUNE THE MODEL RESULTS?

A: All available criteria pollutant data is used in the model, except for data that is known to be impacted by extreme events, such as $PM_{2.5}$ from wildfires, and PM_{10} from windstorms.

Q: ARE THESE BACKGROUND DATA ACCEPTED FOR REGULATORY PURPOSES?

A: The guidance for this background data explicitly states that "these background concentrations could be used in support of most minor source permit applications in Washington, Oregon and Idaho after speaking with your permitting authority."[114] PSCAA routinely uses this data for minor source permitting, as we used it to provide a broader evaluation of air quality as described below.

[114] Agency Collaboration Database, Background Concentrations 2014 – 2017, https://idahodeq.maps.arcgis.com/apps/MapSeries/index.html?appid=0c8a006e11fe4ec5939804b873098dfe

Q: DOES THIS PROCESS ALLOW AN ACCURATE EVALUATION OF WHETHER THE SOURCE HAS THE POTENTIAL TO CAUSE OR CONTRIBUTE TO EXCEEDANCES OF THE WAAQS AND NAAQS?

A: This process is a conservative estimate (*i.e.*, higher) of whether the source that is being permitted has the potential to cause or contribute to an ambient air quality standard. The WAAQS and NAAQS have a form which specifies how many exceedances of a concentration will result in an exceedance of a WAAQS and/or NAAQS. In this case, Landau found only pollutant, for one averaging time, was equal to or exceeded the Threshold Values contained in Table 4a of WAC 173-400-113: 24-hour average of $PM_{2.5}$, where the modeled concentration from the source equaled the threshold value.[115] The form of the $PM_{2.5}$ 24-hour standard is the 98th percentile averaged over three years, or the average of the eighth highest value in each year, not the maximum modeled over the modeling period. Therefore, the addition of the modeled maximum value to the background data is a conservative (*i.e.*, overestimate) of the impact of the proposed source on air quality, as compared to the WAAQS and NAAQS.

[115] RA-68, Final NOC Worksheet at 57.

OPINION 8: THE NOC APPLICATION APPROPRIATELY USED REPRESENTATIVE METEOROLOGICAL DATA IN THE AIR DISPERSION MODELING.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE METEOROLOGICAL DATA USED IN THE MODELING.

A: It is my opinion that the meteorological data used in the air dispersion modeling for the permit application were processed according to the applicable regulatory standards; that the meteorological data are not only representative, but site-specific; and that they provide a reliable basis for the dispersion modeling.

Q: HOW ARE METEOROLOGICAL DATA USED IN AIR DISPERSION MODELING?

A: Meteorological data, or "met data," are used as a critical input into the dispersion models. Meteorological data—including wind speed, wind direction, temperature, and relative humidity—are used to help the model understand where and how pollutants disperse.

Q: HOW DOES THE MODELER DETERMINE WHAT MET DATA TO USE?

A: Guidance on how to determine what meteorological data to use can be found in Appendix W of 40 C.F.R. Part 51. According to Appendix W, "the meteorological data used as input to a dispersion model should be selected on the basis of spatial

and climatological (temporal) representativeness."[116] Appendix W also states that "the representativeness of the measured data is dependent on numerous factors including, but not limited to: (1) The proximity of the meteorological monitoring site to the area under consideration; (2) the complexity of the terrain; (3) the exposure of the meteorological monitoring site; and (4) the period of time during which data are collected." [117] It goes on to note that large distances between the source and the location of the meteorological station, as well as terrain features, can affect the spatial representativeness of the data.

Q: DOES MET DATA NEED TO BE COLLECTED AT THE SITE OF THE PROPOSED FACILITY TO BE REPRESENTATIVE?

A: No. Met data may be representative even if it is collected off-site, pursuant to applicable EPA guidance. Appendix W defines the sources of met data that can be used in this context. These are, in hierarchical order: site-specific meteorological data, surface observations recorded by the National Weather Service ("NWS"), and prognostic meteorological modeling data processed through the Mesoscale Model Interface ("MMIF"). All three sources of data inputs are acceptable, as long as the data are "adequately representative."[118] On-site data are not required. Indeed, the Agency routinely issues permits where modeling has been conducted using representative meteorological data that were not collected "on-site."

[116] A-PTI0419.
[117] *Id.*
[118] *Id.*

Q: WHAT MET DATA DID LANDAU USE IN ITS AIR DISPERSION MODELING FOR TACOMA LNG?

A: The air dispersion modeling assessment for Tacoma LNG used four met data sets. Each of the data sets relied upon met data from the Tideflats monitoring site to characterize wind speeds and wind direction. The Tideflats monitoring site is the closest monitoring site to the Tacoma LNG facility. However, the Tideflats site does not report temperature, relative humidity, atmospheric pressure, or cloud cover. Those parameters were acquired from alternative sites consistent with Appendix W and AERMET modeling norms. These sites include two NWS sites, McChord Air Force Base ("KTCM") and the SeaTac airport ("KSEA"); and one alternative local site, the South Tacoma L Street station.[119] They are depicted below. These were combined to produce four meteorological data sets. The two surface sets were (1) the Tideflats station alone and (2) the Tideflats station with data gaps filled in by data collected at the Tacoma L Street station. The two NWS sites were KTCM and KSEA. These two surface sets were combined with the two NWS data sets to produce four sets of data.

Landau used five years of data from the Tideflats monitoring site,[120] where every quarter in every year used was over 90% complete, as is required by Appendix W. One year, 2012, did not meet that completeness criteria and was excluded.

[119] RA-68, Final NOC Worksheet at 54–55.
[120] RA-27, PSE Submittal on Tacoma LNG Project Air Quality Modeling (September 8, 2017).

Q: IS IT APPROPRIATE TO COMBINE MET DATA FROM VARIOUS MONITORING SITES FOR DISPERSION MODELING?

A: Yes, it is consistent with the applicable regulatory standards and accepted common practice. Modelers use a program called "AERMET" to process met data for use in air dispersion modeling. AERMET includes algorithms to identify and fill any gaps in met data. Data gaps are a common occurrence in met data sets, and the algorithms in AERMET are designed to be consistent with the requirements and recommendations in Appendix W. Appendix W provides that missing records (*i.e.*, individual hours) within a data set that is otherwise considered complete may

be substituted with adequately representative alternative data—often NWS data.[121] This type of data-filling is the default behavior of AERMET when using site-specific data and is standard, accepted practice. The dispersion modeling used all four of the AERMET-processed data sets for both criteria air pollutants and TAPs.

Q: ARE THOSE MET DATA SETS REPRESENTATIVE OF THE METEOROLOGICAL CONDITIONS AT THE TACOMA LNG SITE?

A: Yes. It is my opinion that the meteorological data are not only representative, but site-specific; and that they provide a reliable basis for the dispersion modeling. Contrary to what is stated by Dr. Sahu, this is more than a simple matter of distance to the site. As shown below, the Tideflats monitoring site is within a mile of the Tacoma LNG facility; on the same pier; and has matching terrain, similar land use, and similar distance to over-water influence.

[121] A-PTI0419.

However, because the Tideflats site does not report temperature, relative humidity, atmospheric pressure, or cloud cover, those parameters were acquired from the other listed meteorological stations. Because (1) the data collected at the Tideflats station meet EPA's 90% completeness requirement, (2) the stations providing the alternative data are representative, and (3) the gap-filling was processed by AERMET consistent with Appendix W, the resulting data sets are representative of the spatial and temporal meteorological conditions at the Tacoma LNG site.

Q: HOW DO YOU KNOW THAT THE COMBINED MET DATA SETS RESULTED IN RELIABLE AIR DISPERSION MODELING RESULTS?

A: The results of Landau's air dispersion modeling analysis indicate that the modeled concentrations are not sensitive to the variability of the meteorological parameters that exists across the four scenarios considered, as all of the modeled scenarios provided results very close to one another.[122] Additionally, I assessed the variability of temperature, relative humidity, and atmospheric pressure across the meteorological monitoring sites and found them to be generally consistent with one another.[123]

Q: DOES DR. SAHU'S ANALYSIS OF THE BUOY MET DATA SUPPORT HIS CLAIM THAT THE TIDEFLATS DATA IS NOT REPRESENTATIVE OF THE SITE?

A: No. Dr. Sahu takes met data from a site with poor data and compares it to the Tideflats monitor data. Because they are inconsistent according to his analysis, he deems the Tideflats site "non-representative." It is akin to grading a student's test with the wrong answer key. The student's test answers aren't incorrect, simply because the answer key is. The met data cited by Dr. Sahu appears to be of poor data quality. Although the met data were collected at a site run by NOAA, trees

[122] RA-68, Final NOC Worksheet at 56.

[123] PSE-0212, AERMET-SFC-Data-McChordAFB(TCM)-Data-For-Fig-Comparison-of-met.-parameters-SeaTac-McChordAFB-LStreet (spreadsheet); PSE-0213, AERMET-SFC-Data-SeaTac-Data-For-Fig-Comparison-of-met.-parameters-SeaTac-McChordAFB-LStreet (spreadsheet).

have been permitted to grow very close to the met station, which violates standard siting guidelines for met stations. These guidelines are designed to prevent local features from unduly influencing the wind speed and wind direction data collected at the station. This appears to be the case with the NOAA data.

Q: WHAT IS THE BUOY MET STATION?

A: The NOAA National Data Buoy Center meteorological station TCMW1 is not actually located on a buoy; it is located at the edge of the water on a point of land between the Blair and Sitcum Waterways in the Tacoma Tideflats area. According to information about the station provided by NOAA on the internet the current station was installed on Feb 5, 2005.[124] The anemometers are elevated 22.3 feet above grade.

[124] *See* NOAA Tides & Currents, Tacoma MET, WA - Station ID: 9446482, https://tidesandcurrents.noaa.gov/stationhome.html?id=9446482#info.

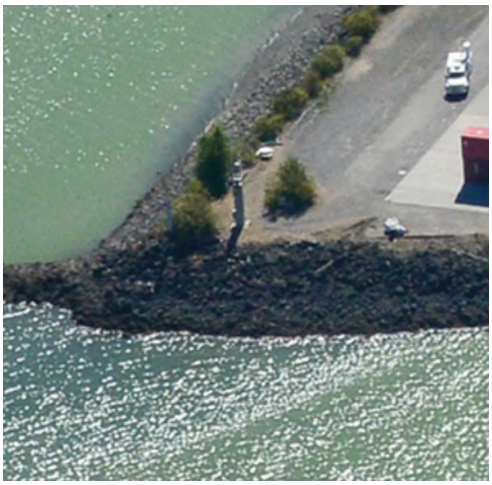
Q: PLEASE DESCRIBE THE TREES THAT ARE GROWING NEAR THE STATION.

Historical photographs indicate that at least one, and possibly more than one, tree has been allowed to grow immediately adjacent to the northeast of the station. A photograph of the station provided on the NOAA station information website (link provided above) shows a tree of a size comparable to that of the station located immediately to the right of the station. In addition, the Oblique Shoreline Aerial Photos database managed by the Washington Department of Ecology[125] show that, in 2006, there were no obstructions in the vicinity of the station.[126] Relevant selections of these photos are shown below. However, in 2016 there were several trees near the station, including one or two located immediately adjacent to the station to the northeast.[127] Relevant sections of these photos are shown below.

[125] *See* Oblique Shoreline Aerial Photos (Mar. 6, 2018), https://wacoastalnetwork.com/oblique-shoreline-aerial-photos.
[126] PSE-0356, Ecology Photo of Tacoma LNG Property Shoreline, July 27, 2006 (1:14 PM); PSE-0357, Ecology Photo of Tacoma LNG Property Shoreline, July 27, 2006 (1:15 PM).
[127] PSE-0358, Ecology Photo of Tacoma LNG Property Shoreline, July 29, 2016 (10:52 AM - Photo 1); PSE-0359, Ecology Photo of Tacoma LNG Property Shoreline, July 29, 2016 (10:52 AM - Photo 2).

2006

2016



Q: WHY ARE THE TREES PROBLEMMATIC?

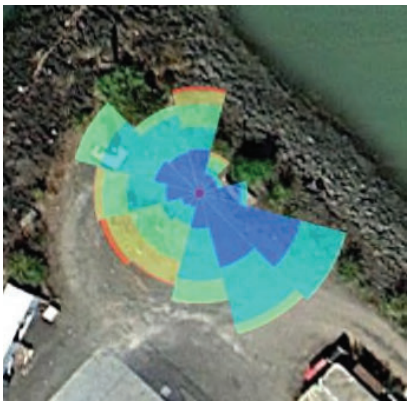
A: The proximity of the trees is inconsistent with the regulatory siting guidelines designed to ensure high-quality met data collection. EPA provides guidance for siting meteorological stations used to collect data to be used for regulatory air dispersion modeling.[128] Section 3 of this document provides guidance on siting and exposure of meteorological towers and sensors for the in-situ measurement of the primary meteorological variables, including wind speed and wind direction.

Q: HOW DO YOU KNOW THE NOAA DATA IS UNDULY INFLUENCED BY THE TREES?

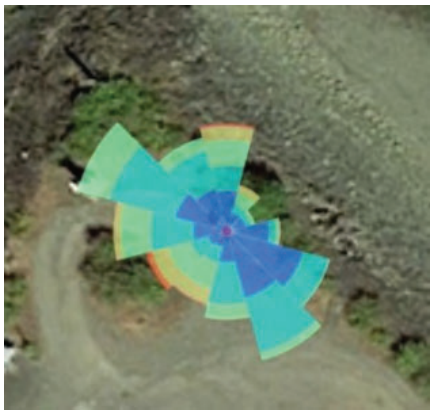
To investigate the potential impact of the adjacent trees on the data collected by TCMW1, I created wind roses for the NOAA met station for each of the years examined by Dr. Sahu (*i.e.*, 2011 and 2013 through 2016).[129] A wind rose is a visual depiction of wind speed and wind direction data over a set period of time. Wind speed and direction are visualized as petals emanating from the location of the monitor site. These wind roses are displayed below, with each superimposed on an aerial photograph of the station site. In each case, the occurrence of winds

[128] PSE-0130, EPA Meteorological Monitoring Guidance for Regulatory Modeling Applications (February 2000), https://www.epa.gov/sites/production/files/2020-10/documents/mmgrma_0.pdf .
[129] PSE-0317; 2011 TCMW1 Windrose with 2011 Aerials (Mar. 18, 2021), PSE-0319, 2013 TCMW1 Windrose with 2013 Aerials (Mar. 18, 2021); PSE-0321, 2014 TCMW1 Windrose with 2014 Aerials (Mar. 18, 2021); PSE-0323, 2015 TCMW1 Windrose with 2015 Aerials (Mar. 18, 2021); PSE-0325, 2016 TCMW1 Windrose with 2016 Aerials (Mar. 18, 2021).

from the north east, the direction of the nearest tree or trees, are notably suppressed. It is likely that the reduced elevation of the anemometers (*i.e.*, 22.3 feet above grade instead of the 32.8 feet recommended by guidance) serves to facilitate the impact of the trees on the wind data collected at the station. EPA guidance indicates that obstructions can be overcome by installing the sensor at such height that it is reasonably unaffected by local obstructions and represents the approximate wind values that would occur at 10 meters in the absence of the obstructions. Based on (1) the siting of this station in close proximity to, and (2) at approximately the same height above grade as, the nearby trees, data collected at TCMW1 in the years investigated by Dr. Sahu are not suitable for use in air dispersion modeling, nor are they appropriate for comparison to another meteorological station, particularly one sited in accordance with EPA guidelines.



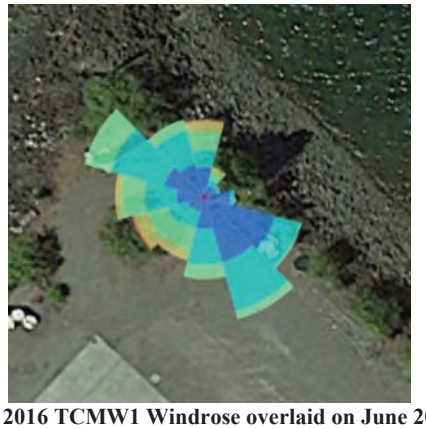
2011 TCMW1 Windrose overlaid on August 2011 Aerial Photograph



2014 TCMW1 Windrose overlaid on July 2014 Aerial Photograph

2013 TCMW1 Windrose overlaid on May 2013 Aerial Photograph

2015 TCMW1 Windrose overlaid on April 2015 Aerial Photograph



2016 TCMW1 Windrose overlaid on June 2016 Aerial Photograph

Q. IS THE TIDEFLATS MONITOR IMPACTED BY NEARBY INFRASTRUCTURE?

A: No. Dr. Sahu shows two photographs from a nearly identical angle to attempt to support his contention that the Tideflats site data collection is "likely impacted by nearby infrastructure (including parked trains)."[130] This met site was chosen by Ecology and is maintained by PSCAA. When it was sited, it is reasonable to assume that Ecology incorporated normal siting requirements. This typically includes taking pictures from the site to every angle. Those pictures can be found on Ecology's website, and a few are repeated below.[131] They show no obstructions consistent with siting guidance from any angle. Dr. Sahu has presented no analysis whatsoever to support his contention that Tideflats data collection is "likely" impacted by nearby infrastructure. This is conjecture, plain and simple. The fact that Ecology not only sited the monitor, but then took photographs confirming their assessment of the siting, indicates that this monitor is sited consistent with guidance and would not be "impacted by nearby infrastructure."

[130] Sahu Testimony ¶ 77.
[131] PSE-0361.

View North of the Tideflats Station

View South of the Tideflats Station

View Northeast of the Tideflats Station

View Southwest of the Tideflats Station

View East of the Tideflats Station

View West of the Tideflats Station

View Southeast of the Tideflats Station

View Northwest of the Tideflats Station

Q. WAS DR. SAHU'S ANALYSIS TO EVALUATE WHETHER METEOROLOGICAL DATA SETS ARE SIMILAR REASONABLE?

A. No. Dr. Sahu adopted a simplistic analysis that has no bearing on whether the sites are similar for the purposes of air dispersion modeling, and is in fact, designed to highlight differences in the meteorological data set. Dr. Sahu had multiple options available to him for appropriately comparing met data, had the buoy station been properly sited. He could have evaluated wind roses. Dr. Sahu did not do that. He could have presented frequency distributions of the two sets of wind speeds and wind directions. Dr. Sahu did not do that. Yet another method would be to prepare a plot of diurnal wind speed or wind direction as a function of time and/or season. But Dr. Sahu did not do that. Dr. Sahu simply presented a comparison of differences in wind speed and wind direction on an hour-by-hour basis which has little bearing on whether the Tideflats monitor is representative of the site, particularly since the buoy monitor is blocked by a large tree hanging over it.

OPINION 9: TACOMA LNG WILL NOT CAUSE OR CONTRIBUTE TO A VIOLATION OF ANY AMBIENT AIR QUALITY STANDARD.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING TACOMA LNG'S IMPACT ON THE AMBIENT AIR QUALITY STANDARDS?

A: Tacoma LNG's emissions are not expected to cause or contribute to a violation of the ambient air quality standards for any criteria pollutants, based on the modeling performed by Landau. As I have already explained in Opinion 8, Landau's air dispersion modeling used proper meteorological data inputs. I performed additional analysis to determine whether different stack temperature and stack velocity inputs would have meaningfully changed the results. I conclude that they would not. Dr. Sahu has undertaken no analysis of his own to support a contrary conclusion. He has undertaken no air dispersion modeling. He therefore has no basis to suppose that "corrected" air dispersion modeling would result in higher results as opposed to lower results. Dr. Sahu merely assumes that the results of corrections that he has not evaluated would be materially higher. Based on my analysis, and the Agency's, Tacoma LNG's emissions will not cause or contribute to a violation of ambient air quality standards. In fact, given how far below those standards the Tacoma area is, even the addition of maximum emissions from Tacoma LNG does not bring the area close to the ambient air quality standards.

Q: WHAT ARE THE AMBIENT AIR QUALITY STANDARDS?

A: The National Ambient Air Quality Standards are the standards for outdoor air for six common air pollutants known as criteria air pollutants ("CAPs"). These CAPs are carbon monoxide ("CO"), lead, nitrogen dioxide ("NO_2"), ozone, PM (both PM_{10} and $PM_{2.5}$), and sulfur dioxide ("SO_2"). There are also Washington Ambient Air Quality Standards ("WAAQS") for CAPs, which are the same as the NAAQS.

Q: DESCRIBE HOW LANDAU ASSESSED WHETHER TACOMA LNG'S EMISSIONS WOULD CAUSE OR CONTRIBUTE TO EXCEEDANCES OF THE WAAQS OR NAAQS.

A: If a proposed new minor source like Tacoma LNG shows that it will not exceed the threshold values for criteria pollutants provided in Table 4a of WAC 173-400-113, then the proposed new source will be deemed to not cause or contribute to a violation of the WAAQS or NAAQS. Landau conducted air dispersion modeling to determine the impact of Tacoma LNG on the WAAQS and NAAQS, even though such modeling was not required by the Agency for this NOC application.[132] Landau's dispersion modeling followed Ecology's protocol for sources that will be constructed in areas that are attaining the WAAQS and NAAQS. Consistent with Ecology's protocol, NOx emissions are used to estimate NO_2 concentrations. Landau identified the air pollutants that would be emitted by each emitting unit at the facility, calculated the criteria pollutant potential to emit for each such unit, modeled those emissions, and compared the modeled ambient concentrations to the Table 4a threshold values.

The table below shows modeling data from the permit application, listing each criteria pollutant, the ambient air quality standard, the applicable threshold value,

[132] *See* RA-68, Final NOC Worksheet at 56.

the modeled concentration from Tacoma LNG, and the operating scenario that resulted in the worst-case modeled concentration.

Modeling Results Compared to NAAQS and WAAQS Values

Criteria Pollutant	Averaging Period	NAAQS/ WAAQS ($\mu g/m^3$)	Threshold Value[a] ($\mu g/m^3$)	Modeled Concentration[b] ($\mu g/m^3$)	Scenario
CO	8-hour	10,000	500	11	Vaporizing + Transfer Case B
	1-hour	40,000	2,000	25	Vaporizing + Transfer Case A2
SO_2	Annual	52	1	0.35	Liquefying Case 1
	24-hour	260	5	3.9	Liquefying Case 1
	3-hour	1,310	25	12	Liquefying Case 1
	1-hour	200	30	26	Liquefying Case 1
PM_{10}	Annual	--	1	0.017	Liquefying Case 3
	24-hour	150	5	1.2	Vaporizing + Transfer Case A2
$PM_{2.5}$	Annual	12	0.3	0.017	Liquefying Case 3
	24-hour	35	1.2	1.2	Vaporizing + Transfer Case A2
NO_2	Annual	100	1	0.043	Liquefying Case 2
	1-hour	188	7.5[c]	5.9	Vaporizing + Transfer Case A2

[a] Cause or contribute threshold value from WAC 173-400-113, Table 4a.

[b] Highest first high value for all receptors over all meteorological data sets.

[c] Represents EPA's interim 1-hour NO_2 significant impact level.

The chart shows that the predicted ambient CAP concentrations from the Tacoma LNG facility as calculated by Landau are below and—in most cases, substantially below—the threshold values for all pollutants or averaging periods other than 24-hour $PM_{2.5}$. All modeled concentrations from Tacoma LNG are a small proportion of the ambient air quality standards. The modeling showed that maximum $PM_{2.5}$ emissions resulted in ambient impacts that were right at the threshold value for $PM_{2.5}$. However, when the Agency considered background concentrations of $PM_{2.5}$ in the area of Tacoma LNG along with the modeled concentration, the maximum impacts of $PM_{2.5}$ directly attributable to Tacoma LNG were determined not to cause or contribute to a violation of the WAAQS or NAAQS. Specifically, on page 57 of the final Notice of Construction Worksheet, the Agency added the modeled 1.2 µg/m3 from Tacoma LNG to the background value of 25.4 µg/m3[133] to reach a total of 26.6 µg/m3. The Agency properly determined that this is well under the 35 µg/m3 level of the ambient air quality standard.

[133] For background values, the Agency used background concentrations of $PM_{2.5}$ measured at the Tideflats $PM_{2.5}$ monitor. The Agency arrived at the background figure by using the average the 98th percentile of ambient measurements over a three years period, as required by the form of the standard. Importantly, PSCAA did not exclude "exceptional events" from this background data. The data from 2017 was impacted by wildfires, which increased the background levels of $PM_{2.5}$. PSE-0360, PSCAA, 2017 Air Quality Data Summary (July 2018). The means that the assumed background levels of $PM_{2.5}$ are likely higher than actually are present under typical (i.e., non-wildfire) conditions, which further strengthens the determination that the predicted concentrations of $PM_{2.5}$ from Tacoma LNG will not exceed the NAAQS/WAAQS.

Q: IN YOUR OPINION, DID LANDAU PROPERLY ADDRESS CRITERIA AIR POLLUTANTS IN THE TACOMA LNG NOC PERMIT APPLICATION?

A: Yes, I believe that Landau's modeling properly addressed the impact that Tacoma LNG will have on the WAAQS and NAAQS. Landau's approach to quantifying the project's impacts on ambient air quality was particularly conservative. As discussed previously, the assumed $PM_{2.5}$ emission rates for Tacoma LNG that were used as inputs for Landau's air dispersion modeling are likely overestimates of what source testing will measure at the facility. $PM_{2.5}$ is the only CAP with a modeled concentration equal to a threshold value.

Q: DID YOU CONDUCT ANY ADDITIONAL ANALYSIS TO SUPPORT THIS OPINION?

A: Yes, I conducted two additional analyses that I have mentioned above: (1) a sensitivity analysis whereby I analyzed results using hypothetical worst-case stack and exit temperature and exit velocity,[134] and (2) re-modeling using stack exit temperature and exit velocity from Dr. Smith's CFD modeling.[135] I undertook these analyses to respond to Dr. Sahu's concerns that Landau's use of a uniform 1600°F stack temperature, and use of exit velocities from CB&I, would result in understated ambient concentrations. The results of these analyses thus add extra

[134] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).
[135] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final, March 19, 2021

conservatism to the results in the permit. I left all other modeling parameters the same.

Q: PLEASE EXPLAIN THE REASONING BEHIND THE SENSITIVITY ANALYSIS.

A: The sensitivity analysis looked at the impact of unrealistic[136] worst-case exit temperatures and exhaust velocities for the flare on the modeling results, leaving everything else the same.[137] A sensitivity analysis is essentially an experiment in changing inputs to a model. It allows you to see whether a change in one, or several, parameters, while keeping all other parameters unchanged, will change the results of the original analysis. This can help you understand how much impact a particular parameter, or set of parameters, has on the outcome of the modeling.

This allowed me to assess whether other temperatures or velocities other than the ones utilized by Landau would impact the modeling results. In other words, how would changes to the flare's expected stack parameters change the expected concentrations of criteria air pollutants?

[136] Dr. Sahu misunderstands the sensitivity analysis. It is not an analysis of "other plausible values for stack temperature and velocity." ¶ 102. The analysis uses worst case values that are not expected to occur, for the purpose of bounding the analysis.

[137] I also conducted a refined sensitivity analysis using Dr. Smith's temperature and exit velocity values. These results similarly show that Tacoma LNG is not predicted to cause or contribute to violations of ambient air quality standards or exceedances of the ASILs. *See* PSE-0138, XQ Modeling Assessment Results – Updated XQ parameters Flare Expert (March 5, 2021).

In the sensitivity analysis, I used unrealistic worst-case stack parameters that were much lower temperature and lower exit velocity than used by Landau, and much lower than would be expected, to evaluate the impact of these parameters on modeled ambient concentrations. Lower temperature and lower exit velocity result in less dispersion and greater ambient impact. For example, while Landau modeled all flaring cases at 1600°F (with varying exit velocities provided by the flare manufacturer), I evaluated at much lower temperatures (and also much lower exit velocities). For example, for temperature, I evaluated worst-case modeling results at temperatures ranging from 800°F to 1340°F for Liquefying Cases 1-5 and a temperature as low as 170°F for the Holding Case (including combinations of holding and purging). These are also significantly lower than the temperatures predicted by Dr. Smith using CFD modeling.

The parameters I used in the sensitivity analysis are shown in the table below, along with the parameters used in the original permit modeling (temperatures are provided in Kelvin rather than Fahrenheit).

	Original NOC Application Parameters		Sensitivity Analysis Parameter Assumption	
	Temperature (K)	Velocity (m/s)	Temperature (K)	Velocity (m/s)
LW1	1144.3	3.87	950	3
SW2	1144.3	0.96	700	0.7
LW3	1144.3	11.82	1000	8
LW4	1144.3	12.47	1000	9
LW5	1144.3	12.73	1000	9
FLAREH	1144.3	0.32	350	0.25
LWSC1A1	1144.3	5.36	950	3
LWSC3A1	1144.3	13.31	1000	8
LWSC4A1	1144.3	13.96	1000	9
LWSC5A1	1144.3	14.22	1000	9
LWSC1A2	1144.3	4.64	950	3
LWSC3A2	1144.3	12.6	1000	8
LWSC4A2	1144.3	13.24	1000	9
LWSC5A2	1144.3	13.5	1000	9
LWSC1B	1144.3	4.23	950	3
LWSC3B	1144.3	12.18	1000	8
LWSC4B	1144.3	12.83	1000	9
LWSC5B	1144.3	13.09	1000	9
SWSC2A1	1144.3	2.45	700	0.7
SWSCHA1	1144.3	1.82	350	0.8
SWSC2A2	1144.3	1.73	700	0.7
SWSCHA2	1144.3	1.1	350	0.8
SWSC2B	1144.3	1.31	700	0.7
SWSCHB	1144.3	0.68	350	0.35

Q: WHAT WERE THE RESULTS OF YOUR SENSITIVITY ANALYSIS?

A: The sensitivity analysis shows that even if the flare were to experience significantly different temperatures or stack velocities (even ones I consider to be so extreme as to be unrealistic), Tacoma LNG's emissions will not cause or contribute to a violation of the ambient air quality standards.[138] This is consistent with the modeling results presented by Landau to the Agency and the conclusion the Agency drew from those modeling results.

[138] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).

More specifically, the analysis demonstrated that the majority of the hypothetical flare operating cases would not result in ambient air concentrations exceeding the threshold values for the WAAQS or NAAQS set forth in Table 4a of WAC 173-400-113. The few exceptions under this sensitivity analysis were for 1-hour NO_2 and 24-hour $PM_{2.5}$ (for certain flare holding and vaporizing cases) and 1-hour SO_2 (for certain liquifying cases). The modeled values for the hypothetical operating scenarios that exceeded the thresholds did so by relatively small amounts.

The results are shown in the following table:

Criteria Pollutant	Averaging Period	NOC Max (µg/m3)	Sensitivity Max (µg/m3)	Screening Threshold (µg/m³)	Sensitivity At/Over Threshold?
CO	8-hour	11	19	500	No
	1-hour	25	49	2,000	No
SO_2	annual	0.35	0.41	1	No
	24-hour	4.0	4.4	5	No
	3-hour	12	15	25	No
	1-hour	26	32	30	Yes
PM_{10}	annual	0.017	0.026	1	No
	24-hour	1.2	2.1	5	No
$PM_{2.5}$	annual	0.017	0.026	0.3	No
	24-hour	1.2	2.1	1.2	Yes
NO_2	annual	0.043	0.046	1	No
	1-hour	5.9	12	7.5	Yes

Q: DID YOU MAKE ADDITIONAL COMPARISONS TO THE AMBIENT AIR QUALITY STANDARDS USING BACKGROUND DATA?

A: Yes. As is appropriate, for those three criteria pollutants exceeding the threshold values in this hypothetical screening analysis, I combined the modeled ambient impacts from Tacoma LNG with background concentrations for these criteria air

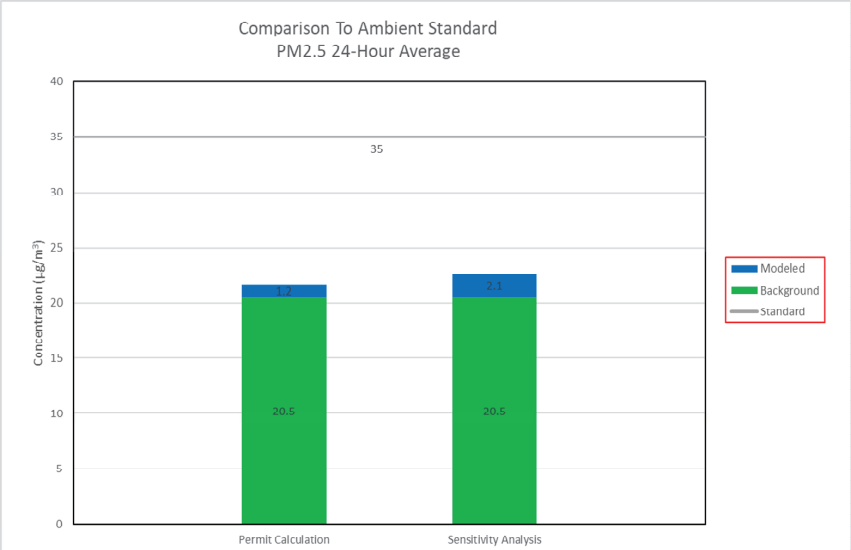
pollutants in the surrounding area as the Agency did for $PM_{2.5}$ in the permit. This analysis shows that these emissions from Tacoma LNG would not cause or contribute to violations of the WAAQS or NAAQS, and in fact, would not be close. Thus, even under these hypothetical operational scenarios, there would be no change to the Agency's conclusions that Tacoma LNG will not cause or contribute to a violation of the ambient air quality standards. This is a very conservative analysis, as the elevated CAP emissions could only occur if the hypothetical flare operating scenario with the very low exhaust velocities and temperatures takes place during the very hour in which the meteorological data maximizes the concentration impacts. In addition, this screening sensitivity analysis artificially inflated modeling results from the vaporizer, which is not subject to this sensitivity analysis

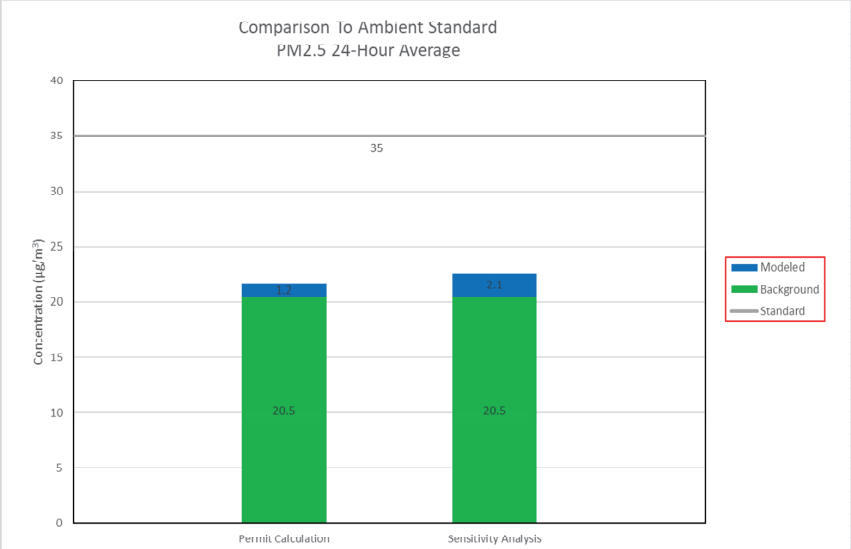
The results of the sensitivity analysis, including background, are shown in the table below.

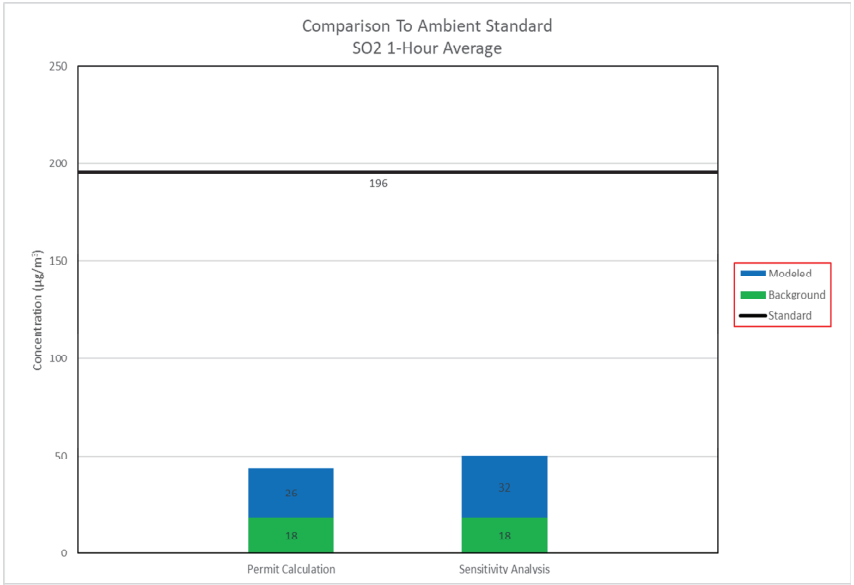
Criteria Pollutant	Averaging Period	Max Concentration	Screening Threshold	Background	Total	Ambient Standard	Max / Standard
		($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	
CO	8-hour	19	500	1,282	1,301	10,000	0.13
	1-hour	49	2,000	1,843	1,892	40,000	0.047
SO_2	Annual	0.41	1	1.6	2.0	52	0.038
	24-hour	4.4	5	7.6	12	260	0.046
	3-hour	15	25	20	35	1,310	0.027
	1-hour	32	30	18	50	196	0.26
PM_{10}	Annual	0.026	1	6.9	6.9	--	--
	24-hour	2.1	5	43.9	46	150	0.31
$PM_{2.5}$	Annual	0.026	0.3	6.9	6.9	12	0.58
	24-hour	2.1	1.2	20.5	23	35	0.65
NO_2	Annual	0.046	1	32.7	33	100	0.33
	1-hour	12	7.5	89.1	101	188	0.54

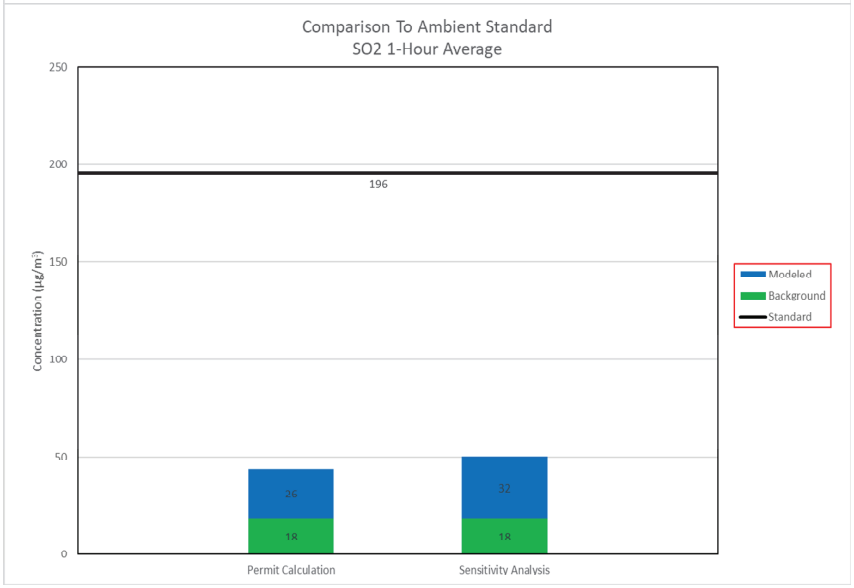
This chart compares the modeled maximum concentration from Tacoma LNG with the screening threshold, adds the background from the collaborative agency effort described earlier, and provides the total, which can be compared with the ambient standards. The final column shows the proportion of the summed amount compared with the ambient standard. So, in other words, for 8-hour CO, the total of Tacoma LNG and background is 13% of the ambient standard. But this is almost all made up of background as can be seen (background is 1,282 and Tacoma LNG is 19).

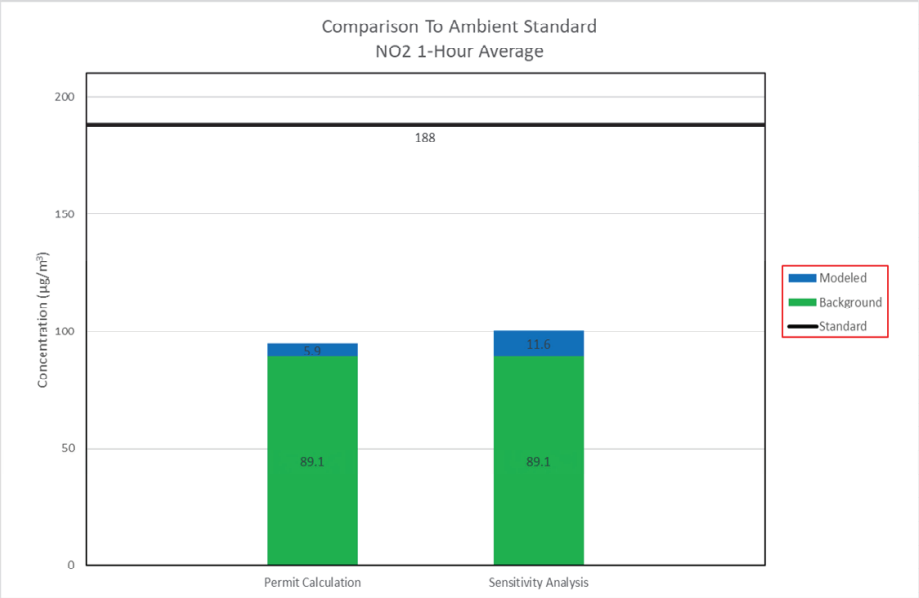
These results can be visualized in some graphs to show that maximum ambient concentrations from Tacoma LNG, even when added to background, are very far below the ambient standards. The examples below are for 24-hour $PM_{2.5}$, 1-hour SO_2, and 1-hour NO_2, which are the three criteria air pollutants that are slightly over the threshold value in this sensitivity analysis. In each chart, the green bar represents background, the blue bar represents the modeled contribution from Tacoma LNG and the black represents the ambient air quality standard. The charts show the original permit modeling and the sensitivity analysis. These charts demonstrate that even with the hypothetical, worst-case stack parameters, with artificially inflated vaporizer impacts, Tacoma LNG does not cause or contribute to violations of the ambient air quality standards.

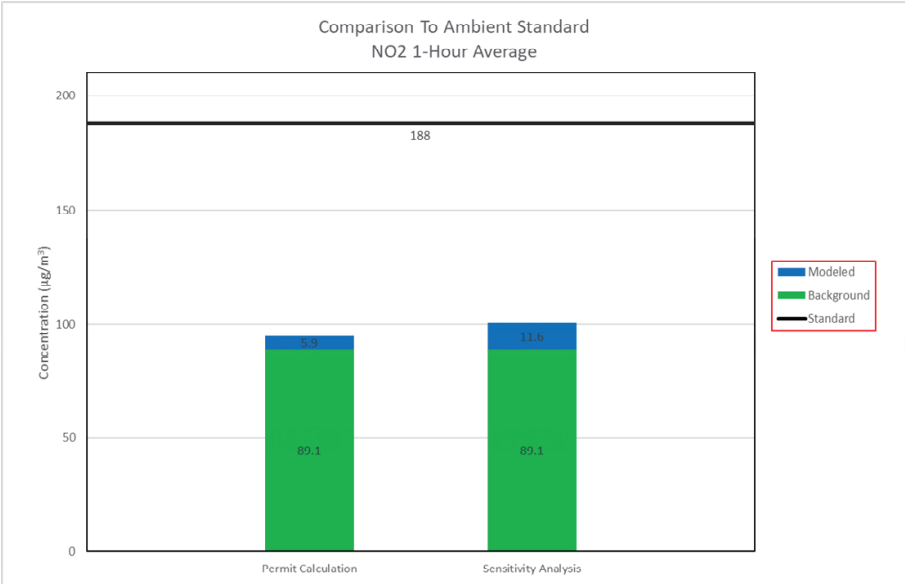

Comparison To Ambient Standard
PM2.5 24-Hour Average
Concentration (µg/m³)
40
35
30
25
20
15
10
5
0
35
1.2
20.5
2.1
20.5
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard


Comparison To Ambient Standard
PM2.5 24-Hour Average
Concentration (µg/m³)
40
35
30
25
20
15
10
5
0
35
1.2
20.5
2.1
20.5
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard


Comparison To Ambient Standard
SO2 1-Hour Average
Concentration (µg/m³)
250
200
150
100
50
0
196
26
18
32
18
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard


Comparison To Ambient Standard
SO2 1-Hour Average
Concentration (µg/m³)
250
200
150
100
50
0
196
26
18
32
18
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard


Comparison To Ambient Standard
NO2 1-Hour Average
200
150
100
50
0
Concentration (µg/m³)
188
5.9
89.1
11.6
89.1
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard


Comparison To Ambient Standard
NO2 1-Hour Average
200
150
100
50
0
Concentration (µg/m³)
188
5.9
89.1
11.6
89.1
Permit Calculation
Sensitivity Analysis
Modeled
Background
Standard

Q: PLEASE DESCRIBE THE RESULTS OF YOUR SECOND ANALYSIS USING STACK PARAMETERS FROM DR. SMITH.

A: The modeling results using Dr. Smith's stack parameters are highly consistent with Landau's results used for the permit. Like the modeling done for the permit, re-running the model using stack parameters from Dr. Smith predicts that ambient impacts from Tacoma LNG will be at or above the screening threshold in WAC 173-400-113 for only 24-hour $PM_{2.5}$, which was just at the threshold.[139]

The following tables show the highest modeled concentrations for each pollutant from both the modeling undertaken by Landau supporting the permit and my re-run modeling using Dr. Smith's stack temperature and exit velocity values.

Criteria Pollutant	Averaging Period	NOC Max (µg/m3)	Re-run Max (µg/m3)	Screening Threshold (µg/m³)	At/Over Threshold?
CO	8-hour	11	11	500	No
	1-hour	25	25	2,000	No
SO_2	annual	0.35	0.38	1	No
	24-hour	4.0	4.1	5	No
	3-hour	12	13	25	No
	1-hour	26	28	30	No
PM_{10}	annual	0.017	0.019	1	No
	24-hour	1.2	1.2	5	No
$PM_{2.5}$	annual	0.017	0.019	0.3	No
	24-hour	1.2	1.2	1.2	Yes
NO_2	annual	0.043	0.061	1	No
	1-hour	5.9	7.1	7.5	No

Thus, using stack parameters provided by Dr. Smith, which have lower

[139] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final (Mar. 19, 2021).

temperatures than modeled by Landau during the permit application, the results are the same. This shows that Dr. Sahu's concerns about temperature are unfounded.

As previously discussed, the Agency determined that the modeled 24-hour $PM_{2.5}$ concentrations will not exceed the WAAQS or NAAQS after accounting for background values.[140] Because the re-run model predicts the exact same worst-case concentration for 24-hour $PM_{2.5}$ (1.2 µg/m3), it confirms the Agency's conclusion that Tacoma LNG will not cause or contribute to a violation of any ambient air quality standard.[141]

Q: DID YOU UNDERTAKE ANY ADDITIONAL ANALYSIS RELATIVE TO SO_2?

A: Yes. I cover this in Opinion 12. In sum, Dr. Sahu's opinions about sulfur do not change the conclusion that Tacoma LNG will not cause or contribute to a violation of the ambient air quality standards.

OPINION 10: TOXIC AIR POLLUTANT EMISSIONS FROM TACOMA LNG WILL NOT EXCEED THE RELEVANT STANDARDS.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING THE ANALYSIS OF TAPS.

[140] RA-68, Final NOC Worksheet at 57.
[141] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final (Mar. 19, 2021).

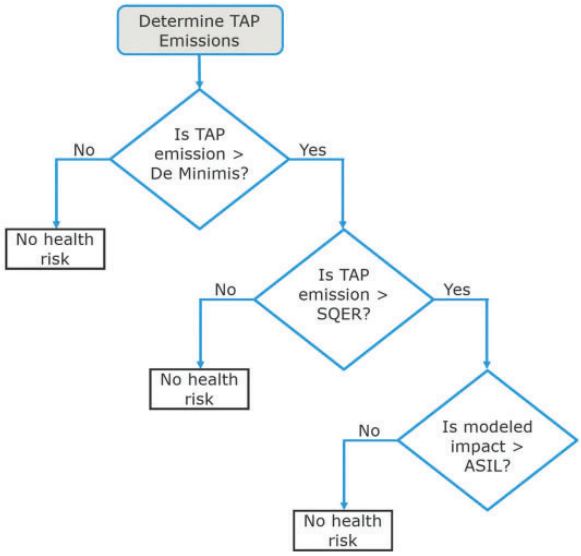
A: Emissions of TAPs were appropriately compared to the Small Quantity Emission Rates ("SQERs"). Seven TAPs exceeded the SQER and were modeled for comparison to the Acceptable Source Impact Level ("ASIL"). None of the seven TAPs exceeded the ASIL, so the analysis was appropriately concluded. None of Dr. Sahu's criticisms would change these results. Dr. Sahu raises a generalized concern that certain TAPs could be above their respective ASIL if different assumptions were used in the analysis. But Dr. Sahu has not undertaken any emissions calculations to support these conclusions and did not undertake any dispersion modeling to compare with the ASILs. In contrast, I evaluated hypothetical worst-case scenarios, as well as modeling using stack parameters from Dr. Joseph Smith, and none of the TAPs reaches more than a small percentage of the applicable ASIL, and most are orders of magnitude (thousands or even millions) of times under the applicable ASIL.

Q: WHAT MUST A FACILITY DO TO ADDRESS TAPS IN AN NOC APPLICATION?

A: Under WAC 173-460-070, a facility must demonstrate that the increase in emissions of TAPs caused by the operation of the facility will be sufficiently low to protect human health and safety from potential carcinogenic and/or other toxic effects. This is determined through a sequential analysis of the facility's TAP emissions, as shown in the graphic below. For each TAP, WAC 173-460-150 provides a table that includes a *de minimis* level, a SQER, and an ASIL. For any TAP emissions above the specified *de minimis* levels, the NOC applicant must either demonstrate that the emission rate for that TAP is lower than the SQER, or

that the modeled ambient impact is less than the ASIL.[142] If the concentrations of a TAP are above its SQER, then that TAP needs to be modeled to confirm that its ambient air concentrations fall below the ASIL. Even then, even if a TAP exceeds its ASIL (which is not the case for Tacoma LNG), the analysis would just move on to an additional second tier analysis for that TAP.

Sequential Flow Diagram Showing TAP Analysis Procedure in the State of



Q: WHAT IS YOUR UNDERSTANDING OF DR. SAHU'S ARGUMENT REGARDING HAPS AND TAPS?

[142] *See* PSE-0118, Washington Department of Ecology, Guidance Document: First, Second and Third Tier Review of Toxic Air Pollution Sources, Chapter 173-460 WAC (2010).

A: My understanding is that Dr. Sahu believes that emissions of HAPs and TAPs were materially underestimated, and that HAPs and TAPs might exceed the SQER or ASIL. Dr. Sahu has raised additional concerns about the calculation of emissions for the BTEX compounds, which are a category of TAPs.

Q: DOES DR. SAHU SHOW THAT THE EMISSIONS OF HAPS AND TAPS ARE UNDERESTIMATED?

A: No. Dr. Sahu has done no analysis to support his conclusions. The analysis for the permit evaluated emissions for dozens of TAPs and compared those emissions to the SQER. For all but seven TAPs, emissions were below the SQER and thus there was no need for further analysis. For the seven TAPs (7,12-DMBA, ammonia, arsenic, cadmium, chromium VI, hydrogen sulfide and sulfur dioxide) for which emissions were above the SQER, ambient modeling results were compared to the corresponding ASIL. None of the seven TAPs exceeded the ASIL, and there was no need for further analysis.

Q: HOW CLOSE WERE THE SEVEN MODELED TAPS TO THE ASIL IN THE PERMIT CALCULATIONS?

A: Not close. In the table below, with data drawn from page 56 of the NOC Worksheet, the highest ambient impact from the worst-case operating scenario from the worst-case meteorological data were compared to the ASIL.[143]

[143] RA-68, Final NOC Worksheet at 56.

Toxic Air Pollutant	Averaging Period	ASIL (µg/m3)	Max. TLNG Concentration (µg/m3)	Max / ASIL
7,12-DMBA	annual	0.0000141	0.00000004	0.0028
Ammonia	24-hour	70.8	1.2	0.017
Arsenic	annual	0.000303	0.00000044	0.0015
Cadmium	annual	0.000238	0.00000241	0.01
Chromium VI*	annual	0.00000667	0.00000307	0.46
Hydrogen Sulfide	24-hour	2	0.021	0.011
SO_2	1-hour	660	26	0.039

The final column shows the proportion of the modeled concentration to the ASIL. As can be seen from this table, none of the seven TAPs are close to the ASIL.

Q: WHY IS THERE AN ASTERISK FOR CHROMIUM?

A: As set forth in the permit, the modeled chromium concentration was only 46% of the ASIL, and this did not require further analysis. However, this emissions calculation contains a very significant overstatement. Chromium comes in many forms, and only hexavalent chromium—Chromium VI—is a TAP. For the permit calculations, Landau assumed that 100 percent of chromium emitted is in the form Chromium VI. However, as Landau explained to the Agency by correspondence dated September 27, 2017, "EPA assumes that 4% of total chromium produced from natural gas production is in the hexavalent form. Therefore, we would anticipate that at most 4 percent of the total chromium generating from the

combustion of natural gas at the Tacoma LNG facility would be Cr(V)."[144] The correspondence goes on to say that applying the 4% approach would decrease the modeled concentration to 0.00000012 which is less than 2% of the ASIL."[145] Thus, like the other six TAPs modeled, Chromium VI is far below the ASIL.

Q: WHAT ARE THE PARTS OF YOUR TAPS ANALYSIS THAT YOU'D LIKE TO DISCUSS?

A: Below I cover multiple responses to points raised by Dr. Sahu. **First**, I respond to his comments about the BTEX compounds. **Second**, I respond to his comments regarding how air dispersion modeling may impact the ASIL analysis. And **third**, I respond to his comments regarding emissions factors used in the ASIL analysis. My conclusion, based on my analysis, is that Dr. Sahu's generalized concerns do not affect the ultimate conclusion, which is that emissions of TAPs from Tacoma LNG do not exceed the ASIL.

[144] RA-31, Email from Keith Faretra, PSE to Ralph Munoz, Agency re: Information request follow-up (Sept, 27, 2017).
[145] *Id.*

RESPONSE TO SAHU TAP COMMENTS ON BTEX

Q: WHAT IS YOUR UNDERSTANDING OF DR. SAHU'S CRITICISMS OF THE BTEX DATA THAT WAS USED IN THE UNDERLYING PERMIT CALCULATIONS?

A: Dr. Sahu appears to have several criticisms. First, Dr. Sahu argues that the Agency relied on BTEX data from 2014 which he says are underestimated based on BTEX data collected in 2019.

Q: WHAT DATA IS HE REFERRING TO?

A: On its public portal, Northwest Pipeline does not provide data on BTEX (which is an acronym for a certain class of compounds including benzene, toluene, ethylbenzene and xylene). My understanding is that Landau therefore sought out other BTEX data to include in its emissions calculations for the permit. Landau received a 2014 analysis of gas sampled from the Northwest Pipeline that contained data on BTEX and subsequently used that information in its permit calculations.[146] In 2019, my understanding is that counsel for PSE obtained an additional gas analysis from the Northwest Pipeline that contained additional data on BTEX.[147]

Q: WHAT IS YOUR RESPONSE TO DR. SAHU'S CRITICISM?

A: The compounds in BTEX are VOCs, HAPs and TAPs. The BTEX data collected in 2019 varies slightly from the data from 2014 but would have no material impact

[146] A-PTI0328, Environmental Partners Inc, Technical Memorandum re: Natural Gas Analysis (Feb. 3, 2014).
[147] *See* PSE-0065, Sampling results from Fremont Analytical.

on Landau's overall permit conclusions if it had been used. BTEX concentrations in natural gas are very small and are measured in parts per billion or micrograms per cubic meter. As a result, the overall amount of BTEX is irrelevant to calculations of total annual tons per year of VOCs, and also represents a very small quantity relative to the SQER. For example, for the permit, Landau calculated worst case emissions of benzene from flaring as 0.00028 tons per year.[148] This is immaterial to the potential to emit calculation for both VOCs and HAPs. Landau also compared emissions of BTEX to the SQER to see whether additional modeling of such compounds was required. This analysis is shown on page 53 of the Agency's Notice of Construction Worksheet.[149] As can be seen from that analysis, reproduced in the table below, none of the BTEX compounds were close to the SQER.

Pollutant	**Averaging Period**	**Worst Case Emission Rate TLNG**	**SQER**	**% of SQER**
		(pounds per averaging period)	(pounds per averaging period)	
Benzene	Year	0.66	6.62	10%
Toluene	24-hour	0.039	657	0.006%
Ethylbenzene	Year	0.013	76.8	0.017%
m,p-Xylene	24-hour	0.029	29	0.1%
o-Xylene	24-hour	0.00012	29	0.0004%

In my analysis, I looked at how different the BTEX readings were in the 2014 versus 2019 samples. For example, benzene was the compound that was closest to

[148] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017).
[149] RA-68, Final NOC Worksheet at 53.

the SQER. For benzene, the 2019 sample was 36 percent higher than the 2014 data point used in Landau's calculation. If the 2019 data point had been used, calculated benzene emissions would have increased from 0.66 pounds per year to 0.90 pounds per year. Thus, benzene would still have been only 13.5% of the SQER and no further analysis would have been required. The other BTEX compounds are much further from the SQER and the 2019 data would not have impacted the analysis whatsoever. Moreover, I do not agree that the use of a single high sample is appropriate for comparison to the SQER for benzene when that SQER is based on annual emissions. It would be far more appropriate to use average benzene data for such comparison, in which case the impact of the 2019 data would be even less.

Q: DID YOU ALSO LOOK AT COMPARISONS TO THE ACCEPTABLE SOURCE IMPACT LEVEL (ASIL)?

A: Yes, even though none of the BTEX compounds exceeded the SQER, and thus no additional modeling was required for comparison to the ASIL, I evaluated modeled ambient impacts for the BTEX (and other toxic air pollutants). When evaluating for comparison to the ASIL, I also varied flare stack modeling parameters to be more conservative than those used in the permit (*i.e.*, to increase ambient impact). I did this in two ways: (1) using hypothetical worst-case stack and exit temperature and exit velocity as part of the sensitivity analysis I described above for CAPs[150] and (2) using stack exit temperature and exit velocity from Dr. Smith's CFD modeling also as described above.[151] Dr. Smith's stack parameters

[150] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).
[151] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final (Mar. 19, 2021).

were also less favorable from a dispersion standpoint than Landau's original modeling, so this choice is conservative. It is important to note that these results assume that the worst-case flaring scenario was taking place 8,760 hours per year, or every hour of every day. In fact, the worst-case scenario will not be taking place every hour of every day, therefore, we would expect that this represents a worst-case scenario. This analysis also artificially increases the impact from the vaporizer scenario, which is over-represented in the short-term (24-hour) ASILs.

Q: WHAT WERE YOUR RESULTS?

A: First I will present the results using stack parameters from Dr. Smith, though as I will explain, the results were the same with my even more conservative sensitivity analysis. My results using stack parameters from Dr. Smith can be seen on the attached table. I have highlighted the BTEX compounds.

Toxic Air Pollutant	Averaging Period	Max. (µg/m³)	ASIL (µg/m³)	Over ASIL?	Max / ASIL
Acetaldehyde	year	2.16E-05	0.37	No	0.000058
Acrolein	24-hr	1.14E-03	0.06	No	0.019
Ammonia	24-hr	1.36E+00	70.8	No	0.019
Benz(a)anthracene	year	4.59E-09	0.00909	No	0.00000050
Benzene	year	4.43E-06	0.0345	No	0.00013
Benzo(a)pyrene	year	3.06E-09	0.00091	No	0.0000034
Benzo(b)fluoranthene	year	4.59E-09	0.00909	No	0.00000050
Benzo(k)fluoranthene	year	4.59E-09	0.00909	No	0.00000050
Beryllium	year	3.06E-08	0.00042	No	0.000073
Chrysene	year	4.59E-09	0.0909	No	0.000000050
Cobalt	24-hr	3.56E-05	0.1	No	0.00036
Copper	1-hr	2.13E-03	100	No	0.000021
Dibenzo(a,h)anthracene	year	3.06E-09	0.00083	No	0.0000037
Dichlorobenzene	year	3.06E-06	0.0909	No	0.000034
Ethylbenzene	year	2.14E-07	0.4	No	0.00000053
Formaldehyde	year	1.91E-04	0.167	No	0.0011
Hexane	24-hr	7.63E-01	700	No	0.0011
Indeno(1,2,3-cd)pyrene	year	4.59E-09	0.00909	No	0.00000050
Lead	year	1.28E-06	0.0833	No	0.000015
Manganese	24-hr	1.61E-04	0.04	No	0.0040
Mercury	24-hr	1.10E-04	0.09	No	0.0012
3-Methylchloranthrene	year	4.59E-09	0.00016	No	0.000029
Naphthalene	year	1.56E-06	0.0294	No	0.000053
Propylene	24-hr	2.25E-01	3000	No	0.000075
Selenium	24-hr	1.02E-05	20	No	0.00000051
Toluene	24-hr	6.35E-04	5000	No	0.00000013
Vanadium	24-hr	9.75E-04	0.2	No	0.0049
m,p-Xylene	24-hr	2.43E-04	221	No	0.0000011
o-Xylene	24-hr	4.07E-05	221	No	0.00000018

Q: CAN YOU EXPLAIN YOUR BTEX RESULTS?

A: Yes. The ambient air concentrations of BTEX resulting from flaring are very small when compared to the ASIL. Benzene, which is the closest to the ASIL, is only 0.013% of the ASIL (last column). In other words, benzene concentrations from flaring would have to increase by a factor of more than 7,000 times to even

approach the ASIL. Toluene concentrations from flaring would have to increase by almost 8 million times to even approach the ASIL. Xylene concentrations from flaring would have to increase by a factor of approximately a million or more to approach the ASIL. The differences between the 2019 and 2014 gas samples are simply irrelevant to the ASIL levels given these results.

Q: ARE THE RESULTS ANY DIFFERENT FOR THE RESULTS OF THE SENSITIVITY ANALYSIS?

A: No, the ambient impacts are higher for the sensitivity analysis because the hypothetical stack parameters are extremely unfavorable for dispersion, and the impacts from the vaporizer are over-represented. I have provided the same chart below from the sensitivity analysis and the results do not materially differ. The BTEX compounds emitted from the flare are not close to the ASIL. Given how much headroom there is between these results and the SQERs and ASILs, none of the concerns raised by Dr. Sahu would change this result.

Toxic Air Pollutant	Averaging Period	Max. (µg/m³)	ASIL (µg/m³)	Over ASIL?	Max / ASIL
Acetaldehyde	year	2.86E-05	0.37	No	0.000077
Acrolein	24-hr	1.80E-03	0.06	No	0.030
Ammonia	24-hr	2.13E+00	70.8	No	0.030
Benz(a)anthracene	year	6.08E-09	0.00909	No	0.00000067
Benzene	year	5.87E-06	0.0345	No	0.00017
Benzo(a)pyrene	year	4.05E-09	0.00091	No	0.0000045
Benzo(b)fluoranthene	year	6.08E-09	0.00909	No	0.00000067
Benzo(k)fluoranthene	year	6.08E-09	0.00909	No	0.00000067
Beryllium	year	4.05E-08	0.00042	No	0.00010
Chrysene	year	6.08E-09	0.0909	No	0.000000067
Cobalt	24-hr	5.60E-05	0.1	No	0.00056
Copper	1-hr	2.48E-03	100	No	0.000025
Dibenzo(a,h)anthracene	year	4.05E-09	0.00083	No	0.0000049
Dichlorobenzene	year	4.05E-06	0.0909	No	0.000045
Ethylbenzene	year	2.83E-07	0.4	No	0.00000071
Formaldehyde	year	2.53E-04	0.167	No	0.0015
Hexane	24-hr	1.20E+00	700	No	0.0017
Indeno(1,2,3-cd)pyrene	year	6.08E-09	0.00909	No	0.00000067
Lead	year	1.69E-06	0.0833	No	0.000020
Manganese	24-hr	2.53E-04	0.04	No	0.0063
Mercury	24-hr	1.73E-04	0.09	No	0.0019
3-Methylchloranthrene	year	6.08E-09	0.00016	No	0.000038
Naphthalene	year	2.06E-06	0.0294	No	0.000070
Propylene	24-hr	3.53E-01	3000	No	0.00012
Selenium	24-hr	1.60E-05	20	No	0.00000080
Toluene	24-hr	9.98E-04	5000	No	0.00000020
Vanadium	24-hr	1.53E-03	0.2	No	0.0077
m,p-Xylene	24-hr	3.83E-04	221	No	0.0000017
o-Xylene	24-hr	6.41E-05	221	No	0.00000029

Q: CAN YOU EXPLAIN THE RESULTS FOR THE OTHER TAPs?

A: I will address Dr. Sahu's specific criticisms regarding other TAPs following my discussion about BTEX. However, the impacts of all of the other TAPs from the flare are well below the ASILs as these charts show. They range from a high of 1.9% of the ASIL for ammonia, to about 1 in 20 million of the ASIL for chrysene,

using the stack parameters from Dr. Smith. Scanning the final column in the above table above, which is based on very unfavorable stack parameters for dispersion, the TAPs will not exceed the ASIL. The Agency's conclusion on this point is sound.

Q: WHAT OTHER ISSUES DOES DR. SAHU RAISE ABOUT BTEX?

A: Another issue Dr. Sahu raises is that the BTEX data in the 2014 and 2019 samples is qualified by the laboratories and that some of the concentrations may therefore be underestimated.[152] Dr. Sahu is correct that the laboratories marked some of the BTEX data with an "E" qualifier stating that "value above quantitation range." However, this means that the concentration indicated for this analyte is an estimated value above the calibration range of the instrument. This value is considered an estimate, and nothing in this this value indicates whether it is a high or low estimate**.** It does not necessarily mean that the value is higher than stated in the laboratory report. Regardless, given the significant headroom between concentrations from Tacoma LNG and any regulatory threshold, this finding is not significant and would not change the analysis.

Q: DOES DR. SAHU RAISE ANY FURTHER ISSUES?

A: Yes. Dr. Sahu argues that the Agency erred by assuming that flare gas concentrations of BTEX were the same as incoming feed gas compositions.

Q: CAN YOU EXPLAIN WHAT HE MEANS?

A: Yes. In the permit calculations provided to the Agency, Landau assumed that flare gas concentrations of BTEX for each flaring case were the same as the

[152] Sahu Testimony ¶ 130.

concentrations of BTEX in the 2014 gas pipeline sample.[153] I understand that BTEX compounds could either end up in the heavy storage vessel, the LNG, or the waste gases that go to the flare. In his testimony, Mr. Stobart stated that CB&I does not model the fate of BTEX because it is present in such small quantities. However, given that BTEX is a heavier hydrocarbon, Mr. Stobart testified that a lot would go to the heavy storage vessel, and potentially all of it. If that were the case, there would be little if any BTEX that goes into the waste gases that go to the flare.

Q: DID DR. SAHU DO ANY ADDITIONAL ANALYSIS?

A: No. Apart from raising a concern, Dr. Sahu has not undertaken any quantitative analysis of this issue, so he has not presented any calculation of the potential significance of this purported error.

Q: WAS LANDAU'S CALCULATION REASONABLE?

A: In the absence of information about the fate of BTEX, and in light of the possibility that much of the BTEX may end up in the heavy storage vessel instead of going to the flare, Landau's calculation was reasonable. Moreover, given my analysis above, and the significant headroom between the BTEX concentrations from the flare and the SQER or ASIL, it is highly unlikely that this would impact the analysis and the conclusions.

[153] RA-61(c), Attachment A - PSE LNG Emissions (rev. November 28, 2017).

RESPONSE TO SAHU TAP COMMENTS ON DISPERSION MODELING

Q: DOES DR. SAHU PROVIDE ANY EVIDENCE TO SUGGEST THAT CONCERNS HE HAS RAISED ABOUT THE DISPERSION MODELING WOULD MEAN THAT THE CONCENTRATIONS OF TAPS HAVE BEEN UNDERESTIMATED AND MAYBE ABOVE THE ASIL?

A: No. Dr. Sahu has provided no analysis to support such a statement. Because the seven TAPs that exceeded the SQER are not even close to the ASIL under the permit calculations, there is no reason to believe that changing the modeling parameters that Dr. Sahu is concerned about would lead to any different result.

Q: AS YOU UNDERSTAND IT, WHAT MODELING PARAMETERS DO YOU UNDERSTAND DR. SAHU IS CRITICIZING REGARDING THE ASIL ANALYSIS?

A: I understand that Dr. Sahu has raised "concerns" about the meteorological data underlying the ambient modeling as well as the stack parameters (*e.g.*, flare exit temperature) used by Landau in undertaking the modeling.

Q: DO EITHER OF THESE CONCERNS EXPRESSED BY DR. SAHU IMPACT YOUR OPINION?

A: No. Again, aside from raising generalized concerns, Dr. Sahu has undertaken no analysis of the impacts of either the meteorological data or stack parameters on the ASIL analysis. Landau's analysis already was conservative by using the highest ambient impact from the worst-case operating scenario from the worst-case set of the four sets of meteorological data. Additionally, my analysis indicates that even

if less beneficial stack parameters or even different meteorological data were used, it would have no impact on the results of the ASIL analysis given how far the various TAPs are below the ASIL.

Q: CAN YOU EXPLAIN?

A: Yes. First, with respect to the stack parameters, as described previously, I undertook two analyses. I did a sensitivity analysis using hypothetical stack parameters that are much worse than would ever be expected.[154] I also re-ran the permit modeling using stack parameters from Dr. Smith's CFD modeling.[155] This addresses Dr. Sahu's incorrect statement that the sensitivity analysis used "plausible values for stack temperature and velocity."[156] I re-ran the permit modeling using stack parameters from Dr. Smith's CFD modeling.

In my sensitivity analysis, reproduced in the table below, I compared the modeled concentrations of the seven TAPs that exceeded the SQER to their respective ASIL as was done in the permit. For chromium, I assumed that 4% of chromium was Chromium VI (per EPA guidance).

[154] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).
[155] PSE-0326, Results Summary – Flare Expert AERMOD Summary-Final (Mar. 19, 2021).
[156] Sahu Testimony ¶ 102.

Toxic Air Pollutant	Averaging Period	ASIL (µg/m3)	Max. TLNG Concentration (µg/m3)	Max / ASIL
7,12-DMBA	annual	1.41E-05	6.1E-08	0.0044
Ammonia	24-hour	70.8	2.1	0.030
Arsenic	annual	3.03E-04	6.8E-07	0.0022
Cadmium	annual	2.38E-04	3.7E-06	0.016
Chromium VI**	annual	6.67E-06	1.9E-07	0.03
Hydrogen Sulfide	24-hour	2.00E+00	2.3E-02	0.012
SO_2	1-hour	660	32	0.05

In this analysis, all seven TAPs remain well below the ASIL, even using the very unfavorable stack parameters I used in the sensitivity analysis. Changes in the stack parameters have no material impact on the ASIL calculation.

Q: DID YOU DO THE SAME ANALYSIS USING THE STACK PARAMETERS FROM DR. SMITH?

A: Yes. I also modeled ambient impacts using the stack parameters that came out of Dr. Smith's CFD model. These stack parameters were in some cases lower than the temperature used by Landau, but also significantly higher temperature than the temperatures I used above in my sensitivity analysis. The chart below shows my results using stack parameters from Dr. Smith. As with the last chart, this chart shows that Tacoma LNG's ambient impacts are well below the ASIL and stack parameters do not have a material impact.

Toxic Air Pollutant	Averaging Period	ASIL (µg/m3)	Max. TLNG Concentration (µg/m3)	Max / ASIL
7,12-DMBA	annual	1.41E-05	4.0E-08	0.0028
Ammonia	24-hour	70.8	1.4	0.019
Arsenic	annual	3.03E-04	5.1E-07	0.0017
Cadmium	annual	2.38E-04	2.8E-06	0.012
Chromium VI**	annual	6.67E-06	1.3E-07	0.02
Hydrogen Sulfide	24-hour	2.00E+00	2.2E-02	0.011
SO_2	1-hour	660	28	0.04

Q: DID YOU ALSO LOOK AT OTHER TAPS?

A: Yes, in each of my analyses, I looked at the full list of TAPs evaluated in the permit. This full chart was set forth above in my discussion of BTEX. The chart shows (either using the sensitivity analysis or modeling using Dr. Smith's stack parameters) shows that none of the TAPs come close to the ASIL. Dr. Sahu's concerns are without merit.

Q: DR. SAHU ALSO SAYS THAT FAULTY METEOROLOGICAL DATA RENDER THE ASIL CALCULATIONS UNRELIABLE. DO YOU AGREE?

A: No. Again, aside from raising a generalized concern, Dr. Sahu has undertaken no analysis of the impacts of meteorological data on the ASIL analysis.

Q: COULD METEOROLOGICAL DATA IMPACT THE MODELED IMPACTS SUFFICIENTLY TO AFFECT THE ASIL ANALYSIS?

A: In my opinion, no. There is so much headroom between the ambient impacts from Tacoma LNG and the ASILs that changing meteorological data could not cause an exceedance of the ASIL.

Q: CAN YOU EXPLAIN?

A: Yes. As I discussed previously, the meteorological data used by Landau was appropriately representative and was a reliable basis for the dispersion modeling. The ASIL calculations in the chart above (using the stack parameters from Dr. Smith) shows that the TAP closest to the ASIL is SO_2, which is approximately 4 percent of the ASIL. Even using those stack parameters, different meteorological data would have to predict concentrations 25 times higher to reach the ASIL. Simply stated, meteorological data would not be expected to have anywhere near that magnitude of impact on the results of dispersion modeling in this case.

RESPONSE TO SAHU TAP COMMENTS ON EMISSIONS FACTORS

Q: DO YOU ALSO UNDERSTAND DR. SAHU TO BE CRITICAL OF THE EMISSION FACTORS USED FOR THE ASIL ANALYSIS?

A: Yes, I understand that Dr. Sahu has generalized concerns about the use of emission factors in the Tacoma LNG permit, and views about the use of emission factors that are out of the mainstream. However, his concerns are not paired with any

analysis. Dr. Sahu did not undertake any quantitative analysis of the impact of emissions factors on the ASIL analysis.

Q: DID DR. SAHU PROVIDE A LIST OF EMISSION FACTORS HE BELIEVES SHOULD HAVE BEEN USED?

A: No. Dr. Sahu has not provided a full list of emissions factors. Instead, he has generalized concerns. Dr. Sahu only identified higher emissions factors for acrolein and formaldehyde, and chose those without much rationale or justification.

Q: WHAT CALCULATIONS DID DR. SAHU DO RELATED TO ACROLEIN AND FORMALDEHYE?

A: Dr. Sahu indicated that the emissions factors he favors for acrolein and formaldehyde would put those TAPs above the SQER. But he did not review the impacts this would have relative to the ASIL.

Q: HAVE YOU DONE AN ANALYSIS FOR ACROLEIN AND FORMALDEHYDE?

A: Yes.

Q: WHAT ANALYSIS DID YOU DO?

A: I recalculated emissions and ambient impacts for acrolein and formaldehyde using Dr. Sahu's proffered emissions factors and compared them to the corresponding ASILs.

Q: WHAT ARE YOUR CONCLUSIONS?

A: Even using Dr. Sahu's proffered emission factors, ambient impacts of acrolein and formaldehyde from Tacoma LNG would still not be above the ASIL. In fact, they would not be close.

Q: PLEASE EXPLAIN.

A: In the table below, I pulled out the data for acrolein and formaldehyde from my analysis shown in my modeling using the stack parameters from Dr. Smith.

Toxic Air Pollutant	Averaging Period	Max.	ASIL (µg/m³)	Max / ASIL
Acrolein	24-hr	1.14E-03	0.06	0.019
Formaldehyde	year	1.91E-04	0.167	0.0011

Based on my modeling analysis, using the original emission factors, neither acrolein nor formaldehyde are close to the ASIL. Indeed, acrolein emissions would need to be over 52 times higher to approach the ASIL, and formaldehyde emissions would have to be 900 times higher. As with the previous 24-hour averages, this estimate for acrolein is an overestimate, as it is largely from the vaporizer, which should not be increased as part of the sensitivity analysis

Dr. Sahu opines that the emission factor for acrolein should be 0.01 lb/MMscf instead 0.0027 lb/MMscf used in the permit calculations. This would increase acrolein by a factor of 3.7. He further opines that the emission factor for formaldehyde should be 1.169 lb/MMscf instead of 0.075 lb/MMscf used in the

permit calculations.[157] This would increase formaldehyde emissions by a factor of 15.6.

Even assuming Dr. Sahu is correct about selection of the emission factors, which is not conceded, utilizing his emission factors would not cause acrolein or formaldehyde to be above the ASIL. In fact, acrolein would still be 14 times below the ASIL (*i.e.*, around 7% of the ASIL), and formaldehyde would be 58 times below the ASIL (*i.e.*, under 2% of the ASIL), based on my analysis. My analysis reaches the same result using the hypothetical worst-case stack parameters from my sensitivity analysis instead of Dr. Smith's stack parameters. Further, consistent with my previous discussion on this point, meteorological data would not be expected to influence modeled ambient concentrations of contaminants sufficiently to cause acrolein or formaldehyde concentrations from Tacoma LNG to be above the ASIL. Simply put, with a full analysis, Dr. Sahu's concerns are not material, and do not change the result that all TAPs are below the ASIL by a comfortable margin.

Q: ASIDE FROM ACROLEIN AND FORMALDEHYDE, HAS DR. SAHU IDENTIFIED ANY OTHER TAPS THAT COULD EXCEED THE SQER AND REQUIRE MODELING FOR COMPARISON TO THE ASIL?

A: Not that I am aware of.

[157] Sahu Testimony ¶ 113.

Q: WHAT IS YOUR OVERALL CONCLUSION REGARDING TAPS?

A: Based on my analysis, it is my opinion that nothing that Dr. Sahu has said changes the TAPs analysis results underlying the permit.

OPINION 11: THE BACT AND tBACT LIMITS FOR THE FLARE ARE REASONABLE.

Q: PLEASE SUMMARIZE YOUR OPINION RELATED TO BACT AND tBACT.

A: It is my opinion that the Agency appropriately determined the Best Available Control Technology ("BACT") for the flare. The BACT determination resulted in the 99% DRE requirement for VOC emissions from the flare, along with the numerical emissions limits for NOx, CO, SO_2, and PM in the permit.[158] These requirements are consistent with requirements for similar facilities. Additionally, the BACT determination for TAPs ("tBACT") is reasonable. BACT for criteria air pollutants is an appropriate surrogate for tBACT for Tacoma LNG, because the facility's TAPs are addressed through the same control technologies that address criteria air pollutants. Finally, I disagree with Dr. Sahu's opinion that CEMS is required as part of the BACT determination. On a minor source like Tacoma LNG, where emissions are far below the NAAQS/WAAQS and ASILs, CEMS are unnecessary for demonstrating continuous compliance with emissions limits.

[158] RA-132, NOC Order of Approval.

Instead, parametric monitoring, input limits, and periodic stack testing are sufficient to demonstrate continuous compliance.

Q: WHAT IS "BACT"?

A: BACT means "an emission limitation based on the maximum degree of reduction for each air pollutant subject to regulation 70.94 RCW emitted from or which results from any new or modified stationary source, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant."[159]

A BACT analysis results in an emission limitation that can be satisfied in any manner selected by the facility. In other words, if a BACT analysis identifies pollution control device A as providing the maximum degree of reduction, the agency would set a BACT emission limit based on the emission reduction achievable through the installation of pollution control device A. The source is not required to install pollution control device A, however. The source can choose to install pollution control device B, as long as that device is able to meet the emission limit set through the BACT process.

[159] PSE-0308, WAC 173-400-030.

Q: HOW IS BACT DETERMINED FOR A MINOR SOURCE?

A: The Agency's BACT analysis for minor sources involves an assessment of existing BACT determinations made for similar sources and/or emission units. These BACT determinations are identified through the permit engineer's review of the application materials, previous experience, and research, which may include information from federal or state clearinghouses. The Agency then determines the maximum degree of reduction for each air pollutant from the source in question, based on the demonstrated implementation of BACT at those other sources.

Q: WHAT BACT DETERMINATION DID THE AGENCY MAKE FOR THE FLARE AT TACOMA LNG?

A: PSCAA determined the following constitute BACT for the enclosed ground flare:

- NOx – emissions to the atmosphere may not exceed 0.066 lb/MMBtu whenever the small warm burner (Burner 3) is operating, 0.060 lb/MMBtu whenever the small cold burner (Burner 2) is operating, and 0.023 lb/MMBtu whenever exclusively one or both of the large burners (Large Warm Burner 1 and Large Cold Burner 4) are operating;

- CO – emissions to the atmosphere may not exceed 0.196 lb/MMBtu whenever the small warm burner (Burner 3) is operating, 0.180 lb/MMBtu whenever the small cold burner (Burner 2) is operating, and 0.075 lb/MMBtu whenever exclusively one or both of the large burners (Large Warm Burner 1 and Large Cold Burner 4) are operating;

- SO_2 – emissions to the atmosphere may not exceed 165 lb/MMscf;
- VOCs - a minimum of 99% destruction of all volatile organic compounds; and
- PM – emissions to the atmosphere by not exceed 0.0075 lb/MMBtu.

Q: WHAT IS THE BASIS FOR THE AGENCY'S BACT DETERMINATION FOR THE FLARE AT TACOMA LNG?

A: PSE submitted a BACT analysis to the Agency that was consistent with the approach described above.[160] Potential emission reduction strategies for criteria pollutants were identified for the enclosed ground flare through a review of previous environmental permitting experience for similar units found in the EPA database known as the RACT/BACT/LAER Clearinghouse (RBLC). Available emission reduction alternatives judged to be technically feasible were further evaluated based on an analysis of economic, environmental, and energy impacts.

In addition to reviewing the BACT analysis provided by PSE, the Agency conducted an independent BACT analysis. The Agency reviewed the RBLC, as well as the California Air Resources Board's (CARB's) BACT Clearinghouse, and conducted a review of available regulatory agency BACT guidelines and past determinations for similar emission units, including the Sacramento Metropolitan Air Quality Management District (SMAQMD), the Bay Area Air Quality Management District (BAAQMD), the South Coast Air Quality Management District (SCAQMD), the San Joaquin Valley Air Pollution Control district (SJVAPCD), the Texas Commission on Environment Quality (TCEQ), the

[160] RA-54, PSE to Agency, Updated materials to NOC Application (March 29, 2019).

Massachusetts Department of Environmental Protection (MassDEP), and the Maine Department of Environmental Protection (MaineDEP). The Agency also reviewed its own files for past flare BACT determinations. Flares utilized by a wide variety of operations were taken into consideration.

The Agency compared the results of its independent BACT analysis with the BACT limits proposed by PSE and determined that they constituted BACT for an enclosed ground flare.

Q: IS THE AGENCY'S BACT DETERMINATION FOR THE FLARE AT TACOMA LNG REASONABLE?

A: Yes, because the final Tacoma LNG permit limits are consistent with prior BACT determinations made by the Agency as well as other agencies for sources similar to Tacoma LNG. My additional independent review did not reveal any enclosed ground flare BACT determinations that imposed more stringent VOC DRE requirements than those in the Order of Approval the Agency has issued to PSE for the Tacoma LNG processing facility. Further, Dr. Sahu has not identified any such determinations either.

Q: WHAT IS "tBACT" AND HOW IS IT DETERMINED?

A: Best available control technology for toxics (tBACT) is defined by regulation to be identical to BACT, as applied to TAPs.[161] Criteria pollutant BACT is a surrogate for tBACT. Because the majority of TAPs are, in general, either VOCs or PM,

[161] PSE-0118, WAC 176-460-020.

BACT for VOC and PM is tBACT for VOC TAPs and PM TAPs, respectively. For inorganic sulfur-containing and nitrogen-containing TAPs, tBACT the same as BACT for SO_2 and NO_X, respectively, as the same processes that reduce incoming sulfur and incoming nitrogen also reduce SO_2 and NO_X. Based on my experience, it is standard practice for permitting agencies to use BACT as a surrogate for tBACT.

Q: WHAT IS "tBACT" FOR TACOMA LNG?

A: TAP emissions will be limited as a result of the limits imposed on the criteria pollutant surrogates, because BACT is a surrogate for tBACT.

Q: IS THE AGENCY'S tBACT DETERMINATION FOR THE FLARE AT TACOMA LNG REASONABLE?

A: Yes. The final permit appropriately accounts for BACT for TAPs, since the BACT analysis for non-TAP emissions encompasses TAP emissions by the nature of those constituents.

Q: DO YOU AGREE WITH DR. SAHU'S OPINION THAT THE AGENCY WAS REQUIRED TO CONSIDER ADDITIONAL CONTROL OPTIONS IN ITS tBACT ANALYSIS?

A: Dr. Sahu provides no support for his claims that the technologies he identified are appropriate for inclusion in a tBACT analysis for Tacoma LNG.[162] Dr. Sahu does

[162] Sahu Testimony ¶ 149-50.

claim that EPA has "required consideration/use of leakless and/or certified low leak components in consent decrees for similar facilities."[163] These are irrelevant to a state or local agency tBACT determination. Federal agency actions in an enforcement context do not impact a state or local agency regulatory determination about tBACT.

Q: DR. SAHU HAS REPEATEDLY ASSERTED THAT A CEMS IS REQUIRED TO DEMONSTRATE CONTINUOUS COMPLIANCE WITH THE PERMIT. DO YOU AGREE THAT A CEMS IS REQUIRED FOR TACOMA LNG TO DEMONSTRATE COMPLIANCE WITH ITS BACT AND tBACT LIMITS?

A: Continuous Emissions Monitoring Systems ("CEMS") can sometimes be an effective manner of assuring continuous compliance with emissions limits; however, CEMS are not the only way to demonstrate continuous compliance with a permit. There are other methods of demonstrating compliance on an ongoing basis, as I can explain. Accordingly, CEMS are not required to demonstrate continuous compliance with emissions limits. Further, it is unusual to require CEMS on a minor source, as described later, so the lack of CEMS requirement in the Tacoma LNG is typical and expected.

[163] Sahu Testimony ¶ 150.

Q: WHAT ARE CEMS?

A: CEMS are a type of monitoring system. A CEMS is comprised of the equipment necessary for the determination of a gas or particulate matter concentration or emission rate using pollutant analyzer measurements and a data acquisition and management system that can produce and record results in units of the applicable emissions. CEMS are required under some EPA regulations, typically for large sources of emissions. Examples of sources that use CEMS by EPA regulations are large thermal electric power plants and certain refinery units. For example, 40 CFR Part 60, subpart Ja requires a CEMs for NOx and SOx emissions from Fluidized Catalytic Cracking Units (FCCU).

EPA regulations specify the reference methods that are used to substantiate the accuracy and precision of the CEMS for certain categories of large emission sources. Procedures in Appendix F to 40 CFR 60 are used to evaluate the effectiveness of quality control (QC) and quality assurance (QA) procedures and the quality of data produced by any CEMS that is used for determining compliance with the emission standards on a continuous basis as specified in the applicable regulation.

Q: ARE CEMS REQUIRED FOR ALL PERMITTED SOURCES?

A: No. In my experience, CEMS are typically installed when required by either federal, state or local regulation, or as a result of a consent decree. CEMS are sometimes installed in situations when emissions must be tracked for emissions banking purposes, but this is also a form of regulatory requirement.

Q: ARE THERE OTHER FORMS OF COMPLIANCE MONITORING FOR EMISSIONS FROM STACKS?

A: Yes, there are a number of ways to monitor compliance for emissions from stacks, including periodic stack testing.[164] Additionally, inputs can be monitored in order to predict outcomes, such as using the number of hours of operation to predict emissions for sources like emergency generators. Another method is to use a parametric monitoring system. A parametric monitoring system includes the equipment necessary for the determination of a parameter related to emissions, such as temperature in a flare, and a data acquisition and management system to record and store the information.

These types of monitoring systems are commonly accepted, even under the federal Compliance Assurance Monitoring ("CAM") rule that is designed to ensure major sources subject to Title V maintain a high level of continuous compliance. For example, the CAM Rule also establishes a sample monitoring approach for thermal oxidizers, which are similar to enclosed ground flares like the flare at Tacoma LNG. This sample monitoring approach provides that temperature monitoring can be used to continuously monitor destruction of VOCs.[165] While the CAM Rule does not apply to Tacoma LNG because it is not a major source for

[164] A-PTI0423, EPA, AP-42 Enforcement Alert (Nov. 2020). The EPA Enforcement Alert regarding AP-42, relied upon by Dr. Sahu, points out that stack testing is an accurate methodology for quantifying source-specific emissions, and that testing may only be necessary every two to five years.

[165] EPA, CAM Technical Guidance Document, Appendix A: Example Monitoring Approach Submittals at A-5 (Aug. 1998), https://www3.epa.gov/ttn/emc/cam/app-a1-7.pdf ("It has been shown that the control efficiency achieved by a thermal incinerator is a function of its operating temperature, or outlet temperature. By maintaining the operating temperature at or above a minimum, a level of control efficiency can be expected to be achieved.").

Title V, it is instructional in that it does not require CEMS for compliance assurance for sources of emissions much larger than Tacoma LNG.

In some cases, even for major sources of emissions such as an FCCU, parametric monitoring is specifically allowed in lieu of a CEMs. For example, in 40 CFR Part 60, Subpart Ja, a source operator has the option to demonstrate compliance either through a CEMS or through source testing and monitoring parameters that impact PM emissions.[166] Similarly, the National Emissions Standards for Hazardous Air Pollutants for cement plants permit the demonstration of compliance with PM emissions limits through the use of a continuous parametric monitoring system.[167] In the permit for Tacoma LNG, VOCs are monitored in much the same way – by monitoring parameters that impact VOC emissions, rather than monitoring VOCs by a CEMS.

Q: DOES STACK TESTING PLAY A ROLE IN PARAMETRIC MONITORING?

A: Stack testing plays an important role in parametric monitoring. Stack testing is used to set the acceptable window for parametric monitoring. For an enclosed ground flare, the key parameters that determine DRE are residence time, temperature, and turbulence.[168] As explained by PSE's expert Dr. Smith, the design of the Tacoma LNG flare establishes its residence time and turbulence, and these parameters are expected to provide for a DRE of 99% or greater provided

[166] 40 CFR 60.102a(b)(1)
[167] 40 CFR 63.1359(b)(1).
[168] *See* Pre-filed Direct Testimony of Dr. Joseph Smith, at 28 (March 29, 2021) (hereinafter "Smith Testimony").

there is sufficient temperature.[169] Accordingly, monitoring temperature in the Tacoma LNG is a parametric monitor for DRE.[170] During the enclosed ground flare stack test, the temperature can be varied to allow the agency to understand the ranges of temperatures that yield results in compliance with the permit conditions. The stack test can help set the appropriate temperature for meeting the required destruction efficiency.

Q: IS IT TYPICAL TO REQUIRE CEMS ON A FLARE THAT IS A MINOR SOURCE?

A: I am not aware of any example of a CEMS at a landfill gas flares or a minor source regenerative thermal oxidizer,[171] despite the fact that I have permitted enclosed ground flares for landfills and regenerative thermal oxidizers for a number of minor sources. I also have reviewed flare permits for landfills and regenerative thermal oxidizers issued by the Agency. Most flares and regenerative thermal oxidizers do have minimum temperature requirements to ensure acceptable combustion.

Q: ARE CEMS APPROPRIATE TO MONITOR EMISSIONS FROM MINOR SOURCES?

A: While I am aware of CEMS for minor sources, they are typically required either by regulation or a part of an emissions trading scheme, and therefore required by

[169] *See* Smith Testimony at 65–66.
[170] *Id.*
[171] It is possible that flares may exist with NOx or SO_2 CEMS for banking purposes, but I am not aware of any specific examples.

permit in order to ensure that emissions are appropriately tracked for emissions trading. Apart from those situations, especially when emissions are far below any applicable threshold (as they are here), requiring CEMs instead of a parametric monitoring system is generally unnecessary.

Q: DO YOU HAVE ANY SPECIFIC CONCERNS ABOUT DR. SAHU'S OPINIONS ABOUT CEMS?

A: Yes. Dr. Sahu makes some statements about the application of CEMS to Tacoma LNG's flare that are not correct and are not supported. In addition to my own knowledge and experience with CEMS, I have reviewed and rely on the Declaration of Laura Kinner ("Kinner Declaration"), attached hereto as Attachment D, which further informs my opinions. Dr. Kinner has decades of experience with developing and implementing stack testing and continuous monitoring methods.

Q: WHAT ARE THE SPECIFIC CONCERNS YOU HAVE WITH DR. SAHU'S OPINIONS ABOUT CEMS?

A: First, Dr. Sahu suggests states that there are available methods by which DRE could be measured continuously for the flare. Dr. Sahu provides no examples of these methods being used in practice. I am not aware of such methods and have never seen a "DRE CEMS" demonstrated in practice. Nor has Dr. Kinner, who explains the challenging engineering problem that comes from trying to match inlet concentrations to outlet concentrations in the same time period.[172] Second, to

[172] *See also* Kinner Declaration at ¶ 11.

the extent Dr. Sahu is suggesting a $PM_{2.5}$ CEMS for the flare, I have never seen a $PM_{2.5}$ CEMS used in such application. Dr. Kinner states that "[t]here is no technology capable of continuously monitoring $PM_{2.5}$ for an enclosed flare" and further that she "is aware of no enclosed flare that employs continuous $PM_{2.5}$ monitoring (or any type of continuous particulate monitoring."[173] I agree with Dr. Kinner that "[s]tack testing is the widely accepted means of verifying compliance with $PM_{2.5}$ limits from sources similar to the Tacoma LNG enclosed ground flare."[174] Finally, Dr. Sahu suggests that the gas chromatographs used at Tacoma LNG are essentially the same as what would be used as VOC CEMS. I agree with Dr. Kinner that the gas chromatographs used for the process are not the same technology that would be needed for a VOC CEMS.[175] As I have previously stated, I believe that the continuous parametric monitoring of temperature is sufficient to demonstrate continuous compliance with the DRE requirement for VOCs.

[173] Kinner Declaration at ¶ 12.
[174] *Id.*
[175] *Id.* at ¶ 10.

OPINION 12: DR. SAHU'S PROPOSED APPROACH FOR CALCULATING SULFUR EMISSIONS WOULD HAVE RESULTED IN A LESS STRINGENT SO_2 LIMIT.

Q: PLEASE EXPLAIN HOW LANDAU CALCULATED THE SO_2 LIMIT FOR THE FLARE.

A: Landau addressed the two major forms of sulfur in the feed gas brought to the plant: hydrogen-sulfide (H2S) and non-H2S sulfur compounds. Both H2S and non-H2S sulfur are found in the pipeline natural gas brought to the plant. And because PSE adds non-H2S sulfur-based odorant to the natural gas when it is taken off the pipeline, Landau added this sulfur into its calculation as well. Landau assumed that all H2S coming into the plant is sent to the flare. And based on information from CB&I, Landau assumed that 80% of the non-H2S sulfur is removed and sent to the flare. So, essentially, Landau determined the mass of sulfur being sent to the flare in each operating scenario and developed emission rates based on the conversion of that sulfur to SO_2. Landau calculated the emission rate as 165 pounds of SO_2 per MMscf, which is the standard adopted in the permit.

Q: WHAT DATA DID LANDAU RELY ON FOR THE PIPELINE SULFUR?

A: Landau relied on publicly available data from Williams Northwest Pipeline for both H2S and total sulfur. Total sulfur includes H_2S, so non-H_2S sulfur is the difference between total sulfur and non-H_2S sulfur. Sulfur on the pipeline is

measured in grains per 100 standard cubic feet. Grain is a measure of weight. There are 7,000 grains in a pound.

Q: WHAT TIME PERIOD DID LANDAU USE FOR THE PIPELINE DATA?

A: Landau had data from August 18, 2015 to July 19, 2017 at the time it did its calculation. Landau utilized data from July 1, 2016 through June 30, 2017, so basically the most recent 12 months of available data at the time. PSE explained in a letter to the Agency dated August 11, 2017 that "Total sulfur and H2S levels reported daily by the Williams Northwest Pipeline have been steadily decreasing in recent years due to changes in natural gas supply sources with a lower sulfur content and are expected to drop."[176] As such, Landau utilized the most recent 12 months of data.

Q: WHAT SPECIFIC DATA WAS USED?

A: For H2S, the pipeline tariff limits H_2S to 0.25 grains/100 SCF. Landau assumed that the full 0.25 grains/100 SCF would be in the gas coming to Tacoma LNG. For total sulfur, Landau chose the highest value in the 12-month period selected, which was 0.603 grains/100 SCF.

[176] RA-25, PSE Letter to Agency (Aug. 11, 2017).

Q: DR. SAHU POINTS OUT THAT THE MAXIMUM VALUE DURING THE FULL PERIOD FOR WHICH LANDAU HAD DATA WAS 1.019 GRAIN/100 SCF. WAS LANDAU WRONG NOT TO USE THAT HIGHER VALUE?

A: No. Landau used a lower value which caused a lower enforceable permit limit. In other words, the permit is more stringent using the lower value that Landau used than the higher value Dr. Sahu references. As a result, the choice was conservative.

Q: DR. SAHU ALSO SUGGESTS THAT LANDAU SHOULD HAVE ASSUMED 100% OF THE NON-H2S SULFUR WOULD GO TO THE FLARE INSTEAD OF 80%. DO YOU AGREE?

A: As with the choice of sulfur data, this result caused a lower enforceable permit limit. Had Landau assumed that 100% of non-H_2S sulfur went to the flare, it would have calculated a higher permit limit. Thus, this choice also was conservative.

Q: DR. SAHU EXPRESSES CONCERN THAT THE SO_2 LIMIT IS NOT ENFORCEABLE AND THAT TACOMA LNG MAY VIOLATE IT. DO YOU AGREE?

A: No, I do not. The permit sets an enforceable limit on SO_2 with which the plant must comply. The permit sets testing requirements regarding SO_2, as well as reporting requirements about and sulfur coming into the plant and a limit on H2S

coming into the plant. Tacoma LNG will need to adjust its operations to stay in compliance with the SO_2 limit in the permit.

Q: DR. SAHU ALSO PROVIDED CALCULATIONS OF WHAT THE PERMIT LIMIT WOULD BE IF THE HIGHER PIPELINE DATA WERE USED AND IF 100% OF NON-H2S SULFUR WENT TO THE FLARE. HAVE YOU REVIEWD HIS CALCULATIONS?

A: Yes. Dr. Sahu re-ran the Landau calculations two ways. In both of his calculations, he assumed 100% of non-H2S sulfur goes to the flare instead of 80%. This is contrary to CB&I's analysis. In one calculation, Dr. Sahu used 1.019 grains/100 SCF of total sulfur, which was the maximum amount in Landau's data set. In the other calculation, Dr. Sahu used 5 grains/100 SCF of total sulfur, which is the pipeline limit. This amount of sulfur does not appear representative of the amount of sulfur on the Northwest Pipeline based on data available.

Q: USING THE 1.019 GRAIN/100 SCF OF TOTAL SULFUR, WHAT EMISSION RATE DID DR. SAHU CALCULATE?

A: Instead of the SO_2 emission factor of 165 lbs/MMScf calculated by Landau, Dr. Sahu calculated that the SO_2 emission factor would be 285 lbs/MMscf. So, Dr. Sahu suggests that the permitted rate should be *higher* than what is in the permit. In other words, the permit is more stringent using the data that Landau used.

Q: WHAT OTHER CONCERNS DOES DR. SAHU EXPRESS?

A: Dr. Sahu suggests that if the permit limit were higher that Tacoma LNG would have exceeded the threshold value for 1-hour SO_2 in WAC 173-400-113.

Q: DO YOU AGREE WITH DR. SAHU?

A: My results from the screening analysis for 1-hour SO_2 are set forth below:[177]

Criteria Pollutant	Max Modeled Concentration (µg/m³)	Screening Threshold (µg/m³)	Background (µg/m³)	Total (µg/m³)	Ambient Standard (µg/m³)	Max / Standard
1-hour SO2	32	30	18	50	196	0.26

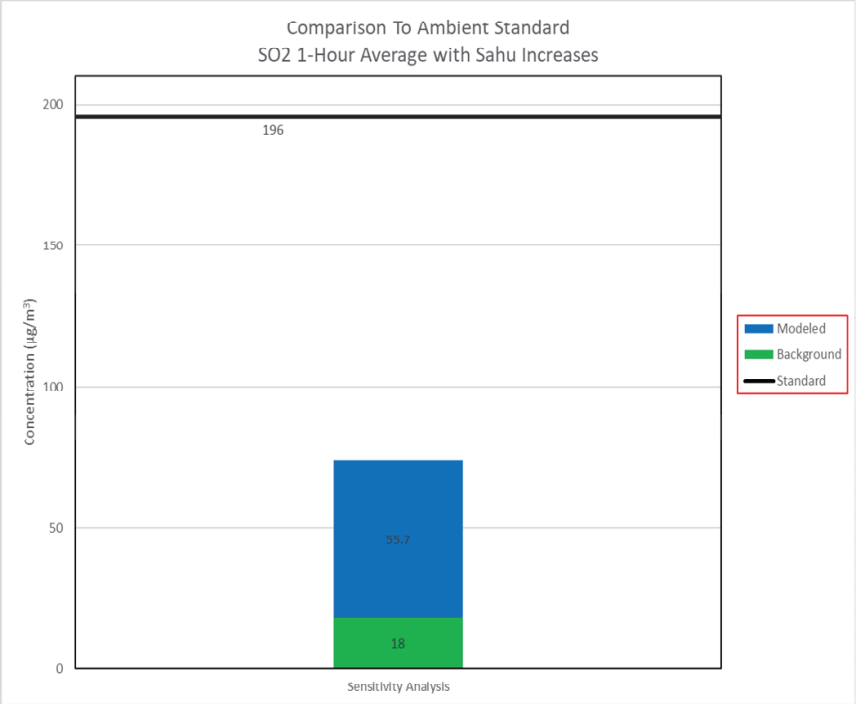
Dr. Sahu's emission factor of 285 lb/MMSCF is 1.73 times higher than the emission factor used by Landau. If Dr. Sahu's factor were used instead, my table would have looked like this:

Criteria Pollutant	Max Modeled Concentration (µg/m³)	Screening Threshold (µg/m³)	Background (µg/m³)	Total (µg/m³)	Ambient Standard (µg/m³)	Max / Standard
1-hour SO2	55.7	30	18	73.7	196	0.38

So, Dr. Sahu is correct that using a higher emission limit in the permit would have resulted in a maximum modeled concentration above the screening threshold. However, when adding in background as was done with $PM_{2.5}$, the result is well below the NAAQS/WAAQS. This is depicted on the chart below. So, even if the

[177] PSE-0078, Adjusted XQ Modeling Assessment Results (February 25, 2021).

permit term were loosened, there would be no issue with Tacoma LNG causing or contributing to a violation of the NAAQS/WAAQS. But the key point is that the permit term is in place, and Tacoma LNG must comply with it, so Landau's calculations showing SO_2 below the screening threshold is correct.



Q: DR. SAHU SUGGESTS THAT LANDAU WAS MANIPULATING THE DATA BY USING THE LOWER SULFUR DATA, DO YOU AGREE?

A: Definitely not. Landau was transparent with the data it was using with the agency, and the Tacoma LNG permit is based on that data. As I have described, this ended up with a more stringent emission limit, which would reduce emissions and impacts from Tacoma LNG.

OPINION 13: THE SMALL AMOUNT OF ADDITIONAL NITROGEN IN THE PURGE GAS WILL NOT DISCERNIBLY CHANGE N_2O EMISSIONS.

Q: PLEASE SUMMARIZE YOUR OPINION REGARDING LANDAU'S N_2O EMISSIONS CALCULATIONS.

A: Nitrogen used as purge gas at Tacoma LNG will not discernibly change nitrous oxide (N_2O) emissions from the flare. There simply is not enough nitrogen in the purge gas to discernably change the flame chemistry enough to cause additional N_2O formation. Dr. Sahu has done no calculations in support of his theory that Landau underestimated N_2O emissions from the combustion of purge gas.

Q: WHAT IS N_2O?

A: N_2O is a nitrogen compound that is regulated by EPA as a greenhouse gas (GHG).

Q: DOES THE PURGE GAS CONTAIN NITROGEN?

A. Yes. The waste gas that is directed to the flare is a mixture of natural gas vapors and nitrogen gas that is used as a purge gas to reduce the contact of natural gas with the oxygen in air as a safety measure.

Q: WILL PURGE GAS BE USED AT TACOMA LNG IN A MANNER THAT SENDS NITROGEN TO THE FLARE?

A: Yes. Elemental nitrogen gas will be used to clear (or "purge") piping at the plant after LNG is transferred to a truck or ship through those pipes. This nitrogen purge gas, which includes small amounts of methane and even smaller amounts of other gases, is sent to the flare for destruction along with other waste gas from Tacoma LNG.

Q: WILL THE NITROGEN IN THE PURGE GAS CAUSE DISCERNIBLE ADDITIONAL N_2O FORMATION?

A: No. The flow of purge gas, which is made up of a nitrogen gas sweep, operates in aggregate (*i.e.*, all transfer systems combined) roughly 692 hours per year,[178] or less than 8% of the year. Large quantities of atmospheric inlet air are needed to sustain combustion in a flare such as the one to be used by Tacoma LNG. That atmospheric inlet air consists of more than 78% nitrogen gas. The amount of atmospheric inlet air needed for the flare varies with the heat value of the gas mix

[178] PSE-0075, Landau Associates. Flare Gas Calculations. Emission Unit Inventory and Rates tab (sum of cells D29, D32, and D35 in the tab "1 Rates").

being combusted. At 250,000 gallons per day of LNG production, the amount of inlet air needed by the Tacoma LNG flare equates to between at least 947 scfm[179] and 12,951 scfm[180] of nitrogen. During most of the purge hours there will be less than 8% additional N2 and sometimes well less than 1% additional N2. This is unlikely to cause discernable additional N_2O formation, on an annual basis, particularly because the system is purged for such a short period of time during the year.

Dr. Sahu states that Tacoma LNG's flared waste gas will contain "much more" nitrogen than typical gaseous waste because nitrogen will be used at Tacoma LNG to clear lines after fueling of ships and trucks, yet he shows no calculations to substantiate this. My calculations above show that the small additional nitrogen in the purge gas is only there 8% of the time, at a maximum for most of the purge gas hours, and that even then, it impacts the nitrogen percentage minimally.

ADDITIONAL RESPONSES TO DR. SAHU'S TESTIMONY

Q: DO YOU AGREE WITH DR. SAHU THAT THE TACOMA LNG PERMIT CONDITIONS INSUFFICENTLY LIMIT EMISSIONS FROM THE FACILITY?

A: I do not agree. The permit contains numerous enforceable conditions that limit Tacoma LNG's emissions, including from the flare, vaporizer, and fugitive emissions. For example:

[179] RA-21, Tacoma LNG NOC Application at 66 (N2 Flare Inlet for Case 2B).
[180] *Id.* at 70 (N2 Flare Inlet for Case 5).

- Condition 1 requires that the facility be installed in accordance with information provided to the Agency.
- Condition 4 limits the vaporizer to operate no more than 240 hours per day for any 12-month consecutive period.
- Condition 6 limits the LNG vaporizer to 66 MMBtu/hr.
- Condition 7 requires a source test for the vaporizer that limits emissions of VOC, CO, and NOx.
- Condition 12 sets operational limitations on the ground-based enclosed flare that require it to operate efficiently and includes a required temperature monitor, to ensure effective operation.
- Condition 13 sets the stack height and inside diameter of the stack.
- Condition 15 requires 99% destruction of all VOCs from the flare.
- Condition 16 limits the SO_2 emitted from the enclosed ground flare.
- Conditions 17 through 30 describe how the ground flare is tested to ensure that emissions remain below the permitted levels.
- Condition 32 details the LDAR program that ensures that emissions from fugitive components are controlled.
- Condition 40 restricts the facility to accepting only pipeline natural gas, which has the effect of limiting VOCs into the facility.

- Conditions 43 through 46 are recordkeeping conditions that ensure that other provisions are tracked, recorded, and reported.

These conditions set emissions limits for the facility that must be met continuously.[181] They also establish monitoring and reporting requirements to demonstrate compliance with these limits. Further, Condition 1 requires Tacoma LNG to be installed consistent with the description provided to the Agency, including in the permit and supplemental submittals. These conditions are enforceable, so any hypothetical future violations of permit conditions could be subject to penalties and Agency enforcement action.

CONCLUDING QUESTIONS

Q: OVERALL, WHAT IS YOUR OPINION REGARDING PSE'S NOC APPLICATION?

A: It is my opinion that PSE and Landau put together a complete NOC application, provided a reasonable and acceptable amount and quality of information to the Agency regarding the Tacoma LNG facility, and developed the facility design in accordance with accepted air permitting practices and consistent with the applicable the Agency regulations.

Q: OVERALL, WHAT IS YOUR OPINION REGARDING THE AGENCY'S TREATMENT OF THE TACOMA LNG NOC APPLICATION?

[181] RA-132, NOC Order of Approval.

A: To the best of my knowledge, I believe the Agency acted appropriately within its discretion under applicable regulations and consistent with standard air permitting practices in relying on the information provided by PSE and Landau in support of its NOC application, and in granting the NOC Order of Approval to the Tacoma LNG facility.

Q: DOES THIS CONCLUDE YOUR TESTIMONY?

A: Yes, it does. However, I reserve the right to supplement this testimony further as needed based on evidence developed at the hearing or in rebuttal to testimony by other experts.

Signed and dated March 29th, 2021.

Dr. Shari Libicki

ATTACHMENT A

RAMBOLL

ENVIRONMENT
& HEALTH

SHARI BETH LIBICKI, PHD

Principal

Shari Beth Libicki, PhD, is a senior member of Ramboll's air quality practice. She has over 30 years of chemical fate and transport experience, as applied to managing greenhouse gas (GHG) emissions and estimating air emissions and dispersion from refineries, chemical processes, landfills, quarries and new developments. Her experience includes providing technical expertise to entitlement and litigation teams. She is an expert on GHG evaluations for California Environmental Quality Act (CEQA) documents and is at the forefront of developing regulations in California, having served on the Regional Targets Advisory Council. She has conducted extensive air quality regulatory assessments for New Source Review/Prevention of Significant Deterioration (NSR/PRD) permitting and compliance auditing. She has lectured widely on evaluating climate change impacts for new developments and estimating chemical exposure for risk assessments. She currently serves as an Adjunct Professor in the Department of Chemical Engineering at Stanford University.

CONTACT INFORMATION
Shari Beth Libicki, PhD

slibicki@ramboll.com
+1 (415) 796.1933

Ramboll
201 California Street
Suite 1200
San Francisco, 94111
United States of America

EDUCATION

PhD, Chemical Engineering, Stanford University, 1985
MS, Chemical Engineering, Stanford University, 1981
BSE, Chemical Engineering, University of Michigan, 1979

EXPERIENCE HIGHLIGHTS

Litigation Support

- Served as an expert witness for a case where exposure to dust and diesel particulate from a quarry was alleged. The plaintiffs put microsensors on their houses to measure dust and posted the data on a public website. We were able to use the publicly available data to show that the dust in the neighborhood was not correlated with mining activities or blasting events. In addition, we estimated the emissions and dispersion of diesel particulate to show that the diesel particulate from mining operations was below a level of significance.
- Served as an expert witness for a series of mass torts where plaintiffs alleged harm resulting from emissions from a flaring event at a refinery. There was nearly a decade of information from ambient air monitors sited in and around the refinery. In addition, there was monitoring information on emissions from the flare during the flaring event. We conducted detailed air dispersion modeling to assess the statistical distribution of exposure among hundreds of named plaintiffs. Issues

centered around using discrete monitoring data and air dispersion modeling to evaluate impacts in the neighborhood.

- Served as an expert witness in defense of claims of property diminution from fugitive dust emissions from an adjacent coke production facility. The work was conducted using nearby monitors that recorded PM_{10} concentrations before and after the establishment of the production facility. A meteorological analysis was also conducted that evaluated whether wind direction impacted measured PM_{10} concentrations. The case was further complicated by the presence of rail lines that transported large amounts of coal fines.
- Served as an expert witness in defense of a remediated wood treatment facility where historical dust emissions were alleged to have contaminated the neighborhood. The analysis included an evaluation of the various factors that would impact dust contamination including vegetation, rainfall, vehicle count, and meteorology.
- Served as an expert witness for several cases where plaintiffs alleged harm as a result of living near a waterway into which oil was released as a result of excessive rainfall at a refinery. Issues in the case included an evaluation of the cause of the release, emissions estimation, dispersion modeling, and an analysis of an extensive set of ambient air quality data.
- Provided technical support to attorneys on a litigation case where an accidental release of a particulate and liquid material from a refinery was alleged to have caused harm to thousands of plaintiffs. This included an engineering evaluation of the release quantity, meteorological data analysis, and an evaluation of dispersion and deposition of aerosols in complex and intervening terrain.
- Served as an expert witness for evaluation of exposure to naturally occurring asbestos (NOA) from roadways potentially paved with rock containing NOA in California. Work included evaluating potential exposure pathways, reviewing relevant regulatory restrictions, evaluating activities that may result in dust emissions, and reviewing alternative methods of asbestos analysis.
- Served as an expert witness evaluating PCB airborne emissions from process emissions and soil contamination from a PCB-producing facility. This included PCB manufacturing process reconstruction since the beginning of PCB manufacturing, as well as an estimate of the amount of PCB emitted from fugitive dust from vehicles traveling over contaminated roads, and dust track-out.
- Served as an expert witness supporting the permitting efforts of a large landfill in Texas. Permit contestants alleged that the landfill gas collection system was improperly designed and was incapable of collecting landfill gas consistent with the requirements. The case included the use of surface methane measurements, odor complaint history, and well measurements to show that the landfill gas system was operating as designed.
- Served as an expert witness for an odor issue at a landfill in Ohio. Plaintiffs alleged that odors were pervasive and persistent over a large area surrounding the landfill. A computer animation of the odor complaints showed that the odors were unidirectional, and occurred only under certain meteorological conditions.
- Served as an expert witness for a several cases where plaintiffs alleged harm as a result of living near a creosote wood treatment plant. Issues in the cases included emissions estimation, dispersion modeling, analysis of air, soil and sediment and attic dust sampling data.
- Served as an expert witness for a mass tort where plaintiffs alleged harm resulting from a wide variety of emissions sources at a pharmaceutical manufacturing facility. Primary issues centered around hexavalent chromium emissions from cooling tower drift. Ramboll Environ's analysis included historical emissions reconstruction and dispersion modeling, and evaluation of monitoring data.
- Provided expert support in a case requiring reconstruction of emissions over a 70-year period from a specialty chemical manufacturer. Emissions estimation involved reconstructing historical processes and process controls and combining them with annual production records. The emissions estimates were used to assist in case settlement.

- Provided expert assistance in estimating airborne emissions and onshore impacts from an offshore oil leak. Evaluation included reviewing monitoring data, data on emissions, meteorology, and the potential for dissolution and degradation.
- Served as an expert witness in a case where exposure to arsenic from the burning of CCA-treated wood was alleged. The case surrounding the potential for a lineman to be exposed to arsenic from CCA-treated utility poles due to utility pole fires.
- Served as an expert witness evaluating impacts from airborne emissions associated with an oil spill into a river. The oil flowed downriver, and odors from the spill were noticed along the river. Ambient air monitoring data was available from soon after the spill occurred. Issues associated with this case included evaluating air monitoring data, and estimating volatilization, dispersion and chemical speciation of the emissions.
- Served as an expert witness in a litigation case where a release of mercaptans from a refinery was alleged to cause harm to students in a nearby school. The work involved analysis of samples to evaluate the composition of the released materials, an analysis of the release quantities, and the dispersion of those emissions.
- Served as an expert witness in a litigation case where vinyl chloride was released from a co-disposal landfill. The work involved deploying an extensive monitoring network to analyze the neighborhood ambient air, and was able to characterize the locations with elevated vinyl chloride ambient air concentrations based on modeling and the monitoring data.
- Provided impartial technical assistance to both the plaintiffs and defense in a toxic tort case involving aerosolized air emissions from a large acid manufacturing facility in Arkansas. Particular issues in the case surrounded the potential for particulate formation under certain meteorological conditions; evaluation of control technology, and overall evaluation of emissions from the facility.
- Provided expert assistance on a litigation case where subsurface methane gas from a rogue landfill was alleged to damage property values in a housing development. Developed methods to evaluate trace chemicals and extent of gas migration.
- Provided independent technical assistance to the court’s mediator on landfill gas migration and control issues for a landfill toxic tort litigation involving a very large landfill (several square miles) in the Eastern United States.
- Served as an expert witness in a litigation case where ammonia was released from a refrigeration system. This included an analysis of the opposing expert's work, creation of a model to describe the release from the system, and evaluating alternative scenarios.
- Served as an expert witness in a litigation case evaluating the potential for cross-contamination via process exhausts, within an industrial facility. The potential for the airborne particulate contaminant to contribute to trace concentrations in the product was analytically evaluated.
- Provided technical support to attorneys in a litigation involving the impacts from a chlorine tank spill. The spill was modeled and the impact of meteorological conditions and varying spill scenarios was evaluated.
- Provided litigation support for an evaluation of pesticide contamination to determine whether pesticide at site was a result of spills and leaks or airborne deposition as a result of pesticide milling at the site.
- Provided expert assistance in cases where the impacts of facility emissions were compared to Proposition 65 thresholds. Several of the cases were in active litigation.

Permitting and Enforcement

- Provided nationwide compliance assistance to six iron and steel mini-mills. Work conducted includes: preparation of Title V permit applications and supporting emissions estimates; preparation of PSD permits and associated emissions and dispersion modeling; evaluation of RACT controls for mini-mills.
- Managed PSD permit applications for two aluminum smelting facilities. This work included preparation of the emissions inventories, managing the Class I and Class II modeling effort,

conducting the best available control technology (BACT) analysis, and preparing the technical document. She also negotiated permit conditions with the agencies, and assisted with cross-border discussions with other impacted agencies.

- Assisted a large landfill in Southern California respond to a series of Notices of Violation surrounding odor issues. Ramboll Environ conducted computational fluid dynamic (CFD) modeling study to evaluate the sources of odors at the landfill, as well as to predict where odors might occur in the neighborhood and under what conditions. Ramboll Environ also conducted a surrogate sampling study where it was found that ethanol was a surrogate for odors. Finally, Ramboll Environ assisted in the negotiations which allowed the landfill to continue operations.
- Managed the preparation of an application for an Authority to Construct for a state-of-the-art hazardous waste treatment storage and disposal facility, which included a risk assessment for the project, and successfully negotiated permit conditions with state and local agencies. Currently working with facility and regulators to implement permit conditions.
- Worked as a technical advisor to the Imperial County Air Pollution Control District (ICAPCD) for the permitting of a rail-haul landfill. This landfill is proposed to be the largest landfill in the United States, and had monitoring, modeling, and enforceability issues associated with the permit. Of particular interest was a phased permitting approach that allowed the landfill operator to take advantage of newer technologies that could reduce emissions of criteria pollutants over time.
- Prepared and submitted several Federal Operating Permit Applications under Title V of the Clean Air Act for industrial facilities. Currently working on ongoing negotiation for permits.

Monitoring

- For a leading environmental non-governmental organization, prepared a white paper on the different types of inexpensive monitors that may be used to monitor emissions around oil and gas operations. We evaluated the scientific literature for monitor accuracy, stability and the potential for cross sensitivity to pollutants, and provided information on commercially available monitors, and also evaluated pre-commercialized monitoring options to determine what may be on the market in the short to medium term.
- Assisted in the design of a refinery monitoring plan in California. The monitoring was required as the result of a settlement with the host city as a result of a fire several years earlier. The refinery monitoring plan was intended to allow the community, on a real-time basis, to evaluate whether there were releases from the refinery, and included Fourier Transform Infra-Red (FTIR) monitors on the fenceline, along with fixed monitors for a variety of criteria pollutants and toxic air contaminants. Our input was primarily designed to make the data more useful to the community and refiner.
- Directed a yearlong ambient air-monitoring program to measure particulate matter and diesel particulate matter (DPM) at the boundary of a large landfill in Los Angeles and a nearby school. The results of the monitoring program were analyzed temporally and as a function of meteorology. The results of the program showed that nearby freeways provided an overwhelming fraction of the measured DPM.
- Designed a complex fourteen-station ambient air monitoring network around a co-disposal landfill to measure the concentrations of 19 toxic chemicals in both gaseous and particulate phase for risk assessment purposes and negotiated approval with local, state and federal regulators.
- Analyzed the results of a complex multi-year total suspended particulate monitoring program to understand the sources of arsenic in the ambient air, and to evaluate the health risks of the arsenic levels that could be related to nearby facility emissions.
- Designed and conducted the compliance ambient air monitoring program for a large hazardous waste facility. The ongoing program collects whole air and total suspended particulate samples at five stationary sites. Prepared risk assessment based on the program, and quarterly reports for review by the local air district and the California Environmental Protection Agency's (EPA')s Department of Toxic Substances and Control (DTSC).

- Designed, negotiated and managed a novel cost-effective ambient air monitoring program that yielded real-time information on the health impacts of a site remediation. This study is the basis of a well-received paper.

Land Use Entitlement

- Project director for the Chevron Renewal Project Revised Environmental Impact Report to allow a large capital project to proceed at the Chevron Richmond Refinery. The Revised EIR fulfilled the requirements of a court decision with specific focus on the Climate Change and Air Quality sections of the EIR. The revision of the Climate Change section described mitigation measures and quantification of the efficacy of those mitigation measures. The Air Quality section included a comprehensive estimate of emissions from the refinery under a range of operating scenarios and addressed a range of process alternatives in the refinery.
- Prepared comprehensive air quality analysis for two large municipal solid waste landfills in Southern California. Evaluation included impact of exhaust from non-road heavy equipment, dust from waste operations, and emissions from landfill gas escaping the collection system, and flares and turbines used to destroy the landfill gas. Projects included public testimony on results of analysis.
- Analyzed the impacts of potential accident scenarios prior to the construction of several new industrial facilities. The results of the analyses were used to make recommendations as to how to improve the safety and minimize the risks to the surrounding community.
- Project director for the development of the California Air Pollution Control Officer's Association (CAPCOA) manual on quantifying mitigation for a wide variety of carbon reduction measures that can be used for residential and commercial development.
- Project director for CalEEMod®, a new software package to estimate GHG, air toxics and criteria pollutant emissions from new development projects in California.
- Evaluated climate change impacts of dozens of new projects under CEQA and National Environmental Policy Act (NEPA). Specific types of projects include large, multi-use developments, landfill expansions, and transportation hubs.
- Provided innovative air quality services for entitlement activities, including evaluating the impacts of freeways on air quality, the estimation of emissions from complex industrial facilities, and the impact on public health of those emissions. Provided testimony at public hearings in support of technical analyses.

Other

- Evaluated the transport of perfluorooctanoic acid (PFOA) in the air and in the ocean as a part of a large multiphase study being carried out by DuPont. The study resulted in a poster presentation at the American Geophysical Union and centered on how the chemical properties of PFOA impact its transport.
- Evaluated the potential contribution of airborne dioxin releases from a refinery to deposit within a defined boundary and contribute to measured dioxin concentrations in wastewater. Analysis included estimation of dioxin releases from a variety of units, including flares; selection of units most likely to contribute to dioxin deposition; selection of deposition modeling technique; and analysis of results.
- Managed the consequence analysis for several Risk Management and Prevention Programs (RMPP). Projects included scenarios with acids, toxic gases, and chemical reactions. Analysis involved using standard analytical tools as well as some state of the art tools.
- Prepared carbon footprints for facilities in a variety of industries, including landfills, large and small manufacturing operations, commercial developments, and municipal services; assisted in development of GHG minimization programs.
- Provided support to a large shipping company in evaluating the effectiveness of its emissions reduction programs; oversaw design of an automated database system to track fuel use and emissions reductions from a variety of innovative programs to improve reporting and streamline the program.

- Evaluated the potential of deposited arsenic-based pesticide to contaminate adjacent property. Transport pathways examined included wind-blown dust, surface water transport, and vehicle trackout.
- Conducted preliminary evaluation of whether patterns of measured lead in soil supported contention that lead resulted from airborne emissions from a lead emitting stack located at the site. Concluded that insufficient data was available for analysis.
- Designed a protocol for estimating the quantities of specific hazardous chemicals disposed of in California by region and waste type, and worked with the Department of Health Services to verify protocol.
- Gave lecture series on the harmonization of the State and Federal Risk Management Programs in California, and how to best implement the unified program.
- Prepared and negotiated a settlement proposal with regulators for a large facility which included new methods for calculation of organic emissions, additional controls on processes, and monitoring requirements.
- Gave an invited lecture series to senior environmental professionals in Mexico on the technical basis of the estimation of the impacts of sudden releases of toxic and flammable materials, in the wake of the Guadalajara explosions. Managed technical support team for large toxic tort litigation that involved estimating current and historical emissions from several large facilities, comparing and choosing appropriate meteorological data for the analysis dispersion modeling, mapping of impacts with respect to plaintiffs, and comparison with air quality guidelines and toxicological end points.
- Analyzed the particulate emissions from a basic chemicals processing plant containing over 90 separate sources, conducting a dispersion and culpability analysis, and evaluating the effectiveness of proposed and implemented source controls.

Prior to joining Ramboll, Shari held the following positions:

- Physical Sciences Officer, Bureau of Oceans and Environmental and Scientific Affairs, US Department of State
  - Developed and implemented a successful negotiation strategy for cooperative scientific projects with Japan and the Soviet Union.
  - Worked with Japan's Science and Technology Agency to initiate a Japanese funding organization for innovative international biotechnological studies.
- Staff Scientist, Alza Corporation
  - Led teams that created, designed, tested, and patented controlled release transdermal and osmotic pump drug delivery systems.
  - Studied the correlation between drug physical chemical data and dermal transport and absorption.
  - Designed and implemented systems to provide effective membrane thickness control in the manufacture of miniature osmotic pumps.
- Lecturer, Department of Chemical Engineering, Stanford University
  - Taught courses in Chemical Engineering Laboratory and Technical Speaking and Writing.

CREDENTIALS

Awards and Honors

American Association for the Advancement of Sciences Diplomacy Fellow, 1987-1988

United States Department of State Meritorious Honor Award, March 1989

PROFESSIONAL AFFILIATIONS AND ACTIVITIES

Member, American Institute of Chemical Engineers

RAMBOLL ENVIRONMENT & HEALTH

Member, Air & Waste Management Association

PATENTS

H.F. Sanders, Y.L. Cheng, D.J. Enscore, S.B. Libicki. Transdermal Drug Composition with Dual Permeation Enhancers. Patent Number: 4,820,720. April 11, 1989.

R.M. Gale, D.J. Enscore, D.E. Nedberge, M. Nelson, Y.L. Cheng, S.B. Libicki. Transdermal Administration of Progesterone, Estradiol Esters, and Mixtures Thereof. Patent Number: 4,788,062. November 29, 1988.

PUBLICATIONS & PRESENTATIONS

Libicki, S.B. 2019. "Using Dispersion Modeling and Monitoring as a Basis of Estimating Emissions from Refineries." Presented at the Refinery and Chemical Symposium. November.

Bandoro, J. T. Olevski, K. Richman, D. Hill, M. Dvorak, J. Luongo, S. B. Libicki, C. Emery, G. Yarwood. 2019. "Ramboll Shair: Integrating real-time sensor measurements and regional/local-scale models in Richmond, California." Presented at the Community Modeling and Analysis System. October.

Vijayaraghavan, K., S.B. Libicki, R. Beardsley, J. Jung, S. Ojha. 2018. "Modelling of Atmospheric Mercury Deposition in India." Published in "Urban Air Quality Monitoring, Modelling and Human Exposure Assessment." Springer Publishing.

Nambiar, M. and S.B. Libicki. 2018. "Residential Indoor Particulate Matter Monitoring: A Comparative Study of Two Low-Cost Sensor Technologies". Presented at Air & Waste Management Association Annual Conference. Hartford. CT. June.

Klug, S.E., K.L. Krieger, D.W. Weaver, M.T. Keinath, S.B. Libicki. 2012. "Quantifying Filtration Impacts on Indoor Exposure to Particulates." Presented at Air & Waste Management Association Conference and Exposition. June 19, 2012.

Bowie, T.; S.B. Libicki, K.L. Davis, C. Emery. 2011. "Strategies for Designing an Odor Monitoring Program for Municipal Solid Waste Landfills." Presented at Air & Waste Management Association Conference and Exposition. June 22, 2011.

Keinath, M.T. and S.B. Libicki. 2010. "Preventing GHG Leakage: Benchmarking Emissions to Design a Fair Cap and Trade System under AB32." Presented at the 2010 California Construction and Industrial Materials Association (CalCIMA) Education Conference. San Diego, CA. September.

Van de Griend, R., R.W. Andersen, S.B. Libicki, J. Ilisco, U. Senturk. 2009. Arsenic In Glass Highway Marking Beads. A&WMA's 102nd Annual Conference & Exhibition, Detroit, MI. June.

Hou, M., M.T. Keinath, C. Helvestine, S.B. Libicki. 2008. Predicting Human Exposure near Freeways: A Comparison of AERMOD and CAL3QHCR. AWMA Annual Conference, Portland, Oregon. June.

Weaver D.W., S.B. Libicki, K.L. Davis. 2008. VMT, GHG Reduction, and Planning: Looking Under the Hood. Presented at American Planning Association California Chapter (APACA) Conference. September 21-24.

Keinath, M.T. and S.B. Libicki. 2008. Local Sourcing for Green Building: How Homegrown Materials Can Reduce Your Carbon Footprint. California Construction & Industrial Materials Association (CalCIMA) Annual Conference. September.

DiBiase, M. and S.B. Libicki. 2008. Emissions and the Shipping Industry: Emission Reductions for Ocean-Going Vessels in California Air & Waste Management Association Conference. June.

Libicki, S.B., D. Weaver, and D. Kim. 2007. A Technical Approach to Addressing Climate Change in Environmental Impact Reports. 2007 Environmental Law Conference at Yosemite. Environmental Law Section of the State Bar of California. October.

Kemball-Cook, S.R. and S.B. Libicki. 2006. "Using surface drifter buoys to estimate oceanic transport of surfactants". Presented at the American Geophysical Union Ocean Sciences Meeting.

Libicki, S.B. 1999. When Good Data Goes Bad: What the Numbers Really Mean. American Bar Association Section of Environment, Energy and Resources 7th Section Fall Meeting, San Diego, California. October.

Libicki, S.B. and R. Van de Griend. 1996. RMPs, RMPPs and SB 1889: Consolidation of State and Federal Risk Management Programs. Presented as a Minimum Continuing Legal Education course at various law firms. San Francisco, California. November-December.

Stuart, A.L., S. Jain and S.B. Libicki. 1996. The Use of Long-Term Meteorological Information to Predict Impact Probabilities Resulting from Toxic Chemical Releases. PSA 96-International Topical Meeting on Probabilistic Safety Assessment. American Nuclear Society, Park City, Utah. October.

Libicki, S.B. 1995. The Use of Simplified Quantitative Risk Analysis in Risk Management Decisions at Small and Medium-Sized Process Plants. 88th Annual Air & Waste Management Association Annual Meeting, San Antonio. June.

Jain, S. and Libicki, S.B. 1995. Estimating the Additional Airborne Release Due to Heat of Reaction and Aerosolization When Strong Acids React With Water during a Release. Air & Waste Management Association Annual Meeting, San Antonio. June.

Libicki, S.B. 1994. Emergency Release Modeling: Software options and usage strategies. Southwest Safety Congress and Exposition. May.

Libicki, S.B. and R. van de Griend. 1994. Practical Compliance Strategies for Laboratory and Production: Ensuring Compliance from the Ground Up. Bio International '94. Toronto. May.

Libicki, S.B., A. Andersen and R. Scofield. 1994. The Use of Ambient Air Monitoring Data for the Evaluation of Risks due to Particulate-Borne Metals: A Case Study. California Mining Association Annual Meeting. April.

Libicki, S.B. and R. Scofield. 1993. Issues and Solutions in Air Toxics Source Impacted Ambient Air Monitoring for Use in Risk Assessment. Fourth Annual West Coast Regional Conference: Current Issues in Air Toxics. November.

Gates, L.J., S.B. Libicki, R. Scofield, and J. Wilhelmi. 1993. A flexible real-time ambient air monitoring program during Superfund Site redevelopment. EPA/AWMA Field Screening Methods for Hazardous wastes and Toxic Chemicals. February 24-26.

P.M. Salmon, S.B. Libicki, and C.R. Robertson. 1988. A theoretical investigation of convective transport in the hollow fiber reactor. Chemical Engineering Communications 66:221 248.

Libicki, S.B., P.M. Salmon, and C.R. Robertson. 1986. Measurement of inert gas permeabilities in compact bacterial cell aggregates using an annular reactor. Annals of the New York Academy of Sciences, Vol. IV; and Biochemical Engineering 469:145 151.

Karel, S., S. Libicki, and C.R. Robertson. 1985. The immobilization of whole cells: Engineering principles. Chemical Engineering Science 40(8):1321 1354.

Campbell, J.H., P. Peters, S.B. Libicki, M.L. Gregg, and J.E. Clarkson. 1981. Analysis of the operation of Occidental's modified in situ retort 6. In Fourteenth Oil Shale Symposium Proceedings, Golden, Colo.: Colorado School of Mines Press.

Campbell, J.H., J.H. Raley, F.H. Ackerman, W.A. Sandholtz, and S.B. Libicki. 1980. Investigation of critical parameters in modified in situ retorting. In Thirteenth Oil Shale Symposium Proceedings, Golden, Colo.: Colorado School of Mines Press