BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC VANCOUVER ENERGY DISTRIBUTION TERMINAL	)))))))))	CASE NO. 15-001 DIRECT TESTIMONY OF RANAJIT SAHU, PH.D.

I. INTRODUCTION

1. The Energy Facility Site Evaluation Council (EFSEC) for Washington State has prepared a Draft Environmental Impact Statement (DEIS[1]) for the proposed Tesoro Savage Vancouver Energy Distribution Terminal Project (hereafter T-S[2]). According to the DEIS, the T-S Project would involve shipment of an average of 360,000 barrels of crude oil per day from the "mid-continent"[3] U.S. to the Port of Vancouver, Washington (Port) via rail. Approximately four "unit trains" consisting of up to 120 crude oil tank cars would arrive at, and depart from, the

[1] Tesoro Savage Vancouver Energy Distribution Terminal Facility Draft Environmental Impact Statement, November 2015.

[2] For the purpose of this testimony, I will distinguish the overall project from the subset of activities and sources that will occur just at the Port of Vancouver's Terminal in order to realize this project. Thus, I will use "T-S Project" when discussing the overall project and "T-S Terminal" when discussing just the terminal.

[3] The Applicant has reported its customers would likely source crude oil primarily from mid-continent North American locations, including the Bakken formation that covers parts of North Dakota and Montana and Saskatchewan, Canada. Depending on market conditions and the needs of the proposed Facility's customers, crude oil may also come from other North American formations, such as the Niobrara in Wyoming and Colorado and the Uinta in northeast Utah…." DEIS, p. 2-2.

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Port each day.[4] The crude oil would be stored at the T-S Terminal and would then be transferred to ships on the Columbia River. The T-S Terminal could, as needed, directly transfer crude oils from rail to vessels by passing storage tanks at the T-S Terminal. About one loaded tanker vessel per day would carry the oil down the river and out to sea for distribution primarily to refineries on the U.S. West Coast, including Alaska and Hawai'i.

2. This testimony focuses on the air quality and greenhouse gas (GHG) emissions aspects of the T-S Project, including but not limited to the T-S Terminal. It does not purport to be a detailed critique of the air quality and GHG analyses presented in the DEIS.[5] Nor does it provide a *detailed* critique of the air quality analyses presented by the project proponent in its Revised Air Quality Permit Application[6] (for the T-S Terminal alone). However, the testimony will, as needed, reference these documents in order to provide contrasts and context for what is being proposed and how air quality and GHG emissions are/are not being addressed.

3. The purpose of this testimony is to provide information on:

(a) the types of activities and/or sources of air pollutants that will unavoidably accompany the T-S Project as a whole. The testimony will discuss what is known and what is not known, or at least not disclosed, in the record available from T-S and/or EFSEC with regard to such sources and activities. This is crucial because the rest of the quantitative analysis (i.e., estimation of air emissions over short and

[4] I note, however, that per the applicant and the DEIS, "[O]n occasion, a fifth train may arrive within the daily 24-hour period and begin unloading within that current 24-hour period, but would complete unloading in the following 24-hour period." VE_INF_0092998 (Email from Dan Gunderson to Steven Manlow dated August 6, 2015. Note that the VE numbers used herein are the Bates numbers on documents received in response to public records and/or discovery requests in this matter). Thus, all short-term air emissions analyzed by the applicant and in the DEIS could underestimate impacts on days when 5 trains arrive instead of the usual 4.

[5] I have previously provided comments on air quality and GHG analytical deficiencies in the DEIS. These prior comments are Exhibit 5520-000010-CRK.

[6] See Application beginning VE_INF_0089386.

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long term time scales) and assessment of their spatial and temporal impacts (such as via air quality modeling) as well as the regulatory implications of air and GHG emissions (such as determination of the spatial and temporal scope of the DEIS analysis or the type of air quality permit required at the T-S Terminal) cannot be properly conducted if there are essential data-gaps for sources and activities;

(b) the types of air pollutants that can and will be emitted as a result of the T-S Project for the sources and activities identified in (a) above. The spatial and temporal nature of these emissions will be noted;

(c) the manner in which air quality and GHG emissions should be estimated from the sources identified in (a) for the pollutants identified in (b) above. In particular, it will discuss the accuracy of emissions estimation techniques. In any emissions estimation exercise a critical issue is the support provided (or not) in the underlying project documents for all assumptions (and certainly for critical or key assumptions) that are used in the analyses. Failing to provide supporting bases and/or not using the correct methodologies for emissions estimation will lead to inaccurate (and often under-prediction of) project emissions. Thus, not recognizing or incorporating variability and accuracy considerations in the emissions estimation exercise will compromise all of the subsequent assessments, including permitting, modeling of emissions, estimation of impacts and resultant risks, etc. This testimony will discuss some specific instances of emissions estimation methodology deficiencies in the DEIS/Revised Air Permit Application as opposed to a comprehensive assessment for all activities/sources for all pollutants.

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4. Based on my review of the record, it is my opinion that the DEIS for the T-S Project, as well as the Air Quality Permit Application for the T-S Terminal are significantly lacking in all of the aspects (a), (b), and (c) noted above. As a result, the analyses presented in these documents, and, importantly, conclusions drawn from such analyses, are likely flawed and unreliable for decision-making by EFSEC or other regulatory bodies.

5. The remainder of this testimony is organized as follows. Section II provides a brief biographical sketch. My resume, list of publications, and prior expert work are attached to this testimony. Section III discusses project boundary issues, as well as sources and activities. Section IV discusses pollutants. Section V discusses emissions estimation, focusing on VOC emissions. Section VI discusses GHG emissions.

II. BACKGROUND AND EXPERIENCE

6. I, Ranajit Sahu, have over 23 years of experience in the fields of environmental, mechanical, and chemical engineering including: program and project management services; design and specification of pollution control equipment; soils and groundwater remediation; combustion engineering evaluations; energy studies; multimedia environmental regulatory compliance (involving statutes and regulations such as the Federal Clean Air Act (CAA) and its Amendments, Clean Water Act (CWA), Toxic Substances Control Act (TSCA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA), Occupational Safety and Health Act (OSHA), the National Environmental Policy Act (NEPA) as well as various related state statutes); transportation air quality impact analysis; multimedia compliance audits; multimedia permitting (including air quality NSR/PSD permitting, Title V permitting, NPDES permitting for industrial and storm water discharges, RCRA permitting, etc.), multimedia/multi-pathway human health risk assessments for toxics; air

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dispersion modeling; and regulatory strategy development and support including negotiation of consent agreements and orders.

7. Specifically, I have over 20 years of air quality consulting experience, providing emissions calculations support including the calculation of potential-to-emit for various pollutants, permitting support, and related technical analyses for clients in all 50 U.S. states and abroad. My consulting experience includes dealing with the types of pollutants (such as volatile organic compounds, or "VOCs" and hazardous air pollutants or "HAPs") and sources similar to those at issue in this matter – for example fugitive emissions from storage tanks; fugitive and stack emissions from vapor capture and control systems from loading of liquids; and fugitive emissions from myriad types of components used in chemical plants, refineries, and bulk liquid terminal facilities.

8. I have a B.S., M.S., and Ph.D., in Mechanical Engineering, the first from the Indian Institute of Technology (Kharagpur, India) and the latter two from the California Institute of Technology (Caltech) in Pasadena, California. My research specialization was in the combustion of coal and, among other things, understanding air pollution aspects of coal combustion in power plants.

9. I have over 21 years of project management experience and have successfully managed and executed numerous projects in this time period. Projects include basic and applied research projects, design projects, regulatory compliance projects, permitting projects, energy studies, risk assessment projects, and projects involving the communication of environmental data and information to the public.

10. I have provided consulting services to numerous private sector, public sector, and public interest group clients. My major clients over the past twenty-one years include various

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steel mills, petroleum refineries, cement companies, aerospace companies, power generation facilities, lawn and garden equipment manufacturers, spa manufacturers, chemical distribution facilities, and various entities in the public sector including the U.S. Environmental Protection Agency ("EPA"), the states of New York, New Jersey, New Mexico, the U.S. Department of Justice, California Department of Toxic Substances Control, and various municipalities. I have performed projects in 48 U.S. states, numerous local jurisdictions and internationally.

11. In addition to consulting, I have taught numerous courses at several Southern California universities as reflected in my attached CV.

12. I have and continue to provide expert witness services in a number of environmental areas discussed above in both state and Federal courts, as well as before administrative bodies.

III. PROJECT BOUNDARIES AND AIR EMITTING SOURCES AND ACTIVITIES

13. In this section of my testimony I will address how the materials provided by the T-S Project proponent to date do not present a complete picture of the potential impacts to citizens of the state of Washington because of constrained or inaccurate or simply unspecific project boundaries necessary for the identification of pollution from or associated with or induced by the T-S Project. Almost every single activity related to loading, transporting, handling, transferring, storing, and unloading the crude oil, associated with the T-S Project, is a potential and actual source of air emissions[7] of several classes of pollutants/pollutants.

A. Lack of Definition of Project Boundaries for the T-S Project

14. For any reasonable analysis of the air impacts of any project, including the T-S

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[7] In most instances I will use the term "air emissions" to include potential or actual emissions of any regulated air pollutant, including GHG.

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Project, it is crucial that the spatial and temporal "boundaries" of the project be defined with proper specificity in order to support later quantitative[8] estimation and assessment. Without this boundary definition, identifying all air emissions sources and activities "within" the project boundary is obviously futile and unnecessarily confusing.

15. Thus, one of the first and most glaring deficiencies in the DEIS analysis is the lack of specificity in defining the project boundary and/or properly supporting the boundary. Examples include:

(i) lack of specificity of all of the types of crude oil that will be handled via this project.[9] This not only includes the properties of crude oil which are essential in the assessment of (not just) air emissions but also points of origin (which I discuss next);

(ii) lack of any specific discussion of where crude oil associated with the T-S Project will actually originate. It is not unfair to state that, basically, if crude oil can be loaded onto a train (including low-viscosity crudes using heated tank cars[10]) anywhere in the US and/or Canada (whether from a pipeline hub, another storage terminal, etc.) and it is economic to do so, the T-S Project could and

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[8] This is a critical point. The air quality and GHG assessments are quantitative in nature and not just qualitative. What is required, as a starting point, is the quantitative mass rate of emissions (over a specified time period such as pounds per day or tons per year) of a particular pollutant from a particular source or activity.

[9] In responses to EFSEC, T-S has stated that "Oil production in portions of the United States (U.S.) and Canada is growing, resulting in the increased availability of crude oil from the well sites, primarily in North Dakota, Montana, Colorado, Wyoming, and Texas to serve the U.S. domestic market." Response to EFSEC Draft EIS Data Request 2, Feb. 23, 2015, VE_INF_0086899. Ex.0011-000020-PEC.

[10] "The 30 unloading stations on Track 4105 would be equipped with steam connections to heat crude oil to approximately 150 degrees Fahrenheit (0 F) to decrease its viscosity and allow it to flow more easily. Application of heat reduces the viscosity of crude oil, allowing it to be more easily pumped through the Facility transfer pipelines." *Id.* VE_INF_0086900.

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would likely handle the crude.[11] Other than vague references to Bakken, Mid-Continent, etc., the record does not define points of origin/crudes with any level of specificity. Instead, the project proponent implies that it could not possibly identify all such origins for a multi-year (or multi-decadal) project.[12] That is understandable. But, in that case, the analysis should be based on specific reasonable (or even worst case) assumptions as to origin. Worst case air quality impacts are often analyzed by using worst case activity/source assumptions – for all projects. This is standard practice. There is however, no excuse for not attempting to identify all/worst case sources[13] – while simultaneously claiming that project impacts have been estimated;

(iii) **compounding (i) above, spatially, the DEIS purports to analyze air quality impacts from crude trains and vessels within Washington State only**.[14] This artificial truncating of the spatial boundary is obviously inconsistent with the very description of the project and its goals. It is a glaring deficiency. And, by so

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[11] Because the spatial boundary is dependent on economics of the global crude market and this can change over the life of the project, it is not unreasonable to include the most distant, technically feasible, points of origin in the air quality (and other impacts) assessments.

[12] "The Proposed Action would rely on the Class 1 railroads to deliver loaded unit trains to the Facility and deliver empty trains back to the loading facilities. As noted above, multiple routes could be used by the Class 1 railroads to deliver trains to the Facility, and the railroads route individual trains based on many factors; therefore, a specific route cannot be identified. Freight rail traffic is dynamic and unlike passenger service it does not adhere to a fixed schedule or particular route. In general, freight trains can go any direction, at any time. Which route a freight train will take on a given day depends not only on convenience or distance, but also on other numerous factors, including weather events, customer needs, and market demands." All train routes from potential crude oil origins can therefore not be identified. *Id.* at VE_INF_0086899

[13] This could be done, for example, by specifying the longest distance from an origin to the T-S terminal or using a combination of distance and crude oil properties to identify a "worst-case" route length, etc.

[14] Vancouver Energy Air Quality Technical Report, at p. 21 of report (VE_INF_0039629). Ex.

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constraining the analysis at the outset, it removes large air emissions of various pollutants associated with loading crude at the point of origin into the railcars, emissions associated with transporting railcars/trains from the point of origin to the Washington State boundary, and emissions associated with transporting crude via marine vessels from the Washington State boundary to the destination. Because the universe of even the obvious crude origination points (Bakken, "Mid Continent", etc.) are thousands of miles from Washington State as are the destinations of the oil (i.e., refineries in Alaska, California, Hawai'i, etc.[15]) even excluding exports[16], this improper spatial boundary definition significantly under predicts air emissions (excluding any methodology aspects that I will discuss later); and

(iv) **the lack of proper temporal boundaries.** Typical temporal boundaries for projects begin with all activities associated with project construction and end with project decommissioning. In this present case, I could not identify where project specific construction emissions of all air pollutants has been presented. Construction emissions include not just construction activities at the T-S Terminal but also through the project's spatial domain (see above) that will be needed to support the project, including construction associated with mitigating other impacts. Thus, if rail safety considerations necessitate construction and certain grade crossings, which would otherwise not occur but for the project, emissions associated with such construction should be included. Similarly, construction

[15] Response to EFSEC at VE_INF_0086900-901. Ex.0011-000020-PEC.

[16] I exclude non-US export of crude oil from the T-S Terminal, but it is not clear if such exports are forever barred for the lifetime of this project, regardless of current or future US governmental policies. I note that there is no technical bar for non-US exports.

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activities associated with improving marine safety throughout the spatial domain (not just at the Port, or even just within Washington State) should be analyzed.

16. Obviously, the temporal boundary includes the actual period of project activities once operations begin. This includes activities at the T-S Terminal and all of the activities associated with bringing the crude to and transporting it from the T-S Terminal. The DEIS assumes a 20-year life of the project[17] but the basis for this is not clear. Unless there is a definite, legally enforceable, end date for operations, a longer period of operational time, consistent with technical ability of the project, should be considered the basis for project life by EFSEC.

17. Finally, there is no specificity in the discussion in the DEIS of what happens after the operational life of the project (even if it is indeed 20 years) is complete. Does the T-S Terminal cease to exist? Of course, there are air emissions associated with decommissioning, repurposing, environmental remediation (if needed) and the like. Lack of specificity in this regard leaves the temporal boundary of the project open-ended.

18. The lack of adequate and/or accurate boundaries for the T-S Project, whether temporal, spatial, or product type mean that any assessment of the impacts of the T-S Project will also lack accuracy and likely, given the errors and omissions outlined above, under-estimate the air pollution impacts of the facility and the overall Project, as well as impact induced by the T-S Project. EFSEC should consider this underestimation problem in analyzing air pollutant effects relative to the public interest of the citizens of the state of Washington and if the boundaries issues are not correct, should consider the potential for air pollutant emissions to be higher than

[17] The timeframe of Project activities considered in this impact analysis includes construction, operations and maintenance, and decommissioning, which are collectively expected to last 20 years. DEIS Section 3.1.3. Ex. 0051-000000-PEC.

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that estimated by Project proponents.

B. Air Emitting Sources and Activities

19. Once proper spatial and temporal boundaries are established (including related boundaries such as crude type), the following types of activities and sources should be included in the analysis:

A. Normal Emissions: includes **all** emissions when the source or activity is occurring as intended.

1) Construction Emissions:

a. At/Within the T-S Terminal; and

b. Outside the T-S Terminal but within the entire spatial boundary of the T-S Project.

2) Operational Emissions:

a. At/Within the T-S Terminal [for sources/activities subject to air quality permitting];

b. At/Within the T-S Terminal [for all other sources/activities such as mobile sources, etc.]; and

c. Outside the T-S Terminal but within the entire spatial boundary of the T-S Project.

3) Post-Operational Emissions:

a. At/Within the T-S Terminal; and

b. Outside the T-S Terminal, but within the entire spatial boundary of the T-S Project.

B. Non-Normal Emissions (due to abnormal or unintended activities and situations).

1. Fires;

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2. Explosions; and

3. Spills.

20. In the framework above, it appears that the DEIS or the record (including the information in the air permit application materials) completely omits types of emissions in Items 1b and 3 as far as any quantitative analysis is concerned;[18] and substantially omits Item 2a (such as by deeming sources/activities as insignificant, without support and by omitting a major source of VOC emissions, which I will discuss in the next section), and 2c (by limiting the analysis to within Washington State only).[19]

21. Thus, the focus of the air quality analyses conducted for the T-S Project primarily focuses on Item A(2a) above. While this is appropriate for the Revised Air Permit Application, it is simply inadequate for the DEIS or for the required breadth of EFSEC's inquiry here. Thus, demonstrably, the record for EFSEC's consideration of air pollution from the T-S Project is lacking.

22. In a later section I will discuss aspects of certain sources and activities within Item A(2a), such as emissions from loading and unloading, emissions from storage tanks, etc. at the T-S Terminal.

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[18] While Section 2.3 of the DEIS describes construction activities and Section 3.2.4.1 of the DEIS in the Air Quality analysis discusses emissions from construction activities at the T-S Terminal only, there is no quantification of construction activities outside the T-S Terminal. The DEIS does not quantify emissions from decommissioning activities. Ex.0051-000000-PEC.

[19] Clearly large quantities of air pollutants can also be emitted due to accidental releases associated with non-normal situations, those types listed in B above. Typically, these are minimized by proper design, maintenance, etc. I will not be addressing these emissions in this testimony although they are, by virtue of the nature of the operations/Project here, not only possible, but also likely. Examples include emissions from leaks and spills of fuels and crude oil over land and water; emissions from spills, fires, and explosions due to derailment of railcars carrying crude oil.

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IV. AIR POLLUTANTS

23. Once the proper spatial, temporal and other project boundaries are properly established, and the resultant sources and activities within these boundaries are also identified – as discussed in Section II earlier – air contaminants/pollutants can then be identified. Lacking such definitions, this testimony cannot identify all of the possible pollutants that can be emitted from the T-S Project, but uses what is available to make the best assessment based on that information.

24. This section, therefore, provides a general discussion of the types/classes of pollutants that should be expected, with examples.

A. Green House Gases

25. GHG include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and numerous other specific compounds such as refrigerants.[20] Fuel combustion sources that burn any type of carbon-based fuel such as natural gas and diesel will emit CO_2 and N_2O. Methane is emitted due to any leaks of natural gas and also from crude oil volatilization (Bakken crude being more volatile than a number of other types of crude oil). Refrigerants can be emitted as fugitive leaks from equipment and also from their disposal.

26. GHG emissions affect the climate system and therefore their impacts are global on a spatial scale rather than just local. Temporally, GHG can adversely affect the earth's climate over long durations.

27. There is ample opportunity for numerous activities and sources in the T-S Project to emit one or more GHG.

[20] See, for example, https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

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B. Criteria Pollutants

28. In the U.S., as a result of the Clean Air Act, several of the more important atmospheric regulated pollutants are designated "criteria" pollutants – as a result of criteria documents developed in setting ambient standards for these pollutants under the Clean Air Act. These pollutants have health-based ambient concentration levels and attaining (and thereafter maintaining) these ambient levels are a major requirement of the Clean Air Act. Examples of criteria pollutants include:

- nitrogen oxide/dioxide ("NO_x");
- ozone (O_3) (whose precursors[21] are volatile organic compounds (VOCs) - themselves a large class of chemical compounds, some of which are also hazardous air pollutants – and nitrogen oxide/dioxide (NO_x));
- particulate matter (PM) of several sizes including PM_{10} and $PM_{2.5}$, where 10 and 2.5 stand for microns and where the smaller particles are a more significant health concern;
- sulfur dioxide (SO_2);
- carbon monoxide (CO); and
- lead (Pb).[22]

29. On a spatial scale criteria air pollutants can adversely affect the local environment around a source, as well as the regional (for example, local city or urban area) and even continental scale distances. Thus, ozone that is formed due to emissions of precursor compounds

[21] A precursor is a defined term in Clean Air Act regulation. It is any pollutant that, when combined with another pollutant(s) or through a chemical reaction such as with sunlight, creates another regulated pollutant.

[22] See, https://www.epa.gov/criteria-air-pollutants

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can travel long distances; as can fine particulate matter such as $PM_{2.5,}$ as well as NO_x, SO_2, etc. Temporally, the National Ambient Air Quality Standards (NAAQS) associated with criteria pollutants have attached time scales that range from 3 hours up to 1 year.

30. Each of the criteria air pollutants (or the precursors for O_3) can be emitted as a result of fuel combustion – such as NOx, various VOCs, SO_2, PM_{10}, $PM_{2.5}$, CO, and even Pb (depending on the fuel). In addition, various VOCs can be emitted due to evaporation of substances, such as fuels and crude oil. PM of various sizes can be emitted due to earth-moving activities such as construction, as well as re-entrainment of dust due to movement of vehicles such as trains. As a result, almost every activity or source that is part of the T-S Project will emit one or more of the criteria pollutants.

C. Hazardous Air Pollutants (HAP) or Toxic Air Pollutants (TAP)

31. The Clean Air Act lists a large number (over several hundred, including families of compounds) of HAP that can cause acute or chronic adverse health impacts to humans and the environment including various cancers in humans. HAP are regulated at the Federal level via a combination of technology-based and risk-based approaches. HAP can be sub-classified into: volatile HAPs (many of which are also VOCs); semi-volatile HAPs; inorganic HAPs such as acid gases like hydrochloric acid; and metals (including volatile metals such as mercury as well as heavy metals such as cadmium, chromium, etc.). Combustion sources can emit, depending on the fuel, all three classes of HAP. Volatilization of fuels and crude oil can emit several types of volatile HAP. Construction activities and re-entrainment of dust can emit numerous semi-volatile and metal HAP, depending on location and activity. Thus, HAP compounds that can be emitted must be identified after all sources and activities are identified – and based on sufficient knowledge of the activity/source itself.

32. HAP emissions can adversely affect the immediate local spatial scale – i.e., local

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neighbors and the local environment – ranging from few meters to few kilometers. Temporally, HAP can act on all time scales from the very small (such as HAP emitted due to a fire or explosion) to carcinogens that can act over a lifetime.

33. Just as with criteria pollutants, almost every single source or activity that is part of the T-S Project will likely emit one or more HAP compounds.

V. EMISSIONS CALCULATIONS

34. As I have discussed earlier, quantitative emissions calculations or estimates for many aspects of the T-S Project have not been done or provided in the record, such as in the DEIS or permit application materials.

35. Basically, the only sources and activities for which quantitative emission estimates have been developed include sources within the T-S Terminal (for which emissions calculations were conducted to support permitting activities) and emissions related to crude transport by rail and vessels to and from the T-S Terminal, but only within Washington State.[23]

36. Basically, emissions have been estimated for the following sources/activities:[24]

- three natural gas-fired boilers used during product unloading;
- eight Marine Vapor Control Units (MVCUs) used to combust vapors displaced during marine vessel loading;
- fugitive emissions of VOCs from product handling components such as valve seals and pressure release valves;
- crude oil storage tank fugitive emissions;
- emergency fire water pump engines; and

[23] See DEIS, Appendix G, p. G-34. See also DEIS Table 3.2-12. Ex.0051-000000-PEC.

[24] DEIS, p. 3.2-14. *Id.*

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- emergency portable diesel engines.

37. And, as noted above, the DEIS accepted emissions estimates developed by the applicant in its Air Permit Application and then supplemented these calculations by adding the emissions due to trains and vessels within Washington.[25]

38. Table 3.2-5 of the DEIS and Table 5.1.11 of the Revised Air Permit Application summarize the annual emissions of criteria pollutants from the considered sources. Ex.0051-000000-PEC. I have reproduced the DEIS table below for ease of reference. Similar tables are provided in the application for HAP emissions, from the same sources.

Table 3.2-5. Estimated Stationary Source Operations Emissions for the Proposed Facility

Activity	Tons Per Year						
	VOCs	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	HAPs
Boiler use (Area 600)	2.70	19.5	5.95	1.99	4.06	4.06	0.02
MVCU	8.64	3.49	8.04	6.59	2.62	2.62	0.77
Component leaks	0.82	NA	NA	NA	NA	NA	<0.00
Tanks	23.58	NA	NA	NA	NA	NA	1.87
Firewater pumps	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Emergency generators*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Stationary Source Emissions	**35.75**	**23.02**	**14.00**	**8.57**	**6.68**	**6.68**	**2.66**

39. Adding in emissions from T-S Terminal mobile sources, the combined emissions from stationary and mobile sources, *just for the T-S Terminal* are presented in DEIS Table 3.2-7, shown below:

[25] DEIS, Appendix G, p. G-34.

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Table 3.2-7. Total Stationary and Mobile Source Emissions for Proposed Facility Operations

Activity	Tons Per Year						
	VOCs	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	HAPs
Stationary source emissions	35.75	23.02	14.00	8.57	6.68	6.68	2.66
Mobile source emissions	7.06	59.45	150.08	42.83	6.42	5.98	0.63*
Combined Total	**42.81**	**82.47**	**164.08**	**51.40**	**13.10**	**12.66**	**3.29**
Comparative thresholds	250	250	250	250	250	250	25
Exceedance?	No	No	No	No	No	No	No

40. At the outset, I note that the emission calculations do not contain any estimates for several other potential sources and activities. Examples of missing sources include:

- fugitive VOC emissions from rail cars during unloading and storage at the facility (prior to unloading);
- fugitive VOC emissions from additional storage tanks (which do not contain crude oil but liquids that can contain hydrocarbons);[26]
- fugitive VOC emissions from occasional tank(s) cleaning; emissions during malfunction events;
- potential emissions from spills; and
- *most* glaringly *fugitive VOC emissions due to the displacement of vapors during marine loading – which are not fully captured and therefore emitted to the atmosphere*.

41. As to this last emission source, the calculations presented in the Air Permit Application (and adopted by the DEIS) assume that 100% of the displaced vapors from the marine vessels will be captured and then treated in the MVCUs.[27] I discuss this in more detail subsequently.

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[26] See Appendix C to Tanks Specifications at VE_INF_0098272. This appears to be page 4-473from the 2013 Terminal application which is at Ex.0002-000000-PEC.
[27] See Air Permit Application at VE_INF_089508. Ex.0002-000000-PEC.

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42. As I have indicated earlier, I am not providing a detailed or fully comprehensive critique of all unsupported or erroneous assumptions that are included in the Air Permit Application. Nor does this testimony purport to create emission calculations for the many missing sources and activities since that would require data not available to the public. Rather, I try to give EFSEC an understanding of what should be considered in full in order to understand the air quality impacts of this Project and how the current application materials and potential regulation of the air pollution will be inadequate to mitigate those impacts. In order to illustrate the many assumptions and methodology issues that affect emission calculations, I will discuss below, as examples, only the VOC emissions from the crude oil storage tanks,[28] as well as the missing fugitive VOC emissions due to uncaptured portion of the displaced vapors during loading of the marine vessels. The fact that I do not conduct a similar analysis and discussion of other air pollutants should not be taken to mean that I believe other air pollutants are adequately analyzed or will not be problematic.

43. As a general matter, as in any calculation, the results will depend on:

(a) the calculation methodology (i.e., the specific equations or models used in the calculation) and their accuracy;

(b) the specific input parameters required by the particular calculation methodology selected in (a) above;

(c) the degree of support or documentation that underlies both the methodology and the specific input parameters; and

(d) the list of assumptions made in the calculations.

44. For my example calculations; i.e., VOC emissions associated with the crude oil

[28] See *Id.* at VE_INF_089514

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storage tanks and uncaptured displaced vapors from marine vessel loading, I will first discuss some of the more important properties of the crude oil which are inputs as in (b) above and which therefore affect the VOC emissions estimates.

A. Key Properties of Crude Oil Relevant for VOC Emissions Calculations

1. Crude Vapor Pressure

45. With regard to the material type that can be handled at the T-S Terminal, as I have noted earlier, it can be any of a number of crude oils from the "mid-continent" of the U.S. The volatility of crude oils can vary; however, as can the VOC emissions when crude oils of varying volatility are transferred, stored, handled etc.[29] Thus, volatility, as indicated by its vapor pressure, is a critical input assumption for VOC calculations. In its application, the applicant has focused heavily on Bakken crudes.[30] I will do the same in my analysis below.

46. Vapor pressure is expressed in a couple different formats, depending on the test method used to measure it – either as true vapor pressure (TVP) or Reid vapor pressure (RVP).[31] TVP is usually smaller than RVP. Bakken crudes are known to be more volatile than other crudes. However, the emissions calculations assume that the maximum TVP of the crudes for the T-S Project will be 11. As the discussion below will amply demonstrate, this is an unfounded and fully-unenforceable assumption. Bakken crude oils can have RVPs greater than

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[29] And again, volatility is important because the higher the volatility the more the vaporization and resulting emissions of VOCs (as well as other related pollutants).

[30] "While projecting future market conditions is nearly impossible, based on the strength of Bakken production and market conditions known at this time, the Washington Energy Facility Site Evaluation Council (EFSEC) believes it is reasonable to assume that the Bakken would be the likely source of the mid-continent North American crude oil delivered to the proposed Facility." DEIS, p. 2-2. Ex.0051-000000-PEC.

[31] Throughout the record, vapor pressure is sometimes noted as "Reid vapor pressure" and at other times as "true vapor pressure." In physical terms both are terms indicating the volatility of the substance. Higher vapor pressures, whether Reid or true, indicate more volatile substances. I will provide additional detail and conversion algorithms between these two vapor pressures later in the report.

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15, (which corresponds to TVP of approximately 13.35).

47. First, as the excerpt below from a recent analysis by the American Petroleum Institute (API) to a Gov't. agency indicates, the RVP of Bakken crude can be as high as 15.37.

		Other Crudes	Bakken
Vapor Pressure PSI (ASTM D6377)	Avg Min Max	7.24 1.43 11.46	11.81 3.60 15.37

[32]

48. Second, and confirming the API value above, the chart below is an excerpt from a Safety Data Sheet for Bakken crudes by ConocoPhilips. The maximum RVP is noted as 15.

SECTION 9 : PHYSICAL and CHEMICAL PROPERTIES

Physical State:	Liquid.
Color:	Amber to Black
Odor:	Petroleum. Rotten egg / sulfurous
Odor Threshold:	Not determined.
Boiling Point:	70 to 110 °F (21 to 43 °C)
Melting Point:	Not determined.
Density:	5.83-8.58 lbs/gal Bulk
Specific Gravity:	0.7-1.03 @ 60°F (15.6°C) Reference water = 1
Solubility:	Negligible solubility in water.
Vapor Density:	>1 (air = 1)
Vapor Pressure:	8.5-15 psia (Reid VP) @ 100°F (37.8°C)

[33]

[32] API Staff Analysis of Crude Oil Samples Submitted to PHMSA May 19, 2014, available at http://www.api.org/~/media/files/news/2014/14-may/staff-analysis-of-data-submitted-to-phmsa.pdf Exhibit 5521-000004-CRK.

[33] ConocoPhillips, Safety Data Sheet for Bakken Crude Oil Sweet, p. 5. Available at http://www.conocophillips.com/sustainable-

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49. Third, a recent survey by the American Fuel and Petrochemical Manufacturers (AFPM) shown below notes the max RVP at 15.4

Summary Table on Bakken Crude Oil Characteristics Evaluated in AFPM's Survey

Characteristic	Reported Values	Hazmat Transportation Regulatory Implications
Flashpoint	Range: -59°C to 50°C	Bakken crude oils meet the criteria for Packing Group I, II, or III flammable liquids or as combustible liquids[3]
Initial Boiling Point	Range: 2.2°C to 66.9°C	Bakken crude oils with an initial boiling point of 35 °C or less meet criteria for Packing Group I flammable liquids; others for Packing Group II or III flammable liquids or combustible liquids according to flashpoint
Vapor Pressure at 50°C	Maximum: 16.72 psia	All Bakken crude oils have a vapor pressure below 43 psia at 50°C and must be transported as liquids
Reid Vapor Pressure at 38°C	Maximum:15.4 psia	Not used by the regulations; confirm the vapor pressure at 50°C is well below the above 43psia limit and Bakken crude oils must be transported as liquids.

[34]

50. Fourth, and importantly, the AFPM survey also shows, per the chart below, that the occurrence of high RVP crudes is not rare. As the chart shows, a significant portion of the tested Bakken crudes had RVP greater than 13.

development/Documents/2014.05.30%20825378%20Bakken%20Crude%20Oil,%20Sweet.pdf. Exhibit 5522-000010-CRK.

[34] A Survey of Bakken Crude Oil Characteristics Assembled for the U.S. Department of Transportation, submitted by the American Fuel & Petrochemical Manufacturers, May 2014, p. 5. Available at https://www.afpm.org/WorkArea/DownloadAsset.aspx?id=4229. Exhibit 5523-000038-CRK.

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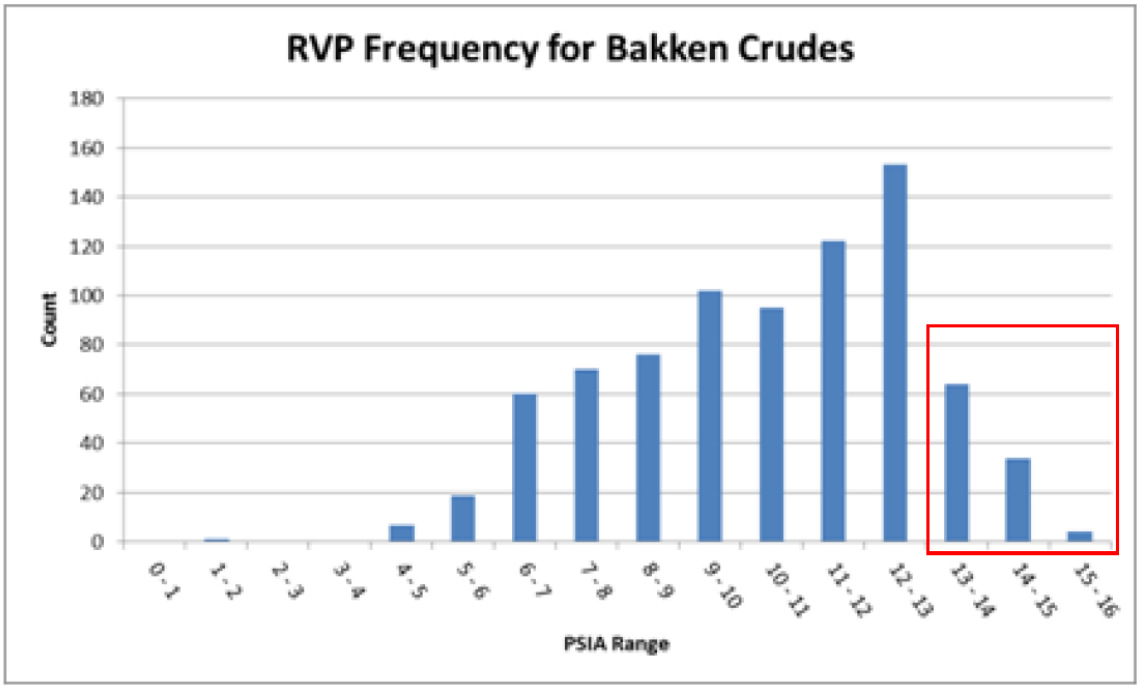

[35]

51. Lastly, I am well aware that since April 2015, North Dakota has asked oil producers to condition the crude produced at the wellhead in order to "improve the marketability and safe transportation of the crude oil" and that, as a result, some of the lighter components of Bakken crude might be removed prior to shipping, thereby affecting its vapor pressure. But, the enforcement of this order, including the level of volatility after conditioning and the verification of post-conditioned volatility or vapor pressure is questionable. As T-S's own comments on the Draft EIS state:

> [I]n the fifth Paragraph, the DEIS misstates the NDIC order. The order went into effect on April 1, 2015 (not in December 2014). Oil producers at the wellhead must condition the crude oil, not Shippers. The intent of the Order was to "improve the marketability and safe transportation of the crude oil" through wellhead conditioning of the crude oil to remove more light ends and essentially put a cap on vapor pressure (not volatility, per se). Then, rail facilities are required to notify NDIC when *discovering* that any crude oil tendered for shipment violates federal safety standards – the rail facilities are not required to

[35] A Survey of Bakken Crude Oil Characteristics Assembled For the U.S. Department of Transportation, submitted by the American Fuel & Petrochemical Manufacturers, May 2014, p. 19. *Id.*

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(and it is not feasible to) test all crude oil coming into or out of the facility for light end content, vapor pressure, or volatility.[36]

52. Thus, without testing and enforcement, it is simply not credible to give much weight to the North Dakota order.

53. For all of the reasons above and noting that there is nothing in the design of the T-S Project that inherently limits its ability to handle Bakken crude with RVP of 15, it is my opinion that any VOC emissions calculations (such as from the storage tanks and also from the marine vessel loading) should use an RVP of 15 or possibly 15.4.

2. Crude Vapor Molecular Weight

54. In some of the VOC calculations that are pertinent to the T-S Project, a critical input parameter is the molecular weight of the vapor for the material being handled. In calculations for the T-S Terminal marine loading, the applicant has used a value of slightly less than 45 lb/lb-mole. EPA clearly notes that the vapor molecular weight for crude oil with RVP of 5 - i.e., far less volatile than Bakken crudes – should be 50 lb/lb-mole. Thus, the value used is suspect.

55. Available literature does indicate that vapor molecular weights could be significantly greater than the assumed value of approximately 45 lb/lb-mole, however. Composition data on Bakken crudes has been provided by Marathon Oil.[37] Making reasonable assumptions as to the components that are likely to be volatile (i.e., that all of the so-called "lighter" hydrocarbons through hexanes and heptanes will vaporize, as well as some of the mid-range hydrocarbons including octanes, nonanes and even decanes can vaporize), I arrive at a vapor molecular weight of 110 lb/lb-mole.

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[36] T-S Comments on the DEIS, January 22, 2016, p. 4-12. Exhibit 5504-000326-CRK.

[37] Peacock, P., Bakken Oil Storage Tank Emission Models, 2010, p. 4. Available at http://www.ndoil.org/image/cache/Peacock_-_March_23_2010._ppt.pdf.

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56. Based on the discussions above, I now address the calculation of VOC Fugitive Emissions from Vessel Loading.

B. VOC Fugitive Emissions from Marine Vessel Loading

1. Capture or Collection Efficiency

57. One of the biggest sources of error in the VOC emissions calculations relates to the assumed capture efficiency for VOCs from marine vessel loading at the T-S Terminal. As the "empty" vessel is loaded with crude oil from the large storage tanks, existing vapors[38] from the barge compartments will be displaced. In addition, the placement of the new liquids will also create vapors, especially for the highly volatile Bakken crude. Collectively, the vapors are supposed to be collected or captured via a hose which then takes them to the MVCUs where they are burned to destroy the VOCs. At issue is the extent of the collection or capture that is actually likely to reliably occur before the vapors can be destroyed in the MVCU. Clearly, the MVCU cannot destroy that fraction of the vapors that are not captured by the vapor hoses system. Rather, vapors that are not captured by the vapor hose system will be vented to the atmosphere.

58. The current calculations appear to assume that the vapor capture from the marine vessel loading would be 100%; i.e., that all of the vapors from the barge would be captured. As the prior summaries for T-S Terminal emissions show, there is no line item for uncaptured VOC emissions from vessel loading – only emissions from the destruction of captured vapors in the MVCUs is shown.

59. Even assuming that the marine vessels that will be used to accept crude cargos at the T-S Terminal are certified to be "vapor tight" pursuant to EPA requirements as specified in

[38] Although a given vessel might arrive at the terminal with "cleaned" tanks, there is always some residual product from the prior cargo. Vapors from this prior cargo will also be displaced as new liquids are pumped into the compartment, in addition to vapors coming from the product that is being loaded.

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40 CFR Part 63, Subpart Y, that does not mean that no vapors can escape the barge. The requirement to demonstrate vapor tightness under these regulations simply means that, on an annual basis, the vessel has to demonstrate that it can "hold" pressure to within a specified tolerance in a given period of time. The vessel compartment is pressurized and the pressure is monitored. Over time, pressure starts dropping and that drop is also monitored. The regulation requires that the final, reduced pressure (indicating a loss of vapors) be within a specified tolerance level and meet a specific test provided in the regulations.[39] Or, the operator can use VOC sniffers similar to those used in EPA Method 21 to show that the level of VOCs detected were below a specified level, such as 10,000 ppm. Neither of these means that no vapors are allowed to escape and that vapor capture is 100%. "Vapor tightness" as part of Coast Guard certification is not a Clean Air Act statutory concept and so it is not surprising that its regulatory definition (even by EPA) allows for less than 100% vapor capture.

60. I have reviewed numerous vessel tightness certificates over the last several years for many different vessels and they all show that even those that can meet the EPA "vapor tight" requirements do so by showing some loss of pressure in a given time period. Therefore, such Coast Guard certificates showing "vapor tightness" once a year are not evidence of negative pressure or 100% capture of VOC emissions from vessel loading and cannot be relied upon to provide support for a 100% capture assumption.

61. The record does not provide any assurance or documentation that all vessel loading will be conducted such that there is significant negative pressure at the vessel compartments, a particular technical process that requires the vapor vacuum hose system to be operated and monitored in very precise ways, with pressure monitored at several locations in the

[39] See 40 CFR 63.565(c).

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process and the negative pressure be maintained at particular measured and monitored levels at all times during loading. Maintaining such negative pressure might demonstrate that there is 100% capture, but, neither the application for the Air Permit, nor the DEIS provide any such design features or details (including details or requirements for the operation and monitoring requirements that I outline above). I note that a typical vessel is hundreds of feet long, and has multiple compartments (along the port and starboard sides) into which cargo is placed. The vapor hose that collects the vapors from the various compartments is typically connected to valves on the vessel somewhere in the middle of the vessel. Thus, for the collection to be 100% effective, a <u>significant</u> negative pressure must exist in order to overcome line pressure losses in the various pipes and manifolds in order for vapors not to escape. Because of this, EPA and states such as Texas have long recognized that it is not enough for there to be negative pressure – but that the negative pressure must meet a threshold.

62. On this issue, Texas specifically states the following for allowed assumptions regarding vessel loading vapor-tightness:

"Capture / Collection techniques and efficiency:

- 65% capture/collection efficiency - if the barge is not leak-tested;
- 95% capture/collection efficiency - if the barge is leak tested based on NESHAPs Subpart BB requirements; and
- 100% capture/collection efficiency – recognized <u>only</u> when a blower system is installed which will produce a vacuum in the barge/ship during all loading operations. The blower system should include a pressure/vacuum gauge on the suction side of the loading rack blower system adjacent to the barge/ship being loaded to verify a vacuum in that

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vessel. Loading shall not occur unless there is a vacuum of at least 1.5 inch water column being maintained by the vacuum-assisted vapor collection system when loading. The vacuum should be recorded every 15 minutes during loading. This information is referenced in the draft TCEQ Guidance Document entitled, "Loading Operations" dated October 2000 and the previous version dated January 1995."[40] (Emphasis added.)

63. In the present instance with the lack of information and enforceable requirements that see in the documents, there is absolutely no basis to assume that "at least 1.5 inch water column" will always be maintained and monitored during vessel loading.

64. Others have used capture values of 98.7%. I show an excerpt from an application made to the Oregon DEQ by the Columbia Pacific Bio Refinery in 2013.

[40] See, p. 2. https://www.tceq.texas.gov/assets/public/permitting/air/NewSourceReview/oilgas/marine-loading.pdf

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COLUMBIA PACIFIC BIO-REFINERY
LOADOUT FUGITIVE LEAKS (FS03)

Pollutant	CAS No	Throughput		Emission Factor		Source	Potential To Emit unrestricted lb/hr	Potential To Emit limited TPY
VOC	—	1,050	kgal/hr	0.0172	lb/kgal	AP 42 Chapter 5.2	18.1	15.82
GHG (CO2e) *	—	1,050	kgal/hr	0.003	lb/kgal	Engineering Estimate	2.8	2.49
H2S	7783-06-4	1,050	kgal/hr	0.000034	lb/kgal	Engineering Estimate	0.04	0.03

* GHG are reported as CO2e and are based on 0.743% methane by weight (based on samples analyzed at the existing VRU inlet).

98.7% capture efficiency (per AP-42 Chapter 5, Section 2)

Per AP42 Chapter 5.2, VOC emisisons account for an average of 85% of total organic compounds

CL = CA + CG =	1.559 lb/kgal	
CA =	0.86	Per Table 5.2-3 of AP 42
CG =	0.699	Per equation (3) of AP 42 Section 5.2
G	1.02	
P	9.651 psia	For RVP12.75 - from annual TANKs simulation
M	49.9677	
T	513.24 R	from annual TANKs simulation

[41]

65. Finally, I will review EPA's guidance on this capture efficiency, which is similar to that of the Texas discussion that I provided earlier. In a 2011 document, EPA states that "[T]ypical capture efficiencies assumed for vapor collection procedures and systems are shown in Table 9-5. Capture efficiency for the vapor collection system can be applied <u>based on the leak check conducted</u> for the tanker truck, rail car, and <u>marine vessel.</u>" (Emphasis added.)

[41] 2013 CPBR Application to Oregon DEQ, p. 41.

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Table 9-5. Capture Efficiencies for Vapor Collection Systems[a]

Loading Characteristics and Leak Check Frequency for Tankers	Capture Efficiencies
▪ No leak check on tanker	65%
▪ No leak check on tanker ▪ Maintain minimum positive pressure below +3 to +5 inches of water	85%
▪ Annual leak check on tanker per 40 CFR Part 60, Subpart XX (nongasoline)	95%
▪ Semi-annual leak check on tanker per 40 CFR Part 60, Subpart XX (nongasoline)	97.5%
▪ Annual leak check on tanker per 40 CFR Part 60, Subpart XX (gasoline)	98.7%
▪ Vacuum loading, maintaining vacuum less than −1.5 inches of water ▪ Hard-piped bolted, flanged connection from tanker to the vapor collection system	100%
▪ Pressure tank that is U.S. Department of Transportation certified ▪ Hard-piped bolted, flanged connection from tanker to the vapor collection system	100%

Note: Use latest available version if updates to this document have occurred since the cited version.

[a] Source: TCEQ, 2000.

[42]

66. In Table 9-5, we can rule out the last two rows since we do not have pressure tanks in the vessels. Nor, as discussed above, is there any documentation or enforceable requirement to show that the loading will always be done meeting a 1.5 inch water gauge vacuum level. We can also rule out the third row from the bottom since it pertains to gasoline. That leaves the first four rows as possible candidates per EPA guidance. I am also recommending ruling out the first two rows since it can be assumed that vessels will conduct annual leak checks, (although that assumption can only be made if there is such an enforceable requirement in the air permit for the T-S Terminal), so I will give the benefit of the doubt on that point. That leaves the third and fourth rows, for non-gasoline products as possible candidates. Here again, the fourth row may not be appropriate until it can be shown that vessels undergo semi-annual leak checks, as opposed to annual leak checks. Thus, the most appropriate (and generous) value for capture efficiency is the third row, or 95%. However, it could be 98.7% depending on the frequency of the leak checks.

[42] Emission Estimation Protocol for Petroleum Refineries, Version 3, (April 2015) p. 9-7.

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2. Calculation of Vessel Loading VOC Fugitive Emissions

67. Clearly, based on the discussion above, a fraction of the displaced vapors during vessel loading (i.e., either 1.3% if the capture is 98.7% or 5% if the capture is 95%) will be directly emitted to the atmosphere without going through any further destruction in the MVCUs.

68. In this section, I will attempt to estimate these emissions. The methodology I use is the same as that used by the applicant in the Revised Air Permit Application.[43] However, I will use the following more appropriate input values for the calculation:

(a) vapor pressure of 13.347 psi (as opposed to 11 used by the applicant), which corresponds to an RVP of 15 (per earlier discussion) at a temperature of 62 F (which is the maximum monthly average for Portland/Vancouver, per AP-42);

(b) vapor molecular weight of 50 lb/lb-mole, per earlier discussion (recognizing that it could be greater);

(c) crude annual throughput at 131,400,000 barrels/year, per the federally enforceable limit referenced in the Revised Air Permit Application; and

(d) capture or collection efficiency of 95% - 98.7% per earlier discussion.

[43] See Air Permit Application at VE_INF_0089508. Exhibit 0002-000000-PEC.

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69. My recalculation is provided below.

[A] Maximum Crude Throughput				
	131400000	bbl/yr		[from Revised Air Application]
	5518800000	gal/yr		[42 gallons = 1 barrel]
	5518800	kgal/yr		[Calculation]
[B] Fugitive VOC Emissions from Marine Loading				
Uncontrolled Emissions		5077.93	tons/yr	[Uncontrolled]
Capture Efficiency (High)		0.978		[per discussion in text]
Uncaptured Fugitive Emissions		**111.7**	tons/yr	[Calculation]
Capture Efficiency (Low)		0.95		[per discussion in text]
Uncaptured Fugitive Emissions		**253.9**	tons/yr	[Calculation]
Emission Factor Calculation for Barge Unloading				[per AP-42 Section 5.2, Equations 2, 3]
	CL=CA+CG			[Equation]
	CA=	0.86	lb/1000 gal	[per AP-42]
	CG=1.84*(0.44*P-0.42)*(M*G/T)		lb/1000 gal	[per AP-42]
	P=	13.347	psia	[TVP corresponding to RVP=15]
	M=	50	lb/lb-mol	[per discussion in text]
	G=	1.02		[per AP-42]
	T=	522	R	[for Portland, per AP-42 Section 7.1]
	CL=	1.840	lb/1000 gal	[Uncontrolled emission factor]

70. As shown in the table above, these uncaptured emissions are significant, in the range of 111.7 to 253.9 tons per year. I note that these values are not included in the DEIS nor the permitting process for the T-S Terminal, thereby underrepresenting the amount of VOC pollutants that will be emitted just from the operation of the T-S Terminal itself. EFSEC should

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consider the 253.0 tons per year emission figure in assessing the full impact to citizens and the environment from VOC pollutant emissions at the Terminal.

71. Then, in addition to the emissions from the transloading operation, EFSEC must consider the emissions from the 6 large crude storage tanks at the T-S Terminal.

C. VOC PTE Emissions from Large Storage Tanks

72. As noted in the record, the T-S Terminal proposes to build six large internal floating roof (IFR) storage tanks to store the crude delivered via rail prior to transloading to the marine vessels.

73. VOC emissions from these storage tanks have been estimated by the applicant in the Revised Air Permit Application by using EPA's TANKS software program (for so-called "normal" emissions), excluding emissions due to tank roof landings, which have been separately estimated.

1. Normal Emissions from Storage Tanks

74. There are a number of issues relating to the storage tank calculations for air pollutant emissions that renders the calculated results suspect and likely too low. The deficiencies can be grouped into two broad categories:

(a) First, even sticking to the TANKS program that was used, the applicant used a lower vapor pressure for the crude oil than I believe is realistic, accurate, or enforceable (per previous discussion), which would in turn artificially reduce estimated VOC emissions in the TANKS program calculations. Because I have discussed the vapor pressure issue above, I do not discuss this further.

(b) Second, and perhaps more importantly, it is now quite clear in the scientific and technical literature that the AP-42 methodology for

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calculating emissions (which methodology is incorporated into the TANKs program) itself likely *significantly* underestimates VOC emissions from tanks.

75. As to point (b) above, due to a number of programming and other flaws, *EPA itself cautions against* the use of the TANKS program and has done so for some time now. EPA has also stopped supporting the TANKS program from a technical point. Therefore, the TANKS program page within EPA's website currently contains the following clear and bold warning:

> *"***The TANKS model was developed using a software that is now outdated. Because of this, the model is not reliably functional on computers using certain operating systems such as Windows Vista or Windows 7. We are anticipating that additional problems will arise as PCs switch to the other operating systems. Therefore, we can no longer provide assistance to users of TANKs 4.09d. The model will remain on the website to be used at your discretion and at your own risk…"*[44]

76. Nor is *this* a secret known only to a few. Consultants and other practitioners are well aware of this problem[45] since EPA has noted shortcomings with its TANKS programs for several years now.[46] Therefore, the applicant should not have used this program to begin with and absolutely should redo the calculations using more current and accurate calculations and methodologies. At a minimum, EFSEC should view the TANKS calculations of pollutant emissions as highly suspect and very likely to under-predict air pollutant emissions from the T-S

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[44] http://www.epa.gov/ttnchie1/software/tanks/

[45] See, for example, presentation entitled Transition Out of EPA TANKS Software, by Gonzalez, J. (Trinity Consultants) February 3, 2015. Available at http://www.epaz.org/userfiles/1-D1-10%20Transition%20Out%20of%20EPA%20TANKS%20Software.pdf

[46] For example, the fact that TANKS 4.09D contained incorrect Deck Fitting Loss Factors, was known and noted by EPA on its TANKS webpage since at least 2011. Other corrections such as the incorrect use of temperatures was known and noted on the TANKS webpage since at least 2013.

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Terminal.

77. As far as the underlying A-42 calculations methodology,[47] as noted in a recent report,

> EPA has been urged by many to revise its tank modeling methods to improve crude oil and mid-refined product default parameter data, and account for the effects of poorly maintained seals and roofs on emissions, and the leakage of propane and butane past floating roof seals. In addition, EPA has also been urged to revise tank modeling methods to account for site specific variables like wind speed, size, seal condition, seal type, roof height, filling rate, tank movements (i.e., mixing), and vapor pressure of the stored material. Some of these variables are not included in the tank calculations, while others are included as defaults or annual averages, which results in serious errors in estimated emissions.[48]

78. It is believed that current methods may underestimate emissions by a factor of 5 to 50.[49] The basis for this is also clear. For about a decade or so now, *actual measurements* of tank emissions (including those in crude oil service) using techniques such as Differential Absorption Lidar (DIAL) show significant and higher emissions as compared to those predicted by TANKS program. I provide a couple of summary citations to substantiate this point.

79. "[T]he primary objective of the DIAL testing was to provide data for comparison with the results of emission estimation procedures that are the currently accepted means of determining emission levels for these types of sources for storage tanks, the results are presented for groups of tanks rather than individual tanks because the DIAL testing generally could not isolate individual tanks. Table 1 also presents two sets of estimated emissions. The estimates in

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[47] Again, to be clear there are two distinct problems with the calculations and methods used. First, the shortcut provided by using the TANKS program is itself unsupported and no longer recommended by EPA. Second, the AP-42 methodologies, on which TANKS is based, have themselves been called into serious question.

[48] See, for example, comments by the Environmental Integrity Project to the EPA, p. 5. Available at http://www.law.uh.edu/faculty/thester/courses/Emerging%20Tech%202011/20100331_EIPCommentsonRefineryEmissionsProtocol.pdf.

[49] *Id.*

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the first set were calculated using standard accepted estimating procedures along with actual conditions at the time of the DIAL testing. The second set of estimates presents the average hourly ozone season emission rates from BP's 2007 emission inventory report. The following key findings and conclusions can be drawn from the test result. For scans under similar conditions the DIAL results often varied widely, by as much as an order of magnitude for scans of the flares and some storage tanks. For storage tanks, the average DIAL results generally are higher than both sets of estimated emissions described above."[50]

80. In fact, the report found that measured emissions were as much as 3 to 7 times greater than the estimated emissions using current EPA (i.e., TANKS and AP-42) methods. Other states have also concluded the same. For example, in Texas, the TCEQ's conclusion relating to the DIAL data was that "Emissions measurements with DIAL were more than 5 times the hourly tank emissions estimated using AP-42 emission factors…"[51] The investigators themselves concluded that actual measured tank emissions were even greater than compared to estimates from EPA's TANKS program: "[C]rude oil and heated oil tank emissions measured by DIAL were 5-10 times higher than estimated by TANKS."[52] Plainly, the problems with the TANKS program underestimating emissions has been known in the oil industry for years and it has been widely reported.

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[50] Critical Review of DIAL Emission Test Data for BP Petroleum Refinery in Texas City, Texas, EPA 453/R-10-002, November 2010, p. ES-1 and ES-2. Available at http://www.epa.gov/airtoxics/bp_dial_review_report_12-3-10.pdf

[51] Presentation by the Texas Commission on Environmental Quality (TCEQ) relating to the Differential Absorption Lidar (DIAL) Project, Summer 2007, Texas City, Texas, April 2010, p. 4. Available at https://www.tceq.texas.gov/assets/public/implementation/air/am/committees/pmt_set/20100407/20100407-Nettles.pdf. Exhibit 5524-000030-CRK.

[52] Robinson, R., The Application of DIAL for Pollutant Emissions Monitoring, January 2015. Available at http://www.h-gac.com/taq/airquality/raqpac/documents/2015/Jan%2015/DIAL%20%202015%20Houston%20Meeting%20January%20(sent%20version).pdf

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81. Based on this alone, it is my opinion that the VOC emissions estimate, without correcting for the vapor pressure as noted previously, is likely to be around 5 times greater than that estimated by the applicant and as used in the DEIS. And therefore, in assessing the potential effects of the T-S project on the public of Washington, particularly the surrounding community, and in acting on the air permit application for the project, EFSEC should either require revised calculations by T-S in accordance with this research and understanding of emissions, or should simply multiple the numbers that EFSEC has estimated for air pollution emissions by a factor of 5 in order to ensure a more accurate representation of the VOC air pollution from the T-S Terminal while in operation.

82. Finally, while I have concentrated my testimony here on VOCs, it is also apparent that at least the DEIS analysis suffers from significant problems in the emissions calculations (and resultant ambient air quality assessments) for pollutants other than VOCs and that this may be an indication of problems with air emission calculations elsewhere. For example, Table 3.2-6 in the DEIS provides annual (tons per year) emissions for mobile sources. The values in Table 3.2-6 are based on emissions calculations in Appendix G of the DEIS. However, Appendix F (the Environ report) Table 8 (p. F-17) to the DEIS reports significantly different and lower annual emissions for mobile sources, even though it purports to be based of the same assumptions used in the analysis in Appendix G. For example, NOx emissions from trains are calculated to be 0.99 tpy in Table 8 of Appendix F, versus 42.78 in Appendix G and Chapter 3. Since the significantly lower (*over 40 times lower*) values in Appendix F appear to have been used in the subsequent ambient air quality assessment in that Appendix, it is clear that the results of that assessment are erroneous and should be set aside and redone. Moreover if those erroneous calculations are relied upon in any other component of the T-S Project applications

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and/or materials, those materials must be corrected as well. At a minimum, EFSEC cannot rely on the calculations that are demonstrably incorrect within T-S's own documents.

83. In summary, while VOCs are not the only pollutant of concern, they are a significant concern since they are precursors of ozone formation in the atmosphere and they contain many volatile HAPs that can present adverse health impacts[53] to the impacted population. The emissions quantification for VOC sources is highly suspect, for both the emissions from the transloading operations and the emissions from the storage tanks, and appears to be significantly underestimated. Reliance on this type of problematic analysis is not advisable on the part of EFSEC for making its decision in this matter. At a minimum, EFSEC should use the revised calculations for transloading emissions and must include the factors outlined above to increase the estimates of storage tank losses to ensure that EFSEC is accurately calculating emissions both for the purposes of estimating the impact on the citizens of the state but also as it relates to EFSEC's Prevention of Significant Deterioration Permitting obligations. These VOC emissions estimated confirm that the T-S Project/Terminal is a major source of VOC emissions and should complete full modeling and BACT analysis commensurate with PSD permitting obligations.

VI. GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE PROJECT

84. As set forth in my comments on the DEIS and also in Section III earlier, T-S and the DEIS have failed to fully identify and assess greenhouse gas emissions attributable to the T-S Project. In order to fully assess the impact of this Project on the public of the state of Washington, EFSEC must extend consideration of GHG emissions and impacts beyond just the boundaries of the T-S Terminal and consider the impacts of transporting the crude oil and the

[53] See testimony of Dr. Elinor Fanning.

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refining and subsequent use of the products derived from crude oil. This is because GHG emissions will affect all the citizens of the state of Washington whether from train traffic, barge or marine vessel traffic, from operation of the T-S Terminal to refining the crude oil and combustion of the derived products. Washington's coastline will be affected, its water supplies will be affected, wildfires will increase as will heat waves and attendant health impacts. The literature on this is significant and clear. All of Washington is and will be affected by climate change, mostly, if not exclusively, negatively.

85. Permitting of this project is the decision point that could allow this Project and, therefore their direct emissions, whether they occur in Washington, Montana, North Dakota, or in distant waters of the Pacific Ocean. CO_2 is a global pollutant and is fungible in the atmosphere such that the impacts to Washington State and the rest of the world do not depend on where the emissions occur. For that reason, it is imperative that all emissions—regardless of location—are considered.

86. The effects of climate change noted here are well-studied, well-known, and well-reported[54]. What I will address in this section of my testimony, is the many sources and relative magnitude of GHG emissions attributable or traceable to the T-S Project.

A. <u>GHG Emissions from Rail</u>

87. The DEIS only analyzed rail GHG emissions from Spokane to Vancouver, Washington (rather than the source of the crude oil in North Dakota or Alberta, Canada or from elsewhere in the "mid-continent" US). *See* DEIS at 3.2-30 and my comments. This is a serious shortcoming since, as the DEIS acknowledges, rail emissions—even considering only emissions that would occur in Washington State—would be the biggest direct driver of direct GHG

[54] See, for example, http://www.ipcc.ch/ and the vast body of work listed therein.

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emissions. *Id.* The rail emissions that would occur in Washington alone are 135,990 metric tons of CO_2 per year. *Id.* That alone would be a 14.6% increase in state rail emissions. *Compare id.* (135,990 metric tons of CO_2/year proposed), *with* Westway Terminal Company DEIS (listing current statewide rail emissions as 1,000,000 metric tons of CO_2/year). Given the distance from North Dakota to the Washington border, total rail emissions are likely more than double that amount, and the EFSEC should consider GHG emissions from rail alone, attributable to the T-S Project as **at least 272,000 metric tons of CO2 per year or more**.

88. I also note that it appears only the trips *to* the Terminal were calculated and while it is amusing to contemplate, I don't think trains will simply be accumulating along the Columbia River at the T-S Terminal. DEIS at 3.2-30 ("Transiting emissions are for loaded inbound trains only"). Rather, those trains will generate GHG emissions all the way back to the oilfields. Those GHG emissions are additional and are nowhere to be found in the analysis to date. The analysis is patently flawed since the inbound trains will not simply disappear after unloading oil at the facility. Presumably, they will leave, generating similar or equal emissions on their way out. When those emissions—resulting proximately from this facility—are added, train emissions skyrocket to 271,980 CO_2e/year, which would add over 29% to statewide rail emissions. *See* DEIS at 3.2-30. And again, that number must be doubled to include rail emissions all the way back to the oil fields.

B. <u>GHG Emissions from Marine Vessels</u>

89. Likewise, the DEIS only analyzed vessel GHG emissions from the proposed terminal to three nautical miles from Washington's coast and therefore, the EFSEC must consider GHG emissions from vessel traffic to be much higher as a result of this Project. DEIS

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at 3.2-30.[55] This is another major shortcoming since the expected amount of marine emissions (18,248 CO_2e/year) could easily increase by several orders of magnitude when the full distances to proposed locations such as Hawai'i, Alaska, and California are considered. *See id.*; *id.* at ES-2 (listing crude oil destinations).

C. GHG Emissions from Refining the Crude Oil that Will be Made Available As a Result of this Project

90. The DEIS also fails to adequately the emissions from refining the crude that will be transloaded. The work of the T-S Project does not occur in a vacuum—it's sole purpose is to increase the flow of crude oil to west coast and Alaska and Hawai'i refineries (much less to global markets.) It is not an end-use product and additional GHG emissions—significant emissions—will come from the refining of the crude oil. And, of course, those emissions will negatively affect climate change and the effects of climate change borne by citizens of Washington. As noted by other experts, very little of that refining will be done here in Washington with whatever small economic benefits might stem from it. It is highly unlikely that vessels will simply travel to Anacortes or Ferndale, as those refineries already produce more refined product than is actually used in the state.[56] More available crude for west coast refineries will only increase overall refinery emissions. The DEIS (chapter 5) discusses U.S. refinery operations and very big picture GHG emissions, but fails to give a detailed picture of the impact of this project. Rather, the DEIS appears to suggest that absent inducing an actual expansion at a refinery that also includes refining more oil, GHGs from refining the crude that will be

[55] It is unclear if, similar to trains, the analysis includes inbound and outbound vessel transits.

[56] I also note that refineries are the second largest source of GHG emissions in this country—second only to coal-fired power plants and coal-fired power plants are reducing emissions and closing. Washington's five refineries emit the equivalent GHGs of many small countries collectively emitting approximately 6 million tons of GHGs per year, the equivalent emissions of 1.25 million cars. EPA GHG equivalent calculator: http://www.epa.gov/cleanenergy/energy-resources/calculator.html.

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transloaded as a result of the T-S Project are not significant. In fact, EFSEC must consider the fact that the point of this Project is to increase availability of crude oil to West Coast and Hawai'i and Alaska refineries and it should estimate the incremental GHG emissions due to the additional crude supplied by the T-S Project.

91. I do not provide calculations of the quantity of GHG emissions that may be attributable to the increase in crude oil and attendant refining that will occur as a result of this Project, but the fact of some amount of emissions is plain and should be considered as EFSEC weighs this Project.

D. Compare with Analysis and Estimates for Millenium Bulk Terminal

92. The half-done analysis of GHG emissions in the T-S DEIS is emphasized when contrasted with the recently -completed Draft EIS for the Millenium Bulk Terminals (GHG Technical Report to Draft EIS), a proposed coal transloading terminal for Longview, Washington. There, the Draft EIS GHG Report acknowledges the full arc of transportation necessary to support and supply the Terminal, including transportation GHG emissions beyond Washington's borders. *See, e.g.* page 3-2 of Millenium Draft EIS GHG Technical Report discussing rail emissions from transport from both Uinta and Powder River basins.[57] Similarly, the Millenium GHG Report assesses the full range of GHG emissions from marine vessel transport of the product that the Terminal will transload, unlike the case here. See page 3-7 and 3-8. The Millenium GHG Report also more fully analyzes what will happen to the fossil fuel and factors in burning the coal made available through the transloading project. See Millenium EIS at page 3-8 *et seq*. The Millenium GHG Report even considers increased motor vehicle GHG emissions from delayed crossings at rail, induced by the significant increase in rail

[57] Exhibit 5525- 000084-CRK.

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traffic.[58]

93. In sum, the DEIS's conclusion that this represents an insignificant GHG impact is simply wrong and should be disregarded by EFSEC in this hearing and its consideration of the T-S Project. This Project alone (even without the omitted emissions described above) would result in a statewide increase in statewide GHG emissions of 0.56% and an increase in rail emissions of 14.6%. *Compare* DEIS at 3.2-30 (512,350 CO_2e proposed), *with* Westway Terminal Company DEIS (listing current statewide emissions as 91,700,000 CO_2e). The conclusion that this dramatic statewide increase in GHG emissions is insignificant is unsupported and unsupportable—this is a sizeable contribution to the State's entire GHG level for only a single project, and especially considering that this number is understated.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Executed this 10th day of May, 2016, at Cleveland, Ohio.

RANAJIT SAHU, PH.D.

[58] *Id.* at page 3-3. I note that the Millenium EIS also does a more complete analysis of cumulative impacts from increases in rail and vessel traffic.

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EXPERIENCE SUMMARY

Dr. Sahu has over twenty three years of experience in the fields of environmental, mechanical, and chemical engineering including: program and project management services; design and specification of pollution control equipment for a wide range of emissions sources; soils and groundwater remediation including landfills as remedy; combustion engineering evaluations; energy studies; multimedia environmental regulatory compliance (involving statutes and regulations such as the Federal CAA and its Amendments, Clean Water Act, TSCA, RCRA, CERCLA, SARA, OSHA, NEPA as well as various related state statutes); transportation air quality impact analysis; multimedia compliance audits; multimedia permitting (including air quality NSR/PSD permitting, Title V permitting, NPDES permitting for industrial and storm water discharges, RCRA permitting, etc.), multimedia/multi-pathway human health risk assessments for toxics; air dispersion modeling; and regulatory strategy development and support including negotiation of consent agreements and orders.

Specifically, over the last 20+ years, Dr. Sahu has consulted on several municipal landfill related projects addressing landfill gas generation, landfill gas collection, and the treatment/disposal/control of such gases in combustion equipment such as engines, turbines, and flares. In particular, Dr. Sahu has executed numerous projects relating to flare emissions from sources such as landfills as well as refineries and chemical plants. He has served as a peer-reviewer for EPA in relation to flare combustion efficiency, flare destruction efficiency, and flaring emissions.

He has over twenty one years of project management experience and has successfully managed and executed numerous projects in this time period. This includes basic and applied research projects, design projects, regulatory compliance projects, permitting projects, energy studies, risk assessment projects, and projects involving the communication of environmental data and information to the public. Notably, he has successfully managed a complex soils and groundwater remediation project with a value of over $140 million involving soils characterization, development and implementation of the remediation strategy including construction of a CAMU/landfill and associated groundwater monitoring, regulatory and public interactions and other challenges.

He has provided consulting services to numerous private sector, public sector and public interest group clients. His major clients over the past twenty three years include various steel mills, petroleum refineries, cement companies, aerospace companies, power generation facilities, lawn and garden equipment manufacturers, spa manufacturers, chemical distribution facilities, and various entities in the public sector including EPA, the US Dept. of Justice, California DTSC, various municipalities, etc.). Dr. Sahu has performed projects in over 44 states, numerous local jurisdictions and internationally.

In addition to consulting, Dr. Sahu has taught numerous courses in several Southern California universities including UCLA (air pollution), UC Riverside (air pollution, process hazard analysis), and Loyola Marymount University (air pollution, risk assessment, hazardous waste management) for the past seventeen years. In this time period he has also taught at Caltech, his alma mater (various engineering courses), at the University of Southern California (air pollution controls) and at California State University, Fullerton (transportation and air quality).

Dr. Sahu has and continues to provide expert witness services in a number of environmental areas discussed above in both state and Federal courts as well as before administrative bodies (see Attachment C).

EXPERIENCE RECORD

2000-present **Independent Consultant.** Providing a variety of private sector (industrial companies, land development companies, law firms, etc.) public sector (such as the US Department of Justice) and public interest group clients with project management, air quality consulting, waste remediation and management consulting, as well as regulatory and engineering support consulting services.

1995-2000 Parsons ES, **Associate, Senior Project Manager and Department Manager for** Air Quality/Geosciences/Hazardous Waste Groups, Pasadena. Responsible for the management of a group of approximately 24 air quality and environmental professionals, 15 geoscience, and 10 hazardous waste professionals providing full-service consulting, project management, regulatory compliance and A/E design assistance in all areas.

Parsons ES, **Manager for Air Source Testing Services**. Responsible for the management of 8 individuals in the area of air source testing and air regulatory permitting projects located in Bakersfield, California.

1992-1995 Engineering-Science, Inc. **Principal Engineer and Senior Project Manager** in the air quality department. Responsibilities included multimedia regulatory compliance and permitting (including hazardous and nuclear materials), air pollution engineering (emissions from stationary and mobile sources, control of criteria and air toxics, dispersion modeling, risk assessment, visibility analysis, odor analysis), supervisory functions and project management.

1990-1992 Engineering-Science, Inc. **Principal Engineer and Project Manager** in the air quality department. Responsibilities included permitting, tracking regulatory issues, technical analysis, and supervisory functions on numerous air, water, and hazardous waste projects. Responsibilities also include client and agency interfacing, project cost and schedule control, and reporting to internal and external upper management regarding project status.

1989-1990 Kinetics Technology International, Corp. **Development Engineer.** Involved in thermal engineering R&D and project work related to low-NOx ceramic radiant burners, fired heater NOx reduction, SCR design, and fired heater retrofitting.

1988-1989 Heat Transfer Research, Inc. **Research Engineer**. Involved in the design of fired heaters, heat exchangers, air coolers, and other non-fired equipment. Also did research in the area of heat exchanger tube vibrations.

EDUCATION

1984-1988 Ph.D., Mechanical Engineering, California Institute of Technology (Caltech), Pasadena, CA.

1984 M. S., Mechanical Engineering, Caltech, Pasadena, CA.

1978-1983 B. Tech (Honors), Mechanical Engineering, Indian Institute of Technology (IIT) Kharagpur, India

TEACHING EXPERIENCE

Caltech

"Thermodynamics," Teaching Assistant, California Institute of Technology, 1983, 1987.

"Air Pollution Control," Teaching Assistant, California Institute of Technology, 1985.

"Caltech Secondary and High School Saturday Program," - taught various mathematics (algebra through calculus) and science (physics and chemistry) courses to high school students, 1983-1989.

"Heat Transfer," - taught this course in the Fall and Winter terms of 1994-1995 in the Division of Engineering and Applied Science.

“Thermodynamics and Heat Transfer,” Fall and Winter Terms of 1996-1997.

U.C. Riverside, Extension

"Toxic and Hazardous Air Contaminants," University of California Extension Program, Riverside, California. Various years since 1992.

"Prevention and Management of Accidental Air Emissions," University of California Extension Program, Riverside, California. Various years since 1992.

"Air Pollution Control Systems and Strategies," University of California Extension Program, Riverside, California, Summer 1992-93, Summer 1993-1994.

"Air Pollution Calculations," University of California Extension Program, Riverside, California, Fall 1993-94, Winter 1993-94, Fall 1994-95.

"Process Safety Management," University of California Extension Program, Riverside, California. Various years since 1992-2010.

"Process Safety Management," University of California Extension Program, Riverside, California, at SCAQMD, Spring 1993-94.

"Advanced Hazard Analysis - A Special Course for LEPCs," University of California Extension Program, Riverside, California, taught at San Diego, California, Spring 1993-1994.

"Advanced Hazardous Waste Management" University of California Extension Program, Riverside, California. 2005.

Loyola Marymount University

"Fundamentals of Air Pollution - Regulations, Controls and Engineering," Loyola Marymount University, Dept. of Civil Engineering. Various years since 1993.

"Air Pollution Control," Loyola Marymount University, Dept. of Civil Engineering, Fall 1994.

"Environmental Risk Assessment," Loyola Marymount University, Dept. of Civil Engineering. Various years since 1998.

"Hazardous Waste Remediation" Loyola Marymount University, Dept. of Civil Engineering. Various years since 2006.

University of Southern California

"Air Pollution Controls," University of Southern California, Dept. of Civil Engineering, Fall 1993, Fall 1994.

"Air Pollution Fundamentals," University of Southern California, Dept. of Civil Engineering, Winter 1994.

University of California, Los Angeles

"Air Pollution Fundamentals," University of California, Los Angeles, Dept. of Civil and Environmental Engineering, Spring 1994, Spring 1999, Spring 2000, Spring 2003, Spring 2006, Spring 2007, Spring 2008, Spring 2009.

International Programs

"Environmental Planning and Management," 5 week program for visiting Chinese delegation, 1994.

"Environmental Planning and Management," 1 day program for visiting Russian delegation, 1995.

"Air Pollution Planning and Management," IEP, UCR, Spring 1996.

"Environmental Issues and Air Pollution," IEP, UCR, October 1996.

PROFESSIONAL AFFILIATIONS AND HONORS

President of India Gold Medal, IIT Kharagpur, India, 1983.

Member of the Alternatives Assessment Committee of the Grand Canyon Visibility Transport Commission, established by the Clean Air Act Amendments of 1990, 1992-present.

American Society of Mechanical Engineers: Los Angeles Section Executive Committee, Heat Transfer Division, and Fuels and Combustion Technology Division, 1987-present.

Air and Waste Management Association, West Coast Section, 1989-present.

PROFESSIONAL CERTIFICATIONS

EIT, California (# XE088305), 1993.

REA I, California (#07438), 2000.

Certified Permitting Professional, South Coast AQMD (#C8320), since 1993.

QEP, Institute of Professional Environmental Practice, since 2000.

CEM, State of Nevada (#EM-1699). Since 2000.

PUBLICATIONS (PARTIAL LIST)

"Physical Properties and Oxidation Rates of Chars from Bituminous Coals," with Y.A. Levendis, R.C. Flagan and G.R. Gavalas, *Fuel*, **67**, 275-283 (1988).

"Char Combustion: Measurement and Analysis of Particle Temperature Histories," with R.C. Flagan, G.R. Gavalas and P.S. Northrop, *Comb. Sci. Tech.* **60**, 215-230 (1988).

"On the Combustion of Bituminous Coal Chars," PhD Thesis, California Institute of Technology (1988).

"Optical Pyrometry: A Powerful Tool for Coal Combustion Diagnostics," *J. Coal Quality*, **8**, 17-22 (1989).

"Post-Ignition Transients in the Combustion of Single Char Particles," with Y.A. Levendis, R.C.Flagan and G.R. Gavalas, *Fuel*, **68**, 849-855 (1989).

"A Model for Single Particle Combustion of Bituminous Coal Char." Proc. ASME National Heat Transfer Conference, Philadelphia, **HTD-Vol. 106**, 505-513 (1989).

"Discrete Simulation of Cenospheric Coal-Char Combustion," with R.C. Flagan and G.R.Gavalas, *Combust. Flame*, **77**, 337-346 (1989).

"Particle Measurements in Coal Combustion," with R.C. Flagan, in "**Combustion Measurements**" (ed. N. Chigier), Hemisphere Publishing Corp. (1991).

"Cross Linking in Pore Structures and Its Effect on Reactivity," with G.R. Gavalas in preparation.

"Natural Frequencies and Mode Shapes of Straight Tubes," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Optimal Tube Layouts for Kamui SL-Series Exchangers," with K. Ishihara, Proprietary Report for Kamui Company Limited, Tokyo, Japan (1990).

"HTRI Process Heater Conceptual Design," Proprietary Report for Heat Transfer Research Institute, Alhambra, CA (1990).

"Asymptotic Theory of Transonic Wind Tunnel Wall Interference," with N.D. Malmuth and others, Arnold Engineering Development Center, Air Force Systems Command, USAF (1990).

"Gas Radiation in a Fired Heater Convection Section," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1990).

"Heat Transfer and Pressure Drop in NTIW Heat Exchangers," Proprietary Report for Heat Transfer Research Institute, College Station, TX (1991).

"NOx Control and Thermal Design," Thermal Engineering Tech Briefs, (1994).

“From Purchase of Landmark Environmental Insurance to Remediation: Case Study in Henderson, Nevada,” with Robin E. Bain and Jill Quillin, presented at the AQMA Annual Meeting, Florida, 2001.

“The Jones Act Contribution to Global Warming, Acid Rain and Toxic Air Contaminants,” with Charles W. Botsford, presented at the AQMA Annual Meeting, Florida, 2001.

PRESENTATIONS (PARTIAL LIST)

"Pore Structure and Combustion Kinetics - Interpretation of Single Particle Temperature-Time Histories," with P.S. Northrop, R.C. Flagan and G.R. Gavalas, presented at the AIChE Annual Meeting, New York (1987).

"Measurement of Temperature-Time Histories of Burning Single Coal Char Particles," with R.C. Flagan, presented at the American Flame Research Committee Fall International Symposium, Pittsburgh, (1988).

"Physical Characterization of a Cenospheric Coal Char Burned at High Temperatures," with R.C. Flagan and G.R. Gavalas, presented at the Fall Meeting of the Western States Section of the Combustion Institute, Laguna Beach, California (1988).

"Control of Nitrogen Oxide Emissions in Gas Fired Heaters - The Retrofit Experience," with G. P. Croce and R. Patel, presented at the International Conference on Environmental Control of Combustion Processes (Jointly sponsored by the American Flame Research Committee and the Japan Flame Research Committee), Honolulu, Hawaii (1991).

"Air Toxics - Past, Present and the Future," presented at the Joint AIChE/AAEE Breakfast Meeting at the AIChE 1991 Annual Meeting, Los Angeles, California, November 17-22 (1991).

"Air Toxics Emissions and Risk Impacts from Automobiles Using Reformulated Gasolines," presented at the Third Annual Current Issues in Air Toxics Conference, Sacramento, California, November 9-10 (1992).

"Air Toxics from Mobile Sources," presented at the Environmental Health Sciences (ESE) Seminar Series, UCLA, Los Angeles, California, November 12, (1992).

"Kilns, Ovens, and Dryers - Present and Future," presented at the Gas Company Air Quality Permit Assistance Seminar, Industry Hills Sheraton, California, November 20, (1992).

"The Design and Implementation of Vehicle Scrapping Programs," presented at the 86th Annual Meeting of the Air and Waste Management Association, Denver, Colorado, June 12, 1993.

"Air Quality Planning and Control in Beijing, China," presented at the 87th Annual Meeting of the Air and Waste Management Association, Cincinnati, Ohio, June 19-24, 1994.

PREVIOUS EXPERT WITNESS TESTIMONY

1. Occasions where Dr. Sahu has provided Written or Oral testimony before Congress:

(a) In July 2012, provided expert written and oral testimony to the House Subcommittee on Energy and the Environment, Committee on Science, Space, and Technology at a Hearing entitled "Hitting the Ethanol Blend Wall – Examining the Science on E15."

2. Matters for which Dr. Sahu has have provided affidavits and expert reports include:

(b) Affidavit for Rocky Mountain Steel Mills, Inc. located in Pueblo Colorado – dealing with the technical uncertainties associated with night-time opacity measurements in general and at this steel mini-mill.

(c) Expert reports and depositions (2/28/2002 and 3/1/2002; 12/2/2003 and 12/3/2003; 5/24/2004) on behalf of the United States in connection with the Ohio Edison NSR Cases. *United States, et al. v. Ohio Edison Co., et al.*, C2-99-1181 (Southern District of Ohio).

(d) Expert reports and depositions (5/23/2002 and 5/24/2002) on behalf of the United States in connection with the Illinois Power NSR Case. *United States v. Illinois Power Co., et al.*, 99-833-MJR (Southern District of Illinois).

(e) Expert reports and depositions (11/25/2002 and 11/26/2002) on behalf of the United States in connection with the Duke Power NSR Case. *United States, et al. v. Duke Energy Corp.*, 1:00-CV-1262 (Middle District of North Carolina).

(f) Expert reports and depositions (10/6/2004 and 10/7/2004; 7/10/2006) on behalf of the United States in connection with the American Electric Power NSR Cases. *United States, et al. v. American Electric Power Service Corp., et al.*, C2-99-1182, C2-99-1250 (Southern District of Ohio).

(g) Affidavit (March 2005) on behalf of the Minnesota Center for Environmental Advocacy and others in the matter of the Application of Heron Lake BioEnergy LLC to construct and operate an ethanol production facility – submitted to the Minnesota Pollution Control Agency.

(h) Expert Report and Deposition (10/31/2005 and 11/1/2005) on behalf of the United States in connection with the East Kentucky Power Cooperative NSR Case. *United States v. East Kentucky Power Cooperative, Inc*., 5:04-cv-00034-KSF (Eastern District of Kentucky).

(i) Affidavits and deposition on behalf of Basic Management Inc. (BMI) Companies in connection with the BMI vs. USA remediation cost recovery Case.

(j) Expert Report on behalf of Penn Future and others in the Cambria Coke plant permit challenge in Pennsylvania.

(k) Expert Report on behalf of the Appalachian Center for the Economy and the Environment and others in the Western Greenbrier permit challenge in West Virginia.

(l) Expert Report, deposition (via telephone on January 26, 2007) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) in the Thompson River Cogeneration LLC Permit No. 3175-04 challenge.

(m) Expert Report and deposition (2/2/07) on behalf of the Texas Clean Air Cities Coalition at the Texas State Office of Administrative Hearings (SOAH) in the matter of the permit challenges to TXU Project Apollo's eight new proposed PRB-fired PC boilers located at seven TX sites.

(n) Expert Testimony (July 2007) on behalf of the Izaak Walton League of America and others in connection with the acquisition of power by Xcel Energy from the proposed Gascoyne Power Plant – at the State of Minnesota, Office of Administrative Hearings for the Minnesota PUC (MPUC No. E002/CN-06-1518; OAH No. 12-2500-17857-2).

(o) Affidavit (July 2007) Comments on the Big Cajun I Draft Permit on behalf of the Sierra Club – submitted to the Louisiana DEQ.

(p) Expert Report and Deposition (12/13/2007) on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case. *Plaintiffs v. Allegheny Energy Inc., et al.,* 2:05cv0885 (Western District of Pennsylvania).

(q) Expert Reports and Pre-filed Testimony before the Utah Air Quality Board on behalf of Sierra Club in the Sevier Power Plant permit challenge.

(r) Expert Report and Deposition (October 2007) on behalf of MTD Products Inc., in connection with *General Power Products, LLC v MTD Products Inc.,* 1:06 CVA 0143 (Southern District of Ohio, Western Division)

(s) Experts Report and Deposition (June 2008) on behalf of Sierra Club and others in the matter of permit challenges (Title V: 28.0801-29 and PSD: 28.0803-PSD) for the Big Stone II unit, proposed to be located near Milbank, South Dakota.

(t) Expert Reports, Affidavit, and Deposition (August 15, 2008) on behalf of Earthjustice in the matter of air permit challenge (CT-4631) for the Basin Electric Dry Fork station, under construction near Gillette, Wyoming before the Environmental Quality Council of the State of Wyoming.

(u) Affidavits (May 2010/June 2010 in the Office of Administrative Hearings))/Declaration and Expert Report (November 2009 in the Office of Administrative Hearings) on behalf of NRDC and the Southern Environmental Law Center in the matter of the air permit challenge for Duke Cliffside Unit 6. Office of Administrative Hearing Matters 08 EHR 0771, 0835 and 0836 and 09 HER 3102, 3174, and 3176 (consolidated).

(v) Declaration (August 2008), Expert Report (January 2009), and Declaration (May 2009) on behalf of *Southern Alliance for Clean Energy et al., v Duke Energy Carolinas, LLC.* in the matter of the air permit challenge for Duke Cliffside Unit 6. *Southern Alliance for Clean Energy et al., v. Duke Energy Carolinas, LLC*, Case No. 1:08-cv-00318-LHT-DLH (Western District of North Carolina, Asheville Division).

(w) Declaration (August 2008) on behalf of the Sierra Club in the matter of Dominion Wise County plant MACT.

(x) Expert Report (June 2008) on behalf of Sierra Club for the Green Energy Resource Recovery Project, MACT Analysis.

(y) Expert Report (February 2009) on behalf of Sierra Club and the Environmental Integrity Project in the matter of the air permit challenge for NRG Limestone's proposed Unit 3 in Texas.

(z) Expert Report (June 2009) on behalf of MTD Products, Inc., in the matter of *Alice Holmes and Vernon Holmes v. Home Depot USA, Inc., et al.*

(aa) Expert Report (August 2009) on behalf of Sierra Club and the Southern Environmental Law Center in the matter of the air permit challenge for Santee Cooper's proposed Pee Dee plant in South Carolina).

(bb) Statements (May 2008 and September 2009) on behalf of the Minnesota Center for Environmental Advocacy to the Minnesota Pollution Control Agency in the matter of the Minnesota Haze State Implementation Plans.

(cc) Expert Report (August 2009) on behalf of Environmental Defense, in the matter of permit challenges to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(dd) Expert Report and Rebuttal Report (September 2009) on behalf of the Sierra Club, in the matter of challenges to the proposed Medicine Bow Fuel and Power IGL plant in Cheyenne, Wyoming.

(ee) Expert Report (December 2009) and Rebuttal reports (May 2010 and June 2010) on behalf of the United States in connection with the Alabama Power Company NSR Case. *United States v. Alabama Power Company*, CV-01-HS-152-S (Northern District of Alabama, Southern Division).

(ff) Pre-filed Testimony (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed White Stallion Energy Center coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(gg) Pre-filed Testimony (July 2010) and Written Rebuttal Testimony (August 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.

(hh) Expert Report (August 2010) and Rebuttal Expert Report (October 2010) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana) – Liability Phase.

(ii) Declaration (August 2010), Reply Declaration (November 2010), Expert Report (April 2011), Supplemental and Rebuttal Expert Report (July 2011) on behalf of the United States in the matter of DTE Energy Company and Detroit Edison Company (Monroe Unit 2). *United States of America v. DTE Energy Company and Detroit Edison Company*, Civil Action No. 2:10-cv-13101-BAF-RSW (US District Court for the Eastern District of Michigan).

(jj) Expert Report and Deposition (August 2010) as well as Affidavit (September 2010) on behalf of Kentucky Waterways Alliance, Sierra Club, and Valley Watch in the matter of challenges to the NPDES permit issued for the Trimble County power plant by the Kentucky Energy and Environment Cabinet to Louisville Gas and Electric, File No. DOW-41106-047.

(kk) Expert Report (August 2010), Rebuttal Expert Report (September 2010), Supplemental Expert Report (September 2011), and Declaration (November 2011) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)'s Cherokee power plant. No. 09-cv-1862 (D. Colo.).

(ll) Written Direct Expert Testimony (August 2010) and Affidavit (February 2012) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).

(mm) Deposition (August 2010) on behalf of Environmental Defense, in the matter of the remanded permit challenge to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(nn) Expert Report, Supplemental/Rebuttal Expert Report, and Declarations (October 2010, November 2010, September 2012) on behalf of New Mexico Environment Department (Plaintiff-Intervenor), Grand Canyon Trust and Sierra Club (Plaintiffs) in the matter of *Plaintiffs v. Public Service Company of New Mexico (PNM)*, Civil No. 1:02-CV-0552 BB/ATC (ACE) (US District Court for the District of New Mexico).

(oo) Expert Report (October 2010) and Rebuttal Expert Report (November 2010) (BART Determinations for PSCo Hayden and CSU Martin Drake units) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.

(pp) Expert Report (November 2010) (BART Determinations for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) to the Colorado Air Quality Commission on behalf of Coalition of Environmental Organizations.

(qq) Declaration (November 2010) on behalf of the Sierra Club in connection with the Martin Lake Station Units 1, 2, and 3. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Case No. 5:10-cv-00156-DF-CMC (US District Court for the Eastern District of Texas, Texarkana Division).

(rr) Pre-Filed Testimony (January 2011) and Declaration (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club).

(ss) Declaration (February 2011) in the matter of the Draft Title V Permit for RRI Energy MidAtlantic Power Holdings LLC Shawville Generating Station (Pennsylvania), ID No. 17-00001 on behalf of the Sierra Club.

(tt) Expert Report (March 2011), Rebuttal Expert Report (Jue 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (US District Court for the District of Colorado).

(uu) Declaration (April 2011) and Expert Report (July 16, 2012) in the matter of the Lower Colorado River Authority (LCRA)'s Fayette (Sam Seymour) Power Plant on behalf of the Texas Campaign for the Environment. *Texas Campaign for the Environment v. Lower Colorado River Authority*, Civil Action No. 4:11-cv-00791 (US District Court for the Southern District of Texas, Houston Division).

(vv) Declaration (June 2011) on behalf of the Plaintiffs MYTAPN in the matter of *Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington*, Matter No. PCHB No. 10-162.

(ww) Expert Report (June 2011) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).

(xx) Declaration (August 2011) in the matter of the Sandy Creek Energy Associates L.P. Sandy Creek Power Plant on behalf of Sierra Club and Public Citizen. *Sierra Club, Inc. and Public Citizen, Inc. v. Sandy Creek Energy Associates, L.P.*, Civil Action No. A-08-CA-648-LY (US District Court for the Western District of Texas, Austin Division).

(yy) Expert Report (October 2011) on behalf of the Defendants in the matter of *John Quiles and Jeanette Quiles, et al. v. Bradford-White Corporation, MTD Products, Inc., Kohler Co., et al.*, Case No. 3:10-cv-747 (TJM/DEP) (US District Court for the Northern District of New York).

(zz) Declaration (February 2012) and Second Declaration (February 2012) in the matter of *Washington Environmental Council and Sierra Club Washington State Chapter v. Washington State Department of Ecology and Western States Petroleum Association*, Case No. 11-417-MJP (US District Court for the Western District of Washington).

(aaa) Expert Report (March 2012) and Supplemental Expert Report (November 2013) in the matter of *Environment Texas Citizen Lobby, Inc. and Sierra Club v. ExxonMobil Corporation, et al.*, Civil Action No. 4:10-cv-4969 (US District Court for the Southern District of Texas, Houston Division).

(bbb) Declaration (March 2012) in the matter of *Center for Biological Diversity, et al. v. United States Environmental Protection Agency*, Case No. 11-1101 (consolidated with 11-1285, 11-1328 and 11-1336) (US Court of Appeals for the District of Columbia Circuit).

(ccc) Declaration (March 2012) in the matter of *Sierra Club v. The Kansas Department of Health and Environment*, Case No. 11-105,493-AS (Holcomb power plant) (Supreme Court of the State of Kansas).

(ddd) Declaration (March 2012) in the matter of the Las Brisas Energy Center *Environmental Defense Fund, et al., v. Texas Commission on Environmental Quality*, Cause No. D-1-GN-11-001364 (District Court of Travis County, Texas, 261st Judicial District).

(eee) Expert Report (April 2012), Supplemental and Rebuttal Expert Report (July 2012), and Supplemental Rebuttal Expert Report (August 2012) on behalf of the states of New Jersey and Connecticut in the matter of the Portland Power plant *State of New Jersey and State of Connecticut (Intervenor-Plaintiff) v. RRI Energy Mid-Atlantic Power Holdings, et al.*, Civil Action No. 07-CV-5298 (JKG) (US District Court for the Eastern District of Pennsylvania).

(fff) Declaration (April 2012) in the matter of the EPA's EGU MATS Rule, on behalf of the Environmental Integrity Project

(ggg) Expert Report (August 2012) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana) – Harm Phase.

(hhh) Declaration (September 2012) in the Matter of the Application of *Energy Answers Incinerator, Inc.* for a Certificate of Public Convenience and Necessity to Construct a 120 MW Generating Facility in Baltimore City, Maryland, before the Public Service Commission of Maryland, Case No. 9199.

(iii) Expert Report (October 2012) on behalf of the Appellants (Robert Concilus and Leah Humes) in the matter of *Robert Concilus and Leah Humes v. Commonwealth of Pennsylvania Department of Environmental Protection and Crawford Renewable Energy*, before the Commonwealth of Pennsylvania Environmental Hearing Board, Docket No. 2011-167-R.

(jjj) Expert Report (October 2012), Supplemental Expert Report (January 2013), and Affidavit (June 2013) in the matter of various *Environmental Petitioners v. North Carolina DENR/DAQ and Carolinas Cement Company*, before the Office of Administrative Hearings, State of North Carolina.

(kkk) Pre-filed Testimony (October 2012) on behalf of No-Sag in the matter of the North Springfield Sustainable Energy Project before the State of Vermont, Public Service Board.

(lll) Pre-filed Testimony (November 2012) on behalf of Clean Wisconsin in the matter of Application of Wisconsin Public Service Corporation for Authority to Construct and Place in Operation a New Multi-Pollutant Control Technology System (ReACT) for Unit 3 of the Weston Generating Station, before the Public Service Commission of Wisconsin, Docket No. 6690-CE-197.

(mmm) Expert Report (February 2013) on behalf of Petitioners in the matter of Credence Crematory, Cause No. 12-A-J-4538 before the Indiana Office of Environmental Adjudication.

(nnn) Expert Report (April 2013), Rebuttal report (July 2013), and Declarations (October 2013, November 2013) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

(ooo) Expert Report (May 2013) and Rebuttal Expert Report (July 2013) on behalf of the Sierra Club in connection with the Luminant Martin Lake Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 5:10-cv-0156-MHS-CMC (Eastern District of Texas, Texarkana Division).

(ppp) Declaration (August 2013) on behalf of A. J. Acosta Company, Inc., in the matter of *A. J. Acosta Company, Inc., v. County of San Bernardino*, Case No. CIVSS803651.

(qqq) Comments (October 2013) on behalf of the Washington Environmental Council and the Sierra Club in the matter of the Washington State Oil Refinery RACT (for Greenhouse Gases), submitted to the Washington State Department of Ecology, the Northwest Clean Air Agency, and the Puget Sound Clean Air Agency.

(rrr) Statement (November 2013) on behalf of various Environmental Organizations in the matter of the Boswell Energy Center (BEC) Unit 4 Environmental Retrofit Project, to the Minnesota Public Utilities Commission, Docket No. E-015/M-12-920.

(sss) Expert Report (December 2013) on behalf of the United States in *United States of America v. Ameren Missouri*, Civil Action No. 4:11-cv-00077-RWS (Eastern District of Missouri, Eastern Division).

(ttt) Expert Testimony (December 2013) on behalf of the Sierra Club in the matter of Public Service Company of New Hampshire Merrimack Station Scrubber Project and Cost Recovery, Docket No. DE 11-250, to the State of New Hampshire Public Utilities Commission.

(uuu) Expert Report (January 2014) on behalf of Baja, Inc., in *Baja, Inc., v. Automotive Testing and Development Services, Inc. et. al.*, Civil Action No. 8:13-CV-02057-GRA (District of South Carolina, Anderson/Greenwood Division).

(vvv) Declaration (March 2014) on behalf of the Center for International Environmental Law, Chesapeake Climate Action Network, Friends of the Earth, Pacific Environment, and the Sierra Club (Plaintiffs) in the matter of *Plaintiffs v. the Export-Import Bank (Ex-Im Bank) of the United States*, Civil Action No. 13-1820 RC (United States District Court for the District of Columbia).

(www) Direct Prefiled Testimony (June 2014) on behalf of the Michigan Environmental Council and the Sierra Club in the matter of the Application of DTE Electric Company for Authority to Implement a Power Supply Cost Recovery (PSCR) Plan in its Rate Schedules for 2014 Metered Jurisdictional Sales of Electricity, Case No. U-17319 (Michigan Public Service Commission).

(xxx) Expert Report (June 2014) on behalf of ECM Biofilms in the matter of the *US Federal Trade Commission (FTC) v. ECM Biofilms* (FTC Docket #9358).

(yyy) Declaration (July 2014) on behalf of Public Health Intervenors in the matter of *EME Homer City Generation v. US EPA* (Case No. 11-1302 and consolidated cases) relating to the lifting of the stay entered by the Court on December 30, 2011 (US Court of Appeals for the District of Columbia).

3. Occasions where Dr. Sahu has provided oral testimony <u>in depositions, at trial or in similar proceedings</u> include the following:

(zzz) Deposition on behalf of Rocky Mountain Steel Mills, Inc. located in Pueblo, Colorado – dealing with the manufacture of steel in mini-mills including methods of air pollution control and BACT in steel mini-mills and opacity issues at this steel mini-mill.

(aaaa) Trial Testimony (February 2002) on behalf of Rocky Mountain Steel Mills, Inc. in Denver District Court.

(bbbb) Trial Testimony (February 2003) on behalf of the United States in the Ohio Edison NSR Cases, *United States, et al. v. Ohio Edison Co., et al.*, C2-99-1181 (Southern District of Ohio).

(cccc) Trial Testimony (June 2003) on behalf of the United States in the Illinois Power NSR Case, *United States v. Illinois Power Co., et al.*, 99-833-MJR (Southern District of Illinois).

(dddd) Deposition (10/20/2005) on behalf of the United States in connection with the Cinergy NSR Case. *United States, et al. v. Cinergy Corp., et al.*, IP 99-1693-C-M/S (Southern District of Indiana).

(eeee) Oral Testimony (August 2006) on behalf of the Appalachian Center for the Economy and the Environment re. the Western Greenbrier plant, West Virginia Department of Environmental Protection.

(ffff) Oral Testimony (May 2007) on behalf of various Montana petitioners (Citizens Awareness Network (CAN), Women's Voices for the Earth (WVE) and the Clark Fork Coalition (CFC)) re. the Thompson River Cogeneration plant before the Montana Board of Environmental Review.

(gggg) Oral Testimony (October 2007) on behalf of the Sierra Club re. the Sevier Power Plant before the Utah Air Quality Board.

(hhhh) Oral Testimony (August 2008) on behalf of the Sierra Club and Clean Water re. Big Stone Unit II before the South Dakota Board of Minerals and the Environment.

(iiii) Oral Testimony (February 2009) on behalf of the Sierra Club and the Southern Environmental Law Center re. Santee Cooper Pee Dee units before the South Carolina Board of Health and Environmental Control.

(jjjj) Oral Testimony (February 2009) on behalf of the Sierra Club and the Environmental Integrity Project re. NRG Limestone Unit 3 before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

(kkkk) Deposition (July 2009) on behalf of MTD Products, Inc., in the matter of *Alice Holmes and Vernon Holmes v. Home Depot USA, Inc., et al*.

(llll) Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Coleto Creek coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(mmmm) Deposition (October 2009) on behalf of Environmental Defense, in the matter of permit challenges to the proposed Las Brisas coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(nnnn) Deposition (October 2009) on behalf of the Sierra Club, in the matter of challenges to the proposed Medicine Bow Fuel and Power IGL plant in Cheyenne, Wyoming.

(oooo) Deposition (October 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed Tenaska coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH) (April 2010).

(pppp) Oral Testimony (November 2009) on behalf of the Environmental Defense Fund re. the Las Brisas Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

(qqqq) Deposition (December 2009) on behalf of Environmental Defense and others, in the matter of challenges to the proposed White Stallion Energy Center coal fired power plant project at the Texas State Office of Administrative Hearings (SOAH).

(rrrr) Oral Testimony (February 2010) on behalf of the Environmental Defense Fund re. the White Stallion Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

(ssss) Deposition (June 2010) on behalf of the United States in connection with the Alabama Power Company NSR Case. *United States v. Alabama Power Company*, CV-01-HS-152-S (Northern District of Alabama, Southern Division).

(tttt) Trial Testimony (September 2010) on behalf of Commonwealth of Pennsylvania – Dept. of Environmental Protection, State of Connecticut, State of New York, State of Maryland, and State of New Jersey (Plaintiffs) in connection with the Allegheny Energy NSR Case in US District Court in the Western District of Pennsylvania. *Plaintiffs v. Allegheny Energy Inc., et al.*, 2:05cv0885 (Western District of Pennsylvania).

(uuuu) Oral Direct and Rebuttal Testimony (September 2010) on behalf of Fall-Line Alliance for a Clean Environment and others in the matter of the PSD Air Permit for Plant Washington issued by Georgia DNR at the Office of State Administrative Hearing, State of Georgia (OSAH-BNR-AQ-1031707-98-WALKER).

(vvvv) Oral Testimony (September 2010) on behalf of the State of New Mexico Environment Department in the matter of Proposed Regulation 20.2.350 NMAC – *Greenhouse Gas Cap and Trade Provisions*, No. EIB 10-04 (R), to the State of New Mexico, Environmental Improvement Board.

(wwww) Oral Testimony (October 2010) on behalf of the Environmental Defense Fund re. the Las Brisas Energy Center before the Texas State Office of Administrative Hearings (SOAH) Administrative Law Judges.

(xxxx) Oral Testimony (November 2010) regarding BART for PSCo Hayden, CSU Martin Drake units before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.

(yyyy) Oral Testimony (December 2010) regarding BART for TriState Craig Units, CSU Nixon Unit, and PRPA Rawhide Unit) before the Colorado Air Quality Commission on behalf of the Coalition of Environmental Organizations.

(zzzz) Deposition (December 2010) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).

(aaaaa) Deposition (February 2011 and January 2012) on behalf of Wild Earth Guardians in the matter of opacity exceedances and monitor downtime at the Public Service Company of Colorado (Xcel)'s Cherokee power plant. No. 09-cv-1862 (D. Colo.).

(bbbbb) Oral Testimony (February 2011) to the Georgia Office of State Administrative Hearings (OSAH) in the matter of Minor Source HAPs status for the proposed Longleaf Energy Associates power plant (OSAH-BNR-AQ-1115157-60-HOWELLS) on behalf of the Friends of the Chattahoochee and the Sierra Club.

(ccccc) Deposition (August 2011) on behalf of the United States in *United States of America v. Cemex, Inc.*, Civil Action No. 09-cv-00019-MSK-MEH (US District Court for the District of Colorado).

(ddddd) Deposition (July 2011) and Oral Testimony at Hearing (February 2012) on behalf of the Plaintiffs MYTAPN in the matter of *Microsoft-Yes, Toxic Air Pollution-No (MYTAPN) v. State of Washington, Department of Ecology and Microsoft Corporation Columbia Data Center to the Pollution Control Hearings Board, State of Washington*, Matter No. PCHB No. 10-162.

(eeeee) Oral Testimony at Hearing (March 2012) on behalf of the United States in connection with the Louisiana Generating NSR Case. *United States v. Louisiana Generating, LLC*, 09-CV100-RET-CN (Middle District of Louisiana).

(fffff) Oral Testimony at Hearing (April 2012) on behalf of the New Hampshire Sierra Club at the State of New Hampshire Public Utilities Commission, Docket No. 10-261 – the 2010 Least Cost Integrated Resource Plan (LCIRP) submitted by the Public Service Company of New Hampshire (re. Merrimack Station Units 1 and 2).

(ggggg) Oral Testimony at Hearing (November 2012) on behalf of Clean Wisconsin in the matter of Application of Wisconsin Public Service Corporation for Authority to Construct and Place in Operation a New Multi-Pollutant Control Technology System (ReACT) for Unit 3 of the Weston Generating Station, before the Public Service Commission of Wisconsin, Docket No. 6690-CE-197.

(hhhhh) Deposition (March 2013) in the matter of various *Environmental Petitioners v. North Carolina DENR/DAQ and Carolinas Cement Company*, before the Office of Administrative Hearings, State of North Carolina.

(iiiii) Deposition (August 2013) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

(jjjjj) Deposition (August 2013) on behalf of the Sierra Club in connection with the Luminant Martin Lake Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 5:10-cv-0156-MHS-CMC (Eastern District of Texas, Texarkana Division).

(kkkkk) Deposition (February 2014) on behalf of the United States in *United States of America v. Ameren Missouri*, Civil Action No. 4:11-cv-00077-RWS (Eastern District of Missouri, Eastern Division).

(lllll) Trial Testimony (February 2014) in the matter of *Environment Texas Citizen Lobby, Inc. and Sierra Club v. ExxonMobil Corporation et al.*, Civil Action No. 4:10-cv-4969 (US District Court for the Southern District of Texas, Houston Division).

(mmmmm) Trial Testimony (February 2014) on behalf of the Sierra Club in connection with the Luminant Big Brown Case. *Sierra Club v. Energy Future Holdings Corporation and Luminant Generation Company LLC*, Civil Action No. 6:12-cv-00108-WSS (Western District of Texas, Waco Division).

(nnnnn) Deposition (June 2014) and Trial (August 2014) on behalf of ECM Biofilms in the matter of the *US Federal Trade Commission (FTC) v. ECM Biofilms* (FTC Docket #9358).