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June 19, 2019

Via Email and Hand Delivery **ITEM 8.A**

ATTN: Architectural Committee
Mr. Lance Saleme
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Re: **Raging Wire SV1 Data Center Project – Mitigated Negative Declaration and Architectural Approval (PLN2018-13128 and CEQ2018-010494)**

Dear Architectural Committee Members:

We are writing on behalf of California Unions for Reliable Energy ("CURE") to urge the Architectural Committee ("Committee") to deny the Initial Study and proposed Mitigated Negative Declaration ("IS/MND") and Architectural Approval for the Raging Wire SV1 Data Center Project ("Project"). The 3.32-acre project site is located in the City of Santa Clara ("City"). The project site is within City limits north of Highway US 101 and west of the Norman Y. Mineta San Jose International Airport ("SJC"). The Project, which is proposed by Raging Wire Data Centers, Inc., involves the demolition of three currently vacant single-story light industrial buildings, paved surfaces, and surface parking areas. These elements would be removed and replaced with a new 67 foot-tall, four-story160,450 square-foot data center. The data center would have 27-megawatt ("MW") connections to Silicon Valley Power ("SVP") service and would use a daily average of approximately 22 MW. The Project would also have one 1,000-kilowatt ("KW") backup diesel generator with an associated 2,000-gallon fuel tank, and ten 3,250-KW backup diesel generators with associated 6,500-gallon fuel tanks. The generators and fuel tanks will be placed outdoors on the eastern side of the data center. The Project will

further include 18 chillers that will be located on the rooftop, and a new electrical substation to be constructed on the western portion of the Project site. Additionally, the Project would include uninterruptable power supplies (UPS) and deep-cycle (DC) plant energy equipment (lithium batteries) for additional backup power. Batteries would provide enough energy to cover the critical load of 16 MW in the event of a power failure. The Project is expected to be constructed over a period of 26 months.

On April 5, 2019, our firm submitted comments on behalf of CURE on the Initial Study and MND prepared for the Project ("Comment Letter"). Our comments were prepared with the assistance of technical experts Dr. Phyllis Fox, Ph.D, CEQ, PE, DEE, and Dr. Robert Earle, PhD. As detailed therein, we identified potentially significant and unmitigated impacts due to nitrogen oxide (NOx) emissions from the Project's backup diesel generators and greenhouse gas (GHG) emissions. Dr. Fox's comments further demonstrated that fugitive dust emissions generated during the Project's construction phase may also cause significant air quality impacts. Based on these potentially significant and unmitigated impacts, as well as other deficiencies in the Initial Study, our comments concluded that the MND in its current form and substance violates CEQA and that substantial evidence supports a fair argument that an Environmental Impact Report is required for the Project. Our previous comments on the Initial Study and MND are incorporated in this letter by reference.

In June 2019, the City provided responses to the IS/MND comments ("RTC"), including our Comment Letter. However, the City's responses are problematic and are partially addressed by letters provided by Ms. Fox and Mr. Earle, attached here as Attachments 1 and 2.[1]

I. STATEMENT OF INTEREST

CURE is a coalition of labor organizations whose members construct, operate, and maintain powerplants and other industrial facilities throughout California. CURE encourages sustainable development of California's energy and natural resources. Environmental degradation destroys cultural and wildlife areas, consumes limited water resources, causes air and water pollution, and imposes other stresses on the environmental carrying capacity of the State. Environmental degradation also jeopardizes future jobs by making it more difficult and expensive

[1] Attachment 1, Phyllis Fox, RTC Rebuttal Letter; Attachment 2 Robert Early, RTC Rebuttal Letter.

for industry to expand in Santa Clara, and by making it less desirable for businesses to locate and for people to live and recreate in the area. Continued environmental degradation can, and has, caused construction moratoriums and other restrictions on growth that, in turn, reduce future employment opportunities for CURE's participating organizations and their members. CURE therefore has a direct interest in enforcing environmental laws and minimizing project impacts that would degrade the environment.

CURE's participating organizations and their members also live, recreate, work, and raise families in the City of Santa Clara and Santa Clara County. Thus, CURE, its participating organizations and their members stand to be directly affected by the Project's adverse environmental and health impacts. Members may also work on the Project itself, and would therefore be first in line to be exposed to any health and safety hazards that the Project may create.

II. CEQA REQUIRES THAT AN ENVIRONMENTAL IMPACT REPORT BE PREPARED FOR THE PROJECT

CEQA contains a strong presumption in favor of requiring a lead agency to prepare an EIR. The "fair argument" standard reflects this presumption. The fair argument standard is an exceptionally low threshold favoring environmental review in an EIR rather than a negative declaration.[2] This standard requires preparation of an EIR if any substantial evidence in the record indicates that a project may have an adverse environmental effect.[3] As a matter of law, substantial evidence includes both expert and lay opinion based on fact.[4] Even if other substantial evidence supports a different conclusion, the agency nevertheless must prepare an EIR.[5] As we have shown in our Comment Letter, there is substantial evidence that the project **may** cause detrimental environmental effects. The RTC fails to rebut this presumption, and instead attempts to dismiss our comments by stating that it provides substantial evidence to support its conclusions. Below we rebut some of the RTC's assertions.

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[2] *Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903, 928.
[3] 14 C.C.R. § 15064(f)(1); *Pocket Protectors,* 124 Cal.App.4th at 931.
[4] PRC § 21080(e)(1) (For purposes of CEQA, "substantial evidence includes fact, a reasonable assumption predicated upon fact, or expert opinion supported by fact."); 14 C.C.R. § 15064(f)(5).
[5] *Arviv Enterprises v. South Valley Area Planning Comm.* (2002) 101 Cal.App.4th 1333, 1346; *Stanislaus Audubon v. County of Stanislaus* (1995) 33 Cal.App.4th 144, 150-151; *Quail Botanical Gardens v. City of Encinitas* (1994) 29 Cal.App.4th 1597.

a. The IS/MND Fails to Describe the Entire Project

CEQA mandates that lead agencies must include in a project description the "whole of an action" which is being approved, including *all* components and future activities that are reasonably anticipated to become part of the project.[6] This includes, but is not limited to, "later phases of the project, and any secondary, support, or off-site features necessary for its implementation."[7] The requirements of CEQA cannot be avoided by chopping a large project into many little ones or by excluding reasonably foreseeable future activities that may become part of the project.[8] The City, as the lead agency, must fully analyze the whole of the project in a single environmental review document and may not piecemeal or split the project into pieces for purposes of analysis. Nevertheless, the IS/MND fails to adequately describe Project decommissioning activities and fails to analyze impacts of decommissioning activities. Instead, the IS/MND defers analysis and creation of a Decommissioning Plan to post-Project approval. As a result, the IS/MND fails to describe the full scope of the Project being approved in the IS/MND, and fails to disclose the full range and severity of the Project's significant environmental impacts. This violates CEQA's fundamental requirement that an environmental review must fully inform the public of a project's environmental consequences. For this reason, every phase of the Project must be assessed with the same level of specific details.

CEQA requires that before a negative declaration can be issued, the initial study must "provide documentation of the factual basis for the finding in a Negative Declaration that a project will not have a significant effect on the environment."[9] In our Comment Letter we provided substantial evidence supporting a fair argument that the IS/MND failed to disclose information on several components of the Project.[10]

As noted in our Comment Letter, the IS/MND fails to address environmental impacts of decommissioning of the Project in 30 years.[11] The RTC stated that

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[6] 14 CCR §15378 (emphasis added).
[7] *Bozung v. Local Agency Formation Com.* (1975) 13 Cal.3d 263, 283-84.
[8] Pub. Resources Code § 21159.27 (prohibiting piecemealing); *see also, Rio Vista Farm Bureau Center v. County of Solano* (1992) 5 Cal.App.4th 351, 370.
[9] 14 C.C.R. § 15063(c)(5).
[10] Comment Letter, at p. 6.
[11] Comment Letter, at p. 24.

attempting to determine Project operations in 30 years is too speculative, there is an assumption that decommissioning will require a permit, and that such permit would reasonably include evaluation of environmental impacts.[12] However, this presumption is unsubstantiated by any evidence in the record.

b. The IS/MND Violates CEQA Because it Defers Mitigation

CEQA states that "[a] public agency should not approve a project as proposed if there are feasible ... mitigation measures available that would substantially lessen any significant effects that the project would have on the environment."[13] Further, these mitigation measures must be enforceable,[14] and identified during the environmental review process. Further:

> Formulation of mitigation measures shall not be deferred until some future time. The specific details of a mitigation measure, however, may be developed after project approval when it is impractical or infeasible to include those details during the project's environmental review provided that the agency (1) commits itself to the mitigation, (2) adopts specific performance standards the mitigation will achieve, and (3) identifies the type(s) of potential action(s) that can feasibly achieve that performance standard and that will considered, analyzed, and potentially incorporated in the mitigation measure.[15]

In this case, the IS/MND relies on a number of plans to mitigate impacts that would be prepared in the future, including: Construction Noise Control Plan,[16] Construction Plan,[17] Construction Vibration Monitoring Plan,[18] Construction Contingency Plan,[19] Risk Management Plan,[20] and Emergency Response and Evacuation Plan.[21] The IS/MND defers these mitigation measures, and does not provide evidence that it was not practical or infeasible to include these specific

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[12] RTC 4-37.
[13] 14 C.C.R. § 15021(a)(2)
[14] 14 C.C.R. § 15126.4(a)(2).
[15] 14 C.C.R. § 15126.4(a)(1)(B).
[16] IS/MND, at p. 80.
[17] *Id.*, at p. 81.
[18] *Id.*, at p. 84.
[19] *Id.*, at p. 85.
[20] *Id.*, at p. 60.
[21] *Id.*

details at the time of environmental review. Therefore, the City impermissibly defers feasible mitigation measures, rendering the IS/MND incomplete.

Thus, because feasible mitigation measures have not been included there is substantial evidence in the record to support a fair argument that the Project may have significant impacts

c. Operational NOx Emissions are Significant and Unmitigated

In our Comment Letter, we noted that the IS/MND failed to accurately account for operation NOx emissions, based on (1) use of wrong baseline; (2) underestimation of mobile source commuter emissions; (3) underestimation of energy use due to use of wrong building size; (4) failure to include emissions from use of generators to supply emergency power; (5) failure to include emissions from off-site power generation.[22] In part, the RTC responds to our Comment Letter in 4-16 and 4-18. However, as Dr. Fox notes, the Project's NOx emissions remain significant even after accounting for the RTC responses.

For example, Dr. Fox notes that while the RTC used CalEEMod default values for mobile commuter emissions based on project area size to arrive at an average 8-mile round trip[23], the IS/MND didn't provide evidence that the default values were applicable to the Project. On the other hand, Dr. Fox provided substantial evidence supporting a fair argument that actual anticipated mobile source commuter emissions would be higher by basing her analysis on a number of sources. According to Dr. Fox's estimates, a more realistic distance would be a 80-mile round trip; a distanced supported by evidence.[24]

Additionally, the RTC argues that evaluating the impact of actual use of the emergency generators is too speculative, and that there is no way to reliably predict if and when power outages may occur, and how long they would last – and therefore the IS/MND did not evaluate NOx emissions from use of the emergency backup generators.[25] However, as Dr. Fox points out, while it may not be possible to predict with accuracy when such events might happen and for how long, Dr. Fox used evidence to support average number and duration of outages at SVP between the

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[22] Comment Letter, at p. 10.
[23] RTC 4-16.
[24] Fox Rebuttal Letter, at p. 3.
[25] RTC 4-19.

years of 2013 and 2017 to provide reasonably foreseeable estimates of NOx emissions due to power outages.[26]

Finally, the RTC states that indirect off-site NOx emissions cannot be predicted with reasonable certainty because SVP purchases energy from a number of sources, and that Dr. Fox's analysis assumes that all electricity would be obtained from SVP and that all of the electricity required for the project would be generated by a natural gas-fired power plant.[27] The RTC is wrong.

First, the RTC does not provide any evidence showing that the Project will obtain energy from any other sources.

Second, as explained by Dr. Fox, her analysis is based on historical information, and that her calculation assumes that only 24% of SVP's power would be supplied by the natural gas-fired plant.[28] Based on Dr. Fox's calculations, these assumptions would increase total operation NOx emissions to 18.4 ton/year and off-site daily emissions to 93.1 lb/day, both of which exceed the significance thresholds used by the IS/MND. Therefore, the RTC doesn't negate the substantial evidence supporting a fair argument that the Project would have significant environmental impacts.

Finally, the RTC states that SVP facilities are subject to separate CEQA review and permitting by the appropriate regional air district, including mitigation measures for air quality impacts, and that the project would not require or result in the construction or expansion of power-generating facilities that result in increased air pollutant emissions. However, the RTC does not provide any evidence to substantiate this claim.

Thus, we have shown that there is more than a fair argument showing that the Project may have significant environmental impacts, and that the City must therefore prepare an EIR.

d. Air Quality Analysis is Incomplete

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[26] Fox Rebuttal Letter, at p. 4.
[27] RTC 4-20.
[28] Fox Rebuttal Letter, at p. 5.

In our Comment Letter, we explained that the IS/MND failed to fully account for the Project's construction and operational emissions impacts on ambient ozone concentrations.[29] The RTC responds that the Project will not impact ozone concentrations because the ozone precursor emissions of Reactive Organic Gases ("ROG") and NOx would be below significance.[30] However, Dr. Fox explains that under her revised NOx calculations (see above) the Project will exceed the threshold of significance.

Therefore, there is substantial evidence supporting a fair argument that the Project may have significant impacts on ozone concentrations.

e. Particulate Matter Emissions are Significant and Unmitigated

In our Comment Letter, we noted that the Project will have significant impacts on air quality and that emissions of particulate matter ("PM") were underestimated, significant, and unmitigated.[31] The IS/MND uses the Bay Area Air Quality Management District ("BAAQMD") CEQA Guidelines to support less than significant impacts from fugitive dust. These guidelines state that by adopting standard control measures, a project would automatically reduce fugitive dust emissions to less than significant.[32] As Dr. Fox explained, this is not a quantitative PM threshold, and falsely assumes that implementing these measures will effectively reduce PM emissions to a less than harmful environmental impact.[33]

The RTC asserts, without providing evidence, that implementing "standard" control measures, will adequately reduce impacts, without attempting to quantify levels of fugitive dust PM emissions.[34] However, in this case, Dr. Fox evaluated fugitive dust PM emissions from the Project and compared them to quantitative levels of significance used by other air districts, providing evidence that fugitive dust PM emissions from the Project would exceed levels of significance.[35]

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[29] Comment Letter, at p. 25.
[30] RTC 4-39.
[31] Comment Letter, at p. 27.
[32] Comment Letter, at p. 29.
[33] Comment Letter, at p. 30.
[34] Fox Rebuttal Letter, at p. 7.
[35] *Id.*

Furthermore, Dr. Fox has argued that control measure proposed by the BAAQMD's CEQA guidelines are ineffective at controlling fugitive dust PM emissions, stating:

> [t]wo of the proposed fugitive dust mitigation measures do not mitigate fugitive dust, but rather exhaust emissions; most of the proposed mitigation measures are not enforceable on the applicant; one is not valid mitigation as it is required by state law; and some only apply during working hours, which ignores windblown dust from disturbed soils during nonworking hours.[36]

Therefore, Dr. Fox has provided substantial evidence supporting a fair argument that the Project will have significant impacts on air quality.

f. Hazards from Battery Use are Significant and Unevaluated

The Project proposes to use lithium batteries for additional backup power in the case of a power outage to supply electricity during the transition to the backup generators. In our Comment Letter we noted that hazardous material impacts can be significant during battery transport, use and disposal, and that lithium-ion battery fires are extremely dangerous.[37] We further noted that the IS/MND does not address these issues, or provide sufficient information, such as number and storage configuration, for the public or decision-makers to effectively evaluate the Project's impacts.[38]

The RTC didn't address these concerns, and argued simply that the type of batteries to be selected by the Project proponent would not affect the hazards analysis in the IS/MND, that transport of the batteries would be "transported to the site along major roads and highways as is typical for construction projects including data centers," and that the Santa Clara Fire Department ("SCFD") would serve the Project which "does not present a unique or unusually high fire risk."[39]

The RTC does not provide any evidence to support these contentions, failing to evaluate reasonably foreseeable events such as fire at the data center, and SCFD's experience and ability in fighting fires of this type. Dr. Fox notes that

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[36] *Id.*, at p. 8.
[37] Comment Letter, at p. 8.
[38] *Id.*
[39] RTC 4-10.

lithium-ion battery fires are extremely difficult to suppress, and provides substantial evidence to support the dangers unique to these kinds of fires.[40] Dr. Fox further notes that such hazards should be analyzed by "[i]dentifying all feasible failure modes, identifying the specific chemicals and the rates at which they could be released during each failure mode, and estimating chronic, acute, and cancer impacts at the locations of sensitive receptors."[41] The IS/MND and the RTC fail to do this.

Dr. Fox cites a number of sources to support her analysis, providing substantial evidence to support a fair argument that the Project may have significant hazards impacts. Therefore, the City cannot adopt the proposed MND, and must conduct full environmental review for the Project.

g. The City's Response to Project Greenhouse Gas ("GHG") Impacts Analysis are Insufficient

The IS/MND states that the Project will be consistent with statewide GHG reduction goals stating the "[p]roject's indirect GHG emissions from electricity under baseline conditions would be 28 percent below the 2016 statewide average rate of GHG emissions from electricity. Moreover, project emissions would be reduced by over 46 percent compared to baseline (2017) conditions by 2030."[42]

Our Comment Letter noted that under relevant case law,[43] limiting discussion to a project's consistency with statewide GHG reductions goals is not sufficient by itself, and that substantial discussion of the applicability of the statewide goals to the specific project is required.[44] Neither the IS/MND nor the RTC address this issue. The RTC's response consists mostly of a re-iteration of the IS/MND wording describing SVP's IRP and the fact that since the Project will receive energy from SVP, it's GHG emissions would be less than significant.

Further, the RTC provides what it considers key features of the 2017 Scoping Plan associated with SB32 relevant to the Project:

- Achieving a 50-percent Renewable Portfolio Standard (RPS) by 2030,

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[40] Fox Rebuttal Comments, at p. 10.
[41] Fox Rebuttal Comments, at p. 12.
[42] IS/MND, at p. 50.
[43] *Center for Biological Diversity v. California Dept. of Fish and Wildlife* (2015) 62 Cal. 4111 204.
[44] Comment Letter, at p. 19.

- Reducing man-made black carbon emissions by 50 percent by 2030,
- Greatly increase the number of electric vehicles on the road and reduce oil demand in half, and
- Develop fuels with an 18-percent reduction in carbon intensity.

Yet, the RTC asserts that the only aspect in its capacity is to "[s]upport statewide GHG reduction efforts through energy efficiency...."[45] The RTC concludes on this issue "[b]ased on the inherent energy efficiency of the project design and the power mix that would be provided to the project, which currently meets the state's renewable portfolio standard, indirect GHG emissions would not represent a significant impact."[46]

However, this does not provide substantial discussion showing that the Project's GHG emissions will not be significant.

Furthermore, Dr. Earle noted that IS/MND's "good faith" reliance on SVP's Integrated Resource Plan ("IRP") for calculating the Project's indirect GHG emissions is misplaced, and leads to an underestimate of GHG emissions. The RTC responds to Dr. Earle's comments by stating:

> Indirect GHG emissions from SVP power generation were estimated based on actual emissions rates provided by SVP from the most recent available data (2017) and future emissions rates predicted by SVP based on their current and planned renewable portfolio, consistent with their adopted strategic plan and consistent with statewide regulatory requirements. This constitutes substantial evidence that the rates used in the IS/proposed MND are reasonable and demonstrates a good faith effort to predict indirect GHG emissions attributable to the project.[47]

However, this response does not address our Comment Letter. There, Dr. Earle provided analysis that the estimated 348 lbs-CO_2/MWh generated by SVP as a whole in 2020 is likely too low because the SVP's IRP uses an emissions rate for market purchases far below that mandated by the California Energy Commission ("CEC").[48] Dr. Earle shows that by applying the emissions rate mandated by the

[45] RTC 4-29.
[46] RTC 4-29.
[47] RTC 4-31.
[48] Earle Rebuttal Letter, at p. 1.

CEC the Project would result in an emissions rate of 465 lbs-CO_2/MWh. Further, Dr. Earle showed that SVP's IRP may not meet SB350 statewide requirements because the IRP fails to count emissions generated from its market purchases. This is contrary to the RTC's assertion that the emissions rates predicted by SVP are consistent with statewide regulatory requirements, as noted in comment 4-31.

In sum, there is substantial evidence supporting a fair argument that the Project will have significant GHG impacts, necessitating an EIR. Therefore, we urge the Committee not to approve the architectural review.

III. THE COMMITTEE LACKS SUBSTANTIAL EVIDENCE TO MAKE THE FINDINGS REQUIRED TO GRANT ARCHITECTURAL APPROVAL UNDER THE SANTA CLARA CITY CODE

Santa Clara City Code Section 18.76.00 provides that one of the Committee's purposes is to "[m]aintain the public health, safety and welfare;" Furthermore Section 18.76.020, subsection (c), provides that to approve a project, the Committee **must** find that the Project is based on the following standards of architectural design, among others:

> (4) That the granting of such approval will not, under the circumstances of the particular case, materially affect adversely the health, comfort or general welfare of persons residing or working in the neighborhood of said development, and will not be materially detrimental to the public welfare or injurious to property or improvements in said neighborhood.[49]

As our comments on the MND explain, substantial evidence supports a fair argument that the Project may have several significant impacts on the environment. These impacts, which directly relate to the Project's potential impacts on public health and the use and enjoyment of neighboring properties, are also such that the Committee cannot properly make the above findings based on the current Project proposal.

a. The Project's Air Quality Impacts Will Have Adverse Impacts on Persons Residing or Working in The Neighborhood

[49] S.C.C.C. § 18.76.020(c).

First, Project construction and operations may cause significant air quality impacts due to NOx emissions. In this case, the IS/MND underestimated NOx emissions for a variety of reasons as explained in our comments. Including all emissions sources, Dr. Fox estimated that an additional 1.26 tons per year of NOx emissions should be added to Project impacts. In her conclusion, Dr. Fox estimated that NOx emissions would exceed the NOx emissions thresholds of significance used by the IS/MND. NOx emissions are a precursor to ozone, and ground-level ozone is known to contribute to a number of adverse public health impacts, including: causing difficulty breathing; aggravating lung diseases such as asthma, emphysema, and chronic bronchitis; and making the lungs more susceptible to infection, among others harmful effects. Therefore, as we show, the Project's actual NOx emissions would have adverse impacts on the public living or working nearby, and cannot be found to be consistent with Santa Clara City Code Section 18.76.020, subsection (c).

b. The Project's Greenhouse Gas Emissions Impacts Will Have Adverse Impacts on Persons Residing or Working in The Neighborhood

Second, as our comments on the IS/MND further explain, GHG emissions resulting from the Project's operations may exceed the BAAQMD's numeric threshold of significance for land use projects, particularly when the Project's substantial electricity demand is accounted for. The IS/MND concludes that the Project's GHG emissions would have a less than significant impact on the environment because 1) GHG emissions from both the construction and operation phase would be below the threshold of significance, and 2) the Project "[w]ould not conflict with an applicable local plan, policy, or regulation adopted for the purpose of reducing the emission of GHGs."

First, the IS/MND underestimates the amount of GHG emissions since it does not evaluate GHG emissions from the construction phase. Second, the IS/MND's reliance on SVP's proposed future reductions in GHG emissions, does not by itself provide evidence that GHG emissions will be in fact reduced by the amount the IS/MND claims, and in fact as shown above, it is likely that GHG emissions will be higher than estimated in the IS/MND.

The IS/MND further fails to support it conclusions of no significant impact by stating that the Project is consistent with state and local GHG reduction goals – however, the IS/MND does not discuss the applicability of the statewide goals to the

Project, or how the amount of GHG's emitted from the Project will go towards meeting the statewide goals. The IS/MND simply asserts that since the Project is projected to reduce GHG emissions in the future by percentages that are consistent with the statewide goals for GHG emission reductions, such reductions are sufficient to support the contention that the Project's GHG emissions would not be significant. This argument is circular, and is insufficient without supporting evidence showing that the particular project will not cause a significant contribution, either individually or cumulatively, to GHG emissions.

Therefore, and as explained in more detail in our IS/MND comments and above, the IS/MND fails to show that GHG emissions are below the adopted threshold of significance, or establish that the Project's consistency with these plans and programs will ensure that the Project's reasonably foreseeable incremental contribution to global climate change is not cumulatively considerable.

Climate change is an impact that not only adversely affects those in the immediate vicinity of the Project, but all Californians in the form of increased drought, wildfires, and rising sea levels. Thus, approval of the Project in its current form may also adversely affect public welfare in this regard.

c. The Project is inconsistent with Santa Clara City Code Section 18.76.00

The project is located less than half a mile northeast of dense City of Santa Clara residential neighborhoods, and is surrounded by office buildings and other industry. The Committee cannot adopt the MND or find in support of architectural approval for the Project since the Project will have an adverse impact on individuals living or working in the Project's neighborhood. For the reasons above, we urge the Committee not to adopt the IS/MND or approve the Project at this time. The City's analysis in the Initial Study and MND does not support a finding that the Project approval will not materially affect adversely the welfare of persons residing or working in the neighborhood of the Project.

IV. CONCLUSION

We have provided in our comments substantial evidence supporting a fair argument that the Project's environmental impacts on air quality and GHG may be significant, and that the IS/MND fails to describe the Project in its entirety. We further show that because the Project will have significant impacts, the

Architectural Committee cannot make findings consistent with Section 18.76.020. Based on the evidence provided, we urge the Committee to deny approval of the Project as currently proposed, and require that an EIR be prepared.

Sincerely,

Yair Chaver

YC:acp

Attachments

Received @ mtg
AC 6.19.19

Attachment 1

Phyllis Fox, PhD, PE
745 White Pine Avenue
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June 19, 2019

Yair Chaver
Adams, Broadwell, Joseph & Cardozo
601 Gateway Blvd, No. 1000
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Re: Responses to Comments on IS/MND for SV1 Data Center

Dear Mr. Chaver:

As you requested, I have reviewed the responses to my comments on the draft Initial Study/Mitigated Negative Declaration (IS/MND) for the 1150 Walsh Avenue SV1 Data Project, with the exception of greenhouse gas emissions, which is legal argument. The responses did not address my comments directly, but rather your summary of them. Thus, some key issues were overlooked and others inadequately responded to. The responses to my comments are generally inadequate to address the issues that I raised in my April 5, 2019 comments[1] as they are superficial, incomplete, and unsupported. After considering the responses, the following issues remain:

- Operational NOx emissions are significant and unmitigated.
- The air quality analyses are incomplete because they fail to include any air dispersion modeling of Project construction and operational emissions to verify compliance with ambient air quality standards.
- Daily and annual PM2.5 and PM10 emissions during construction were significantly underestimated, are significant, and unmitigated.
- Battery hazard impacts were not disclosed or evaluated and are significant.
- Proposed mitigation for several impacts, including noise, vibration, risk management, storm water pollution, and emergency response and evacuation are not valid because mitigation relies on future plans that are not part of the IS/MND.

[1] Phyllis Fox, Comments on the Initial Study/Mitigated Negative Declaration (IS/MND) for the 1150 Walsh Avenue SV1 Data Center, April 5, 2019; Exhibit 1 to Letter from Yair Chaver, Adams Broadwell Joseph & Cardozo, Re: SV1 Data Center Project Initial Study and Mitigated Negative Declaration Comments (PLN2017-12535 and CEQ2017-01034), April 5, 2019.

I. OPERATIONAL NOx EMISSIONS ARE SIGNIFICANT AND UNMITIGATED

I commented that the IS/MND underestimated operational NOx emissions due to five factors: (1) use of wrong baseline; (2) underestimation of mobile source commuter emissions; (3) underestimation of energy use due to use of wrong building size; (4) failure to include emissions from use of generators to supply emergency power; (5) failure to include emissions from off-site power generation.[2] The City's Response to Comments ("RTC") does not adequately address any of these comments.

The IS/MND presents NOx daily and annual emissions for two sources: (1) data center mobile and area (2.2 lb/day, 0.4 ton/yr) and (2) emergency generators (47.9 lb/day, 8.8 ton/yr).[3] However, the supporting calculations in Appendix A to the IS/MND indicate that the summary in IS/MND Table 2-3 is incorrect. The supporting calculations omit important emission sources and underestimate others, as explained in my Comments 2.1.2 to 2.1.5 on the IS/MND. Thus, I calculated NOx emissions from scratch, using the CalEEMod output included in Appendix A to the IS/MND, supplemented by information that was missing from the IS/MND. The responses to my analysis of NOx emissions are in RTCs 4-14 to 4-17. These responses fail to adequately address the numerous errors and omissions I found in the NOx emission calculations in the IS/MND, as explained below. The Project's NOx emissions remain significant after taking into consideration the RTCs.

Baseline

Baseline emissions were improperly subtracted from the Project emission increases in the supporting emission calculations in Appendix A but not in the emission summary in the main body of the IS/MND.[4] Therefore, this issue is resolved as long as all NOx air quality impacts are based on a zero baseline.

Commute Distance

As noted in my Comment 2.1.2, mobile source emissions were significantly underestimated because they were based on a CalEEMod "default" round trip distance of 8 miles, or only 4 miles one way. The RTC does not provide any evidence that this "default" applies to the Project site, which is located in the Silicon Valley of the greater Bay Area. It is well known that commute distances in the greater Bay Area are substantially greater than 4 miles one way due to the very high cost of living in job centers, such as Silicon Valley.[5] In fact, Santa

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[2] Fox Comment 2.1, pp. 3-9.

[3] IS/MND, Table 2-3, p. 28.

[4] Fox Comment 2.1.1, pp. 3-4.

[5] See, e.g., Sal Castaneda, Bay Area Workers Priced Out of Housing Market, Opt for Hours-Long Commutes, Fox KTVU, Video Updated November 1, 2018, available at http://www.ktvu.com/news/bay-area-workers-priced-out-of-housing-market-opt-for-hours-long-commutes; Commute Distance in US Metro Area, June 1, 2018, available at

Clara County, where the Project will be located, has the most "mega commuters" (i.e., those who commute very long distances) in the United States.[6]

The RTC asserts that my 40-mile one-way/80-mile round trip is "arbitrary and not supported with substantial evidence."[7] However, my estimate is based on a recent study, which I cited in my comments.[8] Further, numerous other sources, cited here in footnote 5, support a much higher estimate than an 8-mile roundtrip. In fact, the 8-mile roundtrip estimate used to calculate NOx emissions in the IS/MND is wholly unsupported and as stated in the RTC, is based on a CalEEMod default, not a site-specific estimate.

The IS/MND does not contain any evidence that workers who would commute to the Project site could afford to live only 4 miles away, as assumed in the NOx emission calculations. Further, the IS/MND contains no support for its estimated trip length based on "factoring effects such as pass-by and diverted trip types" as alleged in the RTC.[9] The erroneous trip length assumed in the IS/MND's emission calculations is sufficient by itself to push both annual and daily NOx emissions over the significance thresholds.[10]

The annual results are compelling because the BAAQMD annual significance threshold is based on the "maximum annual emissions."[11] Thus, if an average 80-mile round trip commute distance occurred in any year over the Project life, this one-time occurrence would be sufficient by itself, setting aside all of the other errors and omissions in the NOx emission calculations, to increase NOx emissions above the annual CEQA significance threshold. Given Bay Area commuter trends, an average 80-mile round trip commute cannot be ruled out over the 30-year life of the Project.

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http://meetingthetwain.blogspot.com/2018/06/commute-distance-in-us-metro-areas.html; Greg Miller, Animated Maps Illustrate the Hell of Bay Area Commuting, *Science*, August 5, 2015; available at https://www.wired.com/2015/08/pretty-maps-bay-area-hellish-commutes/; Shawn M. Carter, This 30-Year-Old Commutes 4 Hours, and 140 miles, Every Day So He Doesn't Have to Pay $4,500-a-month San Francisco Rent, *Money*, available at https://www.cnbc.com/2018/08/20/pr-rep-commutes-4-hours-every-day-to-avoid-45000-dollar-san-francisco-rent.html.

[6] Eric Van Susteren, Bay Area Has Most "Mega Commuters" in Nation, *Palo Alto Weekly*, March 6, 2013 ("Santa Clara County among highest in nation in out-of-county commuters"), available at https://www.paloaltoonline.com/news/2013/03/06/bay-area-has-most-mega-commuters-in-the-nation.

[7] RTC 4-16.

[8] Fox Comment 2.1.2, p. 5, footnote 19.

[9] RTC 4-16, p. 10.

[10] Increase in annual IS/MND NOx emissions from changing commute distance: 8.9 ton/yr – 0.4 ton/yr + 2.0 ton/yr = 10.5 ton/yr > 10 ton/yr. Increase in hourly IS/MND NOx emissions from changing commute distance: 48.6 lb/day – 2.2 lb/day + 11.1 lb/day = 57.5 lb/day > 54 lb/day.

[11] BAAQMD, California Environmental Quality Act Air Quality Guidelines, May 2017, Table D-2, available at http://www.baaqmd.gov/~/media/files/planning-and-research/ceqa/ceqa_guidelines_may2017-pdf.pdf?la=en.

In sum, in my professional opinion, the IS/MND significantly underestimated trip length and commuter NOx emissions. When this error is corrected, the increases in annual and daily NOx emissions exceed the BAAQMD annual and daily NOx CEQA significance thresholds. The available evidence indicates that a 4-mile one-way trip for workers is not achievable without an enforceable mitigation plan that limits employee travel distance.

Emergency Generator Operation

Second, the IS/MND did not include NOx emissions from using the emergency generators to supply power during power outages.[12] The RTC states these emissions were excluded because CEQA only requires a "reasonable analysis of possible environmental effects," which excludes "speculative emergency conditions which are unlikely to occur and cannot be predicted with a reasonable certainty."[13] This response is wholly without merit.

The Project includes 11 backup diesel generators to provide power to the data center in the event of an emergency.[14] Thus, the applicant anticipates power outages that would require use of the emergency generators. The mere inclusion of these generators in Project design is sufficient evidence that outages will occur, requiring their use. Otherwise, the Project would not include 11 emergency generators. Thus, outage emissions must be included in the CEQA analysis. They are not.

The RTC asserts that emissions from the use of the generators "cannot be predicted with a reasonable certainty. There is no way to reliably predict if or when a power outage may occur, or the number of hours that a power outage might last."[15] The "if" is beside the point because 11 diesel generators would not be part of the Project if the applicant did not expect power outages. There is no need to predict "when" outage emissions would occur. These emissions are routinely and accurately estimated from historic outage data compiled by the Energy Information Agency (EIA) for each subject utility. I estimated these emissions for Silicon Valley Power ("SVP"), the utility that will supply the Project, based on actual outage data for SVP.[16] These emissions stand unrebutted in the record and must be added to Project total emissions.

Off-Site Generation

The IS/MND failed to include off-site emissions from supplying electricity to the Project. SVP will supply electricity to the Project. The emissions from supplying this power must be included in Project emissions as indirect impacts. This is very important as most data

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[12] Fox Comment 2.1.4, p. 6.

[13] RTC 4-18, p. 10.

[14] IS/MND, p. 3.

[15] RTC 4-18, p. 10.

[16] Fox Comment 2.1.4.

centers, by design, consume vast amounts of energy in a wasteful manner as companies run their facilities at maximum capacity around the clock, whatever the demand. As a result, data centers can waste 90% or more of the electricity they pull off the grid.[17] This wasteful energy use should be mitigated in the IS/MND.

In 2013 to 2017, 24% of SVP's total electricity supply came from a gas-fired power plant in Santa Clara County. The data center would have a 27-MW connection to SVP service. Thus, I calculated the resulting increase in NOx emissions from supplying 24% of SVP's power from this Santa Clara County gas-fired power plant,[18] conservatively assuming no change in the fraction of SVP's total electricity that would come from this Santa Clara plant.

First, the response asserts that my estimate of off-site generation emissions is "speculative" and cannot be predicted with reasonable certainty.[19] This is incorrect. My calculations are conservatively based on historical operation for the period 2013–2017.[20] The IS/MND and RTC contain no evidence that the 2013–2017 period would not be representative of SVP operation during Project operation.

Second, the response asserts that my calculations assume that all of the electricity required by the Project would be generated by the subject natural gas-fired plant. This is incorrect. I assumed, based on cited historical records, that 24% would be supplied by the natural gas-fired plant.

My use of historical average data for the natural-gas fired plant may indeed be incorrect, but for different reasons and in the opposite direction from Applicant's assertions. To the extent SVP is already maximizing its use of non-carbon resources, subject only to resource constraints, then its marginal source of energy to meet incremental demand would be 100% from resources emitting CO2. Once the data center starts operation, a larger fraction of SVP power may come from the subject natural gas-fired plan because renewables are maxed out and data centers typically run at maximum capacity around the clock, regardless of demand.[21] Thus, greater reliance likely will be placed on the local gas-fired plant.

By assuming only 24% of marginal generation to meet demand from the proposed project comes from SVP's existing combined cycle plant,[22] I have underestimated emissions by as much

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[17] James Glanz, Power, Pollution and the Internet, The New York Times, September 22, 2012; available at: https://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html.

[18] Fox Comment 2.1.5.

[19] RTC 4-20, p. 11.

[20] Fox Comment 2.1.5, p. 7.

[21] Glanz, September 22, 2012.

[22] Fox Comment 2.1.5, Table 3.

as a factor of four. A factor of four increase in NOx emissions from off-site generation would increase off-site annual generation emissions from 1.3 ton/yr and 6.9 lb/day to 5.2 ton/yr and 27.6 lb/day and total operational NOx emissions from 12.8 ton/yr to **18.9 ton/yr** and off-site daily generation emissions from 70.7 lb/day to **98.8 lb/day,**[23] which significantly exceed the significance thresholds of 10 ton/yr and 54 lb/day, respectively.

Third, the response asserts that the emissions from SVP facilities are subject to separate CEQA review and are thus exempt in this case. However, the responses do not cite any CEQA document that includes emissions from the subject gas-fired power plant to supply the Project.

Fourth, the response asserts that the emissions from the subject power plant are permitted by the responsible air district. A BAAQMD permit does not assure that the Project will not increase emissions from the subject natural gas plant relative to baseline operation.

Summary

In sum, my revised NOx emission calculations are supported by unrebutted substantial evidence. The revised NOx emissions in Table 3 of my comments exceed the BAAQMD daily and annual CEQA significance thresholds for NOx and must be mitigated. The NOx impacts could be mitigated, for example, by using technologies that allow data centers to safely power down servers when they are not needed, overnight for example.[24]

II. AMBIENT AIR QUALITY IMPACTS WERE NOT EVALUATED

Ozone Impacts

I commented that the IS/MND failed to evaluate the impact of Project construction and operational emissions on ambient ozone concentrations.[25] Response 4-39 asserts that the Project would not cause significant ozone impacts because ozone precursor emissions (ROG and NOx) are less than significance thresholds.[26] However, my revised NOx calculations indicate that both annual and daily operational NOx emissions exceed the NOx significance thresholds. This is substantial evidence that ozone impacts are significant and must be analyzed and mitigated.

Construction Particulate Matter Impacts

Construction particulate matter (PM2.5, PM10) originates from two sources: (1) engine exhaust and (2) fugitive dust. The IS/MND estimated engine exhaust but not fugitive dust.

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[23] From Fox Comment 2.1.5, Table 3: (1.3 ton/yr)(4) = **5.2 ton/yr** and (6.9 lb/day)(4) = **27.6 lb/day.** Total revised NOx emissions: (5.2 + 12.8) = **18.9 ton/yr** and (70.7 + 27.6) = **98.8 lb/day.**

[24] Glanz, September 22, 2012.

[25] Fox Comment 4.1, pp. 29-30.

[26] RTC 4-39.

Fugitive Dust Emissions

The IS/MND did not estimate fugitive dust PM10 and PM2.5 emissions because the BAAQMD CEQA guidelines do not include significance thresholds for fugitive dust. Instead, the BAAQMD CEQA guidelines assume that if a standard suite of mitigation measures is implemented, impacts will be insignificant, without requiring any analysis at all (i.e., quantifying emissions and comparing them to significance thresholds). Rather, the IS/MND assumes, based on BAAQMD guidance, that the adoption of a standard suite of control measures would reduce any impacts to a less than significant level.

I am not aware of any other regulatory agency in California that assumes without any analysis that a "standard" suite of control measures, regardless of site conditions and construction activities, would reduce fugitive PM10 and PM2.5 emissions to a less than significant level. Thus, to verify this conclusion, I calculated fugitive dust PM10 and PM2.5 emissions for the Project and compared them to fugitive dust PM10 and PM2.5 significance thresholds of other air districts. This analysis demonstrated that fugitive dust PM10 and PM2.5 emissions from Project construction are significant,[27] and stands unrebutted in the record.

Instead of addressing my analysis, which stands unrebutted in the record, the RTC argues—without any evidence—that implementing a standard suite of control measures will reduce fugitive dust impacts to a less than significant level.[28] The IS/MND did not estimate fugitive dust PM2.5 and PM10, did not assign control efficiencies to the standard suite of control measures, and did not calculate mitigated PM2.5 and PM10 emissions. Thus, the IS/MND fails as an informational document under CEQA.

The responses also argue that haul distances and routes are "too speculative" to estimate fugitive PM2.5 and PM10 from this major source of fugitive dust.[29] However, this is not believable. This information is also required to estimate other construction emissions and is thus clearly available.

Further, the "standard suite of control measures" argument is contrary to the BAAQMD's own guidance, which requires the use of certain "additional construction mitigation measures" that are not required in the IS/MND.[30] In addition, as noted in my comments, two of the proposed fugitive dust mitigation measures do not mitigate fugitive dust, but rather exhaust emissions; most of the proposed mitigation measures are not enforceable on the applicant; one is not valid mitigation as it is required by state law; and some only apply during working hours,

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[27] Fox Comment 6.1, pp. 33-41.

[28] RTC 4-43.

[29] See Fox Comment 6.1.1.

[30] Fox Comment 6.1.4, p. 42.

which ignores windblown dust from disturbed soils during nonworking hours.[31] In fact, there is no evidence in this record that the proposed standard suite of control measures will reduce the significant fugitive dust PM2.5 and PM10 emissions that I calculated to a less than significant level. My calculations stand unrebutted in the record, demonstrating significant construction PM10 and PM2.5 impacts.

III. BATTERY HAZARD IMPACTS WERE NOT EVALUATED

I commented that hazardous material impacts could be significant during battery transport, use, and disposal due to the proximity of major roadways and residential housing. I further commented that lithium-ion battery fires are some of the most difficult to control, presenting an on-site fire risk that was not analyzed.[32]

The RTC dismisses these issues with no analysis at all, arguing that the specific technology will be selected by the applicant in the future and "does not affect the hazards analysis conducted in the IS/proposed MND."[33] Further, the RTC argues that "the project would be adequately served by the Santa Clara Fire Department (SCFD) and does not present a unique or unusually high risk of fire."[34]

First, the specific battery technology and its layout and use to support the Project must be disclosed in the IS/MND so that its impacts can be evaluated along with other Project components. This information is missing from the IS/MND. The Project includes lithium batteries located in the electrical rooms within the building.[35] The IS/MND fails to disclose any information about these batteries, explain how the batteries would be used, or to estimate any impacts from the transport, use, and ultimate disposal of the batteries. Batteries can result in significant impacts, depending on the type of battery and the specific electrolyte used in the battery.[36]

Second, the IS/MND is totally silent on SCFD's experience with the unique challenges of battery fires and other data center hazards. The IS/MND does not include any evidence that SCFD has the equipment, chemicals, or expertise to address the unique fire situations, as discussed below. Further, the IS/MND fails to disclose the location of the SCFD relative to the Project site, fails to disclose whether SCFD has the resources, equipment, and chemicals required

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[31] Fox Comment 6.1.4, p. 42.

[32] Fox Comment 8.

[33] RTC 3-3, p. 3 and 4-10, p. 8.

[34] Ibid.

[35] IS/MND, pdf 40.

[36] See, e.g., U.S. DOE, Energy Storage Safety Strategic Plan, December, 2014, Sec. 5.4, available at https://www.sandia.gov/ess-ssl/docs/other/DOE_OE_Safety_Strategic_Plan_Dec_2014_final.pdf.

to meet the well-known challenges of fighting a lithium-ion battery fire, and fails to disclose the response time to an emergency.

Transport

The IS/MND is silent on how the batteries would arrive at the site (e.g., rail, truck, ship, air or some combination) and the potential hazards of transport. Thus, the IS/MND fails as an informational document under CEQA. This is a serious omission because lithium-ion batteries have been identified as dangerous goods when they are transported. These batteries present corrosive, flammable, toxic, and explosive characteristics. Transportation of batteries has already resulted in fires, explosions, and the release of hazardous chemicals into the environment.[37]

Lithium-ion batteries are classified under UN category 9 as dangerous goods because they are thermally and electrically unstable if subjected to certain uncontrolled conditions or are mishandled during transportation. Battery hazards include electrolyte leakage, heat production, venting of gases, fire, and explosions. Once a lithium cell/battery ignites and catches fire, it can propagate to nearby batteries, causing collateral overheating, fires, and explosions. These fires produce toxic fumes and are often difficult to put out with water and normal fire extinguishers. Hazardous air pollutants that have been detected include benzene, toluene, styrene, biphenyl, acrolein, carbonyl sulfide, and hydrogen fluoride.

Shipping of lithium-ion batteries presents unique challenges that arise when large quantities are aggregated. In this situation, a thermal runaway and fire can spread rapidly throughout the batteries, resulting in an uncontained fire capable of destroying the transport vehicle and adversely affecting surrounding areas.[38] In fact, there is a fair argument that hazardous material impacts would be significant during battery transport, use, and disposal due to the proximity of major roadways and residential housing and the hazardous nature of the batteries themselves.

The RTC simply concludes that "[t]ransport of batteries to the project site during project construction does not present a unique or substantial risk related to hazards; batteries and other project equipment would be transported to the site along major roads and highways as is typical for construction projects including data centers."[39] However, this response does not provide any evidence to contradict the cited literature, but simply makes conclusory statements.

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[37] Haibo Huo et al., Safety Requirements for Transportation of Lithium Batteries, *Energies*, v. 10, 2017, 793. Exhibit 1.

[38] See, e.g., Alan Hoffman, The Hazards of Lithium Ion Batteries, Technology, Manufacturing & Transportation Industry Insider, August 9, 2016, available at https://www.tmtindustryinsider.com/08-09-2016-the-hazards-of-lithium-ion-batteries/.

[39] RTC 4-10, p. 8.

Fires

It is well known that lithium-ion battery fires are some of the most difficult fires to suppress. Lithium-ion batteries have high power-to-density ratios that allow them to store large amounts of energy. When a lithium-ion battery catches fire, this stored energy coupled with the materials in the battery makes it difficult to suppress or extinguish.[40]

Fires have been reported in battery storage areas of data centers.[41] The IS/MND is silent on the fire risk of the proposed lithium-ion batteries and fails to address design details to minimize fire risk, such as installing the batteries in a room separate from the main data center building,[42] locating the batteries outside of the data center, or requiring routine fire drills,[43] concluding that no additional fire protection would be required.[44] The electrolytes used in lithium-ion batteries are flammable in the presence of oxygen. While the batteries are sealed from external sources of oxygen, some cathodes can release oxygen within the cell under high temperatures.[45] These batteries are susceptible to thermal runaway, which is a chain reaction leading to self-heating and release of stored energy.[46] The National Fire Protection Association has recently developed NFPA 855 to provide safety guidance for the growing use of lithium ion batteries in uninterruptible power supply systems that provide emergency power in data centers.[47]

The IS/MND and the RTCs do not even mention NFPA 855, commit the Project to following it or similar procedures to address the significant fire risk, nor address this issue,

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[40] Jeremy Snow, Suppressing Lithium Ion Battery Fires, available at http://venturaaerospace.com/news/suppressing-lithium-ion-battery-fires/.

[41] See, e.g., Datacenter Dynamics, UPS Fire Brings Down Aruba Data Center, April 28, 2011, available at https://www.datacenterdynamics.com/news/ups-fire-brings-down-aruba-data-center/; and Charles Babcock, 7 Data Center Disasters You'll Never See Coming, Information Week, June 7, 2015, available at https://www.informationweek.com/cloud/7-data-center-disasters-youll-never-see-coming/d/d-id/1320702?image_number=2; Battery Room Explosion, September 2017; available at: https://h2tools.org/lessons/battery-room-explosion.

[42] Ibid.

[43] Simon C. Lin and Eric Yen, Academia Sinica Grid Computing, ASGS Incident Report, March 11, 2009; available at: https://indico.cern.ch/event/45473/sessions/175559/attachments/946586/1342851/ASGC-DCIncident-20090311.pdf.

[44] IS/MND, pp. 89, 91.

[45] Brian Eckhouse and Mark Chediak, Explosions Threatening Lithium-Ion's Edge in a Battery Race, Bloomberg, April 24, 2019, available at https://www.bloomberg.com/news/articles/2019-04-23/explosions-are-threatening-lithium-ion-s-edge-in-a-battery-race.

[46] Todd M. Bandhauer, Srinivas Garimella, and Thomas F. Fuller, A Critical Review of Thermal Issues in Lithium-Ion Batteries, *Journal of the Electrochemical Society*, v. 158, no. 3, R1-R25, January 2011, available at https://wiki.aalto.fi/download/attachments/91692283/a_critical_review_of_thermal_issues_in_li-ion_batteries.pdf?version=1&modificationDate=1398443780029&api=v2.

[47] Rich Miller, New NFPA Battery Standard Could Impact Data Center Design, Data Center Frontier, April 1, 2019, available at https://datacenterfrontier.com/new-nfpa-battery-standard-could-impact-data-center-ups-designs/.

arguing that "the project would be adequately served by the Santa Clara Fire Department (SCFD) and does not present a unique or unusually high risk of fire."[48]

Fires in battery storage facilities can start in the batteries themselves, be ignited by foreign materials, a ground arc fault, or an external forest fire. Conventional sprinkler systems have failed in similar applications because water is a poor fire retardant for the chemicals present in lithium-ion batteries. The IS/MND contains no evidence that the local fire department has the equipment and expertise to fight battery fires.

The layout of battery facilities can prevent adequate firefighting access. The IS/MND does not contain any information on battery system layout. Fire conditions within a battery storage facility are distinct from those addressed in existing fire codes and require site-specific analysis and mitigation design, which is missing from the IS/MND. A recent article explained it this way:[49]

> Moving and storing energy in any form carries inherent risks: Fuel depots can catch on fire. Transmission lines can fall and cause shocks. Gas pipelines can explode. Liquid fuels can leak. But rescue workers have decades of experience fighting these challenges, and the industry has established procedures to prevent problems.
>
> Grid-level energy storage, on the other hand, is a new frontier, and establishing safety standards is crucial not just to protect human life and the environment, but also to safeguard expensive energy investments.

For example, in describing firefighting challenges at a Hawaiian 10-MW battery storage system supporting a 12-turbine, 30-MW wind farm, the Honolulu Fire Department reported:[50,51]

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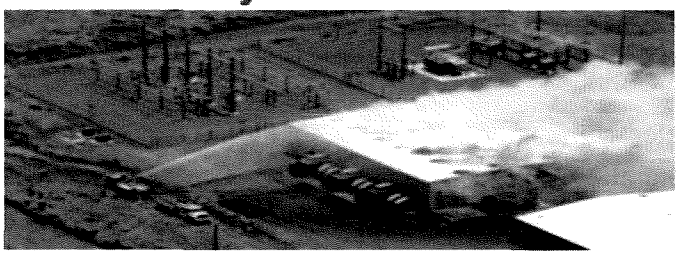
[48] RTC 3-3.

[49] Umair Irfan, Battery Fires Pose New Risks to Firefighters, *E&E News*, February 27, 2015 ("The vast majority of codes were not developed for energy storage"), available at https://www.scientificamerican.com/article/battery-fires-pose-new-risks-to-firefighters/. See also Umair Irfan, Electricity Storage Booms as Regulators Race to Develop Standards, *E&E News* (Reported in *Scientific American*), February 27, 2015, available at https://www.scientificamerican.com/article/battery-fires-pose-new-risks-to-firefighters/.

[50] Fire at Kahuku Wind Farm Destroys Crucial Building, *Hawaii News Now*, August 1, 2012, available at https://www.hawaiinewsnow.com/story/19173811/hfd-battling-kahuku-wind-farm-blaze/.

[51] Michael A. Stosser, What Are the Risks and What Regulations Should We Consider, DOE Energy Storage Safety Meeting, 2014. See also https://www.energy.gov/sites/prod/files/2014/12/f19/OE%20Safety%20Strategic%20Plan%20December%202014.pdf; https://www.scientificamerican.com/article/battery-fires-pose-new-risks-to-firefighters/.

"This is a very dangerous environment to fight a fire in because of the confined nature of the warehouse. It's a big warehouse, but what's inside are rows of racks of batteries that have very small aisles in between"



"The risks from scalding heat, poisonous fumes, a collapsing structure and the potential for battery explosions kept firefighters outside the warehouse."[52] Firefighters at this site faced thick smoke, toxic fumes, and other hazards.[53,54] "The August … fire, the third since opening in March 2011, was so fierce that firefighters could not enter the building for 7 hours."[55]

The typical layout for battery storage facilities is rows of batteries with narrow separating isles. The IS/MND contains no information on the layout of batteries in the data center and thus fails as an informational document under CEQA. Other fire departments have reported: "Basically you need to overwhelm it with more water than you think you need."[56]

The IS/MND is silent on the location of local firefighting resources and response time for responding to a battery fire. In the case of the Hawaii fires discussed above, a recent article in *Scientific American* reported: "By the time you get enough firefighting forces and the right extinguishing sources, the fire is going to progress quite a bit."[57] It also explained: "One important lesson is to have fire response resources on-site, like dry chemicals and deployment systems."

The fires at the Hawaii facility are not the only ones to make it into the press. At least 21 fires have occurred at battery storage projects in South Korea.[58] Another major fire in the US

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[52] Irfan, 2015.

[53] Ibid.

[54] Ibid.

[55] Ros Davidson, Analysis: First Wind Project Avoids Storage After $30m Fire, *Wind Power*, March 6, 2014, available at https://www.windpowermonthly.com/article/1284038/analysis-first-wind-project-avoids-storage-30m-fire.

[56] Cameron Polom, Solar Storage Facilities Present Unique Hazard for Firefighters, *West Valley News*, April 21, 2019, available at https://www.abc15.com/news/region-west-valley/surprise/solar-storage-facilities-present-unique-hazard-for-firefighters.

[57] Irfan, 2015.

[58] Eckhouse and Chediak, April 24, 2019.

recently occurred on April 19, 2019, in Surprise, Arizona, at the APS McMicken Energy Storage Facility, equipped with two 2-MW AES Advancion battery arrays.[59,60] This was not the first APS battery fire. In 2012, a 1.5-MW system near Flagstaff, Arizona, also caught fire.[61] An explosion in the McMicken battery system led to a fire.[62,63] This event injured at least four firefighters. Another smaller fire has been reported at another APS system.[64] Arizona Public Service recently shut down two other battery systems following the explosion.[65] About 40 fires involving lithium-ion batteries in electric cars have been reported.[66,67]

Hazards associated with battery systems are normally analyzed by identifying all feasible failure modes, identifying the specific chemicals and the rates at which they could be released during each failure mode, and estimating chronic, acute, and cancer impacts at the locations of sensitive receptors. The IS/MND contains no analysis at all of impacts of the battery storage facility, thus failing as an informational document under CEQA.

Power Attacks

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[59] Ibid.

[60] Jennifer Runyon, APD Battery Energy Storage Facility Explosion Injures Four Firefighters; Industry Investigates, *Renewable Energy World*, April 23, 2019, available at https://www.renewableenergyworld.com/articles/2019/04/aps-battery-energy-storage-facility-explosion-injures-four-firefighters-industry-investigates.html.

[61] H. J. Mai, APS Storage Facility Explosion Raises Questions about Battery Safety, *Utility Drive*, April 30, 2019, available at https://www.utilitydive.com/news/aps-storage-facility-explosion-raises-questions-about-battery-safety/553540/. See also Eckhouse and Chediak, April 24, 2019.

[62] Arizona Public Service, Equipment Failure at McMicken Battery Facility, April 26, 2019, available at https://www.aps.com/en/ourcompany/news/latestnews/Pages/mcmicken-battery-facility-notes.aspx.

[63] Julian Spector, What We Know and Don't Know About the Fire at an APS Battery Facility, April 23, 2019, available at https://www.greentechmedia.com/articles/read/what-we-know-and-dont-know-about-the-fire-at-an-aps-battery-facility#gs.9czowd.

[64] Karl-Erik Stromsta, APS and Fluence Investigating Explosion at Arizona Energy Storage Facility, GTM, April 22, 2019, available at https://www.greentechmedia.com/articles/read/aps-and-fluence-investigating-explosion-at-arizona-energy-storage-facility#gs.9cnh9x.

[65] Ibid.

[66] Ibid. See also Ashee Vace, *Elon Musk: Tesla, SpaceX, and the Quest for a Fantastic Future*, Harper Collins, 2015.

[67] https://www.google.com/search?q=tesla+battery+fire&oq=telsa+battery+fire&aqs=chrome.1.69i57j0l5.12984j0j4&sourceid=chrome&ie=UTF-8. See also https://electrek.co/2018/06/16/tesla-model-s-battery-fire-investigating/.

Finally, data centers are vulnerable to power attacks.[68] The IS/MND is silent on this issue and resulting emissions. The IS/MND fails to disclose any features to prevent attacks. The emissions from the facility during a power attack may be substantially larger than those disclosed in the IS/MND.

IV. FUTURE PLANS ARE NOT VALID CEQA MITIGATION

The IS/MND relies on a number of plans to mitigate impacts that would be prepared in the future and thus are not valid CEQA mitigation, including:

- Construction Noise Control Plan[69]
- Construction Plan[70]
- Construction Vibration Monitoring Plan[71]
- Construction Contingency Plan[72]
- Risk Management Plan[73]
- Storm Water Pollution Prevention Plan[74]
- Emergency Response and Evacuation Plan[75]

CEQA has clear and specific requirements for the identification of mitigation measures. A CEQA document must include "a detailed statement setting forth ... [m]itigation measures proposed to minimize significant effects on the environment." (Pub. Res. Code § 21100(b).) Mitigation measures must be identified for "each significant environmental effect." (14 Cal. Code Reg. § 15126.4(a)(1)(A).) The IS/MND must identify feasible mitigation measures that would substantially lessen any significant effects that the project would have on the environment. (14 Cal. Code Reg. § 15021(a)(2).) "Feasible" is defined as "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social and technological factors." (Pub. Res. Code § 21061.1.) Mitigation measures must be identified for "each significant environmental effect." (14 Cal. Code Reg. § 15126.4(a)(1)(A).)

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[68] Chao Li and others, Power Attack Defense: Securing battery-Backed Data Centers, 2016 ACM/IEEE 43rd Annual International Symposium on Computer Architecture, 2016; available at: http://www.cs.sjtu.edu.cn/~guo-my/PDF/Conferences/C164.pdf.

[69] IS/MND, pdf 15, 111.

[70] IS/MND, pdf 16, 112.

[71] IS/MND, pdf 17, 115.

[72] IS/MND, pdf 18, 116.

[73] IS/MND, pdf 91.

[74] IS/MND, pdf 99.

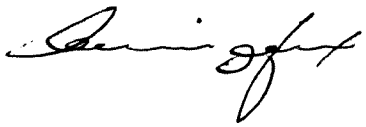
[75] IS/MND, Section 2.8 and RTC 3-3.

CEQA also requires that mitigation be identified during the environmental review process. "Formulation of mitigation measures should not be deferred until some future time." (*Id.* at § 15126.4(a)(1)(B).) Mitigation measures must be "fully enforceable through permit conditions, agreements, or other legally-binding instruments." (*Id.* at § 15126.4(a)(2).)

CEQA's requirements ensure that the public and interested agencies will have an opportunity to review and comment on proposed mitigation and identify any shortcomings. This public and agency review has been called "the strongest assurance of the adequacy" of the environmental review document.[76] "[T]he CEQA process demands that mitigation measures timely be set forth, that environmental information be complete and relevant, and that environmental decisions be made in an accountable arena."[77] Thus, the IS/MND must identify fully enforceable mitigation measures in sufficient detail to comply with CEQA. A future plan, developed after the IS/MND is certified, does not satisfy this requirement.

In sum, the responses to comments do not address most of the issues that I raised in my initial comments. In sum, operational NOx emissions, construction PM2.5 and PM10 emissions, battery hazard impacts remain significant. Further, the IS/MND omits critical information required to evaluate Project impacts, such as details of the battery facilities and emergency response procedures to allow a complete evaluation of impacts. Finally, mitigation is impermissibly deferred to future plans that will be developed outside of CEQA review.

Respectfully Submitted,



Phyllis Fox, PhD, PE

[76] Sundstrom v. Mendocino County (1988) 202 Cal. App. 3d 296, 308 [248 Cal. Rptr. 352, 359].

[77] Oro Fino Gold Mining Corporation v. County of El Dorado (1990) 225 Cal. App. 3d 872, 885 [274 Cal. Rptr. 720, 728].

energies

MDPI

Review

Safety Requirements for Transportation of Lithium Batteries

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Abstract: The demand for battery-powered products, ranging from consumer goods to electric vehicles, keeps increasing. As a result, batteries are manufactured and shipped globally, and the safe and reliable transport of batteries from production sites to suppliers and consumers, as well as for disposal, must be guaranteed at all times. This is especially true of lithium batteries, which have been identified as dangerous goods when they are transported. This paper reviews the international and key national (U.S., Europe, China, South Korea, and Japan) air, road, rail, and sea transportation requirements for lithium batteries. This review is needed because transportation regulations are not consistent across countries and national regulations are not consistent with international regulations. Comparisons are thus provided to enable proper and cost-effective transportation; to aid in the testing, packaging, marking, labelling, and documentation required for safe and reliable lithium cell/battery transport; and to help in developing national and internal policies.

Keywords: regulations; transport; safety; lithium-ion batteries; lithium-metal batteries

1. Introduction

When transporting goods by any mode (air, sea, train, truck), an item is considered hazardous if it is explosive, corrosive, flammable, toxic, or radioactive [1]. Batteries, and in particular, lithium batteries (the term "lithium batteries" includes the family of batteries having lithium-based chemistries and various types of cathodes and electrolytes.) present corrosive, flammable, toxic and explosive characteristics. In fact, the improper care of batteries in transportation, including preconditioning, packaging, and handling, has already resulted in fires, explosions, and the release of hazardous chemicals into the environment [2].

Batteries are classified into primary and secondary forms. A primary (non-rechargeable) cell or battery cannot be recharged and is discarded after the charge is spent. Common examples of their use are in watches, calculators, cameras, smoke detectors and defibrillators. A rechargeable battery is an energy storage device that can be recharged and reused. The most common rechargeable batteries are lead-acid, nickel-cadmium (NiCd), nickel-metal hydride (NiMH), and lithium-ion (Li-ion) batteries.

For the purposes of the regulations concerning dangerous goods, lithium batteries are categorized into lithium-metal (Li-metal) and Li-ion batteries. Li-metal batteries are typically non-rechargeable batteries that have Li-metal and lithium compounds as an anode and cathode, respectively. Li-ion

batteries represent a family of rechargeable batteries where the lithium is only available in ionic form in the electrolyte. Most conventional Li-ion cells use a carbon-based anode, with the positive electrode being a metal oxide that contains lithium such as $LiCoO_2$. Based on the product requirements, a battery may consist of 1 "battery" cell (e.g., smart phones) to more than 1000 cells (e.g., computers, power tools, electric vehicles). A cell is defined as a single encased electrochemical unit consisting of one positive and one negative electrode, which provides a voltage differential across these terminals. A battery is defined generally as two or more cells which are electrically connected together and having some forms of markings and protective devices, often including battery management software. Other terms include battery packs, battery modules and battery assemblies.

Due to their high energy-to-weight ratio, lithium batteries have become the preferred energy source for many products, from smart phones and computers to vehicles. However, lithium batteries present a safety risk since they can generate a great deal of heat if short circuited. Short circuits are possible if there are manufacturing defects or if the batteries have been improperly charged/discharged or used. If batteries are not designed, tested, manufactured, and prepared for transport in accordance with regulations, various hazardous conditions are possible [3,4].

Lithium batteries are classified under UN category 9 as dangerous goods because they are thermally and electrically unstable if they are subjected to certain uncontrolled environmental conditions or are mishandled during transportation. Battery hazards include electrolyte leakage, heat production, venting of gases, fire, and explosions. Battery product sheets also identify chemical hazards: liquid and gas leakage; electrical: short-circuit, high voltage, and failure of the battery management system; and mechanical: vibration, air pressure, shock, and deformation [5,6].

Once a lithium cell/battery ignites and catches fire, it can also propagate to nearby batteries, causing collateral overheating, fires, and explosions. These fires produce toxic fumes and are often difficult to put out with normal fire extinguishers. (The gas species of the toxic fumes are determined by a certain battery material. For a NMC/graphite (LiPF6 in EC:EMC) cell, 11 determinant gas mixture constituents were identified after a Li-ion battery caught fire, including EMC, DEC, EC, benzene, toluene, styrene, biphenyl, acrolein, CO, COS, and hydrogen fluoride [7].) The U.S. Federal Aviation Administration (FAA) studies related to the hazards produced by lithium cells show that aqueous extinguishing agents that contain water are the most effective at preventing thermal runaway propagation of Li-ion cells. Streamed non-aqueous agents are effective at extinguishing electrolyte fires, but ineffective at stopping propagation of thermal runaway from cell to cell [8].

Reports of battery fires and explosions are well known. For example, the FAA banned the Samsung Galaxy Note 7 from all flights since 14 October 2016 [9] due to numerous fires. In December 2015, the major U.S. airlines American, Alaska, Delta, Hawaiian, JetBlue, Southwest and United Airlines banned hoverboards on passenger flights and the U.S. Postal Service no longer ships hoverboards by air because of the possibility of fires [10,11]. Although e-cigarettes are not banned from shipping, from August 2009 to January 2017, 44 of the 214 reported e-cigarette explosions occurred during transport, storage and unknown circumstances [12].

Incidents involving lithium batteries catching fire on board aircraft include the UPS Air Cargo in Louisville, Kentucky on 7 June 2012; the FedEx Air Cargo in Pittsburgh, Pennsylvania on 15 September 2015; the FedEx Air Cargo in Memphis, Tennessee on 21 July 2016; and the Alaska Passenger in Ketchikan, Alaska on 30 October 2016 [13]. Most of these incidents allegedly occurred due to inappropriate packaging or handling that damaged the batteries and triggered an electrical short. However, the grounding of Boeing 787 Dreamliners in January 2013 was a result of operational Li-ion batteries, which served as a backup to the on-board power system. Whereas similar incidents can occur with other battery technologies such as lead, nickel, and alkaline, these chemistries do not pose such a major risk because they do not lead to thermal runaway or explosion. Because of the hazards associated with lithium batteries, transportation of lithium batteries is regulated in order to prevent accidents and damage [14–16].

International, national, and regional governments, as well as other authorities, have developed regulations for air, road, rail, and sea transportation of lithium batteries and the products that incorporate these batteries. The regulations govern conduct, actions, procedures, and arrangements. The regulations are meant to ensure that shippers transport lithium batteries and battery-powered products safely within their country or internationally. The national regulations and the norms (specific standards, models, and patterns) issued by the local government or companies are usually similar to those defined by the international standards for specific transportation modes, but there are differences in compliance [2].

This paper is organized as follows: Section 2 summarizes the testing standards for shipment of lithium batteries. Section 3 reviews the packing methods, hazard communication requirements (i.e., package marking, labelling, and accompanying documents), and handling methods provided in the international regulations for the safe transport of lithium batteries by various transport modes. Sections 4–8 introduce lithium battery transportation regulations in the U.S., China, Europe, South Korea, and Japan, and discuss the differences between the national and international regulations. Section 9 presents conclusions and recommendations for safe transportation of lithium batteries.

The main contributions of this paper include: (1) information on packaging, hazard communication requirements, and handling methods, for companies to better understand and comply with the international regulatory requirements for transporting lithium batteries; (2) information on the differences among U.S., Chinese, European, South Korean, and Japanese regulations for different kinds of lithium batteries and for various transport modes; (3) comparisons between U.S., Chinese, European, South Korean, and Japanese transport regulations, which will help in developing national and international policies and designing criteria for testing, packaging, marking, labelling, documentation, and handling of batteries for transport; and (4) recommendations for companies to ensure success in transporting batteries and in preparing for new regulations.

2. Safety Tests for Shipment of Lithium Batteries

Prior to being shipped to, from, or within any countries, lithium batteries must be certified by passing safety tests. The United Nations (UN) safety tests are widely considered the fundamental global transportation safety testing standards. Other than the UN tests, for some specific products, especially those which have installed batteries, such as cell phones and laptops, additional industry-specific standards must be passed as well. The purposes of these test standards are discussed in this section.

2.1. UN Safety Tests

The UN Manual of Tests and Criteria presents the UN schemes for classification of dangerous goods and describes the test methods and procedures for proper classification of referenced materials for transport. Considered one of the key transportation testing standards, the manual must be followed by manufacturers that ship lithium batteries. The manual was established according to the UN Recommendations on the Transport of Dangerous Goods-Model Regulations and the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) [17]. The UN safety test is a self-certified standard. However, because of potential liability issues, most manufacturers select a third-party certified test lab to conduct the tests.

For any mode of transport, every cell and battery (except for low-production-run or prototype lithium cells or batteries must pass the tests specified in the UN Manual of Tests and Criteria, Part III, Subsection 38.3, prior to their transport. (Low-production-run means annual production runs consisting of no more than 100 lithium cells or batteries [18].) If a cell or battery type does not meet the test requirements, it must be retested after the defects are corrected. Furthermore, test reports must be submitted to the Committee of Experts [19], and include the quantity or number of cells/batteries per package, and the type and construction of the packaging.

The specific test procedures for lithium cells and batteries are summarized in Table 1. In general, test procedures depend on whether the item is a cell or battery type. All cell types need to undergo Tests

T.1 to T.6 and T.8. All non-rechargeable battery types, including those composed of cells previously tested, must pass Tests T.1 to T.5. All rechargeable battery types, including those composed of previously tested cells, need to undergo Tests T.1 to T.5 and T.7. In addition, a single-cell rechargeable battery with overcharge protection needs to pass Test T.7. A cell as a component of a battery that is not transported separately from the battery only needs to be tested in accordance with Tests T.6 and T.8. A cell that is transported separately from the battery must pass Tests T.1 to T.6 and T.8 [19].

Table 1. UN tests T.1 to T.8 for lithium cells and batteries prior to being transported.

Test Step	Test Type	Specific Procedures
Test T.1	Altitude simulation	Test cells and batteries stored at a pressure of 11.6 kPa or less for at least 6 h at ambient temperature (20 ± 5 °C).
Test T.2	Thermal	Rapid thermal cycling between high (75 ± 2 °C) and low (−40 ± 2 °C) storage temperatures, stored for at least 6 h at the test temperature, time interval between high and low test temperature change less than 30 min.
Test T.3	Vibration	The vibration is a sinusoidal waveform with a logarithmic sweep between 7 Hz (1 g_n peak acceleration) and 200 Hz (8 g_n peak acceleration) and back to 7 Hz; 12 times cycle, 3 mutually perpendicular mounting positions.
Test T.4	Shock	Subjected to a half-sine shock (150 g_n peak acceleration) and pulse duration (6 ms); 3 shocks cycling in the positive and negative directions for each of 3 mutually perpendicular mounting positions (total of 18 shocks).
Test T.5	External short circuit	Short circuit with a total external resistance of less than 0.1 Ω at (55 ± 2 °C), 1 h duration.
Test T.6	Impact	A 15.8-mm-diameter bar placed across the sample cell center, and a 9.1-kg mass is dropped from a height of (61 ± 2.5 cm) onto the sample.
Test T.7	Overcharge	Overcharging test should be conducted for 24 h with charge current (twice the manufacturer's recommended maximum) and minimum test voltage. The minimum test voltage is defined in two categories (a) when recommended charge voltage ≤18 V and (b) when recommended charge voltage >18 V: Both categories are further explained as:
		(a) the lesser of 22 V or 2 times the maximum charge voltage or,
		(b) 1.2 times the maximum charge voltage.
Test T.8	Forced discharge	Each cell is forced discharged by connecting it in series with a 12 V DC power supply at an initial current equal to the maximum discharge current specified by the manufacturer.

Tests T.1 to T.5 are conducted in sequence on the same cell or battery. Test T.7 is conducted on undamaged batteries previously tested under tests T.1 to T.5 for purposes of testing on cycled batteries. Tests T.6 and T.8 are conducted on cells and batteries that have not undergone any other test steps.

2.2. Additional International Safety Tests for Lithium Batteries

In addition to the UN 38.3, several international organizations serving the transportation industry have developed international regulatory standards for specific industries/products that contain cells/batteries (see Table 2). Some of these standards, such as the International Electrotechnical Commission (IEC) standards, are widely referenced by different countries/districts to establish their own battery test standards. The impacts of these international standards on different countries will be introduced in the latter sections. This section briefly introduces the scope of these standards.

Table 2. Additional international standards [20,21].

Organization	Safety Standards
IEC	IEC 62133: Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes—Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications. IEC 62281: Safety of Primary and Secondary Lithium Cells and Batteries During Transport.
IEEE	IEEE 1625: Rechargeable Batteries for Multi-Cell Mobile Computing Devices. IEEE 1725: Rechargeable Batteries for Cellular Telephones.
SAE	SAE J 2929: Electric and Hybrid Vehicle Propulsion Battery System Safety Standard Lithium-Based Rechargeable Cells. SAE J 2464: Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System Safety and Abuse Testing.
UL	UL 1642: Lithium Batteries. UL 1973: Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications. UL 2054: Household and Commercial Batteries. UL 2580: Batteries for Use in Electric Vehicles. UL 2271: Batteries for Use in Light Electric Vehicle Applications. UL 2272: Electrical Systems for Self-Balancing Scooters.

The IEC, a non-profit standards organization, publishes international standards for all electric, electronic, and related technologies, including batteries. IEC 62133 has been key for shipping Li-ion batteries used in portable applications such as IT equipment, medical devices, power tools, and household applications, since 2002. In addition to UN 38.3, the cells that are used for portable applications must be certified to IEC 62133. When Europe and South Korea established their own standards for battery transport, for the most part they complied with the IEC standards, including IEC 62133 and IEC 622881.

The Institute of Electrical and Electronics Engineers (IEEE) has developed safety standards for lithium batteries. The key standards related to battery transport are contained in IEEE 1625 and IEEE 1725. IEEE 1625 covers multi-cell mobile computing devices, while IEEE 1725 covers cellular phones.

The Society of Automotive Engineers (SAE) has developed standards for electric vehicle (EV) batteries, including SAE J 2929 and J 2464, which cover propulsion battery system safety standard and energy storage system in the EV industry, respectively.

Underwriters Laboratories (UL) has also developed battery safety standards, which include more abusive tests, to cover different battery applications not covered by UN 38.3. Additionally, UL offers battery safety certification for battery shipping across different countries.

For emerging battery-powered products, such as self-balancing scooters (hoverboards), there have been no international standards until recently. The problem is that, while batteries can be certified individually, there have been no regulations to certify the overall product containing a battery. It was only after numerous fire incidents pertaining to the batteries of hoverboards, that UL issued a change to their safety certification (UL 2272) on 21 November 2016. The change provided the regulations so that self-balancing scooters, as well as other types of personal e-mobility devices can be certified, shipped and sold in the U.S. [22,23].

3. International Regulations for the Safe Transport of Lithium Batteries

The UN Model Regulations provide international guiding principles on all aspects of transporting dangerous goods, with inputs from a variety of organizations involved in designing and governing policies for safe and reliable transport across borders (see Figure 1). In addition, UN offices are spread over countries to help in developing the UN model, the International Air Transport Association Dangerous Goods Regulations (IATA DGR), the International Maritime Dangerous Goods (IMDG) Code, the European Agreement concerning International Carriage of Dangerous Goods by Road

(ADR), and the European Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) [24].

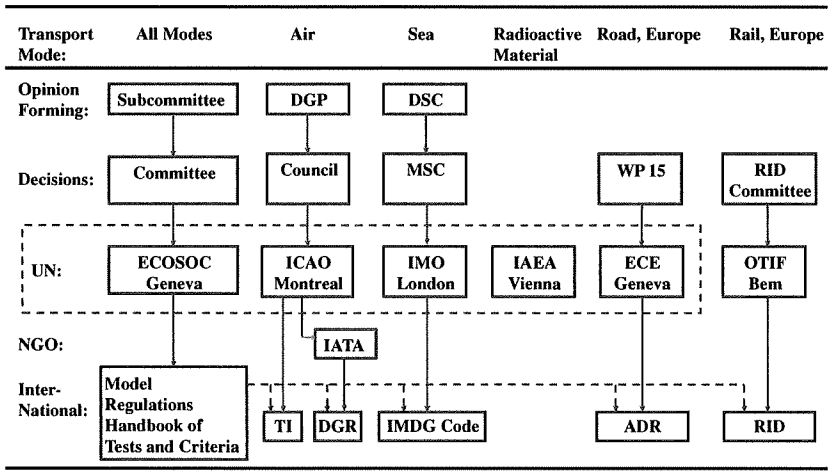


Figure 1. UN committees and councils for safe and reliable transport across borders.

The International Civil Aviation Organization (ICAO) has developed regulations for all international air shipments of hazardous materials. The International Air Transport Association (IATA) builds on the UN/ICAO rules and incorporates individual airline and governmental requirements into their Dangerous Goods Regulations (DGR) documents. The United Nations Economic Commission for Europe (UNECE) sponsors the ADR [25] to increase the safety of international transport of dangerous goods by road (including wastes by road). In addition, the Intergovernmental Organization for International Carriage by Rail (OTIF) develops the RID regulations [26], which apply to the international carriage of dangerous goods by rail. The International Maritime Organization (IMO) is the regulatory body for all shipments of dangerous goods on the high seas [27].

3.1. UN Model Regulations

UN Model Regulations were originally developed by the UN Economic and Social Council (ECOSOC)'s Committee of Experts on the Transport of Dangerous Goods "in the light of technical progress, the advent of new substances and materials, the exigencies of modern transport systems and, above all, the requirement to ensure the safety of people, property, and the environment" [28]. The secretariat of the UNECE has published the latest UN Model Regulations (19th revised edition) and provides secretariat services to the UN Economic and Social Council's Committee of Experts [29]. These regulations allow uniform development of national and international regulations ruling the different transport modes (e.g., air, road, rail, and sea) by presenting a basic scheme of provisions (see Figure 2 for multi-mode transportation based on the UN Model Regulations).

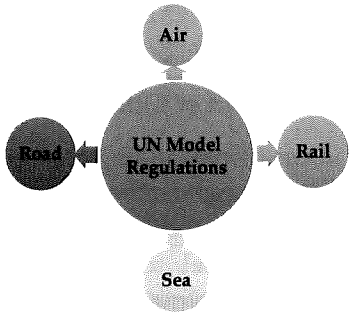


Figure 2. Multi-mode transportation based on the UN Model Regulations.

A four-digit UN number is assigned by the UN Committee of Experts on the Transport of Dangerous Goods and by the Globally Harmonized System of Classification and Labelling of Chemicals for identification of an article or substance or a particular group of articles or substances [30]. Per the Code of Federal Regulations, Title 49 (49 CFR) and the UN Model Regulations, Li-metal and Li-ion batteries are considered Class 9 hazardous materials (In 49 CFR and the UN Model Regulations, the numerical order of the classes does not correspond to the degree of danger).

Hazards associated with Li-metal and Li-ion cells may arise due to: flammable hydrogen gas; internal shorts caused by defects and dendrite formation; thermal runaway effects; and oxidation of organic solvents. For Li-ion batteries, hazards may originate from the side reactions including reactions between the organic solutions and the electrode surface, that is, the instability of the solid-electrolyte interface (SEI) with temperature increasing; and heat generation and thermal management [31]. In order to account for the different possible hazards associated with differential chemical and electrical content, the UN has separated different types of lithium batteries, as shown in Table 3.

Table 3. UN numbers and corresponding proper shipping names for lithium batteries.

UN Number	Proper Shipping Name
UN 3090	Li-metal batteries (including lithium alloy batteries).
UN 3091	Li-metal batteries contained in equipment [1] (including lithium alloy batteries).
UN 3091	Li-metal batteries packed with equipment (including lithium alloy batteries).
UN 3480	Li-ion batteries (including Li-ion polymer batteries).
UN 3481	Li-ion batteries contained in equipment [1] (including Li-ion polymer batteries).
UN 3481	Li-ion batteries packed with equipment (including Li-ion polymer batteries).

[1] Contained in equipment = equipment with cells or batteries properly installed; Packed with equipment = equipment + cells or batteries that are NOT installed in the equipment.

The UN Model Regulations are meant to cover all aspects of transportation necessary to provide international uniformity. They include a criteria-based classification system for substances that pose a significant hazard in transportation [32]. They set standards for packaging used to transport batteries. They also communicate the hazards of batteries in transport through hazard communication requirements, which include labelling and marking of packages, documentation, and emergency response information that is required to accompany each shipment.

In accordance with the UN Model Regulations, every lithium cell/battery has the same test requirements prior to transport, as discussed in Section 2. A safety venting device should be equipped for each battery, or each battery should be designed to prevent rupture under normal incident conditions during transport. External short circuits and reverse current flow should be prevented by adopting effective means for each battery. In addition, batteries should be manufactured under a quality management program. IATA DGR 3.9.2.6 includes the elements that must be included in such a program [18,29].

The UN Model Regulations present information for transport of several types of lithium batteries, including new and undamaged batteries, low-production-run or pre-production prototype batteries, disposable or recyclable lithium batteries, and damaged or defective lithium batteries. Based on the UN recommendations, regulations have been published for transporting lithium batteries using different transportation modes [33]. Transportation information about packing, maximum net quantity per package, maximum number of cells or batteries per package, marking, labelling, and documentation for lithium batteries are formally regulated according to their size (lithium content or watt-hour rating). Net quantity in the package means the weight or volume of the Li-ion batteries contained in a package excluding the weight or volume of any packaging material. For "Li-ion batteries contained in equipment", the net quantity is the net weight of the Li-ion batteries in the package [18].

3.2. International Regulations for Transportation by Air

Two international organizations regulate the international transport of dangerous goods by air: ICAO and IATA. IATA works with governments, the ICAO, and the member airlines to develop regulations that ensure safety and facilitate fast and efficient transport of dangerous goods by air [34]. Specific requirements for safe transportation of lithium batteries by air in both cargo and passenger aircrafts are determined by the ICAO, and these are then reflected in the IATA DGR [5]. The IATA DGR manual is based on the ICAO Technical Instructions (TI); it is the global reference for preparing, shipping, and transporting dangerous goods by air and the only standard recognized by the world's airlines.

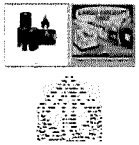
According to the ICAO TI and the IATA DGR, lithium batteries can be transported by air if they meet the general requirements on cell or battery UN tests, ventilation, short-circuit prevention, reverse current flow prevention, and manufacture as discussed in Section 2.1. In addition, low-production-run or prototype lithium batteries may be transported aboard cargo aircraft if approved by the appropriate authority of the State of Origin. Waste lithium batteries and lithium batteries (including UN 3090 and UN 3480) being shipped for recycling or disposal are forbidden from air transport unless approved by the appropriate national authority of the State of Origin and the State of the Operator [35–37]. Furthermore, all kinds of Li-metal and Li-ion batteries (including UN 3090, UN 3091, UN 3480, and UN 3481) are forbidden from transport if they are identified by the manufacturer as being defective or damaged, because they can potentially produce a dangerous risk of heat, fire, or explosion.

Lithium batteries belong to IATA DGR Class 9, and specific shipping requirements for this type of cargo are different from those for other dangerous goods. Tables 4–7 summarize guidance information pertaining to limits on the number and net quantity per package, packaging, package marking, labelling, and documents for air transport based on the ICAO TI, the IATA DGR, and references [38–40]. The guidance information is meant to help transporters, including shippers, freight forwarders, ground handlers, airlines, and passengers, to comply with international requirements for transporting lithium batteries by air. Specifically, Tables 4 and 5 apply to air transportation of new, undamaged, small-size and non-small-size Li-metal batteries, and Tables 6 and 7 apply to new, undamaged, small-size and non-small-size Li-ion batteries. For Li-metal cells or batteries, small size refers to the lithium content in a cell is less than 1.0 g and that in a battery is less than 2.0 g; for Li-ion cells or batteries, small size refers to the watt-hour rating in a cell is less than 20 Wh and that in a battery is less than 100 Wh.

For standalone Li-ion batteries, UN 3480 packaging instruction 965 (PI965), effective from 1 April 2016, requires that the state of charge (SOC) of these batteries must not exceed 30% of their rated design capacity when they are transported. At the same time, these batteries are forbidden from transport on passenger aircraft. Furthermore, only one package prepared according to Section II of PI965 or PI968 is permitted per consignment for transport (consignment means one or more packages of dangerous goods accepted by an operator (airline) from one shipper at one time and at one address, receipted for in one lot and moving to one consignee at one address [18]). This package must also be separated from other cargo and should not be loaded into a unit load device (ULD) prior to being offered to the operator. IATA member airlines have to follow and enforce these regulations more severely than other airlines.

As shown in Tables 4–7, specific handling labels are required for lithium battery transportation according to Section II of PI965, PI966, PI967, PI968, PI969, and PI970. In addition, lithium batteries carried under Section IB of PI965 and PI968 also require the "caution" label besides the "Class 9" and the "Cargo Aircraft Only" labels.

Table 4. Guidelines for international air transportation of new, undamaged, small-size Li-metal batteries.

Packing Instructions	UN 3090-PI968				UN 3091-PI969	UN 3091-PI970	
	PI968-Section II			PI968-Section IB	PI969-Section II	PI970-Section II	
Description	Standalone Li-metal cells/batteries				Li-metal cells/batteries packed with equipment	Li-metal cells/batteries contained in equipment	
Aggregate lithium content (W)	$W_{cel} \leq 0.3$ g or $W_{bat} \leq 0.3$ g	$W_{cel} > 0.3$ g and $W_{cel} \leq 1$g	$W_{bat} > 0.3$ g and $W_{bat} \leq 2$ g	$W_{cel} \leq 1$ g or $W_{bat} \leq 2$ g	$W_{cel} \leq 1$ g or $W_{bat} \leq 2$ g	$W_{cel} \leq 1$ g or $W_{bat} \leq 2$ g	
Number (N) of cells or batteries per package	No limit	$N_{cel} \leq 8$	$N_{bat} \leq 2$	$N_{bat} > 2$ or $N_{cel} > 8$	Those necessary to power the equipment and 2 spares	$N_{bat} \leq 2$ or $N_{cel} \leq 4$	$N_{bat} > 2$ or $N_{cel} > 4$
Maximum net quantity per package	CAO: 2.5 kg; PAX: Forbidden	CAO: N/A; PAX: Forbidden	CAO: N/A; PAX: Forbidden	CAO: 2.5 kg; PAX: Forbidden	CAO: 5 kg PAX: 5 kg	CAO: 5 kg PAX: 5 kg	CAO: 5 kg PAX: 5 kg
Packing	First, Li-metal cells and batteries must be placed in inner packaging that completely encloses the cell or battery, cells and batteries must be protected against short circuits (only for batteries or batteries packed with equipment); Second, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Third, strong outer packaging (e.g., cardboard box) required.						
Labelling						No	
Transport document	General warning statement (see Note 3)			"Shipper's Declaration for Dangerous Goods"	General warning statement	No	General warning statement
Description of content placed on the air waybill	"Li-metal batteries, in compliance with Section II of PI968-CAO"			UN 3090; Li-metal batteries, PI968 IB; Number of packages and gross mass per package	"Li-metal batteries, in compliance with Section II of PI969"	No	"Li-metal batteries, in compliance with Section II of PI970"
Number of packages per consignment or overpack	One			No limit	No limit	No limit	No limit

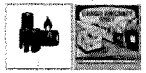
Note 1: W_{cel} denotes the weight of lithium per cell; W_{bat} denotes the weight of lithium per battery; Note 2: CAO: Cargo Aircraft Only; PAX: passenger aircraft; PI: packing instruction; N/A: not applicable. Note 3: The package contains Li-metal cells or batteries; the package must be handled with care and a flammability hazard exists if the package is damaged; special procedures must be followed in the event the package is damaged, to include inspection and repacking if necessary; and a telephone number for additional information.

Table 5. Guidelines for international air transportation of new, undamaged, non-small-size Li-metal batteries.

Description	UN 3090-PI968	UN 3091-PI969	UN 3091-PI970
	Standalone Li-Metal Cells/Batteries	**Li-Metal Cells/Batteries Packed with Equipment**	**Li-Metal Cells/Batteries Contained in Equipment**
Packing instructions	PI968-Section IA	PI969-Section I	PI970-Section I
Aggregate lithium content (W)	$W_{cel} > 1$ g or $W_{bat} > 2$ g		
Number of cells or batteries per package	No limit	Those necessary to power the equipment and 2 spares	No limit
Maximum net quantity per package	CAO: 35 kg PAX: Forbidden	CAO: 35 kg PAX: 5 kg	CAO: 35 kg PAX: 5 kg
Packing	First, Li-metal cells and batteries must be placed in inner packaging that completely enclose the cell or battery, cells and batteries must be protected against short circuits (only for batteries or batteries packed with equipment); Second, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Third, UN approved packaging: Packing Group (PG) II.		First, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Second, strong outer packaging (e.g., cardboard box) required; Third, UN approved packaging not required.
Labelling			
Transport document	Shipper's Declaration for Dangerous Goods: UN 3090 LI-METAL BATTERIES, 9, II	Shipper's Declaration for Dangerous Goods: UN 3091 LI-METAL BATTERIES PACKED WITH EQUIPMENT, 9, II	Shipper's Declaration for Dangerous Goods: UN 3091 LI-METAL BATTERIES CONTAINED IN EQUIPMENT, 9

Note 1: W_{cel} denotes the weight of lithium per cell; W_{bat} denotes the weight of lithium per battery; Note 2: CAO: Cargo Aircraft Only; PAX: passenger aircraft; PI: packing instruction; N/A: not applicable. Note 3: The package contains Li-metal cells or batteries; the package must be handled with care and a flammability hazard exists if the package is damaged; special procedures must be followed in the event the package is damaged, to include inspection and repacking if necessary; and a telephone number for additional information.

Table 6. Guidelines for international air transportation of new, undamaged, small-size Li-ion batteries.

Packing Instructions	UN 3480-PI965				UN 3481-PI966	UN 3481-PI967	
	PI965-Section II			PI965-Section IB	PI966-Section II	PI967-Section II	
Description	Standalone Li-ion cells/batteries (SOC $\leq$ 30%)				Li-ion cells/batteries packed with equipment	Li-ion cells/batteries contained in equipment	
Li-ion cells/batteries Watt-hour (E) rating	$E_{cel} \leq 2.7$ Wh	E_{cel} >2.7 Wh and $E_{cel} \leq 20$ Wh	$E_{bat} > 2.7$ Wh and $E_{bat} \leq 100$ Wh	$E_{cel} \leq 20$ Wh or $E_{bat} \leq 100$ Wh	$E_{cel} \leq 20$ Wh or $E_{bat} \leq 100$ Wh	$E_{cel} \leq 20$ Wh or $E_{bat} \leq 100$ Wh	
Number (N) of cells or batteries per package	No limit	$N_{cel} \leq 8$	$N_{bat} \leq 8$	$N_{bat} > 2$ or $N_{cel} > 8$	Those necessary to power the equipment and 2 spares	$N_{bat} \leq 2$ or $N_{cel} \leq 4$	$N_{bat} > 2$ or $N_{cel} > 4$
Maximum net quantity per package	CAO: 2.5 kg; PAX: Forbidden	CAO: N/A; PAX: Forbidden	CAO: N/A; PAX: Forbidden	CAO: 10 kg; PAX: Forbidden	CAO: 5 kg PAX: 5 kg	CAO: 5 kg PAX: 5 kg	CAO: 5 kg PAX: 5 kg
Packaging	First, Li-ion cells and batteries must be placed in inner packaging that completely encloses the cell or battery, cells and batteries must be protected against short circuits (only for batteries or batteries packed with equipment); Second, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Third, Strong outer packaging (e.g., cardboard box) required.						
Labelling						Not Require	
Transport document	General warning statement (see Note 3)			"Shipper's Declaration for Dangerous Goods"	General warning statement	No limit	General warning statement
Information on the air waybill	"Li-ion batteries, in compliance with Section II of PI965-CAO"			UN 3480; Li-ion batteries, PI965 IB; Number of packages and gross mass per package	"Li-ion batteries, in compliance with Section II of PI966"	Not Require	"Li-ion, batteries in compliance with Section II of PI967"
Number of packages per consignment or overpack	One			No limit	No limit	No limit	No limit

Note 1: E_{cel} denotes the watt-hour per cell; E_{bat} denotes the watt-hour per battery; Note 2: CAO: Cargo Aircraft Only; PAX: passenger aircraft; PI: packing instruction; N/A: not applicable; Note 3: The package contains Li-ion cells or batteries; the package must be handled with care and a flammability hazard exists if the package is damaged; special procedures must be followed in the event the package is damaged, to include inspection and repacking if necessary; and a telephone number for additional information.

Table 7. Guidelines for international air transportation of new, undamaged, non-small-size Li-ion batteries.

Description	UN 3480-PI965	UN 3481-PI966	UN 3481-PI967
	Standalone Li-Ion Cells/Batteries (SOC $\leq$ 30%)	**Li-Ion Cells/Batteries Packed with Equipment**	**Li-Ion Cells/Batteries Contained in Equipment**
Packing instructions	PI965-Section IA	PI966-Section I	PI967-Section I
Li-ion cells/batteries Watt-hour rating (E)	E_{cell} > 20 Wh or E_{bat} > 100 Wh		
Maximum net quantity per package	CAO: 35 kg PAX: Forbidden	CAO: 35 kg PAX: 5 kg	CAO: 35 kg PAX: 5 kg
Number of cells or batteries per package	No limit	Those necessary to power the equipment and 2 spares	No limit
Packaging	First, Li-ion cells and batteries must be placed in inner packaging that completely enclose the cell or battery, cells and batteries must be protected against short circuits (only for batteries or batteries packed with equipment); Second, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Third, UN approved packaging: PG II.		First, equipment must be secured against movement within the outer packaging and packed to prevent accidental activation; Second, strong outer packaging (e.g., cardboard box); Third, UN approved packaging not required.
Labelling			
Transport document	Shipper's Declaration for Dangerous Goods: UN 3480 LI-ION BATTERIES, 9, II	Shipper's Declaration for Dangerous Goods: UN 3481 LI-ION BATTERIES PACKED WITH EQUIPMENT, 9, II	Shipper's Declaration for Dangerous Goods: UN 3481 LI-ION BATTERIES CONTAINED IN EQUIPMENT, 9
Information on the air waybill	"Dangerous Goods as per Shipper's Declaration"		

Note 1: E_{cel} denotes the watt-hour per cell; E_{bat} denotes the watt-hour per battery; Note 2: CAO: Cargo Aircraft Only; PAX: passenger aircraft; PI: packing instruction; N/A: not applicable; Note 3: The package contains Li-ion cells or batteries; the package must be handled with care and a flammability hazard exists if the package is damaged; special procedures must be followed in the event the package is damaged, to include inspection and repacking if necessary; and a telephone number for additional information.

Figure 3 shows the lithium battery handling Label (3a), the Cargo Aircraft Only Label (3b), and the Class 9 hazard Label (3c). Moreover, in 2016, both IATA and ICAO have issued that Li-ion cells and batteries (UN 3480-PI965 as shown in Tables 6 and 7) must be offered for transport at a SOC not exceeding 30% of their rated design capacity. Cells and/or batteries at a SOC of greater than 30% may only be shipped with the approval of the State of Origin and the State of the Operator under the written conditions established by those authorities [39,40].

Figure 3. (**a**) Lithium battery handling label (* Place for UN numbers, ** Place for telephone number for additional information); (**b**) Cargo Aircraft Only label; (**c**) Class 9 hazard label.

3.3. International Regulations for Transport by Surface (Road/Rail/Sea Freight)

International regulations for the transport of lithium batteries by road, rail, and sea are summarized in this section. The UNECE Inland Transport Committee (ITC) facilitates the international movement of persons and goods by inland transport modes. The ADR sponsored by UNECE is intended to increase the safety of international transport of dangerous goods (including wastes) by road. The RID applies to the international transport of dangerous goods by rail. In addition, the International Maritime Dangerous Goods (IMDG) Code [41,42] is the international guideline for the safe shipment of dangerous goods by sea. It contains information on terminology, packaging, labelling, markings, stowage, segregation, handling, and emergency response and is intended for use not only by mariners but also by all those involved in industries and services connected with shipping.

According to the ADR, RID, and IMDG Code, lithium batteries (including UN 3090, UN 3091, UN 3480, and UN 3481) can be transported if they meet the provisions pertaining to the UN tests, ventilation, short-circuit prevention, reverse current flow prevention, and manufacture as noted in Section 3.1. In general, low-production-run or prototype lithium cells and batteries can be carried for testing if each battery can be individually packed in an inner packaging and placed in a suitable outer packaging, which meets the UN packaging criteria for packing group (PG) I. Dangerous goods are assigned to 3 different packing groups according to the degree of danger they present—PG I indicates the greatest danger; PG II indicates medium danger; and PG III indicates low danger. In the IATA DGR, PG II is assigned to Li-metal batteries (UN 3090-PI968, UN 3091-PI969 and UN3091-PI970 as shown in Tables 4 and 5) and Li-ion batteries (UN 3480-PI965, UN 3491-PI966 and UN 3481-PI967 as shown in Tables 6 and 7). In addition, when lithium batteries are carried for disposal or recycling, they must be designed or packed to prevent short circuits and the dangerous risk of heat. At the same time, they must be secured against excessive movement within the outer packaging, which must conform to the PG II performance level. Furthermore, packages for these batteries must be marked "LITHIUM BATTERIES FOR DISPOSAL" or "LITHIUM BATTERIES FOR RECYCLING".

Damaged or defective batteries may lead to short-circuiting or may catch fire through release of stored energy or hazardous contents. Proper packaging is one of the most critical measures that a shipper can consider to improve safety and prevent incidents. Before damaged or defective lithium batteries are transported, their outer packaging must conform to the approved PG I level. PG I must also be assigned to the low-prototype-runs. Batteries should be secured within the outer packaging

against excessive movement, and metal packaging should be fitted with a non-conductive lining material. In addition, batteries that are prone to rapidly disassemble, dangerously react, produce a flame or a dangerous evolution of heat or a dangerous emission of toxic, corrosive, or flammable gases or vapors under normal conditions of carriage should not be carried except under conditions specified by the competent authority [24,25,41,42].

From the ADR and the RID, lithium batteries belong to Class 9 articles and their classification code is M4, which means one category of subdivided substances and articles of Class 9. In addition, the passage of a road transport unit carrying lithium batteries is forbidden in category E road tunnels, which are assigned by the competent authority and indicated by a sign with an additional panel bearing a letter E. In accordance with the RID, lithium batteries are permitted for carriage as "express parcels," however, these parcels should not weigh more than 40 kg. Furthermore, the passage of a sea transport unit carrying lithium batteries is forbidden through category E tunnels if the gross mass of packages is less than 8 tons per transport unit marked in the IMDG Code. Tables 8 and 9 provide detailed information about packaging, hazard communication, and transport documents for international surface transportation of lithium batteries from the ADR, the RID, and the IMDG Code [38,43]. Table 8 discusses small-size batteries, and Table 9 discusses non-small-size batteries.

The details of packing containers and ADR-2015 general provisions are summarized in Table 10. ADR-2015 package instruction group II and special provisions instructions are more or less similar in IATA, ICAO, and IMDG instructions. Most of the common features of packaging requirements are: (a) cells/batteries shall be protected against short circuit and the dangerous evolution of heat and (b) cells and batteries shall be secured within the outer packaging to prevent excessive movement during carriage. ADR packaging instructions cover healthy, damaged, or defective cells and batteries under P903 and P908. ADR also provides packaging guidelines under P909 for recycling and disposal of cells/batteries. LP903 and LP904 are special packaging instructions for large consignment [40,44–48].

In addition, other SPs for packaging are given in the ADR that make exceptional cases for lithium cells and batteries with smaller size and capacity, underproduction, and damaged conditions and if the battery is equipped in powered vehicles. A list of such provisions is given in Table 11. These SPs are categories with UN numbers, for example, for UN 3090 and UN 3091, the SPs are 188, 230, 376, 377, and 636; for UN 3480, the SPs are 188, 230, 310, 348, 376, 377, and 636, and for UN 3481, the SPs are 188, 230, 348, 360, 376, 377, and 636. SP 188 defines the exemption from ADR SPs according to the Wh capacity and weight of the battery [49].

Table 8. Guidelines for international surface transportation of new, undamaged, small-size lithium batteries.

Description	Standalone Lithium Cells/Batteries	Lithium Cells/Batteries Packed with Equipment	Lithium Cells/Batteries Contained in Equipment	
Packing instructions	ADR/RID/IMDG Special Provision (SP)188	ADR/RID/IMDG SP188	ADR/RID/IMDG SP188	
Lithium content (W) or watt-hour rating (E)	Li-metal cells/batteries: $W_{cel} \leq 1$ g; $W_{bat} \leq 2$ g Li-ion cells/batteries: $E_{cel} \leq 20$ Wh; $E_{bat} \leq 100$ Wh			
Number of cells or batteries per package	No limit	No limit	$N_{bat} > 2$ or $N_{cel} > 4$	$N_{bat} \leq 2$ or $N_{cel} \leq 4$
Mass limit	30 kg gross mass of the package	No limit	No limit	No limit
Packaging	First, cells and batteries must be protected against short circuits and damage; Second, cells and batteries must be completely enclosed in inner packaging inside strong outer packaging (only for batteries or batteries packed with equipment); Third, equipment must be protected against accidental activation and packed in applicable strong outer packaging (only for batteries contained in equipment).			
Marking or labelling	First, shipment contains "Li-metal" or "Li-ion" batteries; Second, transport according to SP188; Third, the package shall be handled with care and in case of damage a flammability risk exists; Fourth, if the package is damaged, special procedures including inspection and repacking must be followed. Fourth, for more information, please call *** (phone number).			No limit
Sea freight container-marking	No requirement			
Transport document	General warning statement (document should list the same information as the above marking content)			No limit

Note 1: E_{cel} denotes the watt-hour per cell; E_{bat} denotes the watt-hour per battery; Note 2: W_{cel} denotes the weight of lithium per cell; W_{bat} denotes the weight of lithium per battery.

Table 9. Guidelines for international surface transportation of new, undamaged, non-small-size lithium batteries.

Description	Lithium Cells/Batteries	Lithium Cells/Batteries Packed with Equipment	Lithium Cells/Batteries Contained in Equipment
Packing instructions	ADR/RID/IMDG P903	ADR/RID/IMDG P903	ADR/RID/IMDG P903
Lithium content (W) or watt-hour rating (E)	Li-metal cells/batteries: $W_{cel} > 1$ g; $W_{bat} > 2$ g Li-ion cells/batteries: $E_{cel} > 20$ Wh; $E_{bat} > 100$ Wh		
Mass limit	ADR/RID: maximum 333 kg gross mass per transport unit.		
Packaging	First, cells or batteries must be packed and protected against damage and short circuits; Second, cells or batteries must be completely enclosed in inner packaging and packed with equipment, which must be secured against movement within the outer packaging; Third, applicable strong outer packaging is constructed for cells or batteries contained in equipment to prevent accidental operation; Fourth, UN approved packaging: PG II.		
Labelling			
Sea freight container-marking	 Container-Placards		
Transport document	ADR/RID: UN 3090/UN 3480, LI-METAL BATTERIES/LI-ION BATTERIES, 9, PG II, (E). Transport category 2. Sea freight (IMDG): IMO-DANGEROUS GOODS DECLARATION.	ADR/RID: UN 3091/UN 3481, LI-METAL/LI-ION BATTERIES PACKED WITH EQUIPMENT, 9, PG II, (E). Transport category 2. Sea freight (IMDG): IMO-DANGEROUS GOODS DECLARATION.	ADR/RID: UN 3091/UN 3481, LI-METAL/LI-ION BATTERIES CONTAINED IN EQUIPMENT, 9, (E). Transport category 2. Sea freight (IMDG): IMO-DANGEROUS GOODS DECLARATION.

Table 10. Packaging instructions per ADR-2015.

Packaging Instruction	Description
Instructions applied for all packaging	The following packaging is allowed under ADR general provisions 4.1.1 and 4.1.3: First, Drums (1A2, 1B2, 1N2, 1H2, 1D, 1G) Second, Boxes (4A, 4B, 4N, 4C1, 4C2, 4D, 4F, 4G, 4H1, 4H2) Third, Jerricans (3A2, 3B2, 3H2)
P903 for healthy cells and batteries	It applies if general provisions 4.1.1 and 4.1.3 are met. Cells or batteries shall be packed in packaging so that the cells or batteries are protected against damage that may be caused by the movement or placement of the cells or batteries within the packaging.
P908 for damaged or defective cells and batteries	First, each cell or battery shall be individually packed in inner packaging and placed inside an outer packaging, both packagings being leak-proof; Second, inner packaging shall be non-combustible, non-conductive, and thermally insulated; Third, sealed packaging shall have venting devices; Fourth, vibration, shock, and moving of cells must be prevented; Fifth, sufficient inert absorbent material shall be added to inner or outer packaging; Sixth, a cell or battery with a net mass > 30 kg shall be limited to one piece per outer packaging.
P909 for cells and batteries for disposal or recycling	First, metal packaging shall be fitted with a non-conductive lining material. Second, cells < 20 Wh (1 g Li) or batteries < 100 Wh (2 g Li) may be packed in strong outer packaging up to 30 kg; Third, if cells or batteries are contained in equipment, strong outer packaging may be used.
LP903, LP904	For large packages

Table 11. Special provisions for packaging instruction.

Special Provision	Description
188	Cells and batteries are not subject to other provisions of ADR if they meet the following criteria: First, cell rating is < 20 Wh or < 1 g lithium Second, battery rating is < 100 Wh or < 2 g lithium
230	Cells and batteries must meet provision of 2.2.9.1.7, which describes cell and batteries contained in equipment. The provision specifies pre-tests, cell configurations, and ventilation. QMP etc.
310	Tests of UN Manual Section 38.3 do not apply to production series of no more than 100 cells and batteries when these prototypes are carried for testing, if they are packed in an outer package meeting the criteria of packaging group I. Each cell and battery is individually packed in an inner packaging with cushioning material, which should be non-combustible and non-conductive.
348	Batteries manufactured after 31 December 2011 should be marked with the Wh rating on the outside case.
360	Vehicles only powered by Li-metal or Li-ion batteries should be classified under the entry UN 3171 battery-powered vehicle.
376	Damaged or defective cells or batteries not confirming the UN Manual of Tests and Criteria should comply with the requirements of this special provision: First, cells or batteries identified as being defective for safety reasons, cells or batteries that have leaked or vented, cells or batteries that cannot be diagnosed prior to carriage, and cells or batteries that have sustained physical or mechanical damage. Second, packages should be marked "DAMAGED/DEFECTIVE LI-ION BATTERIES" or "DAMAGED/DEFECTIVE LITHIUM-METAL BATTERIES", as applicable. Cells and batteries should be packed in accordance with packing instructions P908 or LP904, as applicable. Third, cells and batteries expected to react dangerously under the normal conditions of carriage should not be carried except under conditions specified by the competent authority.
377	First, cells and batteries for disposal or recycling may be packaged in accordance with P909. These cells and batteries are not subject to the requirements of 2.2.9.1.7 (a) to (e); Second, packages should be marked "LITHIUM BATTERIES FOR DISPOSAL" or "LITHIUM BATTERIES FOR RECYCLING".
636	Cells contained in equipment, during carriage, should not fall below 2 V or two-thirds of the voltage of the undischarged cell, whichever is the lower. Cells and batteries are not subject to the other provisions of ADR (including 376 and 2.2.9.1.7) if they meet the following conditions: First, P909 is completely applied except for the "additional requirements" of 1 and 2 where both and 1 specifies that cell and battery should be designed and packed to present short circuit and dangerous evolution of heat and 2 specifies the level of protections required for cell and battery; Second, the total amount of lithium cells or batteries per transport unit does not exceed 333 kg; Third, packages are marked "LITHIUM BATTERIES FOR DISPOSAL" or "LITHIUM BATTERIES FOR RECYCLING" as appropriate.

4. Lithium Battery Transportation in the United States

In addition to complying with the international regulations discussed in Section 3, different countries generally have their own regional requirements for transportation of lithium batteries. In general, if the U.S. transportation regulations regulate a material, but the international regulations do not, the material must be transported according to the requirements of the U.S. transportation regulations [50].

4.1. Transportation Regulations Available in the United States

Part 49 of the Code of Federal Regulations (49 CFR Sections 100–185), of the U.S. Hazardous Materials Regulations (HMR) governs the domestic transportation of lithium batteries to, from, and within the U.S. by all modes, i.e., air, road, rail, and sea. It provides information on packaging, hazard communication (e.g., package marking, labelling, and shipping papers), and handling of batteries and battery-powered devices.

The 49 CFR is based on the UN Model Regulations and is in accordance with the international regulations including the ICAO TI and the IMDG Code. However, 49 CFR is not consistent in all respects with international regulations. Compliance with 49 CFR will not guarantee acceptance by regulatory bodies outside the U.S. [51]. Therefore, outside the U.S. (for transport to and from the U.S.), the UN Model Regulations for transporting batteries should be followed. In addition, the other international regulations introduced in Section 2.2 will guide lithium battery transportation by different transport modes internationally.

4.2. Differences between U.S. and International Regulations

Prior to being transported to, from, and within the U.S., lithium batteries must meet the general requirements in 49 CFR and the above-mentioned international transport regulations. As stated in Section 4.1, there are some differences between 49 CFR and the international regulations. In the U.S., each manufacturer must create and make available a record of satisfactory completion of the UN testing prior to offering lithium batteries for shipping. This record must be maintained as long as the design is offered for transportation, and after that it should be sequentially kept for one year [52]. Under 49 CFR, lithium batteries must be placed in non-metallic inner packaging that completely encloses them. Furthermore, 49 CFR provides a medium-size lithium battery category, whereas the international regulations do not. According to 49 CFR, medium-size lithium cells and batteries can only be transported by ground (i.e., by road and rail). Their outer package must be marked "LITHIUM BATTERIES—FORBIDDEN FOR TRANSPORT ABOARD AIRCRAFT AND VESSEL". Moreover, there are some additional requirements in the U.S. for the use of the IMDG Code. Lithium batteries can be transported to, from, or within the U.S. by sea, motor carrier, and rail according to the IMDG Code if all or part of the transportation is by sea. When lithium batteries are transported in accordance with the IMDG Code, for small-size standalone Li-metal batteries transported in accordance with SP 188, each of the outer packages must be marked "PRIMARY LITHIUM BATTERIES—FORBIDDEN FOR TRANSPORT ABOARD PASSENGER AIRCRAFT" or "LITHIUM-METAL BATTERIES-FORBIDDEN FOR TRANSPORT ABOARD PASSENGER AIRCRAFT", or labelled with the "Cargo Aircraft Only" label [53]. The U.S. transport regulations for shipping lithium batteries are also based on the size of the battery to be shipped [2]. Table 12 outlines the size categories covered by 49 CFR in the U.S.

Table 12. Size categories of Li-metal and Li-ion batteries for 49 CFR.

Size	Li-Metal		Li-Ion		Shipping Classification	Special Packaging/Markings Required
	Cell	Battery	Cell	Battery		
Small (no more than)	1 g	2 g	20 Wh	100 Wh	Excepted	Yes
Medium (between)	1 g and 5 g	2 g and 25 g	20 Wh and 60 Wh	100 Wh and 300 Wh	Class 9 (except by motor vehicles or rail) [54]	Yes
Large (more than)	5 g	25 g	60 Wh	300 Wh	Class 9	Yes

49 CFR is consistent with the international regulations for transport of low-production-run or prototype lithium batteries and lithium batteries for disposal or recycling. Specifically, low-production-run or prototype lithium batteries must be approved by the Associate Administrator prior to transportation aboard aircraft [55]. Disposable and recyclable lithium batteries, when packed in a strong outer packaging and carried by motor vehicles, are exempted from the UN testing, record-keeping, and specific packaging requirements. Damaged or defective lithium batteries can be transported by surface only, which follows the same restriction by the international regulations. However, there are some differences for transportation of damaged or defective lithium batteries in the U.S.—a comparison is given in Table 13.

Table 13. Comparison of international vs. U.S. regulations for shipping damaged or defective lithium batteries.

Regulation Category	International Regulations		U.S. HMR (49 CFR)
Available Transport Modes	**Road/Rail/Sea**		**Road/Rail/Sea**
Number of cells or batteries per package	No limit (if net mass per cell or battery $\leq$ 30 kg)	Only one (if net mass per cell or battery > 30 kg)	No limit
Packaging	First, each cell or battery must be individually packed in inner packaging (which is surrounded by thermal insulation material) inside an approved outer packaging; Second, metal packaging should be fitted with a non-conductive lining material; Third, UN approved packaging: PG II.		First, each cell or battery must be placed in individual, non-metallic inner packaging (which is surrounded by cushioning material) inside an approved outer packaging; Second, UN approved packaging: PG I.
Marking	"DAMAGED/DEFECTIVE LITHIUM-METAL BATTERIES" or "DAMAGED/DEFECTIVE LI-ION BATTERIES"		"DAMAGED/DEFECTIVE LITHIUM-METAL BATTERIES" or "DAMAGED/DEFECTIVE LI-ION BATTERIES"

Table 13 shows that the international regulations and 49 CFR follow similar regulations for the same transport modes and marking methods for transporting damaged or defective lithium batteries. However, the allowed number of cells/batteries per package differs. The international regulations allow only one battery per outer package if its net mass exceeds 30 kg. 49 CFR uses PG I packaging level for damaged or defective lithium batteries, whereas international regulations recommend PG II.

The ICAO and IATA have imposed new restrictions on lithium batteries shipped by air starting 1 April 2016. These restrictions include: (1) a 30% SOC limit on all air shipments of standalone Li-ion batteries; (2) a prohibition on transporting standalone Li-ion batteries as cargo aboard passenger aircraft; and (3) a limit of no more than one package containing Section II standalone Li-metal or Li-ion batteries per consignment. However, the U.S. Department of Transportation's Pipeline and Hazardous Material Safety Administration (PHMSA) has not yet added these restrictions to 49 CFR as yet. The PHMSA has only released a general overview of their forthcoming Interim Final Rule to harmonize with the new ICAO/IATA lithium battery restrictions. This Interim Final Rule will likely

take effect in early 2017 [56]. Although the objective of this rule is to harmonize the new regulation with international standards, PHMSA has to consider each proposed change to the HMR on its own merits, and independently evaluate the safety and economic impact of each provision.

4.3. Norms in Practice and Differences between the Norms and Regulations

On 10 February 2016, the U.S. National Transportation Safety Board (NTSB) issued two safety recommendations to "physically separate lithium batteries from other flammable hazardous materials stowed on cargo aircraft" and to establish "maximum loading density requirements" that restrict the quantities of lithium batteries and flammable hazardous materials [57]. The NTSB urged the PHMSA to take positive action on these two safety recommendations to avoid cargo fire and to give the crew extra time to safely land a cargo aircraft once the fire is detected. As a result, the U.S. Congress has given authority to the PHMSA to enforce more strict norms in the case of an on-board fire that can result from inadequate international transportation regulations.

Although many U.S. shipping carriers facilitate battery or lithium battery transportation, this section focuses on the three most popular carriers—United Parcel Service (UPS), DHL Express, and FedEx—to present an overview of the requirements for acceptance and transport of lithium batteries in the U.S. UPS is the world's largest package delivery company. When shipping lithium batteries by UPS's air service, shippers must conform to the applicable regulations published by the IATA (internationally) and/or the PHMSA (within the U.S.). However, UPS has its own additional requirements for shipping lithium batteries by air. Compared with the IATA DGRs and 49 CFR, small-size standalone lithium batteries (except lithium batteries transported according to PI968-Section IB shown in Table 4 and PI965-Section IB shown in Table 6) are not considered as UPS Dangerous Goods. Furthermore, lithium batteries for which the net quantity of each package exceeds the limits, and standalone small-size lithium batteries transported according to PI968-Section IB and PI965-Section IB all need UPS Dangerous Goods contracts prior to being transported [58,59]. Other than these special provisions, UPS transport regulations for lithium batteries are in accordance with the IATA DGR and 49 CFR.

According to 49 CFR, medium-size lithium batteries can only be transported to, from, and within the U.S. by ground. When shipping lithium batteries by UPS's ground service, shippers must comply with the international surface transport regulations (outside the U.S.) and 49 CFR (within the U.S.).

UPS transportation regulations apply to large-, medium-, and small-size standalone lithium batteries. If the gross mass of each package exceeds 30 kg, UPS Dangerous Goods contracts are necessary. In addition, small-size lithium batteries shown in Table 8 do not need to be shipped by ground as UPS Dangerous Goods. UPS transportation regulations for these large- and small-size batteries are in accordance with the international surface transport regulations and 49 CFR. However, medium-size standalone lithium batteries (gross mass of each package not exceeding 30 kg) and medium-size lithium batteries packed with or contained in equipment do not need to be transported as UPS Dangerous Goods.

DHL Express provides international express delivery services for parcels and documents. To transport lithium batteries safely by air, DHL Express shippers must comply with the latest IATA DGR, which became effective 1 April 2016. In addition, DHL Express follows its own norms based on the ICAO TI and the IATA DGR. Standalone Li-ion batteries (PI965-Section II) can be transported by DHL on passenger aircraft after approval of DHL [60]. Moreover, the consignment for lithium batteries contained in equipment (where each piece of equipment contains no more than 4 cells or 2 batteries) cannot exceed 2 packages. If this limit is exceeded, the shippers must apply for permission and use the lithium battery handling label on the package. DHL eCommerce also offers domestic and international standard parcel services, but not for Li-metal and Li-ion batteries within its international network [61]. (DHL eCommerce and DHL Express are separate companies both owned by the same parent company. DHL Express offers only international services; DHL eCommerce offers both international and domestic services.) All shippers must comply with the

latest versions of 49 CFR, the IATA DGR, the IMDG Code when shipping lithium batteries in the U.S. DHL eCommerce must approve ground transport of lithium batteries (including standalone lithium batteries and lithium batteries packed with or contained in equipment) [62,63]. Only lithium batteries contained in equipment can be shipped via DHL eCommerce's domestic expedited network.

FedEx has expanded its service by offering global freight-forwarding services. When shipping lithium batteries with FedEx's air service, all packages containing lithium batteries must strictly adhere to the ICAO TI, the IATA DGR, and 49 CFR. FedEx also has its own requirements for transporting lithium batteries. Shippers of lithium batteries must comply with all FedEx Express variations listed in the latest edition of the IATA DGR [64]. In addition, standalone Li-metal batteries prepared according to Sections IA, IB, and II of PI968 need approval prior to shipping by FedEx Express [65]. Furthermore, standalone Li-metal batteries prepared according to Section II of PI968 must have an additional FedEx Section II label [66], which is not the same as the "Cargo Aircraft Only" label shown in Figure 3b.

On U.S. airlines, the FAA rules allow passengers to carry all small-size Li-metal and Li-ion batteries in the aircraft. With the airline's approval, devices can contain Li-ion batteries with 100 Wh and 160 Wh capacity. However, spare lithium batteries of this size are limited to two per passenger and must be transported in carry-on baggage only.

5. Lithium Battery Transportation in China

Transportation of lithium batteries in China should comply with Chinese safety regulations. However, due to few available local transport regulations in China, lithium cells or batteries are currently transported in accordance with the international transportation regulations to, from, and within China.

5.1. Transportation Regulations Available in China

The Civil Aviation Administration of China (CAAC) has issued regulations on Transport of Dangerous Goods by Air (CCAR-276-R1). Lithium battery shipments by air are subject to both Chinese and international safety regulations (including the ICAO TI and the IATA DGR). CCAR-276-R1 is in compliance with the ICAO TI and the IATA DGR. The ICAO TI in the 2015-2016 edition (DOC 9284-AN/905) with corrigendum No. 1, and CCAR-276-R1 issued provisions for carrying Li-metal batteries in February 2015. The CAAC prohibits transport of standalone Li-metal batteries aboard passenger aircraft, unless the country of origin, transit state, and/or destination country grant an exemption from the prohibition. Li-metal batteries can be transported on aircraft according to the specific provisions of DOC 9284-AN/905 [67]. Furthermore, transporting standalone Li-ion batteries as cargo aboard passenger aircraft is prohibited, effective from 1 April 2016.

At present, the Chinese regulations for transport of lithium batteries by sea and ground are not sufficient. Relevant departments in China mainly follow the international regulations, including the IMDG Code, the ADR, and the RID.

5.2. Norms in Practice and Differences between the Norms and Regulations

Due to the stringent regulations of the IATA DGR for transportation of lithium batteries, Chinese airlines must follow and enforce these regulations rigorously. Chinese airlines are subject to the requirements for UN tests, parameter limits, packaging, marking, labelling, and transport documents of the ICAO TI, the IATA DRG, and CCAR-276-R1. Chinese airlines' transport regulations for low-production-run or prototype lithium batteries, lithium batteries being shipped for recycling or disposal, and damaged or defective lithium batteries are in accordance with those introduced in Section 3.2.

Chinese airlines' transport requirements for Li-metal and Li-ion batteries contained in personal devices are almost the same as those of U.S. airlines. Each spare Li-ion battery must be individually protected to prevent short circuits and carried only in carry-on baggage. In most cases, airlines permit up to two spare Li-ion batteries (more than 100 Wh, but not exceeding 160 Wh) [68]. Except for the

above common provisions, each Chinese airline also has its own requirements. For example, China Eastern Airlines prohibits shipping lithium batteries undeclared by the State of Origin, intermediate country, destination country, and air freight operator [69].

Although the transport requirements in China comply with the international regulations, there is an enforcement gap. Lithium batteries manufactured in China are often shipped internationally from Hong Kong to avoid China's oversight and dangerous goods regulations. The shipping logistics are complex and involve a ground transporter, a freight forwarder, an export agent in Hong Kong, and consolidators. The lack of surveillance and the complex logistics can raise safety issues, such as counterfeit lithium batteries shipped internationally from China and Hong Kong [70]. Therefore, safety regulations for battery transport in China should be enforced starting from the point of origin.

6. Lithium Battery Transportation in Europe

European battery transportation regulations largely follow UN regulations. Even so, as a group of nations and individual national transport authorities, the European Union has designed its own regulations with some special norms. Member states of the European Union and other European countries allow lithium cell/battery transportation only when manufacturers follow a Quality Management System (QMS) specified in ISO-9001 and ISO-1400. Sections 4.3.1 to 4.3.4 of the document describe existing Li-ion battery transportation regulations in Europe and differences between European regulations and international regulations for transport of lithium batteries. The following sections in this paper also cover norms in practice and required documents for battery transportation.

6.1. Transportation Regulations Available in Europe

In general, Europe follows international regulations such as ADR, RID, IATA, ICAO, and IMDG for lithium battery transportation by road, rail, air, and sea. Moreover, additional European agreements were established by the UNECE. These agreements, ADR and the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN), especially address international carriage of dangerous goods by road and inland waterways.

European Standards (ENs) and regulations for lithium battery transportation mostly follow international norms provided by the UN Regulations for the Transport of Dangerous Goods category 9. Lithium battery safety and transport regulations are largely covered by two EN standards—EN 50272-1 and EN 62281:2013 [71]. EN 50272-1:2011-10 defines safety requirements for secondary batteries and battery installations. Part 1 of the EN 50272-1 standard covers detailed safety aspects, hazards associated with electricity (installation, charging, discharging, short circuits, and other points of concerns in the batteries), electrolyte, inflammable gas mixtures, storage, and transportation.

EN 62281:2013 defines the safety of Li-metal and Li-ion cells and batteries during transport. A draft version of EN 62281:2015 is now available with updates. EN 62281 specifies test methods and requirements for primary and secondary lithium cells and batteries to ensure their safety during transport. These test requirements are comparable to the tests defined in the UN Manual of Tests and Criteria, Subsection 38.3, which is discussed in Section 2. However, these standards do not cover any norms or guidelines for recycling or disposal of lithium batteries/cells. Table 14 compares UN Manual of Tests and Criteria, Subsection 38.3, and IEC-EN 62281 standards. IEC and EN standards align with each other. The other standard in practice is IEC 62485-1:2014, which closely aligns with EN 50272-1.

Table 14. Comparison of UN and IEC test criteria.

Test Criteria Standard	UN	IEC	
	Part III S38.3	IEC 62133	IEC 62281
External short circuit	●	●	●
Abnormal charge	●	●	●
Forced discharge	●	●	●
Crush		●	
Impact	●		●
Shock	●	●	●
Vibration	●	●	●
Heating		●	
Temperature cycling	●	●	●
Low pressure (altitude)	●	●	●
Projectile			
Drop		●	●
Continuous low-rate charging		●	
Molded casing heating test			
Open-circuit voltage			
Insulation resistance			
Reverse charge			
Penetration			
Internal short circuit		●	
Immersion			
Fire			

6.2. Differences between European and International Regulations

Besides the battery safety, pre-transportation testing, and transportation regulations specified in the EN and IEC standards, there are a few other regulations in practice for battery transportation in Europe. These regulations are provided by different international and national regulatory bodies and cover various modes of transportation. Section 3 summarizes the international transportation regulations that are also being used in Europe.

In addition to the above international regulations, European countries have multilateral agreements regarding various aspects of transportation and packaging of damaged, recyclable, prototype, and low-production-run lithium batteries. A few agreements make transportation of equipment containing lithium batteries easier within Europe. These multilateral agreements allow countries to have common regulations to accommodate the policies of transportation ministries within individual countries, as well as the diverse safety norms and available infrastructures (tunnels and roads) in individual countries [72]. These agreements became valid on 1 January 2017, and are subject to renewal with mutual consensus between involved parties. A few examples of multilateral agreements are given in Table 15 and described below. For further details, see reference [72].

In 2015, both the International Airlines Group (IAG), a multinational airline holding company located in Europe and Emirates Airlines banned the transport of Li-ion batteries as cargo [54]. In addition, IAG, Emirates, and a few others do not accept booking of UN3480 Li-ion batteries (as shown in Table 3) as cargo on passenger aircraft. However, this restriction does not affect batteries packed or contained in equipment (UN3481 and UN3091 as listed in Table 3). Emirates has a strict policy for carriage of Li-ion batteries and polymer batteries. Especially, Li-ion cells/batteries carried under Sections II, IA, and IB of PI965 (as shown in Tables 6 and 7) are totally restricted for carriage as of 1 April 2015. Road transportation in Europe is actually the preferred transport method for lithium batteries. Being geographically well connected through its road systems, Europe has an advantage of inexpensive road transportation that is less rigidly regulated compared to air and sea.

Table 15. Multilateral agreements between European countries.

Multilateral Agreement	Countries	Differences between Multilateral Agreements and International Regulations
M285	Germany, Italy, The Netherlands, Switzerland	The agreement allows relaxation in packing and in sizing of lithium batteries carried for disposal or recycling while they are still inside equipment and when the equipment can provide the equivalent safety. The agreement overcomes the strict requirement of international regulations on instruction P909 in Subsection 4.1.4.1 about equipment containing lithium cells and batteries.
M292	Germany, France, Austria, Spain, The Netherlands, Switzerland	The agreement allows approval by a country-based competent authority even if the competent authority is not under ADR contract. By derogation from the provisions of chapter 3.3 under SP 376 of the ADR, if Li-ion or Li-metal cells or batteries that have been identified as being damaged or defective, these products are no longer required to be tested in accordance with the applicable provisions of the UN Manual of Tests and Criteria and need approval from authority.
M294	Germany, France, Poland, Switzerland	The agreement concerns SP 310 for pre-production of large Li-ion batteries not tested under UN subsection Manual of Tests and Criteria 38.3, with the gross mass exceeding 100 kg. M294 confirms the requirement of an insulated and sturdy structure to prevent any mechanical movement while transporting pre-production shipment. Under the agreement, large pre-production batteries can be carried in a strong non-approved package that still confirms packing agreement under the treaty.
M295	Germany, France, Switzerland	The agreement provides packaging requirements for prototype or damaged cells/batteries contained in the equipment. These cells/batteries should be transported in accordance with SP 376 and packaged according to international regulations. The consignor should include the phrase "carriage agreement under the terms of Section 1.5.1 of the ADR (M295)" in the transport document.
M296	Germany, France, United Kingdom, Switzerland	The agreement defines carriage of hybrid lithium batteries that contain both primary Li-metal cells and rechargeable Li-ion cells. In the hybrid system, these batteries should not be designed for getting charged externally. In such a case, rechargeable Li-ion batteries can only be charged from the primary lithium cells. The complete system should have overcharging protection and is tested under the UN Manual of Tests and Criteria. The consignment is restricted by weight and capacity.

Air transportation of Li-ion batteries in Europe is becoming more restrictive, and battery manufacturers are encouraged to use road, rail, or sea transportation. For example, the ICAO/IATA organizations require authorization for shipments of prototypes or low-production-run cells/batteries by air. The shipper must first secure a "competent authority approval" from the appropriate transportation agency in the country of origin. In contrast, prototype batteries can be shipped by sea internationally without any approval. However, stringent packaging under provision shipments provided by the IMDG SP310 is required [73]. The requirements associated with road transportation are significantly less restrictive.

6.3. Norms in Practice and Differences between the Norms and Regulations

UN, ADR, ADN, IMDG, and IATA transport regulations are used in Europe (see Section 6.1), while, in practice, EN-IEC standards are also used for lithium battery testing before transportation. Safety regulations during transportation, goods categories, and handling are defined by various authorities such as ADR, DGR, IATA, and IMO. Norms that cover testing, safe parameter limits, and packaging are given by UN and EN.

As specified above, ADN allows bilateral and multilateral agreements among European countries for safe and reliable transportations of dangerous goods including lithium batteries. These agreements are respected within the involved parties/countries and differ from other international regulations in respect to packing and handling of damaged and/or recyclable batteries. These agreements are designed to accommodate differences between transport regulations provided by transport authorities of individual countries and available infrastructures in the countries. A few examples of multilateral agreements are summarized in Table 15.

In practice, most of the transport companies in Europe follow ADR, IATA, DRG, and UN regulations for transportation. International shipping companies such as UPS, FedEx, and DHL also follow similar regulations as described in Section 4.3. Table 16 summarizes some European countries' policies of postal services for Li-ion battery transportation. Most of the postal services allow only built-in or installed batteries. A few postal services allow uninstalled batteries as domestic post where batteries (not more than two) are kept separately from the product but packed within the same package. Uninstalled batteries generally require a material safety data sheet (MSDS) following UN 38.3 instructions [74–77]. An MSDS or product safety data sheet (PSDS) is an essential document in Europe for transporting such lithium batteries. It is a 4–6-page document that contains a product/material description, safety features, hazard identifications, regulatory information, transportation, and other miscellaneous details about handling.

Table 16. Summary of lithium battery restrictions via postal services in Europe.

Postal Company	Standalone Lithium Cells/Batteries	Lithium Cells/Batteries Packed with Equipment	Lithium Cells/Batteries Contained in Equipment
Europe Quick mail	Not allowed	Allowed with MSDS	Allowed
Deutsche Post	Not allowed	Not allowed	Not allowed
Royal Mail	Not allowed	Allowed with MSDS	Allowed with MSDS
Swiss Post	Not allowed	Not allowed	Allowed
European Special line	Not allowed	Allowed with MSDS & UN 38.3 instructions	Allowed with MSDS

7. Lithium Battery Transportation in South Korea

Lithium battery transport regulations in South Korea generally comply with international UN regulations and restrictions. However, lithium battery transport in South Korea is also under the control of the Ministry of Land, Infrastructure and Transport (MOLIT), a national government organization, equivalent to the ICAO, with the goal of strengthening the safety of hazardous materials transported by air [78]. Furthermore, regulated products must also pass Korea Certification (KC) standard testing and obtain the KC certification for transport.

South Korea's Dangerous Goods Safety Management Law also adopted UN GHS classification and labelling standards for hazardous substances (contained within the dangerous goods) that fall under the GHS physical hazards classification criteria (i.e., flash and melting points that are defined by GHS classification). For these substances, companies may use GHS labelling. However, substances not covered by such criteria (e.g., some flammable liquids with flash points that are not within the scope of GHS criteria) are subject to labelling requirements as stipulated by the law. In addition, the national standard for dangerous goods transport provides details of classification of dangerous goods following the IMDG [79].

7.1. Transportation Regulations Available in South Korea

The KC mark is a key prerequisite for lithium battery logistics in South Korea. Lithium batteries transported in South Korea should pass the KC 62133 test standard, which is harmonized with IEC 62133, and should be identified by the KC mark. The KC 62133 standard evolved from the K 62133 standard. It was established 25 July 2012 for Li-ion secondary cells and battery packs. K 62133 standard was similar to the 1st edition of IEC 62133 and covered: (1) lithium secondary cells equal to or more than 400 Wh/L; (2) batteries assembled by the cells for use in portable devices; and (3) cells and batteries for use in portable devices with a navigation function. These standards were identical except storage time for temperature cycling was only required for 24 h after testing [80]. In September 2014, the new KC 62133 standard was established with added coverage for batteries with <400 Wh/L per volume. The new KC 62133 requires testing of all Li-ion batteries irrespective of their energy density value (Wh/L). Accordingly, the old standard (K 62133) was abolished starting in August 2015. The batteries with <400 Wh/L per volume energy density became mandatory starting in April 2016 [81].

Only certified lithium batteries with the KC mark can be transported in South Korea. In-country testing is mandatory. Usually, 21 sample batteries are required to be tested over the course of 10–12 weeks, which can be conducted by the authorized laboratory collaborating with a Korean standard testing institute, such as Korea Testing Laboratory [82]. Labelling (Figure 4) requires specific details in Korean, including product name, model name, designation, nominal voltage, rated capacity, manufacturer, customer service number, and country of manufacture.

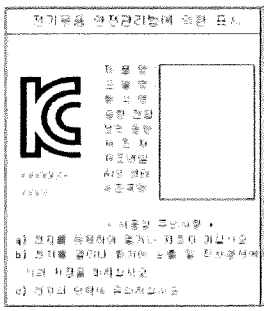


Figure 4. Shipping label with KC mark.

7.2. Differences between South Korean and International Regulations

Although KC 62133 complies with IEC 62133, the IEC standard only refers to a set of portable sealed secondary cells, and the batteries made from them, for use in portable applications. Even if the battery is already KC 62133 certified, some additional requirements for the battery system might still apply. KC 62133 does not consider the implications of integrating the battery within some larger systems, including the charging function outside the battery. Therefore, a battery system standard is needed for products such as hoverboards even when the individual batteries in the system have already been certified. Additionally, even if the battery is marked with the KC 62133 label, it does not mean that any shipment company accepts KC 62133 instead of UN 38.3 because the latter is a requirement directly from IATA for the safe transport of lithium batteries. However, in most cases, the UN 38.3 report would be provided by battery manufacturers prior to KC 62133 [83,84].

7.3. Norms in Practice and Differences between the Norms and Regulations

Different airlines in South Korea have their own norms for transportation of lithium batteries. Most South Korean airlines, such as Korean Air, Air Busan, and Asiana [85–87], clearly regulate that up to five spare lithium batteries are allowed as carry-on only and must be protected to prevent short circuits. Each battery's energy cannot exceed 100 Wh. Exceeding 100 Wh but not exceeding 160 Wh, a maximum of two spare lithium batteries are permitted as carry-on with the approval of the operator.

Two each of 100~160 Wh batteries can be included with five spare batteries. T'way Airlines permits up to four spare batteries that are less than 100 Wh as carry-on, and up to five batteries within 100 Wh mounted on the device are permitted as check-in baggage [88].

These rules are different from FAA regulations that limit spare lithium batteries (more than 100 Wh, but not exceeding 160 Wh) to two per passenger. However, even though there are no strict rules on specific battery products in South Korean airports, some products are still banned, such as portable chargers strictly restricted as spare batteries in China and e-cigarettes in Taiwan [85,87].

South Korean Air prohibits transportation of small vehicles equipped with lithium batteries, including air wheels, solo wheels, hoverboards, mini Segways, and balance wheels by either carry-on or check-in [85]. Lithium batteries within 160 Wh for consumer electronics and medical device are allowed onboard.

Air Busan has more specific restrictions for battery-powered devices. Small vehicles equipped with lithium batteries are also forbidden in either carry-on or check-in baggage. However, medical devices powered with lithium batteries, such as wheelchairs, are permitted with the following restrictions. The batteries should be removed from the wheelchair and only permitted in carry-on baggage with the approval of the operator. For devices operated by one battery, up to two batteries within 300 Wh per each are permitted; whereas for devices with two batteries, up to four batteries within 160 Wh per each are permitted [86]. T'way has the same requirement for medical devices powered by lithium batteries [88].

Air cargo companies such as Korean Air accept shipments of lithium batteries according to the UN regulations (PI965 for Li-metal batteries only, PI968 for Li-ion batteries only, PI966/967/969/970 for batteries with equipment) [89]. South Korean transport companies, covering air, road, and sea shipping, do not list the specific prohibited items on their official websites, including CJ Korea, Korea Post, Hanjin, Lotte, and KGB. South Korea Post claims that electric appliances, which are permitted by the regulation of electric appliances and telecommunications devices, need to be reported to the Ministry of Information and Communication [90]. It does not mention specific requirements for the batteries if they are equipped with the appliance. However, for electric appliances equipped with batteries to be transported in South Korea, they must be affixed with the specific label (KC certification).

8. Lithium Battery Transportation in Japan

In Japan, lithium batteries are classified as dangerous goods by the Japanese Ministry of Economy, Trade and Industry (METI). Lithium batteries are listed as "Category B" (Non-Specified Electrical Appliances and Materials) grade goods according to the DENAN law, which is the Japanese Electrical Appliance and Material Safety Law [91]. In Japan, all electronic goods (including lithium batteries) must be tested in accordance with the DENAN law [92,93]. The Product Safety Electrical Appliance & Material (PSE) mark is mandatory for products falling under the DENAN law. Regulated products must bear the appropriate mark when shipped to Japan in order to clear Japanese customs. Regulations may apply not only to the product itself, but also to packaging, marking or labeling, testing, transportation and storage, and installation. Compliance with "voluntary" standards and obtaining "voluntary" marks of approval can greatly enhance a product's sales potential and help win Japanese consumer acceptance [94]. An MSDS and a composition table are also mandatory for transporting lithium batteries in Japan.

8.1. Transportation Regulations Available in Japan

Lithium batteries shipped to Japan must be tested according to the Japanese DENAN standards. Products regulated by DENAN fall into one of the two categories: Category A products require a PSE certificate from a third-party organization; Category B non-specific products also require compliance, but they may be self-declared.

In order to issue the PSE mark (Figure 5) for specified products (Category A), the testing organization has to be authorized by METI. Lithium batteries fall under Category B of the DENAN law and therefore may be self-declared [93,95].

Figure 5. PSE mark for specified products (**left**) and non-specified products (**right**).

8.2. Differences between Japanese and International Regulations

Even though international testing procedures for lithium batteries do exist under the UN Manual of Tests and Criteria, the tests for DENAN compliance are different from the IEC 62133 standards and UN criteria, mostly exceeding the requirements for the IEC standards [91]. Exceptions apply only for lithium batteries that do not exceed an energy density of 400 Wh/L as well as batteries used in automobiles, motorcycles, medical devices, or industrial appliances. In addition to these exceptions, lithium batteries that are designed as a part of the equipment (e.g., the batteries are fixed into the appliances by soldering or other joining methods) and cannot be removed easily are excluded [96].

Before the DENAN law was introduced, the JIS-C-8714 (Japanese Industrial Standard) plus the IEC 62133 tests were used to cover all of the Japanese requirements. The overlap between the IEC standard and the DENAN law is minimal, however, the DENAN law requires testing at extreme temperatures and a significant amount of additional testing in order to achieve the PSE mark required for the Japanese market [91]. Table 17 compares the DENAN law and the IEC standards for single cell testing. Note that DENAN compliance testing requires the additional 75–95 samples of cells that are already tested by IEC.

Table 17. Comparison of the DENAN law and IEC standards for lithium cell testing.

Test Items	DENAN	IEC 62133:2012
Continuous low-rate charge	At temperature	
Vibration		
Temperature cycling		
	Charge (extremes)	Charge (extremes)
External short circuit	Test (55 °C)	
	At temperature	Test (55 °C)
Free fall		
Mechanical shock		
Thermal abuse		
	Charge (extremes)	Charge (extremes)
Crushing of cells	Test (extremes)	
	At temperature	Test (extremes)
Low pressure		
Overcharge		
Forced discharge	At temperature	
Cell protection—high charge		
Forced internal short circuit		

The DENAN law also differs from IEC standards for testing batteries (cell assemblies). Table 18 illustrates these differences. Mostly, DENAN compliance testing requires additional 29 batteries and one host battery already tested using IEC 62133.

Table 18. Comparison of the DENAN law and IEC standards for lithium battery testing.

Test Items	DENAN	IEC 62133:2012
Vibration Battery enclosure test Temperature cycling External short circuit Free fall Mechanical shock Function of overcharge protection Free fall with appliance	Charge (extremes) Test (20 °C) At temperature	Charge (extremes) Test (55 °C)

The Japanese legal system and regulatory bodies influence the transport of dangerous goods using different modes. If any question arises about transporting lithium batteries in and out of Japan, it is advised to contact the institutions mentioned in Table 19.

Table 19. Japan transportation authorities corresponding to the international regulatory bodies.

Transport Mode	Japanese Legal System	International System
Air	Ministry of Land, Infrastructure and Transport (MLIT) ➢ Civil Aviation Bureau	International Civil Aviation Organization (ICAO)
Sea	MLIT ➢ Maritime Technology and Safety Bureau	International Maritime Organization ➢ International Maritime Dangerous Goods Code
Inland (road)	Ministry of Home Affairs ➢ Fire and Disaster Agency Ministry of Health, Labor and Welfare ➢ Pharmaceutical Affairs Bureau	Inland Transport Committee (ITC) ➢ ADR
Inland (rail)		Central Office for the International Transport by Rail ➢ RID

8.3. Norms in Practice and Differences between the Norms and Regulations

Similar to other countries, some Japanese transport companies apply further restrictions on shipping lithium batteries. These companies, such as Tenso, follow the regulations provided by the Japan Post for international mail. These regulations consist of four different parts [97–99]: (1) unlike a few countries, Japan allows importing of lithium batteries; (2) batteries must be installed or built into the equipment and loose batteries are not acceptable for transportation; (3) standard norms related to the lithium battery capacity or watt-hour rated value must be met as given in Table 20; and (4) lithium batteries must be packaged as 4 lithium electric cells or 2 lithium assembled batteries per mail item.

Nippon Express is a major Japanese transport company that accepts shipments of lithium batteries according to the UN regulations. They refer to the Hong Kong Association of Freight Forwarding and Logistics for more details on the Dangerous Goods Best Practice [100]. There are a few other popular Japanese transport companies such as Sagawa Express and Yamato Transport that do not accept lithium battery shipments. Yamato Transport is Japan's largest door-to-door delivery company, and it does not even accept products equipped with lithium batteries [101,102].

Table 20. Boundary conditions for shipping lithium batteries provided by Japan Post.

Battery Classification		Standard for Batteries That Can Be Sent by International Mail	
Type	**Structure**	**Interior Content of Lithium**	**Watt-Hour Rated Value**
Li-metal battery	Electric cell	1 g or less	-
	Assembled battery	2 g or less	-
Lithium battery	Electric cell	-	20 Wh or less
Lithium-polymer battery	Assembled battery	-	100 Wh or less (must be indicated on the exterior container)

9. Conclusions and Recommendations

With advances in high-energy-density lithium battery technologies, and as a result of numerous fires and explosions of lithium batteries, the regulations concerning the transportation of lithium batteries have been dramatically changing. Today, companies and shippers must be aware of the newest requirements if they do not want disruptions in their schedules and supply chains, or unforeseen costs.

This paper presents the safety considerations for the transportation of lithium batteries with information on pre-transportation tests, packaging norms, limits on the number of packages and quantity of batteries per package, documentation requirements (package marking, labelling, transport document, and air waybill content), and other restrictions. It is noted that international and national norms and regulations for lithium battery transportation depend on the location, transportation mode, and various attributes of the battery itself. It is also noted that national and international regulations are not completely consistent with each other and differ in terminology, procedures, transport records, inner packaging, and battery-sizing categories. Therefore, knowledge of the differences is key to proper and cost-effective transportation.

The transport of lithium batteries to, from, and within the United States is governed by 49 CFR of the U.S. Hazardous Materials Regulations. Within Europe, most of the countries follow IEC European norms and regulations, which have, for the most part, been harmonized with UN regulations, but are not completely consistent with those of the United States. In addition, European countries have signed multilateral agreements to overcome international regulations related to package size requirements and the handling of damaged and recyclable cells and batteries. In Japan, shipping lithium batteries is governed by the DENAN law, which is stricter than the IEC standards. South Korea and China principally follow the international regulations, although transport of lithium batteries in South Korea must be certified by passing the KC mark (similar to IEC 62133 except the KC standard covers all Li-ion batteries irrespective of their energy density value). China requires compliance with international regulations. As the largest and fastest growing market for lithium batteries in the world, China's strict surveillance and enforcement are crucial to minimize the risk from the point of origin to the world.

It is recommended that battery manufacturers, distributors and companies/organizations involved with batteries in their supply chain should follow UN test criteria for cells, packs, and damaged and low-production-run products/systems that include batteries (although in most of the cases, production run and damaged cells are exempted from the test criteria). Companies should then check UN, IATA, ADR, and IMO regulations for packaging, marking, and labelling requirements, because regulations often have their own unique requirements pertaining to weight, size, marking and labelling per the mode of transportation. Companies must also check the regulations of the specific country/countries they will transport from, through, and into, particularly if road transportation is being used for inland transportation. Next, companies must obtain a product certification at the level of cell, pack, or for the entire battery power system, including the battery management system. Transportation regulations for final products depend on the mode of transportation and tend to be easier for road, train, and sea as compared to air; especially for low-production-runs and damaged cells. Companies must then be aware of jurisdiction limits and legal consequences in case of accidents.

In some countries such as Japan, there are defined government authorities who are responsible for accidents during transportation. Finally, companies should prepare an MSDS document and test criteria results before transportation, with the understanding that some countries need specific test criteria for their home market (e.g., Japan needs a PSE mark on the product).

Currently, the number of regulations and the differences in regulations make the logistics of battery transport time-consuming and costly. There is definitely a need to consolidate norms and regulations. Furthermore, there is a need to consolidate safety testing requirements for battery shipments that not only cover cells, but the batteries themselves and the products (equipment, systems). This effort began with the recent IEEE 1625 (Multi-Cell Mobile Computing Devices), IEEE 1725 (Cellular Telephones), and UL 2580 (Use in Electric Vehicles). Finally, there is a need for regulations that address infrastructure requirements at the transport terminals for storing battery consignments.

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Abbreviations

The following abbreviations are used in this manuscript:

49 CFR	Part 49 of the Code of Federal Regulations
ADN	The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
ADR	The European Agreement concerning the International Carriage of Dangerous Goods by Road
CAAC	Civil Aviation Administration of China
CAO	Cargo Aircraft Only
DGR	Dangerous Goods Regulations
ECOSOC	Economic and Social Council
EN	European Norms
FAA	Federal Aviation Administration
HMR	Hazardous Materials Regulations
IAG	International Airlines Group
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and electronics Engineers
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
ITC	Inland Transport Committee
JIS	Japanese Industrial Standard
KC	Korea Certification
METI	Ministry of Economy, Trade and Industry
MLIT	Ministry of Land, Infrastructure and Transport
MSDS	Material Safety Data Sheet
PSE	Product Safety Electrical Appliance & Material
PSD	Product Safety Data Sheet
NTSB	National Transportation Safety Board

OTIF	Intergovernmental Organization for International Carriage by Rail
PAX	passenger aircraft
PG	packing group
PHMSA	Pipeline and Hazardous Material Safety Administration
PI	packing instruction
QMP	quality management program
RID	Regulation concerning the International Carriage of Dangerous Goods by Rail
SAE	Society of Automotive Engineers
SOC	State of charge
SP	Special provision
UL	Underwriters Laboratories
ULD	Unit load device
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UPS	United Parcel Service

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PhyllisFox@gmail.com

Dr. Fox has over 40 years of experience in the field of environmental engineering, including air pollution control (BACT, BART, MACT, LAER, RACT), greenhouse gas emissions and control, cost effectiveness analyses, water quality and water supply investigations, hydrology, hazardous waste investigations, environmental permitting, nuisance investigations (odor, noise), environmental impact reports, CEQA/NEPA documentation, risk assessments, and litigation support.

EDUCATION

Ph.D. Environmental/Civil Engineering, University of California, Berkeley, 1980.
M.S. Environmental/Civil Engineering, University of California, Berkeley, 1975.
B.S. Physics (with high honors), University of Florida, Gainesville, 1971.

REGISTRATION

Registered Professional Engineer: Arizona (2001-2014: #36701; retired), California (2002-present; CH 6058), Florida (2001-present; #57886), Georgia (2002-2014; #PE027643; retired), Washington (2002-2014; #38692; retired), Wisconsin (2005-2014; #37595-006; retired)
Board Certified Environmental Engineer, American Academy of Environmental Engineers, Certified in Air Pollution Control (DEE #01-20014), 2002-present
Qualified Environmental Professional (QEP), Institute of Professional Environmental Practice (QEP #02-010007), 2001-present

PROFESSIONAL HISTORY

Environmental Management, Principal, 1981-present
Lawrence Berkeley National Laboratory, Principal Investigator, 1977-1981
University of California, Berkeley, Program Manager, 1976-1977
Bechtel, Inc., Engineer, 1971-1976, 1964-1966

PROFESSIONAL AFFILIATIONS

American Chemical Society (1981-2010)
Phi Beta Kappa (1970-present)
Sigma Pi Sigma (1970-present)

Who's Who Environmental Registry, PH Publishing, Fort Collins, CO, 1992.
Who's Who in the World, Marquis Who's Who, Inc., Chicago, IL, 11th Ed., p. 371, 1993-present.
Who's Who of American Women, Marquis Who's Who, Inc., Chicago, IL, 13th Ed., p. 264, 1984-present.
Who's Who in Science and Engineering, Marquis Who's Who, Inc., New Providence, NJ, 5th Ed., p. 414, 1999-present.
Who's Who in America, Marquis Who's Who, Inc., 59th Ed., 2005.
Guide to Specialists on Toxic Substances, World Environment Center, New York, NY, p. 80, 1980.
National Research Council Committee on Irrigation-Induced Water Quality Problems (Selenium), Subcommittee on Quality Control/Quality Assurance (1985-1990).
National Research Council Committee on Surface Mining and Reclamation, Subcommittee on Oil Shale (1978-80)

REPRESENTATIVE EXPERIENCE

Performed environmental and engineering investigations, as outlined below, for a wide range of industrial and commercial facilities including: petroleum refineries and upgrades thereto; reformulated fuels projects; refinery upgrades to process heavy sour crudes, including tar sands and light sweet crudes from the Eagle Ford and Bakken Formations; petroleum distribution terminals; coal, coke, and ore/mineral export terminals; LNG export, import, and storage terminals; crude-by-rail projects; shale oil plants; crude oil/condensate marine and rail terminals; coal gasification & liquefaction plants; conventional and thermally enhanced oil production; oil and gas production, including hydraulic fracking and acid stimulation treatments; underground storage tanks; pipelines; compressor stations; gasoline stations; landfills; railyards; hazardous waste treatment facilities; nuclear, hydroelectric, geothermal, wood, biomass, waste, tire-derived fuel, gas, oil, coke and coal-fired power plants; transmission lines; airports; hydrogen plants; petroleum coke calcining plants; coke plants; activated carbon manufacturing facilities; asphalt plants; cement plants; incinerators; flares; manufacturing facilities (e.g., semiconductors, electronic assembly, aerospace components, printed circuit boards, amusement park rides); lanthanide processing plants; ammonia plants; nitric acid plants; urea plants; food processing plants; almond hulling facilities; composting facilities; grain processing facilities; grain elevators; ethanol production facilities; soy bean oil extraction plants; biodiesel plants; paint formulation plants; wastewater treatment plants; marine terminals and ports; gas processing plants; steel mills; iron nugget production facilities; pig iron plant, based on blast furnace technology; direct reduced iron plant; acid regeneration facilities; railcar refinishing facility; battery manufacturing plants; pesticide manufacturing and repackaging facilities; pulp and paper mills; olefin plants; methanol plants; ethylene crackers; desalination plants; selective catalytic reduction (SCR) systems; selective noncatalytic reduction (SNCR) systems; halogen acid furnaces; contaminated

property redevelopment projects (e.g., Mission Bay, Southern Pacific Railyards, Moscone Center expansion, San Diego Padres Ballpark); residential developments; commercial office parks, campuses, and shopping centers; server farms; transportation plans; and a wide range of mines including sand and gravel, hard rock, limestone, nacholite, coal, molybdenum, gold, zinc, and oil shale.

EXPERT WITNESS/LITIGATION SUPPORT

- For the California Attorney General, assist in determining compliance with probation terms in the matter of People v. Chevron USA.
- For plaintiffs, assist in developing Petitioners' proof brief for National Parks Conservation Association et al v. U.S. EPA, Petition for Review of Final Administrative Action of the U.S. EPA, In the U.S. Court of Appeals for the Third Circuit, Docket No. 14-3147.
- For plaintiffs, expert witness in civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1997-2000) at the Cemex cement plant in Lyons, Colorado. Reviewed produced documents, prepared expert and rebuttal reports on PSD applicability based on NOx emission calculations for a collection of changes considered both individually and collectively. Deposed August 2011. *United States v. Cemex, Inc.*, In U.S. District Court for the District of Colorado (Civil Action No. 09-cv-00019-MSK-MEH). Case settled June 13, 2013.
- For plaintiffs, in civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1988 – 2000) at James De Young Units 3, 4, and 5. Reviewed produced documents, analyzed CEMS and EIA data, and prepared netting and BACT analyses for NOx, SO2, and PM10 (PSD case). Expert report February 24, 2010 and affidavit February 20, 2010. *Sierra Club v. City of Holland, et al.*, U.S. District Court, Western District of Michigan (Civil Action 1:08-cv-1183). Case settled. Consent Decree 1/19/14.
- For plaintiffs, in civil action alleging failure to obtain MACT permit, expert on potential to emit hydrogen chloride (HCl) from a new coal-fired boiler. Reviewed record, estimated HCl emissions, wrote expert report June 2010 and March 2013 (Cost to Install a Scrubber at the Lamar Repowering Project Pursuant to Case-by-Case MACT), deposed August 2010 and March 2013. *Wildearth Guardian et al. v. Lamar Utilities Board,* Civil Action No. 09-cv-02974, U.S. District Court, District of Colorado. Case settled August 2013.
- For plaintiffs, expert witness on permitting, emission calculations, and wastewater treatment for coal-to-gasoline plant. Reviewed produced documents. Assisted in preparation of comments on draft minor source permit. Wrote two affidavits on key issues in case. Presented direct and rebuttal testimony 10/27 - 10/28/10 on permit enforceability and failure to properly calculate potential to emit, including underestimate of flaring emissions and

omission of VOC and CO emissions from wastewater treatment, cooling tower, tank roof landings, and malfunctions. *Sierra Club, Ohio Valley Environmental Coalition, Coal River Mountain Watch, West Virginia Highlands Conservancy v. John Benedict, Director, Division of Air Quality, West Virginia Department of Environmental Protection and TransGas Development System, LLC*, Appeal No. 10-01-AQB. Virginia Air Quality Board remanded the permit on March 28, 2011 ordering reconsideration of potential to emit calculations, including: (1) support for assumed flare efficiency; (2) inclusion of startup, shutdown and malfunction emissions; and (3) inclusion of wastewater treatment emissions in potential to emit calculations.

- For plaintiffs, expert on BACT emission limits for gas-fired combined cycle power plant. Prepared declaration in support of CBE's Opposition to the United States' Motion for Entry of Proposed Amended Consent Decree. Assisted in settlement discussions. *U.S. EPA, Plaintiff, Communities for a Better Environment, Intervenor Plaintiff, v. Pacific Gas & Electric Company, et al.*, U.S. District Court, Northern District of California, San Francisco Division, Case No. C-09-4503 SI.
- Technical expert in confidential settlement discussions with large coal-fired utility on BACT control technology and emission limits for NOx, SO2, PM, PM2.5, and CO for new natural gas fired combined cycle and simple cycle turbines with oil backup. (July 2010). Case settled.
- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1998-99) at Gallagher Units 1 and 3. Reviewed produced documents, prepared expert and rebuttal reports on historic and current-day BACT for SO2, control costs, and excess emissions of SO2. Deposed 11/18/09. *United States et al. v. Cinergy, et al.*, In U.S. District Court for the Southern District of Indiana, Indianapolis Division, Civil Action No. IP99-1693 C-M/S. Settled 12/22/09.
- For plaintiffs, expert witness on MACT, BACT for NOx, and enforceability in an administrative appeal of draft state air permit issued for four 300-MW pet-coke-fired CFBs. Reviewed produced documents and prepared prefiled testimony. Deposed 10/8/09 and 11/9/09. Testified 11/10/09. *Application of Las Brisas Energy Center, LLC for State Air Quality Permit*; before the State Office of Administrative Hearings, Texas. Permit remanded 3/29/10 as LBEC failed to meet burden of proof on a number of issues including MACT. Texas Court of Appeals dismissed an appeal to reinstate the permit. The Texas Commission on Environmental Quality and Las Brisas Energy Center, LLC sought to overturn the Court of Appeals decision but moved to have their appeal dismissed in August 2013.
- For defense, expert witness in unlawful detainer case involving a gasoline station, minimart, and residential property with contamination from leaking underground storage tanks. Reviewed agency files and inspected site. Presented expert testimony on July 6, 2009, on

causes of, nature and extent of subsurface contamination. *A. Singh v. S. Assaedi,* in Contra Costa County Superior Court, CA. Settled August 2009.

- For plaintiffs, expert witness on netting and enforceability for refinery being upgraded to process tar sands crude. Reviewed produced documents. Prepared expert and rebuttal reports addressing use of emission factors for baseline, omitted sources including coker, flares, tank landings and cleaning, and enforceability. Deposed. *In the Matter of Objection to the Issuance of Significant Source Modification Permit No. 089-25484-00453 to BP Products North America Inc., Whiting Business Unit, Save the Dunes Council, Inc., Sierra Club., Inc., Hoosier Environmental Council et al., Petitioners, B. P. Products North American, Respondents/Permittee,* before the Indiana Office of Environmental Adjudication.
- For plaintiffs, expert witness on BACT, MACT, and enforceability in appeal of Title V permit issued to 600 MW coal-fired power plant burning Powder River Basin coal. Prepared technical comments on draft air permit. Reviewed record on appeal, drafted BACT, MACT, and enforceability pre-filed testimony. Drafted MACT and enforceability pre-filed rebuttal testimony. Deposed March 24, 2009. Testified June 10, 2009. *In Re: Southwestern Electric Power Company*, Arkansas Pollution Control and Ecology Commission, Consolidated Docket No. 08-006-P. Recommended Decision issued December 9, 2009 upholding issued permit. Commission adopted Recommended Decision January 22, 2010.
- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications (1989-1992) at Wabash Units 2, 3 and 5. Reviewed produced documents, prepared expert and rebuttal report on historic and current-day BACT for NOx and SO2, control costs, and excess emissions of NOx, SO2, and mercury. Deposed 10/21/08. *United States et al. v. Cinergy, et al.*, In U.S. District Court for the Southern District of Indiana, Indianapolis Division, Civil Action No. IP99-1693 C-M/S. Testified 2/3/09. Memorandum Opinion & Order 5-29-09 requiring shutdown of Wabash River Units 2, 3, 5 by September 30, 2009, run at baseline until shutdown, and permanently surrender SO2 emission allowances.
- For plaintiffs, expert witness in liability phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for three historic modifications (1997-2001) at two portland cement plants involving three cement kilns. Reviewed produced documents, analyzed CEMS data covering subject period, prepared netting analysis for NOx, SO_2 and CO, and prepared expert and rebuttal reports. *United States v. Cemex California Cement,* In U.S. District Court for the Central District of California, Eastern Division, Case No. ED CV 07-00223-GW (JCRx), Settled 1/15/09.
- For intervenors Clean Wisconsin and Citizens Utility Board, prepared data requests, reviewed discovery and expert report. Prepared prefiled direct, rebuttal and surrebuttal testimony on cost to extend life of existing Oak Creek Units 5-8 and cost to address future regulatory requirements to determine whether to control or shutdown one or more of the units. Oral testimony 2/5/08. Application for a Certificate of Authority to Install Wet Flue

Gas Desulfurization and Selective Catalytic Reduction Facilities and Associated Equipment for Control of Sulfur Dioxide and Nitrogen Oxide Emissions at Oak Creek Power Plant Units 5, 6, 7 and 8, WPSC Docket No. 6630-CE-299.

- For plaintiffs, expert witness on alternatives analysis and BACT for NOx, SO2, total PM10, and sulfuric acid mist in appeal of PSD permit issued to 1200 MW coal fired power plant burning Powder River Basin and/or Central Appalachian coal (Longleaf). Assisted in drafting technical comments on NOx on draft permit. Prepared expert disclosure. Presented 8+ days of direct and rebuttal expert testimony. Attended all 21 days of evidentiary hearing from 9/5/07 – 10/30/07 assisting in all aspects of hearing. *Friends of the Chatahooche and Sierra Club v. Dr. Carol Couch, Director, Environmental Protection Division of Natural Resources Department, Respondent, and Longleaf Energy Associates, Intervener.* ALJ Final Decision 1/11/08 denying petition. ALJ Order vacated & remanded for further proceedings, Fulton County Superior Court, 6/30/08. Court of Appeals of GA remanded the case with directions that the ALJ's final decision be vacated to consider the evidence under the correct standard of review, July 9, 2009. The ALJ issued an opinion April 2, 2010 in favor of the applicant. Final permit issued April 2010.
- For plaintiffs, expert witness on diesel exhaust in inverse condemnation case in which Port expanded maritime operations into residential neighborhoods, subjecting plaintiffs to noise, light, and diesel fumes. Measured real-time diesel particulate concentrations from marine vessels and tug boats on plaintiffs' property. Reviewed documents, depositions, DVDs, and photographs provided by counsel. Deposed. Testified October 24, 2006. *Ann Chargin, Richard Hackett, Carolyn Hackett, et al. v. Stockton Port District*, Superior Court of California, County of San Joaquin, Stockton Branch, No. CV021015. Judge ruled for plaintiffs.
- For plaintiffs, expert witness on NOx emissions and BACT in case alleging failure to obtain necessary permits and install controls on gas-fired combined-cycle turbines. Prepared and reviewed (applicant analyses) of NOx emissions, BACT analyses (water injection, SCR, ultra low NOx burners), and cost-effectiveness analyses based on site visit, plant operating records, stack tests, CEMS data, and turbine and catalyst vendor design information. Participated in negotiations to scope out consent order. *United States v. Nevada Power.* Case settled June 2007, resulting in installation of dry low NOx burners (5 ppm NOx averaged over 1 hr) on four units and a separate solar array at a local business.
- For plaintiffs, expert witness in appeal of PSD permit issued to 850 MW coal fired boiler burning Powder River Basin coal (Iatan Unit 2) on BACT for particulate matter, sulfuric acid mist and opacity and emission calculations for alleged historic violations of PSD. Assisted in drafting technical comments, petition for review, discovery requests, and responses to discovery requests. Reviewed produced documents. Prepared expert report on BACT for particulate matter. Assisted with expert depositions. Deposed February 7, 8, 27, 28, 2007. *In Re PSD Construction Permit Issued to Great Plains Energy, Kansas City Power & Light – Iatan Generating Station, Sierra Club v. Missouri Department of Natural Resources, Great*

Plains Energy, and Kansas City Power & Light. Case settled March 27, 2007, providing offsets for over 6 million ton/yr of CO2 and lower NOx and SO_2 emission limits.

- For plaintiffs, expert witness in remedy phase of civil action relating to alleged violations of the Clean Air Act, Prevention of Significant Deterioration, for historic modifications of coal-fired boilers and associated equipment. Reviewed produced documents, prepared expert report on cost to retrofit 24 coal-fired power plants with scrubbers designed to remove 99% of the sulfur dioxide from flue gases. Prepared supplemental and expert report on cost estimates and BACT for SO2 for these 24 complaint units. Deposed 1/30/07 and 3/14/07. *United States and State of New York et al. v. American Electric Power*, In U.S. District Court for the Southern District of Ohio, Eastern Division, Consolidated Civil Action Nos. C2-99-1182 and C2-99-1250. Settlement announced 10/9/07.
- For plaintiffs, expert witness on BACT, enforceability, and alternatives analysis in appeal of PSD permit issued for a 270-MW pulverized coal fired boiler burning Powder River Basin coal (City Utilities Springfield Unit 2). Reviewed permitting file and assisted counsel draft petition and prepare and respond to interrogatories and document requests. Reviewed interrogatory responses and produced documents. Assisted with expert depositions. Deposed August 2005. Evidentiary hearings October 2005. *In the Matter of Linda Chipperfield and Sierra Club v. Missouri Department of Natural Resources.* Missouri Supreme Court denied review of adverse lower court rulings August 2007.
- For plaintiffs, expert witness in civil action relating to plume touchdowns at AEP's Gavin coal-fired power plant. Assisted counsel draft interrogatories and document requests. Reviewed responses to interrogatories and produced documents. Prepared expert report "Releases of Sulfuric Acid Mist from the Gavin Power Station." The report evaluates sulfuric acid mist releases to determine if AEP complied with the requirements of CERCLA Section 103(a) and EPCRA Section 304. This report also discusses the formation, chemistry, release characteristics, and abatement of sulfuric acid mist in support of the claim that these releases present an imminent and substantial endangerment to public health under Section 7002(a)(1)(B) of the Resource Conservation and Recovery Act ("RCRA"). *Citizens Against Pollution v. Ohio Power Company*, In the U.S. District Court for the Southern District of Ohio, Eastern Division, Civil Action No. 2-04-cv-371. Case settled 12-8-06.

- For petitioners, expert witness in contested case hearing on BACT, enforceability, and emission estimates for an air permit issued to a 500-MW supercritical Power River Basin coal-fired boiler (Weston Unit 4). Assisted counsel prepare comments on draft air permit and respond to and draft discovery. Reviewed produced file, deposed (7/05), and prepared expert report on BACT and enforceability. Evidentiary hearings September 2005. *In the Matter of an Air Pollution Control Construction Permit Issued to Wisconsin Public Service Corporation for the Construction and Operation of a 500 MW Pulverized Coal-fired Power Plant Known as Weston Unit 4 in Marathon County, Wisconsin*, Case No. IH-04-21. The Final Order, issued 2/10/06, lowered the NOx BACT limit from 0.07 lb/MMBtu to 0.06

lb/MMBtu based on a 30-day average, added a BACT SO2 control efficiency, and required a 0.0005% high efficiency drift eliminator as BACT for the cooling tower. The modified permit, including these provisions, was issued 3/28/07. Additional appeals in progress.

- For plaintiffs, adviser on technical issues related to Citizen Suit against U.S. EPA regarding failure to update New Source Performance Standards for petroleum refineries, 40 CFR 60, Subparts J, VV, and GGG. *Our Children's Earth Foundation and Sierra Club v. U.S. EPA et al.* Case settled July 2005. CD No. C 05-00094 CW, U.S. District Court, Northern District of California – Oakland Division. Proposed revisions to standards of performance for petroleum refineries published 72 FR 27178 (5/14/07).
- For interveners, reviewed proposed Consent Decree settling Clean Air Act violations due to historic modifications of boilers and associated equipment at two coal-fired power plants. In response to stay order, reviewed the record, selected one representative activity at each of seven generating units, and analyzed to identify CAA violations. Identified NSPS and NSR violations for NOx, SO_2, PM/PM10, and sulfuric acid mist. Summarized results in an expert report. *United States of America, and Michael A. Cox, Attorney General of the State of Michigan, ex rel. Michigan Department of Environmental Quality, Plaintiffs, and Clean Wisconsin, Sierra Club, and Citizens' Utility Board, Intervenors, v. Wisconsin Electric Power Company, Defendant*, U.S. District Court for the Eastern District of Wisconsin, Civil Action No. 2:03-CV-00371-CNC. Order issued 10-1-07 denying petition.
- For a coalition of Nevada labor organizations (ACE), reviewed preliminary determination to issue a Class I Air Quality Operating Permit to Construct and supporting files for a 250-MW pulverized coal-fired boiler (Newmont). Prepared about 100 pages of technical analyses and comments on BACT, MACT, emission calculations, and enforceability. Assisted counsel draft petition and reply brief appealing PSD permit to U.S. EPA Environmental Appeals Board (EAB). Order denying review issued 12/21/05. *In re Newmont Nevada Energy Investment, LLC, TS Power Plant*, PSD Appeal No. 05-04 (EAB 2005).
- For petitioners and plaintiffs, reviewed and prepared comments on air quality and hazardous waste based on negative declaration for refinery ultra low sulfur diesel project located in SCAQMD. Reviewed responses to comments and prepared responses. Prepared declaration and presented oral testimony before SCAQMD Hearing Board on exempt sources (cooling towers) and calculation of potential to emit under NSR. Petition for writ of mandate filed March 2005. Case remanded by Court of Appeals to trial court to direct SCAQMD to re-evaluate the potential environmental significance of NOx emissions resulting from the project in accordance with court's opinion. California Court of Appeals, Second Appellate Division, on December 18, 2007, affirmed in part (as to baseline) and denied in part. *Communities for a Better Environment v. South Coast Air Quality Management District and ConocoPhillips and Carlos Valdez et al v. South Coast Air Quality Management District and ConocoPhillips.* Certified for partial publication 1/16/08. Appellate Court opinion upheld by CA Supreme Court 3/15/10. *(2010) 48 Cal.4th 310.*

- For amici seeking to amend a proposed Consent Decree to settle alleged NSR violations at Chevron refineries, reviewed proposed settlement, related files, subject modifications, and emission calculations. Prepared declaration on emission reductions, identification of NSR and NSPS violations, and BACT/LAER for FCCUs, heaters and boilers, flares, and sulfur recovery plants. *U.S. et al. v. Chevron U.S.A.*, Northern District of California, Case No. C 03-04650. Memorandum and Order Entering Consent Decree issued June 2005. Case No. C 03-4650 CRB.
- For petitioners, prepared declaration on enforceability of periodic monitoring requirements, in response to EPA's revised interpretation of 40 CFR 70.6(c)(1). This revision limited additional monitoring required in Title V permits. 69 FR 3203 (Jan. 22, 2004). *Environmental Integrity Project et al. v. EPA* (U.S. Court of Appeals for the District of Columbia). Court ruled the Act requires all Title V permits to contain monitoring requirements to assure compliance. *Sierra Club v. EPA*, 536 F.3d 673 (D.C. Cir. 2008).
- For interveners in application for authority to construct a 500 MW supercritical coal-fired generating unit before the Wisconsin Public Service Commission, prepared pre-filed written direct and rebuttal testimony with oral cross examination and rebuttal on BACT and MACT (Weston 4). Prepared written comments on BACT, MACT, and enforceability on draft air permit for same facility.
- For property owners in Nevada, evaluated the environmental impacts of a 1,450-MW coal-fired power plant proposed in a rural area adjacent to the Black Rock Desert and Granite Range, including emission calculations, air quality modeling, comments on proposed use permit to collect preconstruction monitoring data, and coordination with agencies and other interested parties. Project cancelled.
- For environmental organizations, reviewed draft PSD permit for a 600-MW coal-fired power plant in West Virginia (Longview). Prepared comments on permit enforceability; coal washing; BACT for SO_2 and PM10; Hg MACT; and MACT for HCl, HF, non-Hg metallic HAPs, and enforceability. Assist plaintiffs draft petition appealing air permit. Retained as expert to develop testimony on MACT, BACT, offsets, enforceability. Participate in settlement discussions. Case settled July 2004.
- For petitioners, reviewed record produced in discovery and prepared affidavit on emissions of carbon monoxide and volatile organic compounds during startup of GE 7FA combustion turbines to successfully establish plaintiff standing. *Sierra Club et al. v. Georgia Power Company* (Northern District of Georgia).
- For building trades, reviewed air quality permitting action for 1500-MW coal-fired power plant before the Kentucky Department for Environmental Protection (Thoroughbred).
- For petitioners, expert witness in administrative appeal of the PSD/Title V permit issued to a 1500-MW coal-fired power plant. Reviewed over 60,000 pages of produced documents, prepared discovery index, identified and assembled plaintiff exhibits. Deposed. Assisted

counsel in drafting discovery requests, with over 30 depositions, witness cross examination, and brief drafting. Presented over 20 days of direct testimony, rebuttal and sur-rebuttal, with cross examination on BACT for NOx, SO_2, and PM/PM10; MACT for Hg and non-Hg metallic HAPs; emission estimates for purposes of Class I and II air modeling; risk assessment; and enforceability of permit limits. Evidentiary hearings from November 2003 to June 2004. *Sierra Club et al. v. Natural Resources & Environmental Protection Cabinet, Division of Air Quality and Thoroughbred Generating Company et al.* Hearing Officer Decision issued August 9, 2005 finding in favor of plaintiffs on counts as to risk, BACT (IGCC/CFB, NOx, SO_2, Hg, Be), single source, enforceability, and errors and omissions. Assist counsel draft exceptions. Cabinet Secretary issued Order April 11, 2006 denying Hearing Offer's report, except as to NOx BACT, Hg, 99% SO2 control and certain errors and omissions.

- For citizens group in Massachusetts, reviewed, commented on, and participated in permitting of pollution control retrofits of coal-fired power plant (Salem Harbor).
- Assisted citizens group and labor union challenge issuance of conditional use permit for a 317,000 ft^2 discount store in Honolulu without any environmental review. In support of a motion for preliminary injunction, prepared 7-page declaration addressing public health impacts of diesel exhaust from vehicles serving the Project. In preparation for trial, prepared 20-page preliminary expert report summarizing results of diesel exhaust and noise measurements at two big box retail stores in Honolulu, estimated diesel PM10 concentrations for Project using ISCST, prepared a cancer health risk assessment based on these analyses, and evaluated noise impacts.
- Assisted environmental organizations to challenge the DOE Finding of No Significant Impact (FONSI) for the Baja California Power and Sempra Energy Resources Cross-Border Transmissions Lines in the U.S. and four associated power plants located in Mexico (DOE EA-1391). Prepared 20-page declaration in support of motion for summary judgment addressing emissions, including CO_2 and NH_3, offsets, BACT, cumulative air quality impacts, alternative cooling systems, and water use and water quality impacts. Plaintiff's motion for summary judgment granted in part. U.S. District Court, Southern District decision concluded that the Environmental Assessment and FONSI violated NEPA and the APA due to their inadequate analysis of the potential controversy surrounding the project, water impacts, impacts from NH_3 and CO_2, alternatives, and cumulative impacts. *Border Power Plant Working Group v. Department of Energy and Bureau of Land Management*, Case No. 02-CV-513-IEG (POR) (May 2, 2003).
- For Sacramento school, reviewed draft air permit issued for diesel generator located across from playfield. Prepared comments on emission estimates, enforceability, BACT, and health impacts of diesel exhaust. Case settled. BUG trap installed on the diesel generator.
- Assisted unions in appeal of Title V permit issued by BAAQMD to carbon plant that manufactured coke. Reviewed District files, identified historic modifications that should have triggered PSD review, and prepared technical comments on Title V permit. Reviewed

responses to comments and assisted counsel draft appeal to BAAQMD hearing board, opening brief, motion to strike, and rebuttal brief. Case settled.

- Assisted California Central Coast city obtain controls on a proposed new city that would straddle the Ventura-Los Angeles County boundary. Reviewed several environmental impact reports, prepared an air quality analysis, a diesel exhaust health risk assessment, and detailed review comments. Governor intervened and State dedicated the land for conservation purposes April 2004.
- Assisted Central California city to obtain controls on large alluvial sand quarry and asphalt plant proposing a modernization. Prepared comments on Negative Declaration on air quality, public health, noise, and traffic. Evaluated process flow diagrams and engineering reports to determine whether proposed changes increased plant capacity or substantially modified plant operations. Prepared comments on application for categorical exemption from CEQA. Presented testimony to County Board of Supervisors. Developed controls to mitigate impacts. Assisted counsel draft Petition for Writ. Case settled June 2002. Substantial improvements in plant operations were obtained including cap on throughput, dust control measures, asphalt plant loadout enclosure, and restrictions on truck routes.
- Assisted oil companies on the California Central Coast in defending class action citizen's lawsuit alleging health effects due to emissions from gas processing plant and leaking underground storage tanks. Reviewed regulatory and other files and advised counsel on merits of case. Case settled November 2001.
- Assisted oil company on the California Central Coast in defending property damage claims arising out of a historic oil spill. Reviewed site investigation reports, pump tests, leachability studies, and health risk assessments, participated in design of additional site characterization studies to assess health impacts, and advised counsel on merits of case. Prepare health risk assessment.
- Assisted unions in appeal of Initial Study/Negative Declaration ("IS/ND") for an MTBE phaseout project at a Bay Area refinery. Reviewed IS/ND and supporting agency permitting files and prepared technical comments on air quality, groundwater, and public health impacts. Reviewed responses to comments and final IS/ND and ATC permits and assisted counsel to draft petitions and briefs appealing decision to Air District Hearing Board. Presented sworn direct and rebuttal testimony with cross examination on groundwater impacts of ethanol spills on hydrocarbon contamination at refinery. Hearing Board ruled 5 to 0 in favor of appellants, remanding ATC to district to prepare an EIR.
- Assisted Florida cities in challenging the use of diesel and proposed BACT determinations in prevention of significant deterioration (PSD) permits issued to two 510-MW simple cycle peaking electric generating facilities and one 1,080-MW simple cycle/combined cycle facility. Reviewed permit applications, draft permits, and FDEP engineering evaluations, assisted counsel in drafting petitions and responding to discovery. Participated in settlement discussions. Cases settled or applications withdrawn.

- Assisted large California city in federal lawsuit alleging peaker power plant was violating its federal permit. Reviewed permit file and applicant's engineering and cost feasibility study to reduce emissions through retrofit controls. Advised counsel on feasible and cost-effective NOx, SOx, and PM10 controls for several 1960s diesel-fired Pratt and Whitney peaker turbines. Case settled.
- Assisted coalition of Georgia environmental groups in evaluating BACT determinations and permit conditions in PSD permits issued to several large natural gas-fired simple cycle and combined-cycle power plants. Prepared technical comments on draft PSD permits on BACT, enforceability of limits, and toxic emissions. Reviewed responses to comments, advised counsel on merits of cases, participated in settlement discussions, presented oral and written testimony in adjudicatory hearings, and provided technical assistance as required. Cases settled or won at trial.
- Assisted construction unions in review of air quality permitting actions before the Indiana Department of Environmental Management ("IDEM") for several natural gas-fired simple cycle peaker and combined cycle power plants.
- Assisted coalition of towns and environmental groups in challenging air permits issued to 523 MW dual fuel (natural gas and distillate) combined-cycle power plant in Connecticut. Prepared technical comments on draft permits and 60 pages of written testimony addressing emission estimates, startup/shutdown issues, BACT/LAER analyses, and toxic air emissions. Presented testimony in adjudicatory administrative hearings before the Connecticut Department of Environmental Protection in June 2001 and December 2001.
- Assisted various coalitions of unions, citizens groups, cities, public agencies, and developers in licensing and permitting of over 110 coal, gas, oil, biomass, and pet coke-fired power plants generating over 75,000 MW of electricity. These included base-load, combined cycle, simple cycle, and peaker power plants in Alaska, Arizona, Arkansas, California, Colorado, Georgia, Florida, Illinois, Indiana, Kentucky, Michigan, Missouri, Ohio, Oklahoma, Oregon, Texas, West Virginia, Wisconsin, and elsewhere. Prepared analyses of and comments on applications for certification, preliminary and final staff assessments, and various air, water, wastewater, and solid waste permits issued by local agencies. Presented written and oral testimony before various administrative bodies on hazards of ammonia use and transportation, health effects of air emissions, contaminated property issues, BACT/LAER issues related to SCR and SCONOx, criteria and toxic pollutant emission estimates, MACT analyses, air quality modeling, water supply and water quality issues, and methods to reduce water use, including dry cooling, parallel dry-wet cooling, hybrid cooling, and zero liquid discharge systems.
- Assisted unions, cities, and neighborhood associations in challenging an EIR issued for the proposed expansion of the Oakland Airport. Reviewed two draft EIRs and prepared a health risk assessment and extensive technical comments on air quality and public health impacts. The California Court of Appeals, First Appellate District, ruled in favor of appellants and

plaintiffs, concluding that the EIR "2) erred in using outdated information in assessing the emission of toxic air contaminants (TACs) from jet aircraft; 3) failed to support its decision not to evaluate the health risks associated with the emission of TACs with meaningful analysis," thus accepting my technical arguments and requiring the Port to prepare a new EIR. See *Berkeley Keep Jets Over the Bay Committee, City of San Leandro, and City of Alameda et al. v. Board of Port Commissioners* (August 30, 2001) 111 Cal.Rptr.2d 598.

- Assisted lessor of former gas station with leaking underground storage tanks and TCE contamination from adjacent property. Lessor held option to purchase, which was forfeited based on misrepresentation by remediation contractor as to nature and extent of contamination. Remediation contractor purchased property. Reviewed regulatory agency files and advised counsel on merits of case. Case not filed.
- Advised counsel on merits of several pending actions, including a Proposition 65 case involving groundwater contamination at an explosives manufacturing firm and two former gas stations with leaking underground storage tanks.
- Assisted defendant foundry in Oakland in a lawsuit brought by neighbors alleging property contamination, nuisance, trespass, smoke, and health effects from foundry operation. Inspected and sampled plaintiff's property. Advised counsel on merits of case. Case settled.
- Assisted business owner facing eminent domain eviction. Prepared technical comments on a negative declaration for soil contamination and public health risks from air emissions from a proposed redevelopment project in San Francisco in support of a CEQA lawsuit. Case settled.
- Assisted neighborhood association representing residents living downwind of a Berkeley asphalt plant in separate nuisance and CEQA lawsuits. Prepared technical comments on air quality, odor, and noise impacts, presented testimony at commission and council meetings, participated in community workshops, and participated in settlement discussions. Cases settled. Asphalt plant was upgraded to include air emission and noise controls, including vapor collection system at truck loading station, enclosures for noisy equipment, and improved housekeeping.
- Assisted a Fortune 500 residential home builder in claims alleging health effects from faulty installation of gas appliances. Conducted indoor air quality study, advised counsel on merits of case, and participated in discussions with plaintiffs. Case settled.
- Assisted property owners in Silicon Valley in lawsuit to recover remediation costs from insurer for large TCE plume originating from a manufacturing facility. Conducted investigations to demonstrate sudden and accidental release of TCE, including groundwater modeling, development of method to date spill, preparation of chemical inventory, investigation of historical waste disposal practices and standards, and on-site sewer and storm drainage inspections and sampling. Prepared declaration in opposition to motion for summary judgment. Case settled.

- Assisted residents in east Oakland downwind of a former battery plant in class action lawsuit alleging property contamination from lead emissions. Conducted historical research and dry deposition modeling that substantiated claim. Participated in mediation at JAMS. Case settled.
- Assisted property owners in West Oakland who purchased a former gas station that had leaking underground storage tanks and groundwater contamination. Reviewed agency files and advised counsel on merits of case. Prepared declaration in opposition to summary judgment. Prepared cost estimate to remediate site. Participated in settlement discussions. Case settled.
- Consultant to counsel representing plaintiffs in two Clean Water Act lawsuits involving selenium discharges into San Francisco Bay from refineries. Reviewed files and advised counsel on merits of case. Prepared interrogatory and discovery questions, assisted in deposing opposing experts, and reviewed and interpreted treatability and other technical studies. Judge ruled in favor of plaintiffs.
- Assisted oil company in a complaint filed by a resident of a small California beach community alleging that discharges of tank farm rinse water into the sanitary sewer system caused hydrogen sulfide gas to infiltrate residence, sending occupants to hospital. Inspected accident site, interviewed parties to the event, and reviewed extensive agency files related to incident. Used chemical analysis, field simulations, mass balance calculations, sewer hydraulic simulations with SWMM44, atmospheric dispersion modeling with SCREEN3, odor analyses, and risk assessment calculations to demonstrate that the incident was caused by a faulty drain trap and inadequate slope of sewer lateral on resident's property. Prepared a detailed technical report summarizing these studies. Case settled.
- Assisted large West Coast city in suit alleging that leaking underground storage tanks on city property had damaged the waterproofing on downgradient building, causing leaks in an underground parking structure. Reviewed subsurface hydrogeologic investigations and evaluated studies conducted by others documenting leakage from underground diesel and gasoline tanks. Inspected, tested, and evaluated waterproofing on subsurface parking structure. Waterproofing was substandard. Case settled.
- Assisted residents downwind of gravel mine and asphalt plant in Siskiyou County, California, in suit to obtain CEQA review of air permitting action. Prepared two declarations analyzing air quality and public health impacts. Judge ruled in favor of plaintiffs, closing mine and asphalt plant.
- Assisted defendant oil company on the California Central Coast in class action lawsuit alleging property damage and health effects from subsurface petroleum contamination. Reviewed documents, prepared risk calculations, and advised counsel on merits of case. Participated in settlement discussions. Case settled.

- Assisted defendant oil company in class action lawsuit alleging health impacts from remediation of petroleum contaminated site on California Central Coast. Reviewed documents, designed and conducted monitoring program, and participated in settlement discussions. Case settled.
- Consultant to attorneys representing irrigation districts and municipal water districts to evaluate a potential challenge of USFWS actions under CVPIA section 3406(b)(2). Reviewed agency files and collected and analyzed hydrology, water quality, and fishery data. Advised counsel on merits of case. Case not filed.
- Assisted residents downwind of a Carson refinery in class action lawsuit involving soil and groundwater contamination, nuisance, property damage, and health effects from air emissions. Reviewed files and provided advise on contaminated soil and groundwater, toxic emissions, and health risks. Prepared declaration on refinery fugitive emissions. Prepared deposition questions and reviewed deposition transcripts on air quality, soil contamination, odors, and health impacts. Case settled.
- Assisted residents downwind of a Contra Costa refinery who were affected by an accidental release of naphtha. Characterized spilled naphtha, estimated emissions, and modeled ambient concentrations of hydrocarbons and sulfur compounds. Deposed. Presented testimony in binding arbitration at JAMS. Judge found in favor of plaintiffs.
- Assisted residents downwind of Contra Costa County refinery in class action lawsuit alleging property damage, nuisance, and health effects from several large accidents as well as routine operations. Reviewed files and prepared analyses of environmental impacts. Prepared declarations, deposed, and presented testimony before jury in one trial and judge in second. Case settled.
- Assisted business owner claiming damages from dust, noise, and vibration during a sewer construction project in San Francisco. Reviewed agency files and PM10 monitoring data and advised counsel on merits of case. Case settled.
- Assisted residents downwind of Contra Costa County refinery in class action lawsuit alleging property damage, nuisance, and health effects. Prepared declaration in opposition to summary judgment, deposed, and presented expert testimony on accidental releases, odor, and nuisance before jury. Case thrown out by judge, but reversed on appeal and not retried.
- Presented testimony in small claims court on behalf of residents claiming health effects from hydrogen sulfide from flaring emissions triggered by a power outage at a Contra Costa County refinery. Analyzed meteorological and air quality data and evaluated potential health risks of exposure to low concentrations of hydrogen sulfide. Judge awarded damages to plaintiffs.
- Assisted construction unions in challenging PSD permit for an Indiana steel mill. Prepared technical comments on draft PSD permit, drafted 70-page appeal of agency permit action to

the Environmental Appeals Board challenging permit based on faulty BACT analysis for electric arc furnace and reheat furnace and faulty permit conditions, among others, and drafted briefs responding to four parties. EPA Region V and the EPA General Counsel intervened as amici, supporting petitioners. EAB ruled in favor of petitioners, remanding permit to IDEM on three key issues, including BACT for the reheat furnace and lead emissions from the EAF. Drafted motion to reconsider three issues. Prepared 69 pages of technical comments on revised draft PSD permit. Drafted second EAB appeal addressing lead emissions from the EAF and BACT for reheat furnace based on European experience with SCR/SNCR. Case settled. Permit was substantially improved. See *In re: Steel Dynamics, Inc.*, PSD Appeal Nos. 99-4 & 99-5 (EAB June 22, 2000).

- Assisted defendant urea manufacturer in Alaska in negotiations with USEPA to seek relief from penalties for alleged violations of the Clean Air Act. Reviewed and evaluated regulatory files and monitoring data, prepared technical analysis demonstrating that permit limits were not violated, and participated in negotiations with EPA to dismiss action. Fines were substantially reduced and case closed.
- Assisted construction unions in challenging PSD permitting action for an Indiana grain mill. Prepared technical comments on draft PSD permit and assisted counsel draft appeal of agency permit action to the Environmental Appeals Board challenging permit based on faulty BACT analyses for heaters and boilers and faulty permit conditions, among others. Case settled.
- As part of a consent decree settling a CEQA lawsuit, assisted neighbors of a large west coast port in negotiations with port authority to secure mitigation for air quality impacts. Prepared technical comments on mobile source air quality impacts and mitigation and negotiated a $9 million CEQA mitigation package. Represented neighbors on technical advisory committee established by port to implement the air quality mitigation program. Program successfully implemented.
- Assisted construction unions in challenging permitting action for a California hazardous waste incinerator. Prepared technical comments on draft permit, assisted counsel prepare appeal of EPA permit to the Environmental Appeals Board. Participated in settlement discussions on technical issues with applicant and EPA Region 9. Case settled.
- Assisted environmental group in challenging DTSC Negative Declaration on a hazardous waste treatment facility. Prepared technical comments on risk of upset, water, and health risks. Writ of mandamus issued.
- Assisted several neighborhood associations and cities impacted by quarries, asphalt plants, and cement plants in Alameda, Shasta, Sonoma, and Mendocino counties in obtaining mitigations for dust, air quality, public health, traffic, and noise impacts from facility operations and proposed expansions.

- For over 100 industrial facilities, commercial/campus, and redevelopment projects, developed the record in preparation for CEQA and NEPA lawsuits. Prepared technical comments on hazardous materials, solid wastes, public utilities, noise, worker safety, air quality, public health, water resources, water quality, traffic, and risk of upset sections of EIRs, EISs, FONSIs, initial studies, and negative declarations. Assisted counsel in drafting petitions and briefs and prepared declarations.
- For several large commercial development projects and airports, assisted applicant and counsel prepare defensible CEQA documents, respond to comments, and identify and evaluate "all feasible" mitigation to avoid CEQA challenges. This work included developing mitigation programs to reduce traffic-related air quality impacts based on energy conservation programs, solar, low-emission vehicles, alternative fuels, exhaust treatments, and transportation management associations.

SITE INVESTIGATION/REMEDIATION/CLOSURE

- Technical manager and principal engineer for characterization, remediation, and closure of waste management units at former Colorado oil shale plant. Constituents of concern included BTEX, As, 1,1,1-TCA, and TPH. Completed groundwater monitoring programs, site assessments, work plans, and closure plans for seven process water holding ponds, a refinery sewer system, and processed shale disposal area. Managed design and construction of groundwater treatment system and removal actions and obtained clean closure.
- Principal engineer for characterization, remediation, and closure of process water ponds at a former lanthanide processing plant in Colorado. Designed and implemented groundwater monitoring program and site assessments and prepared closure plan.
- Advised the city of Sacramento on redevelopment of two former railyards. Reviewed work plans, site investigations, risk assessment, RAPS, RI/FSs, and CEQA documents. Participated in the development of mitigation strategies to protect construction and utility workers and the public during remediation, redevelopment, and use of the site, including buffer zones, subslab venting, rail berm containment structure, and an environmental oversight plan.
- Provided technical support for the investigation of a former sanitary landfill that was redeveloped as single family homes. Reviewed and/or prepared portions of numerous documents, including health risk assessments, preliminary endangerment assessments, site investigation reports, work plans, and RI/FSs. Historical research to identify historic waste disposal practices to prepare a preliminary endangerment assessment. Acquired, reviewed, and analyzed the files of 18 federal, state, and local agencies, three sets of construction field notes, analyzed 21 aerial photographs and interviewed 14 individuals associated with operation of former landfill. Assisted counsel in defending lawsuit brought by residents

alleging health impacts and diminution of property value due to residual contamination. Prepared summary reports.

- Technical oversight of characterization and remediation of a nitrate plume at an explosives manufacturing facility in Lincoln, CA. Provided interface between owners and consultants. Reviewed site assessments, work plans, closure plans, and RI/FSs.
- Consultant to owner of large western molybdenum mine proposed for NPL listing. Participated in negotiations to scope out consent order and develop scope of work. Participated in studies to determine premining groundwater background to evaluate applicability of water quality standards. Served on technical committees to develop alternatives to mitigate impacts and close the facility, including resloping and grading, various thickness and types of covers, and reclamation. This work included developing and evaluating methods to control surface runoff and erosion, mitigate impacts of acid rock drainage on surface and ground waters, and stabilize nine waste rock piles containing 328 million tons of pyrite-rich, mixed volcanic waste rock (andesites, rhyolite, tuff). Evaluated stability of waste rock piles. Represented client in hearings and meetings with state and federal oversight agencies.

REGULATORY (PARTIAL LIST)

- In April 2016, prepared supplemental comments on Valero Benicia Crude by Rail Project, focused on on-site impacts and impacts at the unloading terminal, in response to request for a stay to appeal Planning Commission decision.
- In February 2016, prepared comments on Final Environmental Impact Report, Santa Maria Rail Spur Project.
- In February 2016, prepared comments on Final Environmental Impact Report, Valero Benicia Crude by Rail Project.
- In January 2016, prepared comments on Draft Programmatic Environmental Impact Report for the Southern California Association of Government's (SCAG) 2016-2040 Regional Transportation Plan/Sustainable Communities Strategy.
- In November 2015, prepared comments on Final Environmental Impact Report for Revisions to the Kern County Zoning Ordinance – 2015(C) (Focused on Oil and Gas Local Permitting), November 2015.
- In October 2015, prepared comments on Revised Draft Environmental Report, Valero Benicia Crude by Rail Project.
- In September 2015, prepared report, "Environmental, Health and Safety Impacts of the Proposed Oakland Bulk and Oversized Terminal, and presented oral testimony on September 21, 2015 before Oakland City Council on behalf of the Sierra Club.

- In September 2015, prepared comments on revisions to two chapters of EPA's Air Pollution Control Cost Manual: Docket ID No. EPA-HQ-OAR-2015-0341.
- In June 2015, prepared comments on DEIR for the CalAm Monterey Peninsula Water Supply Project.
- In April 2015, prepared comments on proposed Title V Operating Permit Revision and Prevention of Significant Deterioration Permit for Arizona Public Service's Ocotillo Power Plant Modernization Project (5 GE LMS100 105-MW simple cycle turbines operated as peakers), in Tempe, Arizona.
- In March 2015, prepared "Comments on Proposed Title V Air Permit, Yuhuang Chemical Inc. Methanol Plant, St. James, Louisiana".
- In January 2015, prepared cost effectiveness analysis for SCR for a 500-MW coal fire power plant, to address unpermitted upgrades in 2000.
- In January 2015, prepared comments on Revised Final Environmental Impact Report for the Phillips 66 Propane Recovery Project.
- In December 2014, prepared "Report on Bakersfield Crude Terminal Permits to Operate." In response, the U.S. EPA cited the Terminal for 10 violations of the Clean Air Act.
- In December 2014, prepared comments on Revised Draft Environmental Impact Report for the Phillips 66 Propane Recovery Project.
- In November 2014, prepared comments on Revised Draft Environmental Impact Report for Phillips 66 Rail Spur Extension Project and Crude Unloading Project, Santa Maria, CA to allow the import of tar sands crudes.
- In November 2014, prepared comments on Draft Environmental Impact Report for Phillips 66 Ultra Low Sulfur Diesel Project, responding to the California Supreme Court Decision, *Communities for a Better Environment v. South Coast Air Quality Management Dist. (2010) 48 Cal.4th 310.*
- In November 2014, prepared comments on Draft Environmental Impact Report for the Tesoro Avon Marine Oil Terminal Lease Consideration.
- In October 2014, prepared: "Report on Hydrogen Cyanide Emissions from Fluid Catalytic Cracking Units", pursuant to the Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards, 79 FR 36880.
- In October 2014, prepared technical comments on Final Environmental Impact Reports for Alon Bakersfield Crude Flexibility Project to build a rail terminal to allow the import/export of tar sands and Bakken crude oils and to upgrade an existing refinery to allow it to process a wide range of crudes.

- In October 2014, prepared technical comments on the Title V Permit Renewal and three De Minimus Significant Revisions for the Tesoro Logistics Marine Terminal in the SCAQMD.
- In August 2014, for EPA Region 6, prepared technical report on costing methods for upgrades to existing scrubbers at coal-fired power plants.
- In July 2014, prepared technical comments on Draft Final Environmental Impact Reports for Alon Bakersfield Crude Flexibility Project to build a rail terminal to allow the import/export of tar sands and Bakken crude oils and to upgrade an existing refinery to allow it to process a wide range of crudes.
- In June 2014, prepared technical report on Initial Study and Draft Negative Declaration for the Tesoro Logistics Storage Tank Replacement and Modification Project.
- In May 2014, prepared technical comments on Intent to Approve a new refinery and petroleum transloading operation in Utah.
- In March and April 2014, prepared declarations on air permits issued for two crude-by-rail terminals in California, modified to switch from importing ethanol to importing Bakken crude oils by rail and transferring to tanker cars. Permits were issued without undergoing CEQA review. One permit was upheld by the San Francisco Superior Court as statute of limitations had run. The Sacramento Air Quality Management District withdrew the second one due to failure to require BACT and conduct CEQA review.
- In March 2014, prepared technical report on Negative Declaration for a proposed modification of the air permit for a bulk petroleum and storage terminal to the allow the import of tar sands and Bakken crude oil by rail and its export by barge, under the New York State Environmental Quality Review Act (SEQRA).
- In February 2014, prepared technical report on proposed modification of air permit for midwest refinery upgrade/expansion to process tar sands crudes.
- In January 2014, prepared cost estimates to capture, transport, and use CO2 in enhanced oil recovery, from the Freeport LNG project based on both Selexol and Amine systems.
- In January 2014, prepared technical report on Draft Environmental Impact Report for Phillips 66 Rail Spur Extension Project, Santa Maria, CA. Comments addressed project description (piecemealing, crude slate), risk of upset analyses, mitigation measures, alternative analyses and cumulative impacts.
- In November 2013, prepared technical report on3333 the Phillips 66 Propane Recovery Project, Rodeo, CA. Comments addressed project description (piecemealing, crude slate) and air quality impacts.
- In September 2013, prepared technical report on the Draft Authority to Construct Permit for the Casa Diablo IV Geothermal Development Project Environmental Impact Report and Declaration in Support of Appeal and Petition for Stay, U.S. Department of the Interior,

Board of Land Appeals, Appeal of Decision Record for the Casa Diablo IV Geothermal Development Project.

- In September 2013, prepared technical report on Effluent Limitation Guidelines for Best Available Technology Economically Available (BAT) for Bottom Ash Transport Waters from Coal-Fired Power Plants in the Steam Electric Power Generating Point Source Category.
- In July 2013, prepared technical report on Initial Study/Mitigated Negative Declaration for the Valero Crude by Rail Project, Benicia, California, Use Permit Application 12PLN-00063.
- In July 2013, prepared technical report on fugitive particulate matter emissions from coal train staging at the proposed Coyote Island Terminal, Oregon, for draft Permit No. 25-0015-ST-01.
- In July 2013, prepared technical comments on air quality impacts of the Finger Lakes LPG Storage Facility as reported in various Environmental Impact Statements.
- In July 2013, prepared technical comments on proposed Greenhouse Gas PSD Permit for the Celanese Clear Lake Plant, including cost analysis of CO2 capture, transport, and sequestration.
- In June/July 2013, prepared technical comments on proposed Draft PSD Preconstruction Permit for Greenhouse Gas Emission for the ExxonMobil Chemical Company Baytown Olefins Plant, including cost analysis of CO2 capture, transport, and sequestration.
- In June 2013, prepared technical report on a Mitigated Negative Declaration for a new rail terminal at the Valero Benicia Refinery to import increased amounts of "North American" crudes. Comments addressed air quality impacts of refining increased amounts of tar sands crudes.
- In June 2013, prepared technical report on Draft Environmental Impact Report for the California Ethanol and Power Imperial Valley 1 Project.
- In May 2013, prepared comments on draft PSD permit for major expansion of midwest refinery to process 100% tar sands crudes, including a complex netting analysis involving debottlenecking, piecemealing, and BACT analyses.
- In April 2013, prepared technical report on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Keystone XL Pipeline on air quality impacts from refining increased amount of tar sands crudes at Refineries in PADD 3.
- In October 2012, prepared technical report on the Environmental Review for the Coyote Island Terminal Dock at the Port of Morrow on fugitive particulate matter emissions.
- In October 2012-October 2014, review and evaluate Flint Hills West Application for an expansion/modification for increased (Texas, Eagle Ford Shale) crude processing and related modification, including netting and BACT analysis. Assist in settlement discussions.

- In February 2012, prepared comments on BART analysis in PA Regional Haze SIP, 77 FR 3984 (Jan. 26, 2012). On Sept. 29, 2015, a federal appeals court overturned the U.S. EPA's approval of this plan, based in part on my comments, concluding "..we will vacate the 2014 Final Rule to the extent it approved Pennsylvania's source-specific BART analysis and remand to the EPA for further proceedings consistent with this Opinion." Nat'l Parks Conservation Assoc. v. EPA, 3d Cir., No. 14-3147, 9/19/15.
- Prepared cost analyses and comments on New York's proposed BART determinations for NOx, SO2, and PM and EPA's proposed approval of BART determinations for Danskammer Generating Station under New York Regional Haze State Implementation Plan and Federal Implementation Plan, 77 FR 51915 (August 28, 2012).
- Prepared cost analyses and comments on NOx BART determinations for Regional Haze State Implementation Plan for State of Nevada, 77 FR 23191 (April 18, 2012) and 77 FR 25660 (May 1, 2012).
- Prepared analyses of and comments on New Source Performance Standards for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units, 77 FR 22392 (April 13, 2012).
- Prepared comments on CASPR-BART emission equivalency and NOx and PM BART determinations in EPA proposed approval of State Implementation Plan for Pennsylvania Regional Haze Implementation Plan, 77 FR 3984 (January 26, 2012).
- Prepared comments and statistical analyses on hazardous air pollutants (HAPs) emission controls, monitoring, compliance methods, and the use of surrogates for acid gases, organic HAPs, and metallic HAPs for proposed National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units, 76 FR 24976 (May 3, 2011).
- Prepared cost analyses and comments on NOx BART determinations and emission reductions for proposed Federal Implementation Plan for Four Corners Power Plant, 75 FR 64221 (October 19, 2010).
- Prepared cost analyses and comments on NOx BART determinations for Colstrip Units 1- 4 for Montana State Implementation Plan and Regional Haze Federal Implementation Plan, 77 FR 23988 (April 20, 2010).
- For EPA Region 8, prepared report: Revised BART Cost Effectiveness Analysis for Tail-End Selective Catalytic Reduction at the Basin Electric Power Cooperative Leland Olds Station Unit 2 Final Report, March 2011, in support of 76 FR 58570 (Sept. 21, 2011).
- For EPA Region 6, prepared report: Revised BART Cost-Effectiveness Analysis for Selective Catalytic Reduction at the Public Service Company of New Mexico San Juan Generating Station, November 2010, in support of 76 FR 52388 (Aug. 22, 2011).

- For EPA Region 6, prepared report: Revised BART Cost-Effectiveness Analysis for Flue Gas Desulfurization at Coal-Fired Electric Generating Units in Oklahoma: Sooner Units 1 & 2, Muskogee Units 4 & 5, Northeastern Units 3 &4, October 2010, in support of 76 FR 16168 (March 26, 2011). My work was upheld in: *State of Oklahoma v. EPA*, App. Case 12-9526 (10th Cri. July 19, 2013).
- Identified errors in N_2O emission factors in the Mandatory Greenhouse Gas Reporting Rule, 40 CFR 98, and prepared technical analysis to support Petition for Rulemaking to Correct Emissions Factors in the Mandatory Greenhouse Gas Reporting Rule, filed with EPA on 10/28/10.
- Assisted interested parties develop input for and prepare comments on the Information Collection Request for Petroleum Refinery Sector NSPS and NESHAP Residual Risk and Technology Review, 75 FR 60107 (9/29/10).
- Technical reviewer of EPA's "Emission Estimation Protocol for Petroleum Refineries," posted for public comments on CHIEF on 12/23/09, prepared in response to the City of Houston's petition under the Data Quality Act (March 2010).
- Prepared comments on SCR cost effectiveness for EPA's Advanced Notice of Proposed Rulemaking, Assessment of Anticipated Visibility Improvements at Surrounding Class I Areas and Cost Effectiveness of Best Available Retrofit Technology for Four Corners Power Plant and Navajo Generating Station, 74 FR 44313 (August 28, 2009).
- Prepared comments on Proposed Rule for Standards of Performance for Coal Preparation and Processing Plants, 74 FR 25304 (May 27, 2009).
- Prepared comments on draft PSD permit for major expansion of midwest refinery to process up to 100% tar sands crudes. Participated in development of monitoring and controls to mitigate impacts and in negotiating a Consent Decree to settle claims in 2008.
- Reviewed and assisted interested parties prepare comments on proposed Kentucky air toxic regulations at 401 KAR 64:005, 64:010, 64:020, and 64:030 (June 2007).
- Prepared comments on proposed Standards of Performance for Electric Utility Steam Generating Units and Small Industrial-Commercial-Industrial Steam Generating Units, 70 FR 9706 (February 28, 2005).
- Prepared comments on Louisville Air Pollution Control District proposed Strategic Toxic Air Reduction regulations.
- Prepared comments and analysis of BAAQMD Regulation, Rule 11, Flare Monitoring at Petroleum Refineries.
- Prepared comments on Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary

Sources: Electricity Utility Steam Generating Units (MACT standards for coal-fired power plants).

- Prepared Authority to Construct Permit for remediation of a large petroleum-contaminated site on the California Central Coast. Negotiated conditions with agencies and secured permits.
- Prepared Authority to Construct Permit for remediation of a former oil field on the California Central Coast. Participated in negotiations with agencies and secured permits.
- Prepared and/or reviewed hundreds of environmental permits, including NPDES, UIC, Stormwater, Authority to Construct, Prevention of Significant Deterioration, Nonattainment New Source Review, Title V, and RCRA, among others.
- Participated in the development of the CARB document, *Guidance for Power Plant Siting and Best Available Control Technology*, including attending public workshops and filing technical comments.
- Performed data analyses in support of adoption of emergency power restoration standards by the California Public Utilities Commission for "major" power outages, where major is an outage that simultaneously affects 10% of the customer base.
- Drafted portions of the Good Neighbor Ordinance to grant Contra Costa County greater authority over safety of local industry, particularly chemical plants and refineries.
- Participated in drafting BAAQMD Regulation 8, Rule 28, Pressure Relief Devices, including participation in public workshops, review of staff reports, draft rules and other technical materials, preparation of technical comments on staff proposals, research on availability and costs of methods to control PRV releases, and negotiations with staff.
- Participated in amending BAAQMD Regulation 8, Rule 18, Valves and Connectors, including participation in public workshops, review of staff reports, proposed rules and other supporting technical material, preparation of technical comments on staff proposals, research on availability and cost of low-leak technology, and negotiations with staff.
- Participated in amending BAAQMD Regulation 8, Rule 25, Pumps and Compressors, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak and seal-less technology, and negotiations with staff.
- Participated in amending BAAQMD Regulation 8, Rule 5, Storage of Organic Liquids, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of controlling tank emissions, and presentation of testimony before the Board.

- Participated in amending BAAQMD Regulation 8, Rule 18, Valves and Connectors at Petroleum Refinery Complexes, including participation in public workshops, review of staff reports, proposed rules and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak technology, and presentation of testimony before the Board.
- Participated in amending BAAQMD Regulation 8, Rule 22, Valves and Flanges at Chemical Plants, etc, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability and costs of low-leak technology, and presentation of testimony before the Board.
- Participated in amending BAAQMD Regulation 8, Rule 25, Pump and Compressor Seals, including participation in public workshops, review of staff reports, proposed rules, and other supporting technical material, preparation of technical comments on staff proposals, research on availability of low-leak technology, and presentation of testimony before the Board.
- Participated in the development of the BAAQMD Regulation 2, Rule 5, Toxics, including participation in public workshops, review of staff proposals, and preparation of technical comments.
- Participated in the development of SCAQMD Rule 1402, Control of Toxic Air Contaminants from Existing Sources, and proposed amendments to Rule 1401, New Source Review of Toxic Air Contaminants, in 1993, including review of staff proposals and preparation of technical comments on same.
- Participated in the development of the Sunnyvale Ordinance to Regulate the Storage, Use and Handling of Toxic Gas, which was designed to provide engineering controls for gases that are not otherwise regulated by the Uniform Fire Code.
- Participated in the drafting of the Statewide Water Quality Control Plans for Inland Surface Waters and Enclosed Bays and Estuaries, including participation in workshops, review of draft plans, preparation of technical comments on draft plans, and presentation of testimony before the SWRCB.
- Participated in developing Se permit effluent limitations for the five Bay Area refineries, including review of staff proposals, statistical analyses of Se effluent data, review of literature on aquatic toxicity of Se, preparation of technical comments on several staff proposals, and presentation of testimony before the Bay Area RWQCB.
- Represented the California Department of Water Resources in the 1991 Bay-Delta Hearings before the State Water Resources Control Board, presenting sworn expert testimony with cross examination and rebuttal on a striped bass model developed by the California Department of Fish and Game.

- Represented the State Water Contractors in the 1987 Bay-Delta Hearings before the State Water Resources Control Board, presenting sworn expert testimony with cross examination and rebuttal on natural flows, historical salinity trends in San Francisco Bay, Delta outflow, and hydrodynamics of the South Bay.
- Represented interveners in the licensing of over 20 natural-gas-fired power plants and one coal gasification plant at the California Energy Commission and elsewhere. Reviewed and prepared technical comments on applications for certification, preliminary staff assessments, final staff assessments, preliminary determinations of compliance, final determinations of compliance, and prevention of significant deterioration permits in the areas of air quality, water supply, water quality, biology, public health, worker safety, transportation, site contamination, cooling systems, and hazardous materials. Presented written and oral testimony in evidentiary hearings with cross examination and rebuttal. Participated in technical workshops.
- Represented several parties in the proposed merger of San Diego Gas & Electric and Southern California Edison. Prepared independent technical analyses on health risks, air quality, and water quality. Presented written and oral testimony before the Public Utilities Commission administrative law judge with cross examination and rebuttal.
- Represented a PRP in negotiations with local health and other agencies to establish impact of subsurface contamination on overlying residential properties. Reviewed health studies prepared by agency consultants and worked with agencies and their consultants to evaluate health risks.

WATER QUALITY/RESOURCES

- Directed and participated in research on environmental impacts of energy development in the Colorado River Basin, including contamination of surface and subsurface waters and modeling of flow and chemical transport through fractured aquifers.
- Played a major role in Northern California water resource planning studies since the early 1970s. Prepared portions of the Basin Plans for the Sacramento, San Joaquin, and Delta basins including sections on water supply, water quality, beneficial uses, waste load allocation, and agricultural drainage. Developed water quality models for the Sacramento and San Joaquin Rivers.
- Conducted hundreds of studies over the past 40 years on Delta water supplies and the impacts of exports from the Delta on water quality and biological resources of the Central Valley, Sacramento-San Joaquin Delta, and San Francisco Bay. Typical examples include:

    1. Evaluate historical trends in salinity, temperature, and flow in San Francisco Bay and upstream rivers to determine impacts of water exports on the estuary;

2. Evaluate the role of exports and natural factors on the food web by exploring the relationship between salinity and primary productivity in San Francisco Bay, upstream rivers, and ocean;
3. Evaluate the effects of exports, other in-Delta, and upstream factors on the abundance of salmon and striped bass;
4. Review and critique agency fishery models that link water exports with the abundance of striped bass and salmon;
5. Develop a model based on GLMs to estimate the relative impact of exports, water facility operating variables, tidal phase, salinity, temperature, and other variables on the survival of salmon smolts as they migrate through the Delta;
6. Reconstruct the natural hydrology of the Central Valley using water balances, vegetation mapping, reservoir operation models to simulate flood basins, precipitation records, tree ring research, and historical research;
7. Evaluate the relationship between biological indicators of estuary health and down-estuary position of a salinity surrogate (X2);
8. Use real-time fisheries monitoring data to quantify impact of exports on fish migration;
9. Refine/develop statistical theory of autocorrelation and use to assess strength of relationships between biological and flow variables;
10. Collect, compile, and analyze water quality and toxicity data for surface waters in the Central Valley to assess the role of water quality in fishery declines;
11. Assess mitigation measures, including habitat restoration and changes in water project operation, to minimize fishery impacts;
12. Evaluate the impact of unscreened agricultural water diversions on abundance of larval fish;
13. Prepare and present testimony on the impacts of water resources development on Bay hydrodynamics, salinity, and temperature in water rights hearings;
14. Evaluate the impact of boat wakes on shallow water habitat, including interpretation of historical aerial photographs;
15. Evaluate the hydrodynamic and water quality impacts of converting Delta islands into reservoirs;
16. Use a hydrodynamic model to simulate the distribution of larval fish in a tidally influenced estuary;
17. Identify and evaluate non-export factors that may have contributed to fishery declines, including predation, shifts in oceanic conditions, aquatic toxicity from

pesticides and mining wastes, salinity intrusion from channel dredging, loss of riparian and marsh habitat, sedimentation from upstream land alternations, and changes in dissolved oxygen, flow, and temperature below dams.

- Developed, directed, and participated in a broad-based research program on environmental issues and control technology for energy industries including petroleum, oil shale, coal mining, and coal slurry transport. Research included evaluation of air and water pollution, development of novel, low-cost technology to treat and dispose of wastes, and development and application of geohydrologic models to evaluate subsurface contamination from in-situ retorting. The program consisted of government and industry contracts and employed 45 technical and administrative personnel.
- Coordinated an industry task force established to investigate the occurrence, causes, and solutions for corrosion/erosion and mechanical/engineering failures in the waterside systems (e.g., condensers, steam generation equipment) of power plants. Corrosion/erosion failures caused by water and steam contamination that were investigated included waterside corrosion caused by poor microbiological treatment of cooling water, steam-side corrosion caused by ammonia-oxygen attack of copper alloys, stress-corrosion cracking of copper alloys in the air cooling sections of condensers, tube sheet leaks, oxygen in-leakage through condensers, volatilization of silica in boilers and carry over and deposition on turbine blades, and iron corrosion on boiler tube walls. Mechanical/engineering failures investigated included: steam impingement attack on the steam side of condenser tubes, tube-to-tube-sheet joint leakage, flow-induced vibration, structural design problems, and mechanical failures due to stresses induced by shutdown, startup and cycling duty, among others. Worked with electric utility plant owners/operators, condenser and boiler vendors, and architect/engineers to collect data to document the occurrence of and causes for these problems, prepared reports summarizing the investigations, and presented the results and participated on a committee of industry experts tasked with identifying solutions to prevent condenser failures.
- Evaluated the cost effectiveness and technical feasibility of using dry cooling and parallel dry-wet cooling to reduce water demands of several large natural-gas fired power plants in California and Arizona.
- Designed and prepared cost estimates for several dry cooling systems (e.g., fin fan heat exchangers) used in chemical plants and refineries.
- Designed, evaluated, and costed several zero liquid discharge systems for power plants.
- Evaluated the impact of agricultural and mining practices on surface water quality of Central Valley steams. Represented municipal water agencies on several federal and state advisory committees tasked with gathering and assessing relevant technical information, developing work plans, and providing oversight of technical work to investigate toxicity issues in the watershed.

AIR QUALITY/PUBLIC HEALTH

- Prepared or reviewed the air quality and public health sections of hundreds of EIRs and EISs on a wide range of industrial, commercial and residential projects.
- Prepared or reviewed hundreds of NSR and PSD permits for a wide range of industrial facilities.
- Designed, implemented, and directed a 2-year-long community air quality monitoring program to assure that residents downwind of a petroleum-contaminated site were not impacted during remediation of petroleum-contaminated soils. The program included real-time monitoring of particulates, diesel exhaust, and BTEX and time integrated monitoring for over 100 chemicals.
- Designed, implemented, and directed a 5-year long source, industrial hygiene, and ambient monitoring program to characterize air emissions, employee exposure, and downwind environmental impacts of a first-generation shale oil plant. The program included stack monitoring of heaters, boilers, incinerators, sulfur recovery units, rock crushers, API separator vents, and wastewater pond fugitives for arsenic, cadmium, chlorine, chromium, mercury, 15 organic indicators (e.g., quinoline, pyrrole, benzo(a)pyrene, thiophene, benzene), sulfur gases, hydrogen cyanide, and ammonia. In many cases, new methods had to be developed or existing methods modified to accommodate the complex matrices of shale plant gases.
- Conducted investigations on the impact of diesel exhaust from truck traffic from a wide range of facilities including mines, large retail centers, light industrial uses, and sports facilities. Conducted traffic surveys, continuously monitored diesel exhaust using an aethalometer, and prepared health risk assessments using resulting data.
- Conducted indoor air quality investigations to assess exposure to natural gas leaks, pesticides, molds and fungi, soil gas from subsurface contamination, and outgasing of carpets, drapes, furniture and construction materials. Prepared health risk assessments using collected data.
- Prepared health risk assessments, emission inventories, air quality analyses, and assisted in the permitting of over 70 1 to 2 MW emergency diesel generators.
- Prepare over 100 health risk assessments, endangerment assessments, and other health-based studies for a wide range of industrial facilities.
- Developed methods to monitor trace elements in gas streams, including a continuous real-time monitor based on the Zeeman atomic absorption spectrometer, to continuously measure mercury and other elements.

- Performed nuisance investigations (odor, noise, dust, smoke, indoor air quality, soil contamination) for businesses, industrial facilities, and residences located proximate to and downwind of pollution sources.

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Design of Gas Turbine Combined Cycle and Cogeneration Systems, Thermoflow, 12/00
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Noise Exposure Assessment: Sampling Strategy and Data Acquisition, AIHA PDC 205, 6/02
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McIlvaine Hot Topic Hour, Mercury Control, 4/24/08
McIlvaine Hot Topic Hour, Co-Firing Biomass, 5/1/08
McIlvaine Hot Topic Hour, Coal Gasification, 6/5/08
McIlvaine Hot Topic Hour, Spray Driers vs. CFBs, 7/3/08
McIlvaine Hot Topic Hour, Air Pollution Control Cost Escalation, 9/25/08
McIlvaine Hot Topic Hour, Greenhouse Gas Strategies for Coal Fired Power Plant Operators, 10/2/08
McIlvaine Hot Topic Hour, Mercury and Toxics Monitoring, 2/5/09
McIlvaine Hot Topic Hour, Dry Precipitator Efficiency Improvements, 2/12/09
McIlvaine Hot Topic Hour, Coal Selection & Impact on Emissions, 2/26/09
McIlvaine Hot Topic Hour, 98% Limestone Scrubber Efficiency, 7/9/09
McIlvaine Hot Topic Hour, Carbon Management Strategies and Technologies, 6/24/10
McIlvaine Hot Topic Hour, Gas Turbine O&M, 7/22/10
McIlvaine Hot Topic Hour, Industrial Boiler MACT – Impact and Control Options, March 10, 2011
McIlvaine Hot Topic Hour, Fuel Impacts on SCR Catalysts, June 30, 2011.

Interest Rates, PDH P204, 3/9/12
Mechanics Liens, PDHOnline, 2/24/13.
Understanding Concerns with Dry Sorbent Injection as a Coal Plant Pollution Control, Webinar #874-567-839 by Cleanenergy.Org, March 4, 2013
Webinar: Coal-to-Gas Switching: What You Need to Know to Make the Investment, sponsored by PennWell Power Engineering Magazine, March 14, 2013. Available at: https://event.webcasts.com/viewer/event.jsp?ei=1013472.

To: Adams, Broadwell, Joseph & Cardozo

From: Robert Earle

Date: June 17, 2019

Re: MND Response

On April 4th , 2019 I submitted a memo commenting on the proposed Mitigated Negative Declaration ("MND") prepared for the 1150 Walsh Avenue SV1 Data Center data (titled Silicon Valley Power CO_2 Emission Rates in 2017 and 2020. ("Memo")). In June 2019, the City of Santa Clara responded to comments to the MND. I reviewed the City of Santa Clara's response to my Memo on the MND, The City of Santa Clara appears only to have one response:[1]

> Indirect GHG emissions from SVP power generation were estimated based on actual emissions rates provided by SVP from the most recent available data (2017) and future emissions rates predicted by SVP based on their current and planned renewable portfolio, consistent with their adopted strategic plan and consistent with statewide regulatory requirements. This constitutes substantial evidence that the rates used in the IS/proposed MND are reasonable and demonstrates a good faith effort to predict indirect GHG emissions attributable to the project.

This MND response does not address the technical analysis in the Memo at all. It merely states what the source of the data in the MND was and that the data was used in good faith. For example, the MND does not address the issue that the estimate for 348 lbs-CO_2/MWh for Silicon Valley Power ("SVP") as a whole in 2020 is likely too low because the SVP Integrated Resource Plan ("IRP") uses an emissions rate for market purchases far below that mandated by the California Energy Commission (CEC). Using the CEC mandated emissions rate for market purchases results in an emissions rate of 465 lbs-CO_2/MWh. As another example, contrary to the assertion in the MND response, that "the emissions rates predicted by SVP…[are] consistent with statewide regulatory requirements," the Memo shows that the SVP IRP potentially does not meet statewide regulatory requirements stemming from SB 350. This is because the IRP does not count any emissions from market purchases in considering whether the plan meets regulatory emissions targets. As a result, while data obtained from SVP may have been used in good faith, based on my Memo, it is clear that the

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[1] MND response 4-31, pdf page 160.

indirect GHG emissions from the SV1 Data Center are understated, and will likely exceed the estimates used in the MND.

ROBERT EARLE, PH.D.

Dr. Earle is an economist with extensive experience in the energy and telecomm sectors including valuation, environmental mitigation methods and costs, and regulatory economics. Having worked as a consultant as well as an industry manager, he currently supports clients in analyzing market opportunities, strategy, regulatory issues, and litigation. His areas of expertise include electric power sector modeling, economics of environmental mitigation, electric power and gas markets, regulatory policy and ratemaking, demand response, and system optimization.

Dr. Earle has also worked extensively on tariff and market design, including as an expert witness before a number of regulatory commissions. He was the architect of an economic model used to evaluate alternative methods for environmental mitigation including BPM/BACT technology, incentives, and markets. Results from this work were used in numerous studies for investment decisions, policy studies, and litigation.

Dr. Earle was manager of economic analysis at the California Power Exchange where his responsibilities included developing an overall analytic infrastructure for market analysis, analysis of new products, and briefing regulatory and legislative bodies. Dr. Earle holds Ph.D. and M.S. degrees in Operations Research, both from Stanford University.

EDUCATION

Ph.D.	Operations Research, Stanford University
M.S.	Operations Research, Stanford University
A.B.	Mathematics, the College of William & Mary

REPRESENTATIVE PAST EXPERIENCE

Electricity Sector Structure and Regulation

- Advised in the development of transmission strategy for several renewables companies in the United States and Canada (wind and biomass) including analysis of transmission access, planning, cost allocation and siting conditions in regions in North America.
- Developed transmission pricing structure for Saudi Electric Company.
- Advised clients in Canada, the Middle East, and the United States on transmission pricing structures.
- Conducted numerous demand response potential and valuation studies for utilities across the United States.
- Analyzed energy efficiency potential in the Southeast for environmental and ratepayer advocates.
- Provided expert testimony on energy efficiency incentives for Oklahoma Gas & Electric.
- Led analysis for Midwest ISO of wholesale market interface with demand response.

Bidding/Auction Design and Analysis, Market Modeling

- Conducted detailed studies of participant bidding behavior for the purpose of product development, policy changes, and investigations. The results of these studies were used to establish standard

methodologies for staff to use. In addition, Dr. Earle invented new techniques for characterizing bids to examine product ideas and various alternative market structures.

- Led the development of a new type of multivariate statistical model to track market changes and rigorously assess auction participant behavior. Reflecting the auction structure, this model uniquely codetermined all prices at the same time. To do this, a number of new statistical techniques were created.
- Advised two merging companies needing advice on divestiture of their generation assets with respect to both asset value and issues of strategic behavior. For this purpose, Dr. Earle designed and implemented an oligopoly simulation of the market. This game theoretic model explicitly represents company strategies and interactions in the marketplace. Dr. Earle's findings were used to shape the decisions of the investment bank in selling the merged companies' assets and win regulatory approval.

Environment

- Architect of economic model used to evaluate alternative methods for environmental mitigation including BPM/BACT technology, incentives, and markets. Results from this work were used in numerous studies for investment decisions, policy studies, and litigation.
- Advised clients on approaches to environmental mitigation in the oil, electric power, and water sectors.
- Managed a 2-year project to develop a carbon mitigation strategy for a major country in the Middle East.
- Managed a successful water privatization for a city of five million where environmental concerns formed a key part of the privatization effort.

Valuation of Assets, Market Strategies

- For the Electric Power Research Institute (EPRI), developed a methodology for the valuation of alternative market strategies for hydroelectric power plants using stochastic dynamic programming. The changing dynamics of the electricity market, in particular the structure of electricity prices, may have significant implications for the value of a technology that can store energy and release it according to market conditions, thereby leading to a premium value for such resources. The methodology Dr. Earle developed was published in an EPRI report.
- Assessed the impact of market structure changes on plant value that resulted in the restructuring of a bid for generation assets.
- As a result of reorganization, a utility company needed help in valuation of its load management technology and program. At the time, its program was one of the top five in the United States. Dr. Earle directed a team to conduct market research on this technology and teach a class on its current status. As a follow-on, Dr. Earle acted as a facilitator to the client in their development of a valuation methodology. This project resulted in the client deciding to phase-out its efforts in this area.

Corporate Strategy

- In preparation for deregulation of the generation sector in the power industry, Dr. Earle co-led a team to formulate valuation and corporate asset deployment strategies for a $5 billion southeastern utility. The various options considered included: asset spin-off, divestiture, mergers, and acquisitions. Different scenarios implied different trade-offs among the business units of the company. This required extensive financial modeling of the various options and sensitivity to the client's cultural

issues in order to reach a unified decision. These recommendations were adopted by the board as the basis for ongoing company strategy.

- Conducted market research for a company that was considering starting an energy brokerage in California. Key issues investigated were market size and structure, first mover advantage, and risk. As a result of this work, the company selected an effective start-up strategy for its new operation in California.

- Reporting to the CEO, co-negotiated a settlement calculation involving a billion dollars. Co-wrote the filing implementing the settlement and then coordinated its implementation through the IT and settlements process.

EXPERT TESTIMONY

- Before the California Public Utilities Commission, on behalf of the Coalition of California Utility Employees, concerning the Power Charge Indifference Adjustment.
- Before the Ohio Public Utilities Commission, on behalf of FirstEnergy, concerning the market for renewable energy credits.
- Before the District Court in Dallas, Texas, on behalf of O Mart, submitted an expert affidavit concerning the appropriate method to value a breach of an electric power purchase contract.
- Before the Superior Court of California in Los Angeles County, on behalf of several municipal utilities, submitted two expert reports on the structure of California electricity markets and on certain transactions in the California electricity marketplace.
- Before the Oklahoma Corporation Commission, on behalf of Oklahoma Gas & Electric, concerning cost recovery and shareholder incentives for DSM programs.
- Before the Public Utilities Commission of Texas, on behalf of El Paso Electric, concerning the capacity value of certain electric power contracts in a fuel cost reconciliation proceeding.
- Before the Federal Energy Regulatory Commission, on behalf of El Paso Electric, concerning the effect of certain power market transactions on California and western markets and the effect of information sharing on California markets.
- Before the New Brunswick Public Utilities Board, on behalf of J.D. Irving, Ltd. and the Canadian Manufacturers and Exporters, concerning the transmission tariff application by New Brunswick Power.

PUBLICATIONS AND PRESENTED PAPERS

"Hydraulic Fracturing: the regulatory year in review," *Oil and Gas Financial Journal*, January 2012, Vol. 9, No. 1.

"How not to improve surface water quality," with Virginia Perry-Failor, *Regulation*, Fall 2010, Cato Institute Press.

"The Costs of Compliance to EPA's Advance Notice of Proposed Rulemaking on the PCB Use Authorization for Interstate Natural Gas Pipelines," with Susan Tierney, prepared on behalf of the Interstate Natural Gas Association of America ("INGAA"), September 10, 2010.

"Demand Response on Steroids: Extra Value from using the Smart Grid?," *Natural Gas and Electricity*, February 2010.

"Measuring the Capacity Impacts of Demand Response," with Ed Kahn and Edo Macan, *Electricity Journal*, June 2009.

"Ethanol 2.0," with Ahmad Faruqui, *Regulation*, Winter 2008, Cato Institute Press.

"Fostering Economic Demand Response in the Midwest ISO," with Sam Newell, Ahmad Faruqui, Attila Hajos, and Ryan Hledik, prepared for the Midwest ISO, December 30, 2008.

"Transforming America's Power Industry: The Investment Challenge 2010-2030," with Mark Chupka, Peter Fox-Penner, and Ryan Hledik, prepared for the Edison Foundation, November 2008.

"The Role of Expectations in Modeling Costs of Climate Change Policies," with Paul Bernstein and David Montgomery, to appear in *Integrated Assessment of Human-induced Climate Change*, Cambridge University Press, 2007.

"On Price Caps under Uncertainty," with Karl Schmedders and Tymon Tatur, *Review of Economic Studies*, January 2007.

"Demand Response and Advance Metering," with Ahmad Faruqui, *Regulation*, The Cato Institute, Spring 2006.

"Toward a New Paradigm for Valuing Demand Response," with Ahmad Faruqui, *The Electricity Journal*, May 2006.

"Rate Case Mania," with Ahmad Faruqui, *Public Utilities Fortnightly*, February 2006.

"Controlling the Thirst for Demand," with Anees Azzouni and Ahmad Faruqui, *Middle East Economic Digest*, December 2, 2005.

"Reforming Electricity Pricing in the Middle East," with Anees Azzouni and Ahmad Faruqui, *Middle East Economic Survey*, December 5, 2005.

"Ontario Demand-Supply Balance Update: Where will the hot trading occur?," Interjurisdictional Power Transaction Conference, The Canadian Institute, Toronto, invited talk, April 8, 2002.

"Price Caps and Uncertain Demand," with Karl Schmedders and Tymon Tatur, Discussion Paper #1340, CMS-EMS: The Center for Mathematical Studies in Economics and Management Sciences, Kellogg School of Management, Northwestern University, March 6, 2002.

"Demand Uncertainty and Risk-Aversion: Why Price Caps May Lead to Higher Prices," with Karl Schmedders, Discussion Paper #1330, CMS-EMS: The Center for Mathematical Studies in Economics and Management Sciences, Kellogg School of Management, Northwestern University, October 2, 2001.

"Demand Elasticity in the California Day-Ahead Market," *Electricity Journal*, October 2000.

"Electric Power Deregulation and Market Monitoring," with Philip Q. Hanser and James D. Reitzes, *Electricity Journal*, October 2000.

"How Many Firms Are Enough?—Deregulating Electric Generation," with Philip Q. Hanser and James D. Reitzes, Western Economic Association Conference, Vancouver, B.C., July 2000.

"Review of Price Behavior in the California Power Exchange," Western Power Trading Forum, invited talk, May 2000.

"Electric Power Restructuring: Industrial Organization," Department of Management and Strategy, Kellogg School of Management, Northwestern University, invited talk, April 26, 2000.

"Reply to Borenstein and Bushnell," with Philip Q. Hanser and James D. Reitzes, *Electricity Journal*, March 2000.

"Market Power Basics," IEEE Los Angeles Chapter, invited talk, March 14, 2000.

"Lessons from the Early Days of Competition in California," with Philip Q. Hanser, Weldon C. Johnson, and James D. Reitzes, *Electricity Journal*, October 1999.

"Optionality in Energy and Ancillary Services Markets," with Jason A. Hicks, Deregulation Progress Report: Issues and Insights Conference, invited talk, August 4, 1999.

"Measuring Market Power: Back to the Basics," with Jason A. Hicks, invited talk, Deregulation Progress Report: Issues and Insights Conference, August 4, 1999.

Mechanisms for Evaluating the Role of Hydroelectric Generation in Ancillary Services Markets, with R.P. Broehm, F.C. Graves, T.J. Jenkin, and D.M. Murphy, EPRI, Palo Alto, CA: 1998. Report TR-111707.

"Power Market Price Forecasting: Pitfalls and Unresolved Issues," with Frank C. Graves and Philip Q. Hanser, *USAEE/IAEE Annual North American Conference Proceedings*, October 1998.

"Capacity Expansion/Investment Dynamics: Price Forecasting in Deregulated Electric Power Markets," presentation to Market Price Forecasting Conference, Baltimore, Maryland, August 25, 1998.

"Planning Reserve Requirements in a Deregulated Industry: One-Part vs. Two-Part Pricing -or- How I Learned to Stop Worrying and Love Regulation," with Frank C. Graves and Philip Q. Hanser, presentation to ISO Operations, Planning, and Design: An MIT Energy Laboratory, Massachusetts Institute of Technology, June 10, 1998.

"One-Part Markets for Electric Power: Ensuring the Benefits of Competition," with Frank C. Graves, Philip Q. Hanser, and E. Grant Read, in *Power Systems Restructuring: Engineering and Economics*, Marija Ilic, Francisco Galiana, and Lester Fink, eds., Kluwer Academic Publishers, Boston, 1998.

"Computation of Electric Power Production Cost with Transmission Constraints," Energy Modeling Forum, Stanford University, EMF-SR6, December 1996.

TEACHING

Guest lecturer for Master's level seminars, Department of Quantitative Business Administration, University of Zurich

○ Reinforcement Learning	Autumn 2017
○ Neural Networks and Deep Learning	Spring 2017
○ Machine Learning for Managers	Autumn 2016, Spring 2018
○ Methods in Economic Consulting	Autumn 2015

POSITIONS HELD

2009-2015	Analysis Group, Vice President
2007-2009	Brattle Group, Principal and San Francisco Office Director
2001-2007	Charles River Associates, Principal
1999-2001	California Power Exchange, Manager of Economic Analysis
1997-1999	Brattle Group, Associate