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TN #:	223851
Document Title:	Request for Reconsideration of Commission's Treatment of Proposed Exception 5 to Section 140.9(a)1
Description:	Request for Reconsideration of Commission's Treatment of Proposed Exception 5 to Section 140.9(a)1 to the 2019 Energy Efficiency Building Standards in Resolution Adopting Negative Declaration and Proposed Regulation (May 17, 2018)
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BENEDICT J. DOLCICH, P.E.
Director, Lifecycle Engineering-Thermal Products
O + 614 841-5789
M + 614 325-1452
E ben.dolcich@Vertivco.com

June 18, 2018
California Energy Commission
1516 Ninth Street, MS 34
Sacramento, CA 95814

Re: Docket No. 17-BSTD-02 – Request for Reconsideration of Commission's Treatment of Proposed Exception 5 to Section 140.9(a)1 to the 2019 Energy Efficiency Building Standards in Resolution Adopting Negative Declaration and Proposed Regulation (May 17, 2018)

Dear Commissioners:

On May 17, 2018, the California Energy Commission ("Commission") issued a Resolution Adopting Negative Declaration and Proposed Regulations in Docket No. 17-BTSD-2 ("Resolution"). The Resolution, among other things, omitted a Proposed Exception 5 to Section 140.9(a) of the Energy Efficiency Building Standards for Residential and Non Residential Buildings ("2019 Energy Efficiency Standards"). The omitted Exception 5 – initially proposed for adoption but removed at the last minute – reads as follows:

"A computer room located in Climate Zones 1-9, 11-14, and 16 may be served by an integrated pumped refrigerant economizer certified by AHRI using AHRI 1360."

Liebert Corporation ("Liebert"), a wholly-owned subsidiary of Vertiv Group Corporation ("Vertiv"), formerly known as Emerson Network Power ("Emerson"), manufactures data center cooling systems with integrated pumped refrigerant economizers ("PREs") particularly the Liebert DSE. Liebert respectfully asks the Commission to reconsider this aspect of its May 17 Resolution. The last-minute excision of Proposed Exception 5 appears to be based entirely on a February 7, 2018 letter submitted in this docket by Mr. Jeff Stein of Taylor Engineering, alleging that Liebert's PREs are ineligible for such an exception, and therefore asserting that no market participants should be eligible for a PRE exception. As more fully set forth herein, we submit this letter to (a) rebut the erroneous and unsupportable allegations set forth in Stein's February 17 letter and (b) ask the Commission to reinstate Proposed Exception 5 in the 2019 Energy Efficiency Standards to be sent to Building Standards Commission.

<u>Background</u>

Liebert and Vertiv design, build and service infrastructure for data centers, communications networks, and commercial and industrial facilities. For years, we have worked collaboratively with the Commission to ensure that their products meet or exceed applicable laws and the Commission's regulations. When appropriate, Liebert and Vertiv have sought and received approval of compliance options for new products and service offerings that improve energy efficiency.

PRE technologies have been deployed around the world since 2012 to deliver thermal management benefits to data center cooling systems at an efficiency level that meets or exceeds traditional economization methods. Because PREs were not included in the Commission's 2013 Building Energy Efficiency Standards for Residential and Non Residential Buildings, Emerson (now Vertiv) submitted an application to the Commission asking that PREs be approved for use in computer rooms as an alternative component package to airside and waterside economizers. Commission staff launched a comprehensive public process, during which the company worked closely with Commission staff to address questions, and during which Emerson provided extensive data supporting its proposal. The application was made available to the public for a 60 day comment period,[1] and Commission staff prepared a report analyzing PREs as an alternate component package.[2] Based on these extensive materials, Commission staff and the Commission's Executive Director recommended that PREs be approved as an alternative component package.[3] On September 9, 2015, the Commission approved the use of PREs in data rooms in 14 of California's 16 Climate Zones.[4] This Commission approval was not challenged, and remains in effect. The Commission's 2015 Resolution is attached hereto as Exhibit A.

Docket No. 17-BTSD-2

On December 15, 2017, the Commission opened a new docket for its triennial update of the Energy Efficiency Building Standards for Residential and Non Residential Buildings ("2019 Energy Efficiency Standards"). Commission staff proposed to codify in the forthcoming (2019) Energy Efficiency Standards the previously obtained Commission approval to use PREs in most of California's climate zones.

On January 18, 2018, Commission staff issued its Initial Statement of Reasons ("ISOR"), which included its recommendation that the Commission adopt proposed Exception 5 to Section 140.9(a)1. Consistent with the Commission's 2015 approval of refrigerant economizers for use in computer rooms in certain climate zones, the Commission staff's proposal stated that "A computer room located in Climate Zones 1-9, 11-14, and 16 may be served by an integrated pumped refrigerant economizer certified by AHRI using AHRI 1360." The ISOR recommended adoption of the PRE exception because it:

> "allow[s] the use of refrigerant-based economizers to satisfy requirements for economizing, in climate zones where this equipment will provide the same or superior energy benefits as use of traditional economizing technologies. The use of pumped refrigerant economizers was approved by the Commission during

[1] *Resolution of the Energy Commission Approving Recommendation by the Executive Director to Approve Refrigerant Economizers As An Alternative Component Package for Use in Computer Rooms in Certain Climate Zones* ("2015 Resolution"), Docket No. 15-MISC-03 (Sept. 9, 2015) at page 1.
[2] Mark Alatorre, P.E., *Pumped Refrigerant Economizers for Use in Computer Rooms,* CEC-400-2015-029, California Energy Commission, (Aug. 2015).
[3] 2015 Resolution at page 1.
[4] *Id.* at page 2.

> the 2013 Standards cycle as a compliance option. *This change is necessary to allow additional approaches to economizing, and is therefore is necessary to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy consistent with Public Resources Code §25402*." ISOR at 67 (emphasis added).

On February 7, 2018, Jeff Stein, a principal of Taylor Engineering, submitted comments objecting to the Commission's inclusion of Exception 5. Taylor Engineering is a California engineering firm that both develops data room cooling systems utilizing directly competing technologies to PREs, and has also previously served as a consultant to the Commission, in fact recommending in 2015 that the Commission adopt PREs as an alternative component package.

It is unclear from Mr. Stein's letter if he is speaking just for himself, for Taylor Engineering, or for undisclosed clients. What is clear is that much of the letter seeks to rebut, recharacterize, and partially recant Taylor Engineering's own previous support of PREs, based on what appears to be a selective sample of internal, 2015 e-mails from within Taylor Engineering and never previously provided to Liebert, Commission staff or the public, until now.

Exception 5 was proposed for removal from the Efficiency Standards in 15-day changes. While this may have been based on Taylor Engineering's comments, the rationale was not stated or justified in 15-day changes. In any case, as shown in the ISOR and herein, Exception 5 should be reinstated and adopted, consistent with the ISOR analysis.

Leaving aside the anomaly of Taylor Engineering's starkly conflicting statements about PREs over the past few years, Liebert respectfully suggests that the Commission ought not to base its determination as to whether to codify the PRE exception on a single letter, deposited into the record under such questionable circumstances, and raising questions about a particular PRE, not the proposed new exception. In any event, as summarized below and as supported by the attached exhibits to this letter, Mr. Stein's comments are materially inaccurate in numerous respects, and should therefore be either discounted or outright ignored.

<u>Stein's Comment #1</u>

A refrigerant economizer is not nearly as efficient as an airside economizer or a waterside economizer.

a. *Figure 1 shows the hours per year in San Jose when each type of economizer is typically in 100% free cooling, no free cooling, and integrated free cooling. For example, a refrigerant economizer can meet 100% of the load only about 8% of the year, compared to 33% for a water economizer and 78% for an air economizer. Clearly the refrigerant economizer is the worst in terms of potential free cooling.*

b. *Supply fan: Refrigerant economizer CRAC units and water econ CRAH units have similar components and similar pressure drops but CRAC units have higher minimum fan speeds. So the refrigerant economizer is worse in terms of supply fan energy.*
c. *Compressor: Air-cooled DX compressors are not close to the efficiency of water-cooled compressors. For example, see the T-24 limitation on air-cooled chillers. So, the refrigerant economizer is worse in terms of compressor energy.*
d. *Condenser/Tower Fan: The refrigerant economizer is basically a dry-cooler. A water-side economizer is a wet cooler (cooling tower). Water has far better heat transfer than air. A dry-cooler uses about 5 to 10 times as much fan power as a cooling tower to achieve the same approach. So the refrigerant economizer is worse in terms of condenser/tower fan energy.*
e. *A water economizer has some CHW/CW pump energy that a refrigerant economizer does not have, but that is in the noise compared to the supply fan, compressor, and condenser/tower fan.*

Liebert's Response

Mr. Stein states that a PRE is "not nearly as efficient as an airside economizer or a waterside economizer," and lists several examples that purport to show this. But Mr. Stein's assertion appears to be based on an assumption of 100% load, which is not a real-world assumption for data centers, which rarely operate at 100% load. For example, the U.S. Department of Energy estimated in its July 2017 proposed rule document EERE-2017-BT-TP-0018-0003, https://www.regulations.gov/document?D=EERE-2017-BT-TP-0018-0003, that Computer Room Air Conditioner units operate on average at a sensible cooling load of only 65%. Indeed, the CEC's own CBECC-Com compliance software load profile assumes that data centers operate at 100% load only 25% of the year, meaning that 75% of the year data centers operate at less, and often significantly less, than 100% load. Using CEC's CBECC-Com's load profile, and not Mr. Stein's hypothetical 100% load assumption, Liebert demonstrated in its 2015 application that PREs "passed" in 14 out of 16 California climate zones, and indeed out-performed the equivalent chilled-water system, as confirmed by the report generated by CEC staff engineer Mark Alatorre, P.E., in August 2015 (CEC-400-2015-029), attached hereto as Exhibit B ("Alatorre Report").

Mr. Stein also takes issue with the modeling used by Liebert to support its 2015 PRE exception. But Liebert's 2015 application appropriately followed the methodology directed by the CEC, using the Exceptional Calculation Method under section 10-104 of the California Building Energy Efficiency Standards.

Mr. Stein's other comments ((c), (d) and (e)) are also based on a 100% load assumption, not the far lower load profiles utilized by the CEC and others for computer rooms, and should therefore be disregarded. Mr. Stein's comments are general statements about how different types of systems are designed, and do not address the overall annual efficiency of different types of products. For example, in comment (c), Mr. Stein compares the energy use of DX compressors (also known as mechanical cooling compressors) to the annual energy use of the systems they reside in. But the more appropriate comparison, *i.e.*, of the equivalent energy use on a system level, shows that the PRE is equivalent or superior. This is in fact the comparison that was performed by Commission staff and described in the Alatorre Report.

In comment (d), Mr. Stein concludes that "the refrigerant economizer is worse in terms of condenser/tower fan energy." But that conclusion rests on Mr. Stein's assumption that the PRE is "basically" (Mr. Stein's word) a dry cooler, which is generally understood to use a single-phase fluid. That assumption is false: the PRE actually utilizes a two-phase refrigerant, which has far superior heat transfer to a single-phase fluid. In fact, the PRE consumes no water, and, rather, saves water when compared to other competing systems, which is one of the reasons the Commission approved the PRE exception in 2015. Further, the PRE saves energy consumed by processing and delivering water to sites using waterside economizers (see attached Exhibit C - Vertiv Memo).

<u>Stein's Comment #2</u>

There are no truly integrated pumped refrigerant economizers available on the market.

a. *The Liebert DSE has 2 circuits that can be in either compressor mode or economizer pump mode. In partial economizer mode (1 compressor running and one economizer pump running) the DSE loses half of its DX capacity. So, to switch from 2 circuits in compressor mode to 1 circuit in economizer the economizer must be able to meet enough of the load that the remaining compressor can meet the rest of the load. The controls must estimate if the economizer can do enough based on the current load, setpoints, and ambient conditions. The controls have to predict if the economizer can meet the load before dropping a compressor and losing 50% of its DX capacity.*

b. *Similarly, to go from one circuit on compressor to both circuits on compressor, the economizer must be able to meet the entire load because there are no compressors available. If the controls guess wrong the load could be lost very quickly so they need to be very conservative. Liebert refuses to share their control algorithms with us.*

c. *In a best-case scenario, the controls would work roughly as shown in Figure 2. This shows that even if the ambient temperature is low enough to enable the economizer, the economizer cannot be enabled if the load is high.*

d. *Here is another example of the non-integration: Suppose the OAT is 45 and you are in 100% econ. Then the OAT rises to 46 and you need 98% capacity from the econ and 2% from the DX. To get any capacity from the DX you lose half the economizer so now your DX is doing 50% of the load when a chiller might only do 2% in a water econ.*

e. At best, the Liebert DSE is half way between a fully integrated economizer and a non-integrated economizer.

Liebert's Response

Mr. Stein states that "[t]here are no truly integrated [PREs] available on the market," and then offers his own definition of integrated economizers that assumes partial economization with a 100% load condition.

Mr. Stein is wrong both as to what constitutes an integrated PRE and as to his assertion that no such PREs exist in the market. CEC Title 24-2016, Section 140.4(e)2B references only "the remainder of the cooling load," not a 100% load condition: "Economizer shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load." This is confirmed in the CEC's 2016 non-residential compliance manual, which states that if an economizer is required, it must be fully integrated into the cooling system controls so that the economizers can provide partial cooling even when mechanical cooling is required to meet the remainder of the cooling load.[5] As such, the Liebert DSE system with PRE complies with the code, which specifically references "partial cooling," not the 100% availability suggested by Mr. Stein's letter, which the code simply does not require.

Mr. Stein also argues that PRE functionality, and the Liebert DSE's functionality in particular, rests on the product's control system. But all economizing systems, including waterside economizer systems, depend on properly designed and executed controls to enable optimized switchover between mechanical cooling and economization. Liebert believes that its controls work as well or better than others in the industry, and we believe our record and reputation speak for itself. "If the controls guess wrong," says Mr. Stein, the economizing system will not function properly – but there is no evidence that Liebert's controls don't function precisely as designed and intended, and Mr. Stein's argument is thus based on an assumption plucked out of thin air.

Finally, Mr. Stein alleges that Liebert's PRE fails to meet certain prescriptive requirements for individual components. Here, again, Mr. Stein is misconstruing applicable requirements. Liebert utilizes a whole building model, under which the manufacturer need only show that the building as a whole meets or exceeds applicable mandatory requirements. In such models, tradeoffs between individual prescriptive components are permitted, so long as the proposed model's time-dependent valued ("TDV") energy budget is better than the baseline model's TDV energy budget. This is precisely what Liebert did, and Mr. Stein's critique is thus completely off base.

[5] CEC-400-2015-033-CMF, Section 4.5.2.2, (b)(2), "Economizers".

Stein's Comment #3

> *A dry-cooler in series with an air-cooled chiller is more efficient than the Liebert DSE because the dry-cooler can pick up any amount of load without affecting the capacity of the air-cooled chiller, i.e. it is fully integrated. Of course, an a/c chiller + dry-cooler is not nearly as efficient as a water economizer and would not deserve an exception.*

Liebert's Response

Mr. Stein states that a dry-cooler in series with an air-cooled chiller is more efficient than the Liebert DSE. We think this statement is wrong, for the reasons we set forth in our response to Mr. Stein's first Comment. The Alatorre Report compared PRE vs waterside economization, not PRE vs the system Taylor describes in Comment #3.

Stein's Comment #4

> *The economizer requirement is a prescriptive requirement. A refrigerant economizer can use the performance approach. Liebert has claimed that a refrigerant economizer cannot be properly modeled in the current software so they deserve the prescriptive exception. Unfortunately, there are many systems that cannot be properly modeled but none of them have prescriptive exceptions. VRF, for example, cannot be modeled. But that has not stop [sic] hundreds of VRF buildings from using the performance approach. It is very common to use work around and/or exceptional calculation methods that are acceptable to the AHJs. CBECC-Com also allows the user to use a customized EnergyPlus model for the proposed design.*

Liebert's Response

Mr. Stein essentially argues that the Commission should establish prescriptive requirements for PREs, rather than permit their use through an exception to Section 140.9.

The exception is valid as written. PRE is a mature technology, which economizes equal to or better than waterside economizers, saves energy, and uses no water. PRE technology has been proven in terms of efficiency alongside competing systems, meets the code in terms of being an "integrated" solution, and reflects the overall need to continue allowing PRE to be sold into the market. Stein's concerns are misplaced. Consulting engineers have told us they will not spend the significant time necessary to create exceptional calculation methods, and the Authorities Having Jurisdiction, i.e. the cities, localities and other entities responsible for implementing exceptions to Section 140.9, have neither the time nor the resources to review the modeling for every PRE unit servicing a computer room in California. As an example, VRF (Variable Refrigerant Flow) has been added to EnergyPro to make these submissions less burdensome. If Exception 5 is not adopted, the Commission will effectively restrict access to a viable, efficient technology.

Stein's Comment #5

> *I suspect the only reason this is being considered by the CEC is due to a misunderstanding of a poorly worded Taylor Engineering memo in 2015. Shortly before leaving Taylor Engineering, Mark Hydeman reviewed the data Liebert submitted to the CEC for a special exception. Mark later admitted that he only briefly looked at the calibration data for the DX curves and not at the simulation models. When presented with some obvious flaws in the Liebert analysis, Mark agreed that Liebert's analysis was flawed and did not warrant the exception. See attached emails.*

Liebert's Response

Stein seeks to impugn Taylor Engineering's own expert testimony written by its former employee Mark Hydeman and submitted by Taylor Engineering to the Commission in 2015 in support of the PRE exception. Stein does so by citing excerpts from some three year old internal Taylor Engineering emails that he selected and that purport to show that Mr. Hydeman may have had some doubts about his assessment of PREs. That is both unfair to Mr. Hydeman, and irrelevant to the current proceeding. Stein ignores the detailed review process undertaken not just by Liebert, but by Commission staff and the CEC itself in 2015. The Commission approved PREs as an alternative compliance option on the basis of work done by many individuals, a report issued by Commission staff, and numerous data requests which are all available in the public docket. That Stein now seeks to undermine work performed by his own company has no bearing on the work performed by the many individuals and Commission staff who participated in that earlier proceeding nor does it undermine the Commission's order. If Taylor Engineering doubted its own sworn testimony, why did it wait three years to disclose its concerns, rather than slipping them at the eleventh hour into a rulemaking proceeding?

Stein's Comment #6

> *To qualify for an exception an independent 3rd party should perform the simulations, not Liebert. For example, when JCI and Carrier asked for exceptions to the 300 ton air-cooled chiller limitation, the CEC engaged an independent 3rd party to run the simulations and demonstrate equivalence.*

Liebert's Response

Mr. Stein is wrong. The performance of Liebert's PREs have been fully verified by third party, independent engineers. We attach as Exhibit D one such verification, performed by 2020

Engineering on behalf of Liebert's client. In fact, Liebert has sold more than 240 Liebert DSE units with PRE for data centers in California since 2014 at more than 50 job sites. Both customers and engineers have been pleased with the results. Commission staff also performed an independent analysis of the PRE, which was reviewed and validated by Taylor Engineering in 2015, and accepted by the Commission. It is notable that Mr. Stein's assertion in his Comment #6, like many of his assertions, could have been easily corrected had he raised his purported concerns either in the 2015 docket in which the Commission specifically addressed Liebert's technology, or if he had contacted Liebert prior to filing his remarks.

Stein's Comments #7 and 8

> *The analysis that Liebert submitted was based on their unit which has modulating compressors and variable speed fans that make it more efficient than other CRAC units. This new exception does not capture any of those efficiencies. So Liebert and other manufacturers can now use this exception for systems that are less efficient than the Liebert DSE.*
>
> *This exception does not say anything about the minimum performance of the refrigerant economizer. The airside and waterside economizer requirements say what ambient conditions the economizer must meet the entire load. This new exception allows the refrigerant economizer to be sized to meet the load at any conditions. For example, a refrigerant economizer that couldn't even meet the load at 10°F OA drybulb would still meet this exception.*

Liebert's Response

Stein's concern is that inferior products will come to the market if only the exception is adopted. The Liebert PRE meets all Commission code requirements and has successfully proven its efficiency using a Commission-prescribed process. One of the important reasons for approving the PRE in September 2015 was, in part, related to water usage, as well as energy efficiency. The Alatorre report states in its Executive Summary: "This proposed alternative will provide energy savings in 14 out of 16 climate zones, and will offset the use of water that will otherwise be consumed by the installation of a water-side economizer." In fact, the CBECC-Com study reviewed by Alatorre in 2015 showed that the Liebert PRE has the potential to save over 4 million gallons of water annually for a typical data center in California. These gains should be given great weight in the evaluation of the PRE's energy efficiency. Mr. Stein's approach, on the other hand, would throw the baby out with the bath water, by eliminating the PRE exception entirely, based on his wholly inaccurate allegations that some PREs might not meet his own exacting standard.

Conclusion

In light of the inaccuracies in Stein's comments identified below, Liebert respectfully asks the Commission to reinstate Proposed Exception 5 in its 2019 Energy Efficiency Standards. Exception 5 was included in the Commission's initially-proposed amendments and is clearly within the scope of the 45-day notice. It is a very narrow exception, and as shown in Exhibit B, would not reduce the efficiency standards' environmental and economic benefits. While staff proposed its removal in 15-day changes, this was based on incomplete information as explained above, and this change should not ultimately be adopted. For instance, as explained at the May 9, 2018 hearing, two changes included in the 15-day language were not ultimately adopted and the 45-day language was reinstated. The Commission can and should similarly reinstate the 45-day language here such that Exception 5 is included in section 140.9(a)(1).

Respectfully submitted,

Benedict J. Dolcich, P.E. ASHRAE Member
Director, Lifecycle Engineering-Thermal Products
Vertiv Co.

EXHIBIT A

DOCKETED

Docket Number:	15-MISC-03
Project Title:	Proposed Compliance Option for Data Centers Using a Refrigerant Economizer
TN #:	206117
Document Title:	Resolution of the Energy Commission re Refrigerant Economizers as Alternative Component Package for Use in Computer Rooms
Description:	N/A
Filer:	Tiffani Winter
Organization:	California Energy Commission
Submitter Role:	Energy Commission
Submission Date:	9/16/2015 9:51:17 AM
Docketed Date:	9/16/2015

STATE OF CALIFORNIA

Energy Resources Conservation
And Development Commission

Building Energy Efficiency Standards, California Code of Regulations, Title 24, Parts 1 and 6	**Docket No. 15-MISC-03** **Resolution No. 15-0909-10**

RESOLUTION OF THE ENERGY COMMISSION APPROVING RECOMMENDATION BY THE EXECUTIVE DIRECTOR TO APPROVE REFRIGERANT ECONOMIZERS AS AN ALTERNATIVE COMPONENT PACKAGE FOR USE IN COMPUTER ROOMS IN CERTAIN CLIMATE ZONES

WHEREAS, Section 25402.1(b) of the California Public Resources Code and Section 10-109(d) of Part 1 of Title 24 authorizes the Commission to approve compliance options and alternative component packages for demonstrating compliance with the Building Energy Efficiency Standards set forth in California Code of Regulations, Title 24, Part 6, and the associated administrative regulations in Part 1, Chapter 10; and

WHEREAS, Emerson Network Power submitted an application to the Energy Commission requesting that refrigerant economizers be approved as an alternative component package for demonstrating compliance with the prescriptive requirements set forth in Section 140.9(a)1B of Title 24, Part 6; and

WHEREAS, pursuant to Section 10-110(a) of Part 1 of Title 24 the Executive Director determined that the application for this alternative component package was complete, and staff of the Energy Commission made the application package available to interested parties for a 60 day comment period; and

WHEREAS, Energy staff prepared a report analyzing this alternate component package, which recommended that refrigerant economizers should be approved for use in computer rooms in climate zones 1-9, 11-14 and 16 as an alternative component package for demonstrating compliance with the prescriptive requirements set forth in Section 140.9(a)1B of Part 6 of Title 24; and

WHEREAS, based on the analysis and recommendation of staff, the Executive Director recommends that the California Energy Commission approve refrigerant economizers for use in computer rooms in climate zones 1-9, 11-14 and 16 as an alternative component package for demonstrating compliance with the prescriptive requirements in Section 140.9(a)1B of Part 6 of Title 24.

THEREFORE, the Energy Commission accepts the recommendation of the Executive Director and approves refrigerant economizers for use in computer rooms in climate zones 1-9, 11-14 and 16 as an alternative component package pursuant to Section 10-109 of Part 1 of Title 24, for demonstrating compliance with the prescriptive standard in Section 140.9(a)1B of Part 6 of Title 24, and directs the Executive Director to take, on behalf of the Energy Commission, all actions reasonably necessary to implement this resolution.

Date: September 9, 2015

CERTIFICATION

The undersigned Secretariat to the Commission does hereby certify that the foregoing is a full, true, and correct copy of a Resolution duly and regularly approved at a meeting of the California Energy Commission held on September 9, 2015.

AYE: Weisenmiller, Douglas, McAllister, Scott
NAY: None
ABSENT: Hochschild
ABSTAIN: None

Tiffani Winter,
Secretariat

EXHIBIT B

STAFF PAPER

Pumped Refrigerant Economizers for Use in Computer Rooms

Mark Alatorre, P.E.
Building Standards Office
Efficiency Division
California Energy Commission

California Energy Commission
Edmund G. Brown Jr., Governor

August 2015 | CEC-400-2015-029

DISCLAIMER

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ABSTRACT

California's *Building Energy Efficiency Standards* require the mechanical cooling equipment serving a computer room to be equipped with either an integrated air-side economizer or an integrated water-side economizer. A mechanical cooling system integrated with one of these features can provide cool air to the space without operating the mechanical cooling system when the outside conditions are cool enough to provide sufficient cooling to the space. This results in energy savings due to not having to operate a compressor to cool the air or water mechanically.

Pumped refrigerant economizing uses the same concept for energy savings, in that it bypasses the compressor for mechanical cooling by using a pump to move the refrigerant through the evaporator and condenser. The energy savings is achieved by the difference in energy consumption between the pump and compressor.

California Energy Commission staff proposes that the Commission approve a compliance option for pumped refrigerant-based economizers to be used as an alternative to water-side economizing for computer rooms. The proposed alternative is based on building simulations using CBECC-Com 3b (Build 717).

The proposed alternative of a pumped refrigerant economizer will allow this emerging technology to be used for standards compliance, where feasible. The benefit of this technology is not only energy savings, but water savings.

Keywords: California Energy Commission, refrigerant economizer, economizing, Liebert DSE, Emerson Network Power, AlaJor Engineering, *Building Energy Efficiency Standards*, CBECC-Com

Alatorre, Mark, 2015. *Pumped Refrigerant Economizers for Use in Computer Rooms*. California Energy Commission. Publication Number: CEC-400-2015-029.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

Public Resources Code, Section 25402.1 (b) requires that the California Energy Commission establish a formal process for certification of compliance options relating to new products, materials, or calculation methods that are usable for showing compliance with the *Building Energy Efficiency Standards*. In response to this requirement, Section 10-109 of the *Building Energy Efficiency Standards* establishes the process for introducing designs, materials, or devices that cannot be adequately modeled in any currently approved alternative calculation methods or that are not appropriately accounted for in currently approved compliance approaches.

Currently, the *Building Energy Efficiency Standards* prescriptively require that the mechanical cooling equipment serving a computer room be equipped with either an integrated air-side economizer or an integrated water-side economizer. A mechanical cooling system integrated with one of these features can provide cool air to the space without operating the mechanical cooling system provided the outside conditions are sufficiently cool. This results in energy savings due to not having to operate a compressor to mechanically cool the air or water.

Emerson Network Power (Emerson) used the established compliance option process of Section 10-109 to submit an application for approval of their Liebert DSE data center cooling system to be accounted for in the currently approved prescriptive compliance approach. This system features a pumped refrigerant economizer that follows the same principle of "economizing," in that it provides cool air to the space when the compressor is off or assisted and is still able to provide sufficient cooling. The Liebert DSE system uses pumps to move the refrigerant from the condenser to the evaporator, absorbing heat from the computer room and rejecting that heat to the outdoors. The energy savings is the difference in energy consumption between the pump and compressor. The proper outside conditions must be present for this process to work, just like air or water-side economizing, but unlike a water-side economizer the Liebert DSE system does not consume any water.

As part of their application Emerson included building simulation files comparing their system to a water-side economizer using the approved public domain software CBECC-Com. The results showed energy savings in 14 of the 16 climate zones. The climate zones where their system does not perform as well as a water-side economizer are climate zones 10 and 15.

Staff therefore recommends approval of this compliance option for pumped refrigerant based economizers as a prescriptive alternative to water-side economizing for computer rooms for climate zones 1-9, 11-14 and 16. This proposed alternative will provide energy savings in 14 out of the 16 climate zones, and will offset the use of water that would otherwise be consumed by the installation of a water-side economizer.

Introduction

This report presents California Energy Commission staff's recommendation for approval of a compliance option for the Liebert DSE data center cooling system for computer rooms. The compliance option is based on energy simulations using approved public domain software CBECC-Com 3b (Build 717) that shows energy savings in 14 of the 16 climate zones for computer rooms that use a pumped refrigerant economizer opposed to a water-side economizer.

Compliance Options

Public Resources Code, Section 25402.1 (b) requires the California Energy Commission to establish a formal certification process for compliance options relating to new products, materials, or calculation methods that are usable for showing compliance with the *Building Energy Efficiency Standards* (Standards). In response to this requirement of the Public Resources Code, Section 10-109 of the Standards establishes the process for introducing designs, materials, or devices that cannot be adequately modeled in any currently approved alternative calculation methods or that are not appropriately accounted for in the current approved compliance approaches.

The compliance option process enables the use of new or additional products, materials, designs, or procedures for demonstrating compliance with applicable building standards. In doing so, the process encourages market innovation and allows the Energy Commission to respond to changes in building design, construction, installation, and enforcement.

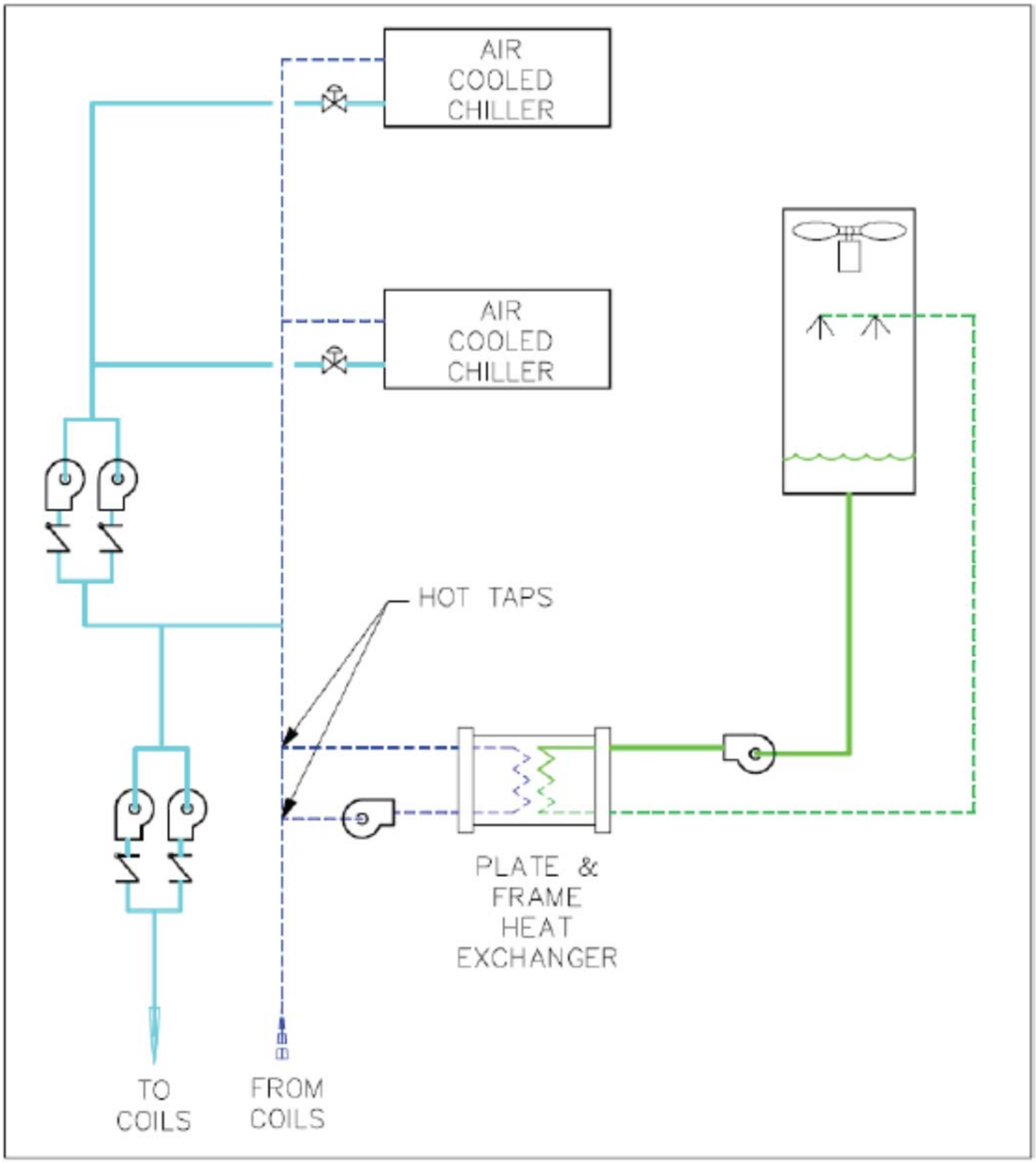
Compliance Option for Refrigerant Economizers

To comply with the Standards, mechanical cooling equipment serving computer rooms must be equipped with an integrated air-side or water-side economizer. The choice of air-side or water-side economization depends on the mechanical cooling system type.

Chilled water systems are a type of mechanical cooling that has an integrated water-side economizer and takes advantage of cooler outside conditions to provide cooling to the space. Generally, during favorable conditions, the chiller can be turned off, and the cooling tower provides the means of cooling the chilled water used to cool the space. The water-side economizer loop can also precool the supply air to help lower the load to the chiller and reduce energy use when the cooling load cannot be satisfied with the economizer alone.

When the water-side economizer is enabled, pumps are used to move the water between the cooling tower and the heat exchanger. The "economizing" happens in the form of energy savings due to the chiller being off or assisted and still being able to provide sufficient cooling to the space. Given the constant cooling load of a computer room due to always-on heat-generating electronic equipment, these economizing conditions appear on most days and can be very favorable in certain climate zones.

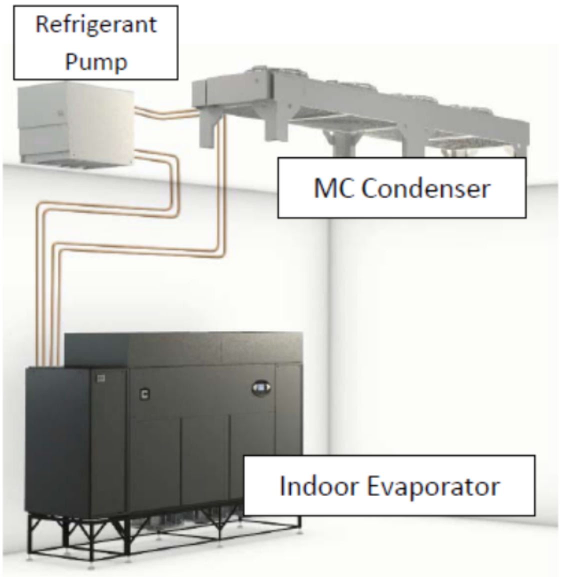
Figure 1: Example of Water-Side Economizer on a Chilled Water Plant



Source: *2013 Nonresidential Compliance Manual*

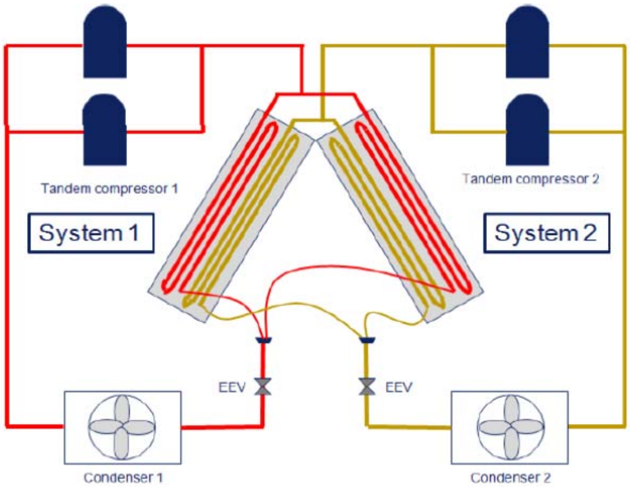
Pumped refrigerant economizing follows the same principle of "economizing" in that it provides cooling when the compressor is off or assisted and still being able to provide sufficient cooling. The Liebert DSE data center cooling system features a pumped refrigerant economizer that uses pumps to move the refrigerant from the condenser to the evaporator, absorbing heat from the computer room and rejecting that heat to the outdoors. The proper outside conditions must be present for this process to work; just like water-side economizing but unlike a water-side economizer, this system does not consume any water.

Figure 2: Emerson Pumped Refrigerant Component Layout



Source: Emerson Proposal to Include Refrigerant Economizers in Title 24

Figure 3: Emerson Pumped Refrigerant Schematic



Source: Emerson Response to Energy Commission Questions

Staff Evaluation

Computer Rooms and the Standards

Prior to the *2008 Standards*, process loads were generally considered exempt from the standards. The Standards define a *process load* as a load due to an "activity or treatment that is not related to the space conditioning, lighting, service water heating or ventilation of a building as it relates to human occupancy"[1]. The Standards began to regulate process loads in 2008 with requirements for refrigerated warehouses. The *2013 Standards* added requirements for computer rooms and other process load types.

Review of Computer Room Economizing

The Standards define a computer room as "a room whose primary function is to house electronic equipment and that has a design equipment power density exceeding 20 watts per square foot of conditioned space."[1]

Computer rooms have a unique set of design requirements necessary for controlling key indoor air quality features such as dew point, temperature, and relative humidity. The electronic equipment (computers, servers, networking equipment) housed in these areas are sensitive to these variables in that they may fail due to high heat or electrostatic charge. Along with controlling the air quality, personnel must exercise caution, for example, by implementing personal grounding practices to avoid damaging the equipment or components.

Direct air economizing is a cost-effective option for computer rooms; however some care must be exercised depending on the air source. Certain contaminants, such as dust, may be introduced through poor outdoor air quality. Air-to-air heat exchangers can be used to control outdoor air contaminants and prevent them from entering the computer room, but at an added cost and consequently lower efficiency due to the heat exchange. It was been shown to still be cost-effective, however.

Water-side economizing is more desirable than air-side economizing for large data centers. An advantage to this type of economizing versus air-side is improved control of the indoor environment, such as humidity and dust particles, by avoiding the introduction of large quantities of outside air.

Pumped refrigerant economizing has similar advantages to water-side systems. Indoor environments can be better controlled by not introducing outdoor air. These systems

1 *2013 Building Energy Efficiency Standards,* Title 24, Part 6, Section 100.1.

also reduce the amount of equipment (such as pumps, fans, cooling towers) needed to operate in full or partial economizer modes.

Results of Refrigerant Economizer Analysis

As part of the Emerson submittal package, Christian Hurd of AlaJor Engineering, Inc. performed a simulation analysis comparing the Liebert DSE system to a chilled water system with an integrated water-side economizer. The results showed that the Liebert DSE system outperformed the chilled water system with an integrated water-side economizer in 14 of the 16 California climate zones.

The method used by AlaJor Engineering, Inc. was to create a baseline energy budget by using the Energy Commission's public domain software CBECC-Com (Build 717). Once a baseline energy budget was established, the proposed Liebert DSE model was created using the CBECC-Com software, by extracting the IDF model (IDF is a format used by EnergyPlus) and then adding custom curves for the Liebert DSE equipment. The custom curves were developed from a regression analysis of Liebert pumped refrigerant system data, following the AHRI 1360 standard used for determining the efficiency rating. The researchers then simulated the proposed model.

Once both models were created and simulated, the results were extracted to the Exceptional Design Compliance - End-Use Summary Comparison spreadsheet. An excerpt of the spreadsheet is shown below where the results for each climate zone can be seen:

Table 1: End-Use Summary Comparison – All Climate Zones

Climate Zone 1	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,073.5	1,333.2	1,278.1	1,643.2	(310.1)
	Fans	949.5	1,186.3	285.0	358.6	827.7
	Lighting	42.7	56.8	42.7	56.8	-
	Pumps	197.5	242.8	-	-	242.8
	Heat Rejection	29.4	43.4	-	-	43.4
	Compliance Total	2,292.5	2,862.4	1,605.8	2,058.6	803.8
	Interior Equipment	7,925.0	9,802.2	7,925.0	9,802.2	-
	Total	10,217.6	12,664.6	9,530.8	11,860.8	803.8
						PASS

Climate Zone 2	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,105.9	1,415.3	1,468.8	2,006.5	(591.2)
	Fans	891.2	1,114.1	427.9	539.3	574.8
	Lighting	42.7	56.2	42.7	56.2	-
	Pumps	189.5	230.0	-	-	230.0
	Heat Rejection	48.1	72.3	-	-	72.3
	Compliance Total	2,277.4	2,887.9	1,939.4	2,602.0	285.9
	Interior Equipment	7,925.0	9,737.3	7,925.0	9,737.3	-
	Total	10,202.4	12,625.2	9,864.4	12,339.3	285.9
						PASS

Climate Zone 3	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,064.0	1,313.5	1,654.1	2,119.3	(805.8)
	Fans	888.1	1,110.8	171.9	214.9	895.9
	Lighting	42.8	63.5	42.8	63.5	-
	Pumps	197.1	239.3	-	-	239.3
	Heat Rejection	41.3	58.6	-	-	58.6
	Compliance Total	2,233.3	2,785.7	1,868.9	2,397.7	388.1
	Interior Equipment	7,925.0	9,611.6	7,925.0	9,611.6	-
	Total	10,158.4	12,397.4	9,793.9	12,009.3	388.1
						PASS

Climate Zone 4	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,116.2	1,390.5	1,524.0	2,014.3	(623.7)
	Fans	929.1	1,155.2	428.8	542.2	613.0
	Lighting	42.7	55.6	42.7	55.6	-
	Pumps	190.8	229.0	-	-	229.0
	Heat Rejection	53.1	75.8	-	-	75.8
	Compliance Total	2,332.0	2,906.1	1,995.5	2,612.1	294.0
	Interior Equipment	7,925.0	9,592.8	7,925.0	9,592.8	-
	Total	10,257.0	12,498.9	9,920.5	12,204.9	294.0
						PASS

Climate Zone 5	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,090.4	1,345.3	1,417.1	1,827.2	(481.9)
	Fans	955.4	1,196.8	430.9	542.5	654.3
	Lighting	42.7	56.2	42.7	56.2	-
	Pumps	190.2	229.6	-	-	229.6
	Heat Rejection	38.0	55.0	-	-	55.0
	Compliance Total	2,316.7	2,882.8	1,890.6	2,425.8	457.0
	Interior Equipment	7,925.0	9,638.4	7,925.0	9,638.4	-
	Total	10,241.7	12,521.2	9,815.6	12,064.2	457.0
						PASS

Climate Zone 6	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,113.6	1,369.5	1,584.6	1,996.1	(626.6)
	Fans	870.9	1,076.5	428.4	541.6	534.9
	Lighting	42.7	57.1	42.7	57.1	-
	Pumps	197.5	236.6	-	-	236.6
	Heat Rejection	68.0	89.1	-	-	89.1
	Compliance Total	2,292.7	2,828.8	2,055.7	2,594.8	234.0
	Interior Equipment	7,925.0	9,565.6	7,925.0	9,565.6	(0.0)
	Total	10,217.7	12,394.3	9,980.7	12,160.4	233.9
						PASS

Climate Zone 7	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,113.7	1,409.2	1,607.3	2,063.8	(654.6)
	Fans	884.7	1,112.8	426.9	549.3	563.5
	Lighting	42.7	57.4	42.7	57.4	-
	Pumps	195.7	238.6	-	-	238.6
	Heat Rejection	65.2	87.6	-	-	87.6
	Compliance Total	2,302.0	2,905.6	2,076.9	2,670.5	235.0
	Interior Equipment	7,925.0	9,776.8	7,925.0	9,776.7	0.0
	Total	10,227.0	12,682.3	10,001.9	12,447.3	235.1
						PASS

Climate Zone 8	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,128.2	1,408.8	1,609.7	2,079.7	(670.9)
	Fans	893.2	1,092.1	426.6	537.5	554.6
	Lighting	42.7	57.1	42.7	57.1	-
	Pumps	189.9	228.4	-	-	228.4
	Heat Rejection	64.1	86.1	-	-	86.1
	Compliance Total	2,318.1	2,872.6	2,079.0	2,674.3	198.3
	Interior Equipment	7,925.0	9,655.5	7,925.0	9,655.5	-
	Total	10,243.1	12,528.1	10,004.0	12,329.8	198.3
						PASS

Climate Zone 9	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,139.2	1,411.4	1,629.2	2,074.7	(663.3)
	Fans	875.1	1,067.7	429.8	542.6	525.1
	Lighting	42.7	56.3	42.7	56.3	-
	Pumps	191.1	230.0	-	-	230.0
	Heat Rejection	70.9	94.9	-	-	94.9
	Compliance Total	2,318.9	2,860.2	2,101.7	2,673.5	186.7
	Interior Equipment	7,925.0	9,516.6	7,925.0	9,516.6	-
	Total	10,243.9	12,376.8	10,026.7	12,190.1	186.7
						PASS

Climate Zone 10	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,059.0	1,359.2	1,669.6	2,231.7	(872.5)
	Fans	938.6	1,158.3	434.1	546.6	611.7
	Lighting	42.7	55.6	42.7	55.6	-
	Pumps	165.3	195.8	-	-	195.8
	Heat Rejection	42.8	63.2	-	-	63.2
	Compliance Total	2,248.3	2,832.1	2,146.4	2,834.0	(1.8)
	Interior Equipment	7,925.0	9,598.6	7,925.0	9,598.6	-
	Total	10,173.3	12,430.7	10,071.4	12,432.5	(1.8)
						FAIL

Climate Zone 11	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,181.0	1,526.7	1,666.1	2,332.6	(806.0)
	Fans	1,076.1	1,308.7	429.3	541.3	767.4
	Lighting	42.7	56.5	42.7	56.5	-
	Pumps	180.4	218.7	-	-	218.7
	Heat Rejection	54.3	79.2	-	-	79.2
	Compliance Total	2,534.5	3,189.7	2,138.1	2,930.4	259.3
	Interior Equipment	7,925.0	9,884.7	7,925.0	9,884.7	-
	Total	10,459.5	13,074.4	10,063.1	12,815.1	259.3
						PASS

Climate Zone 12	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,126.7	1,454.8	1,577.1	2,170.3	(715.6)
	Fans	927.8	1,163.7	426.0	537.8	625.9
	Lighting	42.7	56.2	42.7	56.2	-
	Pumps	191.1	230.1	-	-	230.1
	Heat Rejection	53.7	78.7	-	-	78.7
	Compliance Total	2,342.0	2,983.5	2,045.7	2,764.4	219.2
	Interior Equipment	7,925.0	9,785.6	7,925.0	9,785.6	-
	Total	10,267.0	12,769.2	9,970.7	12,550.0	219.2
						PASS

Climate Zone 13	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,145.7	1,464.9	1,684.2	2,299.9	(835.0)
	Fans	911.6	1,122.1	429.0	539.8	582.2
	Lighting	42.7	56.3	42.7	56.3	-
	Pumps	189.3	229.5	-	-	229.5
	Heat Rejection	57.5	83.7	-	-	83.7
	Compliance Total	2,346.8	2,956.5	2,155.9	2,896.0	60.4
	Interior Equipment	7,925.0	9,781.4	7,925.0	9,781.4	-
	Total	10,271.8	12,737.8	10,080.9	12,677.4	60.4
						PASS

Climate Zone 14	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,143.7	1,457.3	1,727.8	2,404.3	(947.0)
	Fans	1,021.0	1,269.5	450.2	562.9	706.6
	Lighting	42.7	55.8	42.7	55.8	-
	Pumps	182.4	220.7	-	-	220.7
	Heat Rejection	35.4	57.3	-	-	57.3
	Compliance Total	2,425.2	3,060.6	2,220.7	3,023.0	37.6
	Interior Equipment	7,925.0	9,774.9	7,925.0	9,774.9	-
	Total	10,350.2	12,835.5	10,145.7	12,797.9	37.6
						PASS

Climate Zone 15	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,227.9	1,575.5	1,996.8	2,671.7	(1,096.1)
	Fans	834.3	1,003.9	421.1	527.1	476.8
	Lighting	42.7	55.8	42.7	55.8	-
	Pumps	182.9	219.5	-	-	219.5
	Heat Rejection	78.9	107.9	-	-	107.9
	Compliance Total	2,366.6	2,962.7	2,460.6	3,254.6	(291.9)
	Interior Equipment	7,925.0	9,702.3	7,925.0	9,802.2	(99.9)
	Total	10,291.6	12,665.0	10,385.6	13,056.8	(391.8)
						FAIL

Climate Zone 16	End Use	Baseline Waterside Economizer		DSE Proposed Design - Custom Curves		
		MWh	TDV kBtuh/ft^2	MWh	TDV kBtuh/ft^2	TDV Margin
	Space Cooling	1,118.6	1,438.3	1,297.0	1,824.4	(386.1)
	Fans	1,067.7	1,311.4	472.7	591.1	720.3
	Lighting	42.7	56.3	42.7	56.3	-
	Pumps	185.8	223.4	-	-	223.4
	Heat Rejection	29.7	52.5	-	-	52.5
	Compliance Total	2,444.5	3,081.9	1,812.4	2,471.7	610.1
	Interior Equipment	7,925.0	9,749.2	7,925.0	9,749.2	(0.0)
	Total	10,369.5	12,831.0	9,737.4	12,221.0	610.1
						PASS

Source: *Proposal to Include Refrigerant Economizers in the California Energy Commission 2013 Building Energy Efficiency Standards.*

Public Review of Refrigerant Economizer Analysis

The entire submittal packaged was posted for a 60-day public review and comment period, including the simulation run files, end-use summary comparison, and custom curves.

After the 60-day public review and comment period was completed, only one comment was docketed. The commenter, Mark Hydeman from Taylor Engineering, was the primary author of the original Codes and Standards Enhancement Initiative (CASE) report that was the basis of the *2013 Standards* computer room requirements, and he expressed that the "proposed energy savings calculations are reasonable." Mr. Hydeman, did have some concerns with a lack of both scope and clarity, however, and included recommended changes to the submitted materials.

Proposed Alternative for Computer Room Economizing

Staff proposes that an alternative to the prescriptive requirement found in Section 140.9(a)1B be given for pumped refrigerant economizers installed in Climate Zones 1-9, 11-14, and 16. This alternative prescriptive requirement will have little impact in the implementation compared to the existing requirement. Some changes to the existing compliance forms will be needed.

When complying under the performance approach, the proposed design should assume the same default as a standard design chilled water system with an integrated water-side economizer. No further compliance credit should be granted for this system until a rule set is developed and incorporated into CBECC-Com.

Conclusion

Staff proposes that pumped refrigerant economizers be allowed as an alternative component package. The proposed alternative will provide energy savings in 14 out of the 16 climate zones and will offset the use of water that will otherwise be consumed by the installation of a water-side economizer. Allowing the use of this technology is consistent with the compliance options process prescribed by Public Resources Code, Section 25402.1(b) and Section 10-109 of the *Building Energy Efficiency Standards*, which allows for the introduction of designs, materials, or devices that cannot be adequately modeled in the currently approved alternative calculation methods or are not appropriately accounted for the currently approved approaches.

References

ASHRAE Handbook – HVAC Applications 2007, Chapter 17, DATA PROCESSING AND ELECTRONIC OFFICE AREAS.

CALIFORNIA ENERGY COMMISSION. *2013 Building Energy Efficiency Standards, Title 24, Part 6.*

CALIFORNIA ENERGY COMMISSION. *2013 Nonresidential Compliance Manual*, Chapter 10.

CALIFORNIA ENERGY COMMISSION. 2013 Codes and Standards Enhancement Initiative, Data Centers.

EMERSON NETWORK POWER. "Emerson Response to California Energy Commission Request for Additional Information and Questions."

EMERSON NETWORK POWER. "Proposal to Include Refrigerant Economizers in the California Energy Commission *2013 Building Energy Efficiency Standards.*"

EXHIBIT C

MEMO

To: Greg Haggy | **No. of Pages** 1

From: Tim Schrader, Manager, Advanced Product Development

Date: 14-Jun-2018 | **Subject**: Water usage energy

The use of water in waterside economizers is quantified in the CeC's Energy Pro modeling software. However, the energy required to supply the water is left out of the calculation. As seen in Figure 1, a CBECC-Com compliance software example of a 1.2MW Data Center annual energy and water usage analysis in California Climate Zone 14, 5.1 million gallons of water per year are required.

Figure 1: California Climate Zone 14 energy and water usage (1.2MW Data Center results from the CBECC-Com compliance software)

	End Use	Baseline Waterside Economizer				Estimated Water Use	Baseline Airside Economizer (Modified)		Estimated Water Use
		GJ	MWh	TDV MJ/m^2	TDV kBtuh/ft^2	Gal / Year	TDV MJ/m^2	TDV kBtuh/ft^2	Gal / Year
Climate Zone 14	Space Cooling	4,116.9	1,143.7	16,544.2	1,457.3	-	12,184.9	1,073.3	-
	Fans	3,675.4	1,021.0	14,411.4	1,269.5	-	15,604.7	1,374.6	-
	Lighting	153.6	42.7	633.4	55.8	-	715.5	63.0	-
	Pumps	656.4	182.4	2,504.9	220.7	-	1,515.6	133.5	-
	Heat Rejection	127.6	35.4	651.0	57.3	-	663.7	58.5	-
	Add for Low DP control	-	-	-	-	-	-	565.5	-
	Compliance Total	8,729.9	2,425.2	34,744.8	3,060.6	-	30,684.5	3,268.4	-
	Interior Equipment	28,527.8	7,925.0	110,968.5	9,774.9	-	110,968.5	9,774.9	-
	Total	37,257.7	10,350.2	145,713.4	12,835.5	5,061,000	141,653.0	13,043.3	3,689,000

Congressional Research Service prepared a report for members and committees of Congress, dated January 24, 2017, showing the relationship between water usage and energy consumption (https://fas.org/sgp/crs/misc/R43200.pdf.) In the paper, it is stated that "*In California, the energy intensity of the water use cycle ranges from 4,000 kWh per million gallons in the northern part of the state to 12,700 kWh per million gallons in southern California, reflecting differences in the volume of water pumped, lifted, and transported hundreds of miles and over mountains from points of collection to points of need in the southern part of the state.*" Climate Zone 14 is in southern California. As such, an additional 64.3 MWh are consumed that are not reflected in the Energy Pro model for this example.

EXHIBIT D

2020 engineering

2020 Engineering, LLC
13 Crescent Street
Natick, MA 01760
617-763-8862

June 13, 2018

Re: **Vertiv DSE Performance Modeling**

To whom it may concern:

As a part of consulting work for a confidential client, 2020 Engineering reviewed performance data provided by Vertiv (at that time branded Emerson) for their DSE data hall cooling products.

The DSE cooling product uses a pumped refrigerant economizer such that during periods of cold ambient temperatures, refrigerant compressors will not be necessary. This is accomplished in three steps; two circuits operating using the normal refrigeration cycle, one in economizer and one in refrigeration cycle, and both in economizer.

We compared Vertiv's efficiency numbers with our own model. The model uses approach temperatures to simulate refrigerant condenser and evaporator temperatures, curve fit compressor power, and nominal inputs for refrigerant pumps and condenser fans. Evaporator fans were modeled using fan laws. Our modeling used conservative numbers for these parameters. Air Force bin data was applied to the model to achieve PUE calculations for various potential locations.

In all cases, the 2020 Engineering model closely matched those efficiencies published by Vertiv.

Please call if you have any questions.

Very truly yours,
2020 Engineering, LLC

REGISTERED PROFESSIONAL ENGINEER
JOE W. HALE
M 30350
MECHANICAL
STATE OF CALIFORNIA

Joe W. Hale, PE
617-763-8862
joehale@2020mep.com