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To: Payam Bozorgchami, Mark Alatorre, California Energy Commission

## Cooling Tower Efficiency LCC Addendum

This document describes an update to the LCC analysis for cooling tower efficiency, in support of a revision to the Cooling Tower Efficiency CASE Measure. The docketed CASE measure provides an in-depth life-cycle cost analysis and market study in support of a proposed tower efficiency level of 80 gpm/hp. While this level has been shown to be cost effective, NORESCO under direction of the California Energy Commission provided additional analysis to show that a less efficient proposed efficiency level, 60 gpm/hp, is also cost effective. This level provides significant energy savings over the mandatory minimum requirements in Section 110.2, while allowing industry to offer a greater array of products that meet the Standard.

NORESCO conducted a similar LCC analysis to the docketed CASE study, but with the proposed efficiency level of 60 gpm/hp. Energy savings were estimated using "zero compliance" CBECC simulation models for a large office prototype and a large school prototype in each of the 16 California climate zones. Incremental costs were developed from existing data in the CASE report.

## Calibration against CASE results

The first step in the study was to align the energy saving results from the CASE study with NORESCO simulation results, using identical prototypes. The simulation results for site electricity savings and TDV energy savings from the base case matched the results for the CASE proposed efficiency level of 80 gpm/hp. However, the CASE authors used a research version (v876) that had a TDV dataset which was updated by the CEC in 2017. NORESCO applied the latest TDV dataset (v877) in its analysis to estimate savings for the building prototypes.

## Energy Simulation Results

**Table 1 – Energy Savings per Square Foot (Replaces Table 9 in CASE Report)**

| Climate Zone | Site Electricity Savings kWh/sf | Electric Demand Savings, kW | TDV Energy Savings (kBtu/sf) |
|---|---|---|---|
| | Large Office Prototype | | |
| 1 | 0.000542 | 1.93E-07 | 0.0444 |
| 2 | 0.019936 | 1.40E-05 | 1.025 |
| 3 | 0.007461 | 6.47E-06 | 0.3621 |
| 4 | 0.022704 | 1.65E-05 | 1.119 |
| 5 | 0.007561 | 3.71E-06 | 0.2822 |
| 6 | 0.033073 | 1.47E-05 | 1.329 |
| 7 | 0.025713 | 1.39E-05 | 1.134 |
| 8 | 0.033675 | 1.58E-05 | 1.437 |

| | | | |
|---|---|---|---|
| 9 | 0.039491 | 2.45E-05 | 1.747 |
| 10 | 0.037947 | 2.13E-05 | 1.75 |
| 11 | 0.036443 | 1.94E-05 | 1.603 |
| 12 | 0.030145 | 1.95E-05 | 1.406 |
| 13 | 0.038569 | 2.29E-05 | 1.649 |
| 14 | 0.028902 | 1.75E-05 | 1.306 |
| 15 | 0.074811 | 3.41E-05 | 2.843 |
| 16 | 0.006177 | 3.93E-06 | 0.2046 |
| | **Large School Prototype** | | |
| 1 | 0.000351 | 2.37E-08 | 0.033 |
| 2 | 0.019869 | 1.73E-05 | 1.166 |
| 3 | 0.004742 | 5.64E-06 | 0.287 |
| 4 | 0.022951 | 2.05E-05 | 1.22 |
| 5 | 0.004315 | 2.74E-06 | 0.18 |
| 6 | 0.032482 | 1.64E-05 | 1.368 |
| 7 | 0.024468 | 1.08E-05 | 1.043 |
| 8 | 0.035137 | 1.92E-05 | 1.618 |
| 9 | 0.04685 | 3.54E-05 | 2.328 |
| 10 | 0.042962 | 2.81E-05 | 2.112 |
| 11 | 0.043341 | 2.59E-05 | 2.064 |
| 12 | 0.033336 | 2.49E-05 | 1.698 |
| 13 | 0.045854 | 3.14E-05 | 2.011 |
| 14 | 0.033004 | 2.15E-05 | 1.572 |
| 15 | 0.114612 | 6.51E-05 | 4.739 |
| 16 | 0.003224 | 1.30E-06 | 0.1 |

**Table 2 – Life-Cycle Cost Effectiveness Summary (Replaces Table 11 in CASE report)**

| **Climate Zone** | 15-Year TDV Electricity Cost Savings (2020 PV $ per sf) | 15-Year TDV Natural Gas Cost Savings (2020 PV $ per sf) | Total 15-Year TDV Energy Cost Savings (2020 PV $ per sf) |
|---|---|---|---|
| | Large Office Prototype | | |
| 1 | $0.0040 | N/A | $0.0040 |
| 2 | $0.0912 | N/A | $0.0912 |
| 3 | $0.0322 | N/A | $0.0322 |
| 4 | $0.0996 | N/A | $0.0996 |
| 5 | $0.0251 | N/A | $0.0251 |
| 6 | $0.1183 | N/A | $0.1183 |
| 7 | $0.1009 | N/A | $0.1009 |
| 8 | $0.1279 | N/A | $0.1279 |
| 9 | $0.1555 | N/A | $0.1555 |
| 10 | $0.1558 | N/A | $0.1558 |
| 11 | $0.1427 | N/A | $0.1427 |
| 12 | $0.1251 | N/A | $0.1251 |
| 13 | $0.1468 | N/A | $0.1468 |
| 14 | $0.1162 | N/A | $0.1162 |
| 15 | $0.2530 | N/A | $0.2530 |

| | | | |
|---|---|---|---|
| 16 | $0.0182 | N/A | $0.0182 |
| | **Large School Prototype** | | |
| 1 | $0.0029 | N/A | $0.0029 |
| 2 | $0.1038 | N/A | $0.1038 |
| 3 | $0.0255 | N/A | $0.0255 |
| 4 | $0.1086 | N/A | $0.1086 |
| 5 | $0.0160 | N/A | $0.0160 |
| 6 | $0.1218 | N/A | $0.1218 |
| 7 | $0.0928 | N/A | $0.0928 |
| 8 | $0.1440 | N/A | $0.1440 |
| 9 | $0.2072 | N/A | $0.2072 |
| 10 | $0.1880 | N/A | $0.1880 |
| 11 | $0.1837 | N/A | $0.1837 |
| 12 | $0.1511 | N/A | $0.1511 |
| 13 | $0.1790 | N/A | $0.1790 |
| 14 | $0.1399 | N/A | $0.1399 |
| 15 | $0.4218 | N/A | $0.4218 |
| 16 | $0.0089 | N/A | $0.0089 |

**Life-Cycle Cost Effectiveness**

Detailed cost information for a range of axial-fan cooling towers has been provided by the CASE authors for this measure. This analysis leverages existing cost information, which considered incremental cooling tower costs, including any incremental structural costs resulting from incremental tower weight (and water weight) for roof-mounted towers.

Base costs of $120/ton were applied to the tower sizes for each of the prototypes in each climate zone. Incremental costs varied by climate zone and were set to match the percentage savings from the docketed CASE study.

Table 3 shows that even when using a conservative incremental cost estimate that matches the higher 80 gpm/hp proposed efficiency level from the CASE study, the measure is still cost effective in all of the recommended climate zones except climate zones 1, 3, 5, and 16. (The docketed CASE proposal shows that the higher efficiency level of 80 gpm/hp is not cost-effective in climate zones 1 and 16.)

It is not feasible to adjust the incremental costs from the CASE study, since they include specific make and model costs, as well as incremental structural costs for the roof-mounted towers for the large office. Either component of the incremental cost may not scale with tower capacity and efficiency level.

**Table 3 - Lifecycle Cost-Effectiveness Summary per Square Foot**

| **Climate Zone** | Benefits<br>TDV Energy Cost Savings +<br>Other PV Savings (2020 PV $) | Costs<br>Total Incremental Present Valued (PV) Costs<br>(2020 PV $) | Benefit-to-Cost Ratio |
|---|---|---|---|
| | Large Office Prototype | | |
| 1 | $0.0040 | $0.04 | 0.10 |
| 2 | $0.0912 | $0.07 | 1.30 |
| 3 | $0.0322 | $0.05 | 0.64 |
| 4 | $0.0996 | $0.05 | 1.99 |
| 5 | $0.0251 | $0.04 | 0.63 |
| 6 | $0.1183 | $0.05 | 2.37 |
| 7 | $0.1009 | $0.05 | 2.02 |
| 8 | $0.1279 | $0.06 | 2.13 |
| 9 | $0.1555 | $0.06 | 2.59 |
| 10 | $0.1558 | $0.05 | 3.12 |
| 11 | $0.1427 | $0.05 | 2.85 |
| 12 | $0.1251 | $0.06 | 2.09 |
| 13 | $0.1468 | $0.05 | 2.94 |
| 14 | $0.1162 | $0.06 | 1.94 |
| 15 | $0.2530 | $0.04 | 6.33 |
| 16 | $0.0182 | $0.06 | 0.30 |
| | **Large School Prototype** | | |
| 1 | $0.0029 | $0.02 | 0.15 |
| 2 | $0.1038 | $0.03 | 3.46 |
| 3 | $0.0255 | $0.01 | 2.55 |
| 4 | $0.1086 | $0.03 | 3.62 |
| 5 | $0.0160 | $0.01 | 1.60 |
| 6 | $0.1218 | $0.02 | 6.09 |
| 7 | $0.0928 | $0.02 | 4.64 |
| 8 | $0.1440 | $0.02 | 7.20 |
| 9 | $0.2072 | $0.04 | 5.18 |
| 10 | $0.1880 | $0.04 | 4.70 |
| 11 | $0.1837 | $0.03 | 6.12 |
| 12 | $0.1511 | $0.03 | 5.04 |
| 13 | $0.1790 | $0.03 | 5.97 |
| 14 | $0.1399 | $0.02 | 7.00 |
| 15 | $0.4218 | $0.05 | 8.44 |
| 16 | $0.0089 | $0.01 | 0.89 |

## CODE LANGUAGE

**Current CASE Proposal**

6. **Cooling Tower Efficiency.** New or replacement open-circuit cooling towers serving condenser water systems with a combined rated capacity of 900 gpm at design conditions, shall have a rated efficiency of no less than 80 gpm/hp when rated in accordance to the test procedures and rating conditions as listed in Table 110.2-G.
**EXCEPTION 1 to Section 140.4(h)6:** Replacement of existing cooling towers that are inside an existing building or on an existing roof.
**EXCEPTION 2 to Section 140.4(h)6:** Buildings in Climate Zone 1 and 16 that are not connected to a water economizer system

**NORESCO Revised Proposal**

6. **Cooling Tower Efficiency.** New or replacement open-circuit cooling towers serving condenser water systems with a combined rated capacity of 900 gpm at design conditions, shall have a rated efficiency of no less than 60 gpm/hp when rated in accordance to the test procedures and rating conditions as listed in Table 110.2-G.
**EXCEPTION 1 to Section 140.4(h)6:** Replacement of existing cooling towers that are inside an existing building or on an existing roof.
**EXCEPTION 2 to Section 140.4(h)6:** Buildings in Climate Zone 1, 3, 5 or 16 that are not connected to a water economizer system.

**Assumptions Used in Revised Analysis**

NORESCO applied cost data from the September 2017 CASE Report on tower efficiency requirements[1]. That study developed detailed cost information for cooling towers from manufacturer's costing software, and accounted for any structural implications for roof-mounted towers. Since detailed cost data for 60 gpm/hp cooling towers was not readily available, this analysis used the incremental costs for 80 gpm/hp towers, as a conservative estimate.

The revised analysis also uses the latest revision to the 2019 TDV dataset, which is incorporated in CBECC-Com V3.0, build v877. A previous version (v876) had a TDV dataset that required a minor correction. This does not change the methodology or energy savings results, but changes the TDV first-year savings slightly.

Statewide impacts are not provided in this memorandum. However, the measure would affect the same building types and the same square footage of commercial building stock. Since the unit savings are lower in the revised proposal, the statewide impact would be adjusted accordingly.

[1] Gracik, Stefan, M. Delghani, A. Brannon 2017. "Prescriptive Efficiency Requirements for Cooling Towers – Final Report", Integral Group on behalf of the California Utilities Statewide Codes and Standards Team

Best regards,

John Arent P.E.

NORESCO Sustainability Services