# DOCKETED

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|---|---|
| **Docket Number:** | 17-BSTD-01 |
| **Project Title:** | 2019 Building Energy Efficiency Standards PreRulemaking |
| **TN #:** | 219857 |
| **Document Title:** | Presentation - Exhaust Air Heat Recovery |
| **Description:** | By: Mark Alatorre, PE |
| **Filer:** | Hilary Fiese |
| **Organization:** | California Energy Commission |
| **Submitter Role:** | Commission Staff |
| **Submission Date:** | 6/23/2017 10:31:54 AM |
| **Docketed Date:** | 6/23/2017 |

# Exhaust Air Heat Recovery

Mark Alatorre, PE
Building Standards Office
Efficiency Division

Pre-Rulemaking Workshop
Imbrecht Hearing Room
June 20, 2017

# Acknowledgements

California Statewide Codes and Standards Team

CASE Authors:

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# Background

- Not Currently required under the Building Energy Efficiency Standards
- Compliance Option for Dedicated Outside Air Systems
- Under certain conditions it could yield energy savings

# Background

- Currently required by ASHRAE 90.1-2016
- AHRI Standard 1060/1061
- Listed in the AHRI Directory
- Many Different Manufacturers
- Stand Alone or Packaged

# Product Availability

- Current AHRI Listings
- 1,254 plate type
- 2,894 wheel type

| Minimum Requirement (Prescriptive) | Plate Type | Wheel Type |
|---|---|---|
| **50% recovery** | 86% | 95% |
| **60% recovery** | 48% | 93% |
| **70% recovery** | 9% | 24% |

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# Certificate of Product Ratings

**AHRI Certified Reference Number: 10272424** Date: 6/16/2017 †Status: Active

**Product: Component Air-to-Air Energy Recovery Ventilator**

**Model Number: XLT-H 100(47)-42**

**Manufacturer: AIROTOR, LLC**

**Trade/Brand name: AIROTOR**

**Rated as follows in accordance with AHRI Standard 1060-2014 for Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:**

| | | |
|---|---|---|
| Product Type: | Plate | Leaving Supply Air Flow (SCFM): 12900 |
| Pressure Drop (inches): | 0.75 | Additional Notes: |

| Leakage Ratings | Pressure Differential | EATR(%) | OACF | Purge Angle/Setting |
|---|---|---|---|---|
| Test 1: | -5.00 | 0.00 | 1.00 | 0 |
| Test 2: | 0.00 | 0.00 | 1.00 | 0 |
| Test 3: | 5.00 | 0.00 | 1.00 | 0 |

Thermal Effectiveness Ratings at 0" Pressure Differential

| | *Sensible(%)* | *Latent(%)* | *Total(%)* |
|---|---|---|---|
| 100% Air Flow Heating | 65 | 0 | 43 |
| 75% Air Flow Heating | 66 | 0 | 43 |
| 100% Air Flow Cooling | 63 | 0 | 24 |
| 75% Air Flow Cooling | 64 | 0 | 24 |

| | *Net Sensible(%)* | *Net Latent(%)* | *Net Total(%)* |
|---|---|---|---|
| 100% Air Flow Heating | 65 | 0 | 43 |
| 75% Air Flow Heating | 66 | 0 | 43 |
| 100% Air Flow Cooling | 63 | 0 | 24 |
| 75% Air Flow Cooling | 64 | 0 | 24 |

| | | |
|---|---|---|
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| Test 1: | -5.00 | 0.00 | 1.00 | 0 |
| Test 2: | 0.00 | 0.00 | 1.00 | 0 |
| Test 3: | 5.00 | 0.00 | 1.00 | 0 |

Thermal Effectiveness Ratings at 0" Pressure Differential

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|---|---|---|---|
| 100% Air Flow Heating | 65 | 0 | 43 |
| 75% Air Flow Heating | 65 | 0 | 43 |
| 100% Air Flow Cooling | 63 | 0 | 24 |
| 75% Air Flow Cooling | 64 | 0 | 24 |

# Energy Analysis

- Prototypes Used
  - Small office – packaged single zone
  - Medium office – variable air volume
  - Medium office/lab – high ventilation fraction

| Prototype ID | Occupancy Type (Residential, Retail, Office, etc.) | Area ($ft^2$) | Number of Stories | Statewide Area (million $ft^2$) |
|---|---|---|---|---|
| **Prototype 2** | Small Office | 24,413 | 1 | 15.288 |
| **Prototype 3** | Medium Office | 53,628 | 3 | 42.358 |
| **Prototype 15** | Medium Office-Lab | 53,628 | 3 | 1.742 |

# Key Assumptions

- Added static pressure to air stream will be based on ASHRAE 90.1 Section 6.5.3.1 under the fan pressure drop adjustment table for energy recovery device.
- Outdoor air intake will bypass the heat recovery ventilator when the outdoor conditions are more suitable for economizer operation.
- No fan energy savings during bypass mode
- Analysis will maintain the same fan total static pressure for all operating hours.
- Result in increased fan power, even during economizer bypass

# Energy Analysis – First Year Impact

**Small Office First Year Impacts per Square Foot**

| Climate Zone | Electricity Savings (kWh/ft2-yr) | Peak Electricity Demand Reductions (kW/ft2) | Natural Gas Savings (therms/ft2-yr) | TDV Energy Savings (TDV kBtu/ft2-yr) |
|---|---|---|---|---|
| 1 | -1.25 | -1.49 x 10-4 | 0.07 | -22.20 |
| 2 | -1.27 | -8.05 x 10-7 | 0.04 | -25.08 |
| 3 | -1.30 | -7.69 x 10-5 | 0.03 | -30.31 |
| 4 | -1.27 | -4.22 x 10-5 | 0.02 | -28.19 |
| 5 | -1.30 | -1.18 x 10-4 | 0.03 | -31.22 |
| 6 | -1.28 | 2.10 x 10-5 | 0.01 | -32.44 |
| 7 | -1.30 | -1.01 x 10-4 | 0.00 | -35.21 |
| 8 | -1.27 | 6.00 x 10-6 | 0.01 | -31.64 |
| 9 | -1.26 | 1.24 x 10-5 | 0.01 | -29.86 |
| 10 | -1.29 | 3.57 x 10-5 | 0.01 | -29.78 |
| 11 | -1.18 | 1.34 x 10-4 | 0.04 | -19.39 |
| 12 | -1.21 | 4.86 x 10-5 | 0.04 | -21.42 |
| 13 | -1.16 | -2.60 x 10-5 | 0.04 | -21.06 |
| 14 | -1.22 | -5.46 x 10-6 | 0.04 | -23.31 |
| 15 | -0.99 | -1.08 x 10-5 | 0.00 | -21.97 |
| 16 | -1.37 | -1.31 x 10-4 | 0.09 | -17.79 |

# Energy Analysis – 15 Year Impact

| Small Office 15 Year Impacts per Square Foot | | | |
|---|---|---|---|
| Climate Zone | 15-Year TDV Electricity Cost Savings (2020 PV$) | 15-Year TDV Natural Gas Cost Savings (2020 PV$) | Total 15-Year TDV Energy Cost Savings (2020 PV$) |
| 1 | -$3.16 | $1.18 | -$1.98 |
| 2 | -$2.90 | $0.67 | -$2.23 |
| 3 | -$3.20 | $0.50 | -$2.70 |
| 4 | -$2.91 | $0.41 | -$2.51 |
| 5 | -$3.30 | $0.52 | -$2.78 |
| 6 | -$3.08 | $0.19 | -$2.89 |
| 7 | -$3.21 | $0.08 | -$3.13 |
| 8 | -$2.97 | $0.15 | -$2.82 |
| 9 | -$2.83 | $0.17 | -$2.66 |
| 10 | -$2.85 | $0.20 | -$2.65 |
| 11 | -$2.41 | $0.69 | -$1.73 |
| 12 | -$2.59 | $0.69 | -$1.91 |
| 13 | -$2.53 | $0.65 | -$1.87 |
| 14 | -$2.73 | $0.66 | -$2.07 |
| 15 | -$2.02 | $0.07 | -$1.96 |
| 16 | -$3.20 | $1.62 | -$1.58 |

# Energy Analysis – First Year Impact

**Medium Office First Year Impacts per Square Foot**

| Climate Zone | Electricity Savings (kWh/ft2-yr) | Peak Electricity Demand Reductions (kW/ft2) | Natural Gas Savings (therms/ft2-yr) | TDV Energy Savings (TDV kBtu/ft2-yr) |
|---|---|---|---|---|
| 1 | -0.17 | -4.84 x 10-5 | 1.16 x 10-3 | -4.38 |
| 2 | -0.14 | 9.67 x 10-5 | 8.13 x 10-4 | -0.82 |
| 3 | -0.19 | 2.16 x 10-5 | 7.21 x 10-4 | -4.60 |
| 4 | -0.16 | 9.48 x 10-5 | 5.55 x 10-4 | -0.76 |
| 5 | -0.20 | 4.10 x 10-5 | 7.96 x 10-4 | -4.91 |
| 6 | -0.21 | 1.78 x 10-4 | 3.61 x 10-4 | -4.22 |
| 7 | -0.23 | -9.09 x 10-5 | 2.32 x 10-4 | -5.72 |
| 8 | -0.18 | 1.79 x 10-4 | 3.08 x 10-4 | -2.16 |
| 9 | -0.14 | 1.57 x 10-4 | 3.69 x 10-4 | -0.13 |
| 10 | -0.09 | 2.26 x 10-4 | 3.71 x 10-4 | 2.68 |
| 11 | -0.03 | 3.13 x 10-4 | 6.13 x 10-4 | 4.90 |
| 12 | -0.09 | 2.38 x 10-4 | 7.67 x 10-4 | 2.25 |
| 13 | -0.03 | 2.20 x 10-4 | 5.82 x 10-4 | 3.88 |
| 14 | -0.05 | 9.81 x 10-5 | 5.62 x 10-4 | 2.25 |
| 15 | 0.20 | 2.87 x 10-4 | 1.47 x 10-4 | 10.90 |
| 16 | -0.21 | 1.39 x 10-5 | 1.07 x 10-3 | -5.49 |

# Energy Analysis – 15 Year Impact

| Medum Office 15 Year Impacts per Square Foot | | | |
|---|---|---|---|
| Climate Zone | 15-Year TDV Electricity Cost Savings (2020 PV$) | 15-Year TDV Natural Gas Cost Savings (2020 PV$) | Total 15-Year TDV Energy Cost Savings (2020 PV$) |
| 1 | -$0.41 | $0.02 | -$0.39 |
| 2 | -$0.09 | $0.01 | -$0.07 |
| 3 | -$0.42 | $0.01 | -$0.41 |
| 4 | -$0.08 | $0.01 | -$0.07 |
| 5 | -$0.45 | $0.01 | -$0.44 |
| 6 | -$0.38 | $0.01 | -$0.38 |
| 7 | -$0.51 | $0.00 | -$0.51 |
| 8 | -$0.20 | $0.01 | -$0.19 |
| 9 | -$0.02 | $0.01 | -$0.01 |
| 10 | $0.23 | $0.01 | $0.24 |
| 11 | $0.42 | $0.01 | $0.44 |
| 12 | $0.19 | $0.01 | $0.20 |
| 13 | $0.33 | $0.01 | $0.35 |
| 14 | $0.19 | $0.01 | $0.20 |
| 15 | $0.97 | $0.00 | $0.97 |
| 16 | -$0.51 | $0.02 | -$0.49 |

# Energy Analysis – First Year Impact

**Medium Office/Lab First Year Impacts per Square Foot**

| Climate Zone | Electricity Savings (kWh/ft2-yr) | Peak Electricity Demand Reductions (kW/ft2) | Natural Gas Savings (therms/ft2-yr) | TDV Energy Savings (TDV kBtu/ft2-yr) |
|---|---|---|---|---|
| 1 | -1.91 | 5.01 x 10-5 | 0.04 | -46.13 |
| 2 | -0.88 | 3.81 x 10-4 | 0.02 | 16.77 |
| 3 | -1.99 | 7.89 x 10-4 | 0.02 | -44.39 |
| 4 | -1.36 | 6.14 x 10-4 | 0.02 | 11.21 |
| 5 | -1.91 | 3.46 x 10-4 | 0.02 | -46.49 |
| 6 | -1.92 | 1.11 x 10-4 | 0.01 | -30.35 |
| 7 | -2.27 | -8.26 x 10-5 | 0.01 | -53.60 |
| 8 | -1.16 | 1.30 x 10-3 | 0.01 | 6.46 |
| 9 | -0.34 | 1.20 x 10-3 | 0.01 | 38.20 |
| 10 | 0.23 | 2.72 x 10-3 | 0.01 | 66.84 |
| 11 | 1.25 | 3.34 x 10-3 | 0.01 | 121.24 |
| 12 | 0.02 | 2.20 x 10-3 | 0.01 | 69.95 |
| 13 | 0.95 | 1.52 x 10-3 | 0.01 | 89.43 |
| 14 | 1.20 | 1.32 x 10-3 | 0.01 | 82.84 |
| 15 | 4.32 | 4.63 x 10-4 | 0.00 | 189.69 |
| 16 | -1.71 | -1.21 x 10-4 | 0.03 | -38.45 |

# Energy Analysis – 15 Year Impact

| Medum Office 15 Year Impacts per Square Foot | | | |
|---|---|---|---|
| Climate Zone | 15-Year TDV Electricity Cost Savings (2020 PV$) | 15-Year TDV Natural Gas Cost Savings (2020 PV$) | Total 15-Year TDV Energy Cost Savings (2020 PV$) |
| 1 | -$4.71 | $0.61 | -$4.11 |
| 2 | $1.19 | $0.30 | $1.49 |
| 3 | -$4.31 | $0.36 | -$3.95 |
| 4 | $0.72 | $0.28 | $1.00 |
| 5 | -$4.49 | $0.35 | -$4.14 |
| 6 | -$2.87 | $0.17 | -$2.70 |
| 7 | -$4.88 | $0.11 | -$4.77 |
| 8 | $0.43 | $0.15 | $0.57 |
| 9 | $3.26 | $0.14 | $3.40 |
| 10 | $5.80 | $0.15 | $5.95 |
| 11 | $10.60 | $0.19 | $10.79 |
| 12 | $5.98 | $0.25 | $6.23 |
| 13 | $7.73 | $0.23 | $7.96 |
| 14 | $7.20 | $0.18 | $7.37 |
| 15 | $16.84 | $0.04 | $16.88 |
| 16 | -$3.91 | $0.48 | -$3.42 |

# Incremental Cost

- From manufacturer data
- RS Means
- Including bypass dampers/controls/labor

| Size (cfm) | Base Cost | $/cfm |
|---|---|---|
| **1000** | $6,775 | $6.78 |
| **2000** | $7,925 | $3.96 |
| **4000** | $9,175 | $2.29 |
| **6000** | $10,700 | $1.78 |
| **8000** | $11,800 | $1.48 |
| **10000** | $14,200 | $1.42 |
| **20000** | $25,700 | $1.29 |
| **25000** | $31,400 | $1.26 |
| **30000** | $34,800 | $1.16 |
| **40000** | $48,000 | $1.20 |
| **50000** | $56,000 | $1.12 |

# Reduced Cost

- Incorporating a heat recovery ventilator results in reduced capacity
- Calculated for each climate zone
- Incremental cost was adjusted due to smaller heating/cooling equipment

| Climate Zone | Cooling Design Condition (0.4%) [°F] | Heating Design Condition (99.6%) [°F] | Small Office | Medium Office | Medium Office/Lab |
|---|---|---|---|---|---|
| **1** | 70.4 | 30.4 | $0.15 | $0.00 | $1.14 |
| **2** | 95.3 | 29.6 | $0.23 | $0.08 | $1.75 |
| **3** | 82.3 | 36.7 | $0.16 | $0.03 | $0.21 |
| **4** | 88.4 | 36.2 | $0.18 | $0.05 | $0.39 |
| **5** | 83.8 | 32.6 | $0.18 | $0.03 | $0.25 |
| **6** | 83.7 | 44.5 | $0.13 | $0.03 | $0.25 |
| **7** | 83.1 | 44.8 | $0.13 | $0.03 | $0.23 |
| **8** | 93.4 | 39.2 | $0.19 | $0.07 | $0.53 |
| **9** | 97.7 | 38.6 | $0.21 | $0.09 | $0.65 |
| **10** | 100.0 | 36.1 | $0.23 | $0.10 | $0.72 |
| **11** | 105.4 | 29.9 | $0.27 | $0.12 | $2.03 |
| **12** | 100.5 | 30.4 | $0.25 | $0.10 | $1.88 |
| **13** | 103.5 | 31.4 | $0.26 | $0.11 | $1.93 |
| **14** | 101.9 | 25.1 | $0.28 | $0.10 | $2.07 |
| **15** | 111.2 | 41.4 | $0.25 | $0.14 | $1.04 |
| **16** | 83.7 | 20.8 | $0.22 | $0.03 | $1.67 |

# Lifecycle Cost-Effectiveness

| Small Office | | | |
|---|---|---|---|
| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$) | Costs Total Incremental PV Costs2 (2020 PV$) | Benefit-to- Cost Ratio |
| 1 | -$1.98 | $1.25 | -1.58 |
| 2 | -$2.23 | $1.21 | -1.84 |
| 3 | -$2.70 | $1.23 | -2.20 |
| 4 | -$2.51 | $1.27 | -1.97 |
| 5 | -$2.78 | $1.22 | -2.29 |
| 6 | -$2.89 | $1.32 | -2.19 |
| 7 | -$3.13 | $1.30 | -2.40 |
| 8 | -$2.82 | $1.31 | -2.15 |
| 9 | -$2.66 | $1.30 | -2.04 |
| 10 | -$2.65 | $1.38 | -1.92 |
| 11 | -$1.73 | $1.30 | -1.32 |
| 12 | -$1.91 | $1.24 | -1.54 |
| 13 | -$1.87 | $1.28 | -1.46 |
| 14 | -$2.07 | $1.36 | -1.52 |
| 15 | -$1.96 | $1.39 | -1.40 |
| 16 | -$1.58 | $1.50 | -1.05 |

# Lifecycle Cost-Effectiveness

| Medium Office | | | |
|---|---|---|---|
| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$) | Costs Total Incremental PV Costs2 (2020 PV$) | Benefit-to- Cost Ratio |
| 1 | -$0.39 | $0.86 | -0.45 |
| 2 | -$0.07 | $0.82 | -0.09 |
| 3 | -$0.41 | $0.85 | -0.48 |
| 4 | -$0.07 | $0.89 | -0.08 |
| 5 | -$0.44 | $0.84 | -0.52 |
| 6 | -$0.38 | $0.90 | -0.42 |
| 7 | -$0.51 | $0.89 | -0.57 |
| 8 | -$0.19 | $0.86 | -0.22 |
| 9 | -$0.01 | $0.86 | -0.01 |
| 10 | $0.24 | $1.00 | 0.24 |
| 11 | $0.44 | $0.88 | 0.50 |
| 12 | $0.20 | $0.85 | 0.24 |
| 13 | $0.35 | $0.88 | 0.39 |
| 14 | $0.20 | $0.95 | 0.21 |
| 15 | $0.97 | $0.92 | 1.05 |
| 16 | -$0.49 | $1.15 | -0.43 |

# Lifecycle Cost-Effectiveness

| Medium Office/Lab | | | |
|---|---|---|---|
| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$) | Costs Total Incremental PV Costs2 (2020 PV$) | Benefit-to- Cost Ratio |
| 1 | -$4.11 | $0.96 | -4.28 |
| 2 | $1.49 | $0.67 | 2.24 |
| 3 | -$3.95 | $1.91 | -2.07 |
| 4 | $1.00 | $1.74 | 0.57 |
| 5 | -$4.14 | $1.87 | -2.21 |
| 6 | -$2.70 | $1.91 | -1.42 |
| 7 | -$4.77 | $1.89 | -2.53 |
| 8 | $0.57 | $1.66 | 0.35 |
| 9 | $3.40 | $1.99 | 1.71 |
| 10 | $5.95 | $1.94 | 3.07 |
| 11 | $10.79 | $0.86 | 12.52 |
| 12 | $6.23 | $0.66 | 9.48 |
| 13 | $7.96 | $0.52 | 15.22 |
| 14 | $7.37 | $1.04 | 7.06 |
| 15 | $16.88 | $2.03 | 8.33 |
| 16 | -$3.42 | $0.51 | -6.76 |

# Proposed Code Language

**SECTION 140.4 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS**

**(o) – Exhaust Air Heat Recovery.**

1. Each fan system shall have a heat recovery system when the system supply airflow rate exceeds the value listed in Tables 140.4-E-1 or 140.4-E-2.
2. Heat recovery systems required by this section shall result in a net sensible energy recovery ratio of at least 60% for both heating and cooling as tested using AHRI 1060-2014 or 1061- 2014 and certified by AHRI. A 60% sensible energy recovery ratio shall mean a change in the dry bulb of the outdoor air supply equal to 60% of the difference between the outdoor air and exhaust air dry bulb at design conditions. Provision shall be made to bypass or control the energy recovery system to permit air economizer operation as required by Section 140.4(e): Economizers.

**EXCEPTION 1 to Section 140.4(o):** Systems serving spaces that are not cooled and that are heated to less than 60°F.

**EXCEPTION 2 to Section 140.4(o):** Where more than 60% of the outdoor air heating energy is provided from site-recovered energy.

**EXCEPTION 3 to Section 140.4(o):** Where the sum of the airflow rates exhausted and relieved within 20 ft. of each other is less than 75% of the design outdoor airflow rate, excluding exhaust air that is either:

1. used for another energy recovery system,
2. not allowed by ASHRAE Standard 170 for use in energy recovery systems with leakage potential, or
3. of Class 4 as defined in ASHRAE Standard 62.1.

**EXCEPTION 4 to Section 140.4(o):** Systems expected to operate less than 20 hours per week

# Proposed Code Language

*TABLE 140.4-E-1 EXHAUST AIR ENERGY RECOVERY REQUIREMENTS FOR VENTILATION SYSTEMS OPERATING LESS THAN 8000 HOURS PER YEAR*

| Climate Zone | % *Outdoor Air* at Full Design Airflow Rate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ≥10% and <20% | ≥20% and <30% | ≥30% and <40% | ≥40% and <50% | ≥50% and <60% | ≥60% and <70% | ≥70% and <80% | ≥80% |
| | Design Supply Fan Airflow Rate, cfm | | | | | | | |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16 | NR | NR | NR | NR | NR | NR | NR | NR |
| 15 | NR | NR | NR | NR | ~~≥26000~~ | ≥12000 | ≥5000 | ≥4000 |

*TABLE 140.4-E-2 EXHAUST AIR ENERGY RECOVERY REQUIREMENTS FOR VENTILATION SYSTEMS OPERATING GREATER THAN OR EQUAL TO 8000 HOURS PER YEAR*

| Climate Zone | % *Outdoor Air* at Full Design Airflow Rate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ≥10% and <20% | ≥20% and <30% | ≥30% and <40% | ≥40% and <50% | ≥50% and <60% | ≥60% and <70% | ≥70% and <80% | ≥80% |
| | Design Supply Fan Airflow Rate, cfm | | | | | | | |
| ~~2~~, 1,7,3, 4, 5, 6 | NR | NR | NR | NR | NR | NR | NR | NR |
| ~~1, 7~~, 2,8, 9, 10, 11, 12, 13, 14, 15 | NR | ~~≥19,500~~ | ~~≥9000~~ | ~~≥5000~~ | ~~≥4000~~ | ≥3000 | ≥1500 | ≥120 |
| ~~16~~ | ~~≥2500~~ | ~~≥2000~~ | ~~≥1000~~ | ~~≥500~~ | ~~≥140~~ | ~~≥120~~ | ~~≥100~~ | ~~≥80~~ |

# Questions?

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Comments Due by July 7th
Docket Number 2017-BSTD-01
docket@energy.ca.gov