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Docket Number:	17-BSTD-01
Project Title:	2019 Building Energy Efficiency Standards PreRulemaking
TN #:	219859
Document Title:	Presentation - Demand Control Ventilation for Classrooms
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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

Demand Control Ventilation for Classrooms

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Pre-Rulemaking Workshop
Imbrecht Hearing Room
June 20, 2017

Acknowledgements

California Statewide Codes and Standards Team

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Background

- Carbon Dioxide (CO2) based Demand Control Ventilation (DCV) has been in use for over thirty years.
- ASHRAE 90.1 has mandated DCV for classrooms since 1999
- ASHRAE 90.1 has continually reduced the space density for triggering DCV
  - 25 people per 1000 square feet

Background

- Demand Control Ventilation (DCV) has part of the Energy Efficiency Standards since 1992
- 2001 Title 24, Part 6 – mandated for high-density spaces (including classrooms)
- 2005 Title 24, Part 6 – classrooms were exempt from DCV

Background

- Given CO2 based DCV have been in high use both in California and nationally
  - Improvement in sensor reliability
  - Reduction in sensor cost
- CASE Team contends that systems incorporating CO2 DCV results in better indoor air quality compared to non DCV

Background

- Product availability
  - Many manufacturers of standalone CO2 sensors
  - Building Automation Systems (BAS), most offer thermostats with embedded CO2 sensors
- Technology
  - Variety in sensor type, which should be understood by designers based on application

Proposed Code Change

- Amend Section 120.1(c)3 to apply to more spaces, including classrooms
- Also add “modulating outside air control” and “design outdoor airflow rate > 3000 cfm” as triggers for DCV
- These changes will align Section 120.1(c)3 with ASHRAE 90.1

Energy Analysis

- CBECC-Com can model DCV
- No changes to the proposed model other than DCV

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (ft2)	Number of Stories	Statewide Area (million ft2)
Prototype 1	Small Schools	24,413	1	9.17
Prototype 2	Large Schools	210,886	2	6.12

Energy Analysis – First Year Impact per ft^2

Small School Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.08	2.34 x 10-5	0.06	13.20
2	0.23	2.89 x 10-4	0.04	22.35
3	0.08	6.64 x 10-5	0.03	10.13
4	0.22	1.39 x 10-4	0.03	19.90
5	0.08	2.88 x 10-5	0.04	10.01
6	0.12	1.20 x 10-4	0.01	11.07
7	0.05	1.72 x 10-4	0.01	6.53
8	0.23	2.70 x 10-4	0.01	17.22
9	0.33	2.08 x 10-4	0.02	25.52
10	0.36	2.77 x 10-4	0.02	25.97
11	0.43	2.04 x 10-4	0.03	33.04
12	0.35	2.32 x 10-4	0.03	28.19
13	0.44	1.50 x 10-4	0.03	27.67
14	0.44	2.85 x 10-4	0.03	29.60
15	0.73	2.43 x 10-4	0.01	36.30
16	0.16	8.03 x 10-5	0.06	17.43

Energy Analysis – First Year Impact per ft^2

Large School Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.07	2.85 x 10-5	0.06	12.95
2	0.13	6.33 x 10-5	0.04	15.24
3	0.06	4.52 x 10-5	0.03	8.46
4	0.12	5.53 x 10-5	0.03	13.07
5	0.06	5.42 x 10-5	0.04	9.55
6	0.07	9.38 x 10-5	0.02	7.43
7	0.03	7.35 x 10-5	0.01	4.16
8	0.12	5.38 x 10-5	0.01	9.14
9	0.16	1.19 x 10-4	0.02	13.01
10	0.16	2.78 x 10-5	0.02	13.34
11	0.22	9.24 x 10-5	0.03	19.58
12	0.18	7.44 x 10-5	0.03	17.31
13	0.23	5.48 x 10-5	0.03	17.57
14	0.23	2.52 x 10-5	0.03	17.39
15	0.34	4.99 x 10-5	0.01	17.43
16	0.10	6.08 x 10-5	0.05	13.94

Energy Analysis – 15 Year Costs per ft^2

Small School 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	$0.20	$0.97	$1.17
2	$1.30	$0.68	$1.99
3	$0.39	$0.51	$0.90
4	$1.30	$0.47	$1.77
5	$0.29	$0.60	$0.89
6	$0.73	$0.25	$0.98
7	$0.45	$0.13	$0.58
8	$1.30	$0.23	$1.53
9	$1.98	$0.29	$2.27
10	$1.96	$0.35	$2.31
11	$2.35	$0.59	$2.94
12	$1.91	$0.60	$2.51
13	$1.89	$0.57	$2.46
14	$2.04	$0.59	$2.63
15	$3.05	$0.18	$3.23
16	$0.56	$0.99	$1.55

Energy Analysis – 15 Year Costs per ft^2

Large School 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	$0.18	$0.97	$1.15
2	$0.64	$0.71	$1.36
3	$0.22	$0.53	$0.75
4	$0.66	$0.50	$1.16
5	$0.19	$0.66	$0.85
6	$0.37	$0.29	$0.66
7	$0.21	$0.16	$0.37
8	$0.56	$0.26	$0.81
9	$0.83	$0.33	$1.16
10	$0.81	$0.38	$1.19
11	$1.14	$0.60	$1.74
12	$0.93	$0.61	$1.54
13	$0.98	$0.58	$1.56
14	$0.95	$0.60	$1.55
15	$1.35	$0.20	$1.55
16	$0.33	$0.91	$1.24

Lifecycle Cost-Effectiveness per ft^2

Small School Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$)	Costs Total Incremental PV Costs2 (2020 PV$)	Benefit-to- Cost Ratio
1	$1.17	$0.21	5.6
2	$1.99	$0.21	9.5
3	$0.90	$0.21	4.3
4	$1.77	$0.21	8.4
5	$0.89	$0.21	4.2
6	$0.98	$0.21	4.7
7	$0.58	$0.21	2.8
8	$1.53	$0.21	7.3
9	$2.27	$0.21	10.8
10	$2.31	$0.21	11.0
11	$2.94	$0.21	14.0
12	$2.51	$0.21	11.9
13	$2.46	$0.21	11.7
14	$2.63	$0.21	12.5
15	$3.23	$0.21	15.4
16	$1.55	$0.21	7.4

Lifecycle Cost-Effectiveness per ft^2

Large School Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings1 (2020 PV$)	Costs Total Incremental PV Costs2 (2020 PV$)	Benefit-to- Cost Ratio
1	$1.15	$0.21	5.5
2	$1.36	$0.21	6.5
3	$0.75	$0.21	3.6
4	$1.16	$0.21	5.5
5	$0.85	$0.21	4.0
6	$0.66	$0.21	3.1
7	$0.37	$0.21	1.8
8	$0.81	$0.21	3.9
9	$1.16	$0.21	5.5
10	$1.19	$0.21	5.7
11	$1.74	$0.21	8.3
12	$1.54	$0.21	7.3
13	$1.56	$0.21	7.4
14	$1.55	$0.21	7.4
15	$1.55	$0.21	7.4
16	$1.24	$0.21	5.9

Statewide Energy and Cost Savings

Small School Climate Zone	Statewide Construction in 2020 (million ft2)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	Lifecycle2 Present Valued Energy Cost Savings (PV$ million)
1	0.0498	0.004	0.001	0.003	$0.06
2	0.2474	0.056	0.071	0.010	$0.49
3	0.9078	0.073	0.060	0.027	$0.82
4	0.5588	0.125	0.078	0.015	$0.99
5	0.1085	0.008	0.003	0.004	$0.10
6	0.5999	0.069	0.072	0.009	$0.59
7	0.6454	0.032	0.111	0.005	$0.38
8	0.8754	0.199	0.236	0.011	$1.34
9	0.8878	0.293	0.185	0.015	$2.02
10	1.2399	0.447	0.343	0.025	$2.87
11	0.3230	0.139	0.066	0.011	$0.95
12	1.3180	0.459	0.306	0.045	$3.31
13	0.7148	0.314	0.107	0.023	$1.76
14	0.2255	0.100	0.064	0.007	$0.59
15	0.2278	0.166	0.055	0.002	$0.74
16	0.2433	0.039	0.020	0.014	$0.38
Total	**9.1729**	**2.525**	**1.779**	**0.226**	**$17.37**

Statewide Energy and Cost Savings

Small School Climate Zone	Statewide Construction in 2020 (million ft2)	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	Lifecycle2 Present Valued Energy Cost Savings (PV$ million)
1	0.0332	0.002	0.001	0.002	$0.04
2	0.1649	0.021	0.010	0.007	$0.22
3	0.6052	0.034	0.027	0.019	$0.46
4	0.3725	0.043	0.021	0.011	$0.43
5	0.0723	0.004	0.004	0.003	$0.06
6	0.3999	0.029	0.037	0.007	$0.26
7	0.4302	0.014	0.032	0.004	$0.16
8	0.5836	0.068	0.031	0.009	$0.47
9	0.5918	0.096	0.070	0.011	$0.69
10	0.8266	0.135	0.023	0.018	$0.98
11	0.2153	0.048	0.020	0.007	$0.38
12	0.8786	0.154	0.065	0.031	$1.35
13	0.4765	0.108	0.026	0.016	$0.74
14	0.1504	0.034	0.004	0.005	$0.23
15	0.1519	0.051	0.008	0.002	$0.24
16	0.1622	0.017	0.010	0.009	$0.20
Total	**6.1153**	**0.859**	**0.390**	**0.158**	**$6.92**

Proposed Code Language

SECTION 120.1- REQUIREMENTS FOR VENTILATION 120.1(c)3 as follows:

~~**3. Required Demand Control Ventilation.** HVAC systems with the following characteristics shall have demand ventilation controls complying with 120.1(c)4:~~

~~A. They have an air economizer; and~~

~~B. They serve a space with a design occupant density, or a~~ maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 square feet (40 square feet or less per person); and

~~C. They are either:~~

~~i.~~ Single zone systems with any controls; or

~~ii.~~ Multiple zone systems with Direct Digital Controls (DDC) to the zone level.

Proposed Code Language

3. **Required Demand Control Ventilation.** Demand ventilation controls complying with 120.1(c)4 are required for a space with a design occupant density, or a maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 square feet (40 square feet or less per person) if the system serving the space has one or more of the following:

   A. an air economizer

   B. modulating outside air control

   C. design outdoor airflow rate > 3000 cfm

EXCEPTION 1 to Section 120.1(c)3: ~~Classrooms, call centers, office spaces served by multiple zone systems that are continuously occupied during normal business hours with occupant density greater than 25 people per 1000 ft² as specified by Section 120.1(b)2B, healthcare facilities and medical buildings, and public areas of social services buildings are not required to have demand control ventilation.~~ Spaces with one of the following occupancy categories as defined in the California Mechanical Code: correctional cells, daycare sickrooms, science labs, barber shops, beauty and nail salons, and bowling alley seating.

~~**EXCEPTION 5 to Section 120.1(c)3:** Spaces with an area of less than 1,500 square feet complying with Section 120.1(c)5.~~

Questions?

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Comments Due by July 7th
Docket Number 2017-BSTD-01
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