Energy Savings of Commercial Energy Code Compliance In Washington and Oregon

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1 Summary

The purpose of this report is to address the question of how much energy would be saved if all new commercial buildings permitted in 1990 met the envelope, mechanical system, and lighting budget requirements of the Washington and Oregon energy codes. The evaluation was done using computer simulation and the Bonneville Power Administration (BPA) new commercial building prototypes (SBW 1990) to represent the region-wide commercial sector for purposes of demand forecasting and energy conservation impacts. In summary, 1 average megawatt of electricity and 98,000 therms of natural gas could have been saved through full compliance to the Washington and Oregon commercial energy codes during 1990.

Year to year variation in the frequency of violations, the amount of construction, design and fuel type trends in different sectors, mean that results from this sample are only an indicator of potential energy savings. The relationship of a particular energy code to the cost and ease of compliance will have a significant effect upon the energy savings associated with code compliance. If the code was much more stringent with a similar level of enforcement the level of non-compliance might likely change and the potential impact of non-compliance would increase dramatically.

2 Methodology

The frequency and characteristics of non-compliance in the commercial building sector were determined from the sample of buildings examined in the *Energy Code Compliance In Commercial Buildings in Washington and Oregon* study completed by Ecotope and Clark's Energy Service (Baylon et al, 1992). Buildings were assigned to BPA commercial sub-sector categories (eg. small office, large office, grocery, etc.). The BPA new construction prototypes (1989 base year) for each sector, in conjunction with DOE2.1d, a building energy analysis program, were used as the basis for evaluation of non-compliance. Energy use simulations were conducted for typical non-complying prototypes and compared with same prototype adjusted to comply with the code. The difference in energy use between the complying and non-complying simulations was taken to be the savings that would result from code compliance. The energy estimates were normalized by prototype area and adjusted to reflect different heating fuel types and HVAC systems. The adjusted energy savings predictions were extended to each sector based upon the frequency of violation and fuel type/heating system saturations found by Baylon et al (1992), and upon the permitted square footage in the sector during 1990.

Table 1 summarizes the percentage of building area not-complying with the energy code in each sector, broken down by reason for non-compliance. Percentages represent the portion of the floor area reviewed in both states which was found to be out of compliance. This has been modified to correct for sampling biases associated with building size. (see Baylon et al, Section 2.6).

Table 1. Percentage Floor Area in Non-Compliance									
Category	Heat Loss Rate	OTTV	Interior LPD	Exterior Lighting	Cooling Equip Eff.	Heating Equip. Eff.	Heating Equip Capacity	Cooling Equip. Capacity	Econo-mizer
Small Office	0.00	6.07	57.71	14.51	3.30	0.00	7.81	0.00	5.81
Large Office	44.17	11.48	0.00	10.50	0.00	0.00	7.30	0.00	5.76
Small Retail	23.28	14.69	12.58	11.52	0.00	0.00	29.46	0.00	0.00
Large Retail	44.17	10.72	45.43	54.23	0.00	0.00	5.37	0.00	6.39
Grocery	9.84	0.00	0.00	33.35	0.00	0.00	3.88	3.88	20.72
Restaurant	12.43	0.00	54.17	39.16	0.00	0.00	8.45	0.00	0.00
School	7.73	0.00	8.35	7.35	3.49	3.74	4.81	0.00	0.00
Warehouse	87.02	0.00	4.16	0.00	0.00	0.00	0.00	59.45	0.00
Assembly	0.00	0.00	11.04	11.04	0.00	0.00	0.00	0.00	0.00
Public Inst.	15.88	0.00	0.00	0.00	49.45	0.00	0.00	0.00	0.00
Lodging	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00
Health	50.87	0.00	26.85	0.00	0.00	0.00	0.00	0.00	0.00
Other	2.37	0.00	3.40	0.00	0.00	0.00	0.00	0.00	41.62
Total	35.41	5.87	14.25	15.20	1.66	0.54	5.35	7.42	4.56

To properly calculate energy savings we have separated the sample into sectors, infraction types, and states. However, the sample size was too small when divided this way to determine representative energy impacts for each case. Therefore, the energy use due to code non-compliance in each sub-sector was combined, based upon floor area, to achieve an estimate of energy savings resulting from code enforcement in the whole commercial sector. Any disaggregation of results severely reduces the statistical reliability of the data. The fact that more violators were of one type of building or in one state is not statistically significant due to the sample size.

The field study showed no relationship between code failure in one aspect of the code and code failure in another. Generally, we evaluated each code infraction against a base case which had no other code infractions. Each prototype building description was modified to comply with the state code in the area we were evaluating; all other characteristics were held constant. For example, when evaluating envelope infractions, we did not adjust the prototype lighting or HVAC system characteristics. This modified prototype which complies with the codes and is in exact compliance with the envelope code is the "baseline" prototype.

Separate simulations were done for each reason for code non-compliance in each state. Reasons for non-compliance which we evaluated were shell heat loss rate (OR and WA), Overall Thermal Transmittance Value (OTTV) (OR), interior lighting density (LPD) (WA and OR), exterior lighting density (WA and OR), equipment efficiency deficits (WA and OR), missing economizers (WA and OR), and oversized heating equipment (WA).

The space conditioning system non-compliance due to cooling system sizing and air transport factor were not evaluated due to the difficulty in modeling and the small number of infractions. Buildings assigned to the public institution, lodging, assembly and other sectors also were not examined for any code failures. The applicability of the prototypes to the sample buildings in these sectors was questionable and their overall contribution to the sector was small. These omissions account for 17.7% of the sampled buildings, and 15.5% of the floor area weighted for the sample stratification.

The baseline prototypes were simulated to establish base energy usage for each sector/state code infraction category. For each sector/state, "reason for failure" combination, we calculated the average characteristics which contributed to the code non-compliance, for the group of buildings failing. The baseline prototypes were then modified to reflect these average over code conditions. These non-complying prototypes were simulated to establish the added energy use resulting from the code violation.

Both baseline and non-complying prototypes were simulated with DOE2.1d. The energy consumption difference between the runs, normalized by building area, was taken as the energy impact per square foot of the code violation, in the particular sector.

We calculated the energy impact for three heating system scenarios: fossil fuel combustion, electric resistance and heat pump. Energy consumption was adjusted from the base system used in the DOE2.1D runs assuming an 80% combustion efficiency and a heat pump COP of 2. The heating type saturations are presented in Table 2.

Table 2. Distribution of Heating Types (Percent of Floor Area)

Category	Percentage Electric	Percentage Gas	Percentage Heat Pump
Small Office	5.8	70.3	23.9
Large Office	70.7	29.3	0.0
Small Retail	5.4	85.3	9.3
Large Retail	6.0	94.1	0.0
Grocery	0	98.4	1.6
Restaurant	0	100.0	0.0
School	14.4	83.7	1.9
Warehouse	10.1	89.9	0.0
Public Institution	0	32.4	67.7
Total	31.8	64.5	3.7

From the sample, we calculated the fraction of building floor area violating the code in question, in the sector and state in question. This was projected, in combination with heating type fractions, to the floor areas permitted for each sector during 1990, thus arriving at the floor area in violation of the code for each sector and fuel type. We combined the non-complying floor area with the energy savings for each sector and heating fuel combination, to calculate the commercial sector energy savings from code compliance.

2.1 Envelope Code Violations

A major trait of buildings violating envelope aspects of the code was high levels of glazing. We assumed that glazing area was integral to building design, and that shell changes to bring a building into code compliance would focus on thermal improvements to the wall and ceiling. So that the prototype would better represent the typical non-complying building, the glazing area was adjusted so that the prototypes percent glazing agreed with the average percent window found in the non-complying buildings. To establish the baseline prototype, the wall and ceiling U-values were adjusted so that the prototype's shell heat loss rate just met the relevant state code. To establish the non-complying prototype the baseline prototype wall and ceiling U-values were further modified to achieve the overall heat loss rate equivalent to the baseline prototype plus the heat loss rate over code typical of the non-complying buildings.

The heat loss rate over code is calculated as the floor area weighted, average heat loss rate per square foot and is extended to the prototype on a floor area basis. Adjustments to wall and ceiling U-values were made by adjusting the thickness of the specified insulation layer.

Overall Thermal Transmittance Value (OTTV) violations were more complicated. Half the OTTV violations occurred in buildings which also had problems with the heat loss rate part of the code. Since heat loss rate affects the OTTV calculation, we wanted to avoid double counting energy impacts of non-compliance. Therefore, we separated the OTTV non-compliance in each sector by whether the building passed the heat loss rate part of the code or not.

For the non-complying buildings which failed CTTV requirements without heat loss infractions, the typical OTTV over code and percentage glass were calculated. To establish the non-complying prototype, the prototype glazing area was adjusted so the percentage glass was similar to the average for the non-complying buildings. This same window area was used in the baseline prototype. To establish the baseline prototype, we adjusted the glazing shading coefficient downward, so that the difference in OTTV between the non-complying and baseline prototypes, matched the typical OTTV over code of the non-complying buildings in the sample.

For buildings with OTTV and heat loss rate infractions we used a slightly different approach. After the baseline and non-complying prototypes were developed for heat loss rate non-compliance, we calculated the OTTV of each. The improvement in OTTV resulting from heat loss rate code compliance was also accounted toward meeting the OTTV code. This was done by subtracting the change in OTTV resulting from the improvements in overall heat loss rate from the average OTTV over code of the non-complying buildings. We then used the heat loss rate of the baseline prototype and established an OTTV from the remaining level of non-compliance in OTTV non-complying prototype. The OTTV baseline prototype code compliance was established by lowering the shading coefficient, so that the difference in OTTV between the baseline and non-complying prototypes matched the adjusted OTTV over code of the non-complying buildings in the sample. The change in energy use from the non-complying prototype and this baseline prototype was taken as the impact of non-compliance with the OTTV provisions of the energy code.

2.2 Lighting Code Violations

For interior lighting code violations, we averaged the lighting power density (LPD) over code level. For exterior lighting, the installed kW was averaged. We adjusted the lighting which exceeded code, in Washington buildings, for the allowed combination of the interior and exterior lighting budgets. To establish the baseline prototype for evaluating interior lighting infractions, we adjusted the prototype interior lighting levels to the relevant state code and left the shell and system parameters as they were. The non-complying prototypes, reflecting interior lighting code violations, were created by changing the baseline lighting densities so that the new LPD reflected code lighting plus the average amount of lighting wattage beyond the code lighting budget for violating buildings.

Exterior lighting baseline prototypes were left unaltered. The non-complying prototypes had the exterior lighting increased by the installed kW over code typical in the violating buildings.

2.3 HVAC System Violations

Maximum heating capacity baseline prototypes were created by adjusting the prototype heating capacities to reflect code levels. To establish non-complying prototypes, heating capacities were again adjusted to reflect typical sizes of non-complying Washington buildings. In small offices we also adjusted the air handler CFM, since the non-complying systems were large enough to require larger air handlers. Other sectors showed less extreme violations, and we assumed that air handlers were matched to the air conditioning capacity, not the heating capacity. If we had assumed that the CFM varied with the installed heating capacity then electric savings from enforcing this aspect of the code would be substantially larger.

Impacts of heating and cooling efficiency violations used the BPA prototype as the baseline prototype. If the prototype shell violated state code, then the shell was adjusted to meet code. To establish the non-complying prototype, the baseline system efficiency was adjusted to reflect the typical efficiency violation in each sector and state.

The economizer operation baseline prototype was the unaltered BPA prototype. To establish the non-complying prototype, the maximum outside air was adjusted downward to reflect the levels found in the violating buildings.

3 Simulation Results

The results of this analysis are summarized in Table 3, by state and end use. The overall total energy savings which would have resulted from full compliance in both states during 1990 was 8900 mWh (1.0 average mW) of electricity and 98,000 therms of natural gas. Any number of trends could alter this analysis. If the penetration of electric heat changed, or was not represented correctly in our sample, then the electric savings for the envelope could vary substantially. If one assumed that air handlers are sized strictly based upon system capacity, particularly heating system capacity, the impacts of system oversizing would be dramatically higher.

Statistically, the total savings estimate is the only number with any significance. Sample size and frame, and the nature of a prototype building analysis, diminishes the reliability of the state and end use sector savings predictions. To estimate reliable savings estimates for each state we suggest that the aggregate energy savings (0.35 kWh/ft^2) be applied to the area of new commercial construction in each state. Even though the apparent savings in Oregon are about 20% of the total from the direct simulation, the use of a square footage would lead to an estimate of 32% based on the square footage of commercial building in Oregon.

Area normalized energy impacts are included for each end use, state, and the sample as a whole. The total building area used for this normalization is 25.65 million square feet in both states with 17.36 million in Washington and 8.29 million in Oregon. Individual measures are not renormalized since different code provisions apply differently by state, and building type, confusing the area normalization.

Table 3. Energy Savings Due to Energy Code Non-Compliance						
Category	Electric Savings		Gas Savings		Total Savings	
	kWh (000)	kWh/ft^2	Therms (000)	MBTU/ft^2	MMBTU	MBTU/ft^2
Envelope	1049	.04	135	.53	17032	.66
Lighting	7292	.28	-47	-.18	20160	.79
Systems	567	.02	11	.04	3028	.12
Washington	7202	.42	91	.52	33656	1.94
Oregon	1706	.21	7	.08	6564	.79
Heatloss Rate	1025	-	137	-	17174	-
Lighting	7291	-	-47	-	20160	-
OTTV	24	-	-2	-	-142	-
System Eff.	88	-	1	-	375	-
System Cap.	479	-	10	-	2653	-
Total	8908	.35	98	.38	40220	1.57

4 Prototype Building Comparison to Sample Buildings

The use of the prototype descriptions and the normalization of many factors based upon square footage made this work possible within the finite constraints of the scope of work. Error introduced by this approach is well within sampling error and year to year variation associated with this work. Perhaps more systematic and therefore significant is the true applicability of the prototypes to their sectors. Many facets of the prototypes differ from buildings found in this sample. If the sample is more typical of the sector, then use of the erroneous prototypes could lead to substantial errors. If the prototypes, which have been developed in the context of several data sources, are more typical of the sector, then use of the prototype could actually lead to better results than if we had modelled the buildings exactly. It follows that if the sample as a whole is not representative, then code infractions and their effects, as determined by this sample, are not representative either.

The paucity of prototypes seems to be a major limitation to robust results using the prototypes. In the large office category, a wide variety of HVAC system types, envelope specifications, and occupancy patterns are represented by this prototype. It is very unlikely that the single prototype can represent this variation, or more to the point, it is unlikely that we will ever know if the prototype represents this variation well. Using multiple prototypes to capture the office sector would be more appropriate and entail less implicit assumptions. It is our opinion that several prototypes would be required to represent each sector adequately.

We have included a comparison of several features of the BPA prototypes to this sample, and, as an example of the subtle problems associated with prototype analysis, a discussion of the large office prototype HVAC system. For future work with the prototypes, a thorough review of the prototypes and the effect of modeling a single system and building configuration for each sector should be looked at closely. No substantial changes were made to the prototypes for this analysis. Since we are modeling variations of several prototypes, we have assumed that inaccuracies and non-representativeness in the prototypes will generally cancel out. This is yet another reason the results should be viewed only in aggregate.

The following paragraphs discuss an idiosyncrasy found with the large office prototype which is demonstrative of the sensitivity of results to the chosen prototype system. It highlights the difficulties in evaluating a wide range of technologies on a wide range of buildings with a single prototype. Explicit modeling of different prototype systems should be considered.

The large office prototype HVAC system was examined for compatibility with the large office buildings reviewed in the code compliance study. The prototype system was found in many of the sample buildings, however, the specifics of the systems were very different from the prototype system. The prototype system is a fan powered VAV system with a ceiling plenum return. The induction source for the perimeter fan boxes is the core zone return air. Most of the buildings found in the sample used the entire return plenum as the induction source. Since the core zone return air is generally warmer than the average plenum return air temperature, particularly during the morning warm-up sequence, the energy requirements will be higher in the sampled buildings than in the prototype. This has a significant impact on the lighting-space heat interaction. Using core zone air, the interaction is 38%. Using plenum air, the interaction is 20%.

Additionally, we noticed that in the prototype the space temperature of the core zone is allowed to float substantially above setpoint providing a substantial source of heat. This second effect not only affects base conditioning energy requirements but has a substantial impact on the energy savings predictions from lighting improvements. In the core zone, lighting reductions result in lower temperatures, not reduced cooling requirements. The cooler core temperatures also increase the reheat demand in the peripheral zones. In the peripheral zones, the increased heating demands must be met with increased reheat since not only are loads higher but the induced air is cooler. While this may reflect operation in some retrofit situations, it does not reflect operation in new systems where the system is designed to the load and would be redesigned for the reduced lighting to provide the same level of comfort. The interaction penalty for lighting in the prototype was -3% if the system sizing was adjusted to maintain comparable comfort levels, that is, reduced light levels resulted in an extra 3% energy savings beyond the savings from the lighting measured alone.

This range in the lighting interaction is substantial and affects the energy impacts of reduced lighting, lighting ECM savings and lighting code compliance savings. Buildings conforming to the later scenario would have lighting measure energy savings 65% higher than the base prototype. For this aspect of the new office prototype we suggest two courses of action in the future: one, change the induction zone to a ceiling plenum, and second, adjust system capacity to maintain constant space conditions when evaluating ECMs which impact the space conditioning load.

The magnitude of impacts from small changes in system operation within a single system type indicates that using a single prototype system to represent all systems types is folly. Establishing a prototype system for each common system type would seem to provide a much better basis for evaluation of conservation resources. If the prototype system is actually present in buildings, establishment of a second prototype, rather than adjusting the current one, offers an attractive option for handling the two different induction setups.

The tables in Appendix A present the summary data from the sample buildings, along with the values used in the BPA 1989 new construction prototypes. Only buildings complying with the energy code in the particular area are included. Several of the prototypes differ substantially from the sample of buildings studied here, the small office prototype being the worst offender. The last table in Appendix A, Table 12, presents a summary of the system types found.

5 References

SBW Consulting, 11/90, *Analysis of Commercial Model Conservation Standards Study*, for Bonneville Power Administration, Portland, OR.

Baylon, Frankel and Clark, 5/92, *Energy Code Compliance in Commercial Buildings in Washington and Oregon*, Ecotope, Inc., for Washington State Energy Office, Olympia, WA, and Oregon Department of Energy, Salem, OR.

Appendix A

Tables:

Prototype Comparison With New Construction Sample

Table 4. Parameter Comparison - Small Office

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	4880	13	8362	7245	4684	3062	19818	10	13115	8428	9275	3806	27090
Roof U Value	0.070	13	0.040	0.037	0.007	0.026	0.051	10	0.050	0.060	0.017	0.030	0.069
Wall U Value	0.140	12	0.077	0.074	0.032	0.030	0.147	10	0.096	0.098	0.027	0.064	0.171
Window U Value	0.720	13	0.559	0.520	0.117	0.350	0.750	10	0.692	0.710	0.051	0.540	0.790
Window SC	0.835	13	0.794	0.880	0.157	0.500	0.900	10	0.818	0.910	0.140	0.570	0.920
Glass Percent	25.0	13	13.7	12.0	5.2	5.7	23.8	10	18.7	19.8	9.3	8.2	44.4
Ua/ft2	0.33	13	0.17	0.16	0.06	0.08	0.29	10	0.22	0.23	0.06	0.11	0.32
Light/ft^2	1.70	5	1.330	1.480	0.480	0.620	1.900	7	1.525	1.500	0.230	1.260	2.190
Light/ft^2 (adjusted)	1.70	5	1.33	1.48	0.48	0.62	1.90	7	1.53	1.50	0.23	1.26	2.19
Fluorescent (%)		5	69.45	67.00	16.28	48.00	90.20	7	87.05	88.09	13.29	65.79	100.00
Electronic Bal. (%)		5	0.00	0.00	0.00	0.00	0.00	6	28.22	0.00	45.14	0.00	90.00
Exterior Light (kW)	1.50	6	3.42	3.50	2.16	0.36	5.30	10	1.22	1.58	0.91	0.00	2.29
Heating Eff (%)	81.3	8	84.15	81.00	9.38	75.00	100.00	8	79.91	79.56	1.72	75.50	82.00
Cooling EER	7.99	10	9.70	9.30	1.28	8.50	12.20	10	9.66	9.34	0.84	8.40	11.00
Hcap/design	1.81	9	1.96	1.73	0.68	1.43	3.52	10	2.56	2.01	1.60	1.01	5.48
Ccap/design	0.48	11	1.17	1.18	0.49	0.49	1.83	10	0.82	0.76	0.34	0.33	1.26

Table 5. Parameter Comparison - Large Office

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	408000	3	259573	312000	186084	52900	413820	5	116342	50197	109770	30338	266953
Roof U Value	0.053	3	0.050	0.043	0.009	0.043	0.059	5	0.074	0.080	0.015	0.030	0.080
Wall U Value	0.137	3	0.067	0.061	0.008	0.061	0.081	5	0.084	0.075	0.015	0.061	0.099
Window U Value	0.720	3	0.526	0.460	0.086	0.460	0.600	5	0.669	0.690	0.051	0.500	0.710
Window SC	0.300	3	0.302	0.300	0.089	0.260	0.560	5	0.454	0.550	0.211	0.270	0.910
Glass Percent	40.0%	3	37.0	30.0	10.9	27.7	47.9	5	19.9	23.9	5.0	8.8	23.9
Ua/ft2	0.15	3	0.11	0.07	0.06	0.07	0.17	5	0.13	0.12	0.04	0.09	0.16
Light/ft^2	1.70	5	1.237	1.170	0.259	1.010	1.700	5	1.283	1.160	0.243	1.150	1.670
Light/ft^2 (adjusted)	1.70	5	1.24	1.17	0.26	1.01	1.70	5	1.11	0.98	0.23	0.98	1.67
Fluorescent (%)		4	92.13	92.00	3.39	90.10	100.00	5	88.92	86.33	7.22	80.09	100.00
Electronic Bal. (%)		4	23.20	0.00	35.25	0.00	65.40	5	6.38	4.22	6.70	0.00	13.36
Exterior Light (kW)	20.00	2	92.70	107.40	51.08	5.97	107.40	3	2.53	3.26	1.36	0.92	4.37
Heating Eff (%)	100.0	7	94.02	100.00	7.10	78.00	100.00	5	90.41	100.00	11.60	76.00	100.00
Heating Eff (field)		7	94.02	100.00	7.10	78.00	100.00	5	90.56	100.00	11.39	77.05	100.00
Cooling EER	14.22	7	13.43	15.09	2.59	8.50	15.26	7	17.01	16.89	2.64	8.50	19.55
Cooling EER (field)		7	13.43	15.09	2.59	8.50	15.26	7	17.01	16.89	2.64	8.50	19.55
Hcap/design	1.83	6	1.25	1.16	0.30	0.82	1.59	5	2.20	1.40	1.20	1.09	4.93
Ccap/design	0.82	7	1.23	1.21	0.13	1.08	1.52	4	3.37	4.52	2.04	1.02	4.52

Table 6. Parameter Comparison - Small Retail

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	13125	3	10072	9022	7036	3620	17574	7	10665	7800	8196	2700	27291
Roof U Value	0.075	3	0.036	0.034	0.003	0.034	0.040	7	0.048	0.032	0.023	0.030	0.080
Wall U Value	0.112	3	0.137	0.178	0.060	0.073	0.178	7	0.218	0.206	0.127	0.070	0.362
Window U Value	0.720	3	0.723	0.750	0.050	0.660	0.750	7	0.986	1.230	0.297	0.560	1.230
Window SC	0.880	3	0.898	0.900	0.008	0.880	0.900	7	0.877	0.910	0.144	0.550	1.000
Glass Percent	10.0%	3	16.4	12.0	6.6	12.0	23.8	7	12.7	9.2	10.4	6.2	32.7
Ua/ft2	0.15	3	0.17	0.18	0.01	0.16	0.19	7	0.22	0.22	0.04	0.19	0.29
Light/ft^2	2.10	4	1.990	1.580	0.634	1.070	2.560	7	1.789	1.870	0.321	1.200	2.160
Light/ft^2 (adjusted)	2.10	4	1.99	1.58	0.63	1.07	2.56	7	1.64	1.59	0.36	1.20	2.16
Fluorescent (%)		4	86.94	99.00	16.70	69.80	100.00	7	90.19	92.96	17.58	50.20	100.00
Electronic Bal. (%)		4	1.05	0.00	4.10	0.00	13.00	6	0.00	0.00	0.00	0.00	0.00
Exterior Light (kW)	2.60	3	2.72	3.10	0.74	1.70	3.10	6	2.64	2.12	1.10	0.63	3.81
Heating Eff (%)	81.3%	4	79.30	79.00	0.42	79.00	79.75	7	81.91	80.00	5.08	79.00	96.00
Heating Eff (field)		4	79.10	79.00	0.14	79.00	79.24	7	81.91	80.00	5.08	79.00	96.00
Cooling EER	7.55	5	9.05	9.50	0.59	8.50	9.70	8	8.77	8.70	0.38	8.30	9.40
Cooling EER (field)		5	9.12	9.50	0.51	8.55	9.70	8	8.78	8.72	0.38	8.30	9.40
Hcap/design	1.33	1	1.32	1.32	.	1.32	1.32	8	1.66	1.38	1.16	0.71	4.98
Ccap/design	0.72	5	0.91	0.84	0.25	0.72	1.39	8	1.16	1.13	0.56	0.41	2.51

Table 7. Parameter Comparison - Large Retail													
	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	120000	2	77914	77914	45376	45828	110000	5	73579	43030	63610	32000	183000
Roof U Value	0.079	2	0.060	0.070	0.022	0.036	0.070	5	0.065	0.060	0.013	0.050	0.077
Wall U Value	0.125	2	0.123	0.129	0.014	0.108	0.129	5	0.131	0.109	0.050	0.105	0.256
Window U Value	0.720	2	0.718	0.600	0.258	0.600	1.000	5	1.085	1.191	0.222	0.710	1.230
Window SC	0.880	2	0.829	0.800	0.064	0.800	0.900	5	0.956	0.993	0.078	0.820	1.000
Glass Percent	2.9%	2	4.7	5.3	1.3	3.3	5.3	5	6.4	5.5	3.4	0.8	9.3
Ua/ft2	0.08	2	0.11	0.12	0.02	0.09	0.12	5	0.14	0.13	0.03	0.11	0.21
Light/ft^2	2.52	1	1.300	1.300	.	1.300	1.300	6	1.995	2.020	0.527	1.100	2.430
Light/ft^2 (adjusted)	2.52	1	1.30	1.30	.	1.30	1.30	6	1.83	2.02	0.47	0.94	2.10
Fluorescent (%)		1	0.00	0.00	.	0.00	0.00	6	55.70	29.70	33.18	24.58	99.51
Electronic Bal. (%)		1	0.00	0.00	.	0.00	0.00	6	17.66	0.00	41.77	0.00	100.00
Exterior Light (kW)	7.20	1	11.00	11.00	.	11.00	11.00	3	3.83	6.03	3.19	0.00	6.03
Heating Eff (%)	80.0	4	82.23	78.00	9.12	77.25	96.59	7	79.46	79.00	6.34	76.00	100.00
Heating Eff (field)		4	83.37	79.11	8.55	78.00	96.59	7	79.67	79.00	6.21	76.52	100.00
Cooling EER	9.78	4	8.65	8.60	0.51	8.20	9.40	7	8.79	8.86	0.41	8.20	9.32
Cooling EER (field)		4	8.73	8.60	0.44	8.30	9.40	7	8.78	8.60	0.35	8.30	9.32
Hcap/design	0.60	3	1.05	0.98	0.18	0.95	1.30	7	1.33	1.46	0.53	0.56	1.81
Ccap/design	0.85	4	0.82	0.92	0.51	0.06	1.40	7	0.74	0.91	0.33	0.16	1.08

Table 8. Parameter Comparison - Grocery													
	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	26052	4	26051	26300	24785	2709	48893	4	52939	41750	34965	24355	103900
Roof U Value	0.041	4	0.054	0.047	0.011	0.034	0.064	4	0.052	0.060	0.015	0.033	0.070
Wall U Value	0.113	4	0.094	0.084	0.016	0.060	0.107	4	0.260	0.260	0.053	0.152	0.320
Window U Value	0.720	4	0.669	0.650	0.090	0.590	0.750	4	0.851	0.710	0.270	0.500	1.140
Window SC	0.000	4	0.844	0.880	0.048	0.800	0.900	4	0.864	0.910	0.125	0.570	0.926
Glass Percent	5.0%	4	4.1	3.4	2.7	3.4	13.0	4	3.1	2.2	1.8	2.2	6.2
Ua/ft2	0.11	4	0.12	0.12	0.04	0.11	0.30	4	0.18	0.17	0.02	0.16	0.22
Light/ft^2	1.80	4	1.662	1.900	0.434	1.300	2.850	5	1.538	1.490	0.218	1.390	2.050
Light/ft^2 (adjusted)	1.80	4	1.66	1.90	0.43	1.30	2.85	5	1.54	1.49	0.22	1.39	2.05
Fluorescent (%)		4	60.82	85.00	33.22	28.60	96.00	5	57.39	84.04	49.39	4.40	100.00
Electronic Bal. (%)		3	0.00	0.00	0.00	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
Exterior Light (kW)	8.70	4	4.82	5.00	1.47	0.41	6.00	3	3.81	3.52	1.26	2.34	5.00
Heating Eff (%)	78.2%	3	77.04	78.00	1.22	76.00	78.00	5	77.68	78.36	1.26	75.50	79.00
Heating Eff (field)		3	78.48	78.00	0.61	78.00	79.00	5	77.68	78.36	1.26	75.50	79.00
Cooling EER	7.57	4	8.96	8.50	0.59	8.30	9.50	5	9.36	9.25	1.23	8.44	11.80
Cooling EER (field)		4	8.96	8.50	0.59	8.30	9.50	5	9.36	9.25	1.23	8.44	11.80
Hcap/design	1.59	3	1.27	1.29	0.05	1.08	1.29	5	1.62	1.40	0.92	0.96	3.40
Ccap/design	0.24	3	0.76	0.59	0.21	0.59	1.12	5	0.30	0.34	0.28	0.03	0.72

Table 9. Parameter Comparison - Restaurant

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	2624	2	4091	4091	2077	2622	5559	5	4448	4347	1713	2297	7014
Roof U Value	0.056	2	0.064	0.070	0.013	0.050	0.070	5	0.034	0.035	0.008	0.026	0.043
Wall U Value	0.078	2	0.096	0.096	0.000	0.096	0.096	5	0.085	0.102	0.024	0.059	0.107
Window U Value	0.720	2	0.623	0.610	0.026	0.610	0.650	5	0.595	0.498	0.121	0.490	0.710
Window SC	0.000	2	0.800	0.800	0.000	0.800	0.800	5	0.889	0.910	0.039	0.820	0.910
Glass Percent	13.8%	2	16.0	12.2	7.9	12.2	24.2	5	17.1	18.5	6.0	10.8	26.3
Ua/ft2	0.27	2	0.28	0.25	0.06	0.25	0.33	5	0.22	0.19	0.04	0.17	0.27
Light/ft^2	1.90	2	1.603	1.510	0.191	1.510	1.800	2	1.747	1.770	0.046	1.700	1.770
Light/ft^2 (adjusted)	1.90	2	1.60	1.51	0.19	1.51	1.80	2	1.75	1.77	0.05	1.70	1.77
Fluorescent (%)		2	21.96	21.00	1.98	21.00	24.00	2	28.94	19.00	20.28	19.00	49.62
Electronic Bal. (%)		2	0.00	0.00	0.00	0.00	0.00	2	0.00	0.00	0.00	0.00	0.00
Exterior Light (kW)	3.70	1	2.90	2.90	.	2.90	2.90	3	1.29	1.47	0.85	0.12	1.96
Heating Eff (%)	80.0%	3	77.65	77.00	1.52	77.00	80.00	5	78.56	79.00	1.56	76.60	80.00
Heating Eff (field)		3	77.65	77.00	1.52	77.00	80.00	5	78.76	80.00	1.68	76.60	80.00
Cooling EER	8.71	3	8.77	8.60	0.26	8.55	9.00	5	8.08	8.20	0.86	6.60	8.81
Cooling EER (field)		3	8.77	8.60	0.26	8.55	9.00	5	8.08	8.20	0.86	6.60	8.81
Hcap/design	1.03	2	1.30	0.90	0.67	0.90	1.86	5	1.36	1.30	0.33	1.01	1.80
Ccap/design	0.40	3	0.98	1.00	0.09	0.84	1.05	5	0.86	0.65	0.48	0.53	1.68

Table 10. Parameter Comparison - Schools

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	67784	20	67023	55299	32991	5298	124539	9	58201	55419	57619	6000	187000
Roof U Value	0.053	20	0.047	0.041	0.017	0.026	0.084	9	0.077	0.080	0.039	0.030	0.120
Wall U Value	0.091	20	0.094	0.084	0.036	0.062	0.204	9	0.098	0.103	0.024	0.064	0.143
Window U Value	0.720	20	0.617	0.600	0.134	0.500	1.000	9	0.695	0.710	0.066	0.490	0.860
Window SC	0.835	20	0.824	0.850	0.096	0.570	0.900	9	0.534	0.550	0.202	0.340	0.910
Glass Percent	6.0%	20	9.2	7.8	5.3	0.9	20.3	9	11.8	13.1	5.0	2.6	28.0
Ua/ft2	0.14	20	0.12	0.11	0.04	0.05	0.26	9	0.14	0.12	0.05	0.10	0.22
Light/ft^2	1.81	15	1.477	1.550	0.247	0.900	1.950	10	1.426	1.430	0.129	1.170	1.600
Light/ft^2 (adjusted)	1.81	15	1.48	1.55	0.25	0.90	1.95	10	1.33	1.42	0.21	1.03	1.60
Fluorescent (%)		15	82.33	78.00	12.51	61.00	100.00	10	84.91	91.09	14.01	57.40	100.00
Electronic Bal. (%)		15	17.67	0.00	38.63	0.00	100.00	8	35.70	0.00	51.07	0.00	100.00
Exterior Light (kW)	10.00	15	9.76	7.50	7.94	0.90	27.70	10	5.78	4.40	3.66	0.60	11.50
Heating Eff (%)	80.0%	15	91.02	93.00	6.98	79.40	100.00	8	82.15	81.00	3.60	77.00	88.60
Heating Eff (field)		15	90.77	93.00	7.00	79.40	100.00	8	82.15	81.00	3.60	77.00	88.60
Cooling EER		9	10.10	9.88	0.99	8.50	11.60	7	13.74	10.92	4.95	8.30	19.11
Cooling EER (field)		9	10.09	10.00	0.95	8.50	11.60	7	13.74	10.92	4.95	8.30	19.11
Hcap/design	1.68	15	1.15	1.13	0.33	0.60	1.81	10	1.47	1.30	0.66	0.58	2.37
Ccap/design	0.00	8	1.00	1.05	0.40	0.42	1.53	7	0.80	1.17	0.55	0.04	1.19

Table 11. Parameter Comparison - Warehouses

	Prototype	Washington Sample						Oregon Sample					
	89 Base	Obs	Mean	Median	Std	Min	Max	Obs	Mean	Median	Std	Min	Max
Floor Area	18025	0	.	.	.	.	.	1	144900	144900	.		144900
Roof U Value	0.073	0	.	.	.	.	.	1	0.060	0.060	.	144900	0.060
Wall U Value	0.083	0	.	.	.	.	.	1	0.310	0.310	.	0.060	0.310
Window U Value	0.720	0	.	.	.	.	.	1	0.710	0.710	.	0.310	0.710
Window SC	0.570	0	.	.	.	.	.	1	0.800	0.800	.	0.710	0.800
Glass Percent	5.0%	0	.	.	.	.	.	1	7.6	7.6	.	0.800	7.6
Ua/ft2	0.15	0	.	.	.	.	.	1	0.28	0.28	.	7.6	0.28
Light/ft^2	0.85	3	1.642	1.700	0.298	0.600	1.700	4	0.915	0.760	0.540	0.28	1.440
Light/ft^2 (adjusted)	0.85	3	1.64	1.70	0.30	0.60	1.70	4	0.91	0.76	0.54	0.180	1.44
Fluorescent (%)		2	13.92	13.50	0.93	13.50	16.00	4	47.32	51.72	28.63	0.19	100.00
Electronic Bal. (%)		2	0.00	0.00	0.00	0.00	0.00	4	0.00	0.00	0.00	25.76	0.00
Exterior Light (kW)	1.08	2	1.74	1.90	0.36	0.93	1.90	5	4.50	3.36	2.35	0.00	7.19
Heating Eff (%)	80.0%	3	87.32	88.00	3.25	77.00	88.00	4	84.79	77.77	12.07	0.97	100.00
Heating Eff (field)		3	87.32	88.00	3.25	77.00	88.00	4	84.79	77.77	12.07	75.00	100.00
Cooling EER	7.72	1	8.30	8.30	.	8.30	8.30	4	8.78	8.70	0.54	75.00	9.60
Cooling EER (field)		1	8.30	8.30	.	8.30	8.30	4	8.78	8.70	0.54	8.35	9.60
Hcap/design	2.68	3	0.98	0.99	0.08	0.69	1.07	4	1.80	1.51	1.17	8.35	2.99
Ccap/design	0.37	0	.	.	.	.	.	3	0.74	0.57	0.48	0.79	1.13
												0.03	

Category	PRPZ	TAC/ SHPZ	PTHP	AHPZ /CP	FPZ	PR VAV	BUC VAV	FP	WSHP	DD VAV	Other	
Small Office	35.9	5.6	1.6	0.0	36.6	1.6	0.0	0.0	18.7	0.0	0.0	
Large Office	4.5	0.0	0.0	0.0	0.0	14.3	81.2	0.0	0.0	0.0	0.0	
Small Retail	94.4	0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	
Large Retail	91.6	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	
Grocery	59.1	0.0	0.0	0.0	40.9	0.0	0.0	0.0	0.0	0.0	0.0	
Restaurant	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
School	0.0	0.0	0.0	26.6	36.0	0.0	14.5	2.3	17.2	0.0	3.5	
Warehouse	72.8	0.0	0.0	0.0	14.5	12.8	0.0	0.0	0.0	0.0	0.0	
Assembly	0.0	0.0	0.0	0.0	40.7	0.0	8.8	0.0	50.5	0.0	0.0	
Public Inst.	10.1	0.0	28.7	0.0	61.2	0.0	0.0	0.0	0.0	0.0	0.0	
Lodging	0.0	0.0	00.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Health	4.7	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.9	47.2	
Other	5.9	0.0	0.0	1.9	1.2	40.4	50.6	0.0	0.0	0.0	0.0	
All Sectors	25.9	0.9	0.5	6.6	14.6	8.7	31.7	0.6	5.6	1.9	3.4	100.0

Table 12. HVAC System Type (percent of sector floor area)

PRPZ	Packaged rooftop per zone
TAC/SHPZ	Package Terminal Air Conditioner w/ space heat per zone
PTHP	Packaged terminal heat pump per zone
AHPZ/CP	Air handler per zone w/ central plant
FPZ	Furnace per zone
PRVAV	Packaged Rooftop VAV
BUCVAV	Built-up central VAV
FP	Four pipe fan coil
WSHP	Water source heat pump
DDVAV	Dual duct vav