



Using the Reference Building Models for the Standard 90.1-2010 Development

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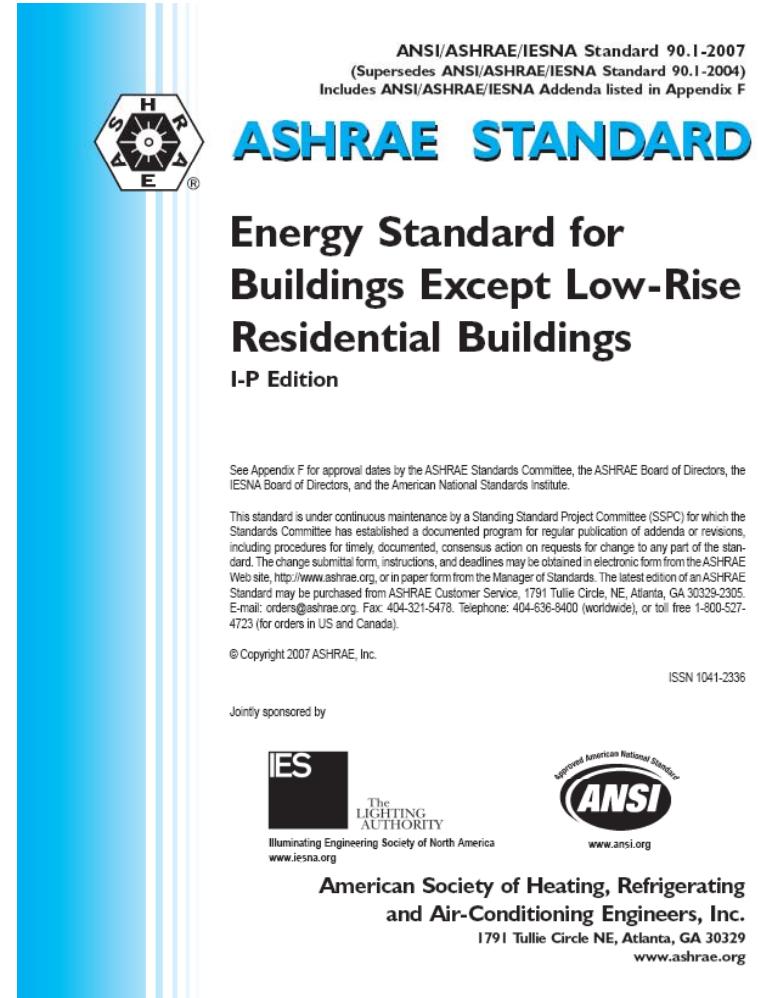
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ASHRAE Standard 90.1

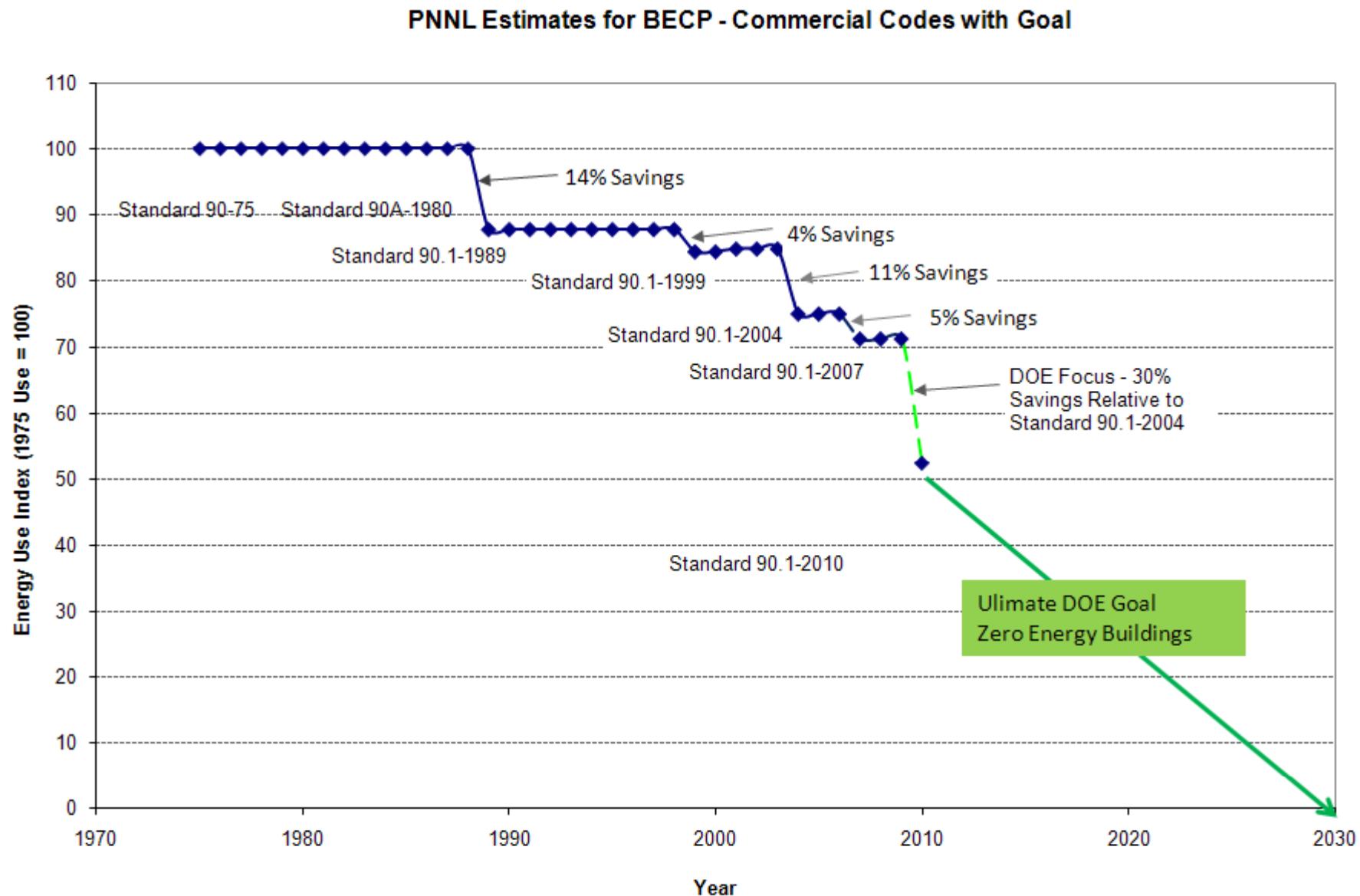
- ▶ Energy design standard for commercial and multi-family residential buildings (>3 stories)
- ▶ Baseline of many above-code programs for commercial building energy efficiency, including AEDGs, Standard 189.1, and LEED
- ▶ Developed in an ANSI consensus process by ASHRAE and IES in a 3-year publication cycle



American Society of Heating, Refrigerating
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1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org



History of ASHRAE Standard 90.1



PNNL's Building Simulation Support to ASHRAE Standard 90.1

- DOE's Determination
 - Estimate the energy savings of 90.1-2007 and 90.1-2010 as part of DOE's Determination Quantitative Analysis.
- Energy Saving Analyses
 - Support subcommittees' new proposals
 - Develop the building load profile spreadsheet tools for mechanical subcommittee
- Progress Indicator
 - Track the energy saving impacts during development of the 90.1-2010 in achieving the 30% goal

PNNL's Building Simulation Support to ASHRAE Standard 90.1

- Basic steps for determining savings from one version of Standard 90.1 to the next
 1. Develop suite of prototypical building models attempting to capture some percentage of the new construction market (base code compliant)
 2. Qualitative comparison of the two versions of the code – develop list of changes
 3. Characterize each change – impact, no impact, able to model, not able to model
 4. Apply changes to prototypes as applicable
 5. Run simulations
 6. Weight results by construction volume and climate zone for each prototype resulting in a single national savings number



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90.1 Simulation - Prototype Buildings

McGraw-Hill New Construction Data by Building Type

Serial No	ASHRAE Prototype	Total Floor Area (x1000 ft ²)	Construction Weights
1	Large Office	220,134	2.66%
2	Medium Office	400,091	4.84%
3	Small Office	371,009	4.49%
4	Standalone Retail	1,009,246	12.21%
5	Strip Mall	375,093	4.54%
6	Primary School	330,418	4.00%
7	Secondary School	685,508	8.29%
8	Hospital	228,131	2.76%
9	Outpatient Health Care	289,171	3.50%
10	Full Service Restaurant	43,650	0.53%
11	Quick Service Restaurant	38,809	0.47%
12	Large Hotel	327,562	3.96%
13	Small hotel/motel	113,837	1.38%
14	Non-refrigerated warehouse	1,105,951	13.38%
15	High-rise apartment	593,241	7.18%
16	Mid-rise apartment	484,343	5.86%
Covered by Prototypes		6,616,193	80.0%
17	No Prototype	1,649,785	20.0%
18	Total	8,265,977	100.0%

Free download PNNL report on construction weights:

http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19116.pdf

	CBECS Type	Total Floor Area (x1000 ft ²)	Weights
17A	Pubic Assembly	414,953	5.02%
17B	Food Sales	96,990	1.17%
17C	Other	769,423	9.31%
17D	Public Order and Safety	121,907	1.47%
17E	Religious Worship	184,143	2.23%
17F	Service	62,369	0.75%

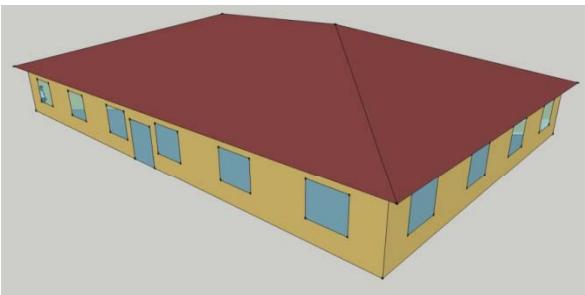
90.1 Simulation – Construction Weights

The construction weights for new construction in commercial sector, including the mid-rise and high-rise apartment.

	1	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8	weights by bldg type
Large office	0.102	0.326	0.061	0.445	0.285	0.117	1.132	0.000	0.154	0.442	0.121	0.133	0.000	0.011	0.000	3.327
Medium office	0.129	0.813	0.292	0.766	0.715	0.136	1.190	0.036	0.196	1.060	0.342	0.298	0.035	0.033	0.007	6.047
Small office	0.084	1.064	0.289	0.963	0.475	0.078	0.936	0.047	0.123	0.920	0.322	0.241	0.030	0.032	0.005	5.608
Standalone retail	0.224	2.220	0.507	2.386	1.250	0.191	2.545	0.119	0.428	3.429	0.792	0.948	0.091	0.109	0.014	15.254
Strip mall retail	0.137	0.991	0.254	1.021	0.626	0.103	1.008	0.023	0.107	1.023	0.201	0.153	0.016	0.007	0.001	5.669
Primary school	0.064	0.933	0.164	0.944	0.446	0.048	0.895	0.030	0.094	0.920	0.224	0.168	0.037	0.023	0.003	4.994
Secondary school	0.160	1.523	0.230	1.893	0.819	0.109	2.013	0.063	0.243	2.282	0.438	0.415	0.086	0.075	0.012	10.361
Hospital	0.040	0.479	0.096	0.468	0.273	0.039	0.615	0.022	0.106	0.812	0.218	0.221	0.024	0.034	0.001	3.448
Outpatient health care	0.037	0.567	0.134	0.581	0.275	0.061	0.818	0.023	0.181	1.058	0.218	0.342	0.033	0.039	0.002	4.371
Sit down restaurant	0.009	0.106	0.025	0.111	0.047	0.006	0.127	0.006	0.010	0.143	0.031	0.031	0.004	0.004	0.000	0.660
Fast food restaurant	0.008	0.092	0.020	0.102	0.063	0.007	0.089	0.005	0.014	0.128	0.026	0.025	0.003	0.004	0.000	0.587
Large hotel	0.109	0.621	0.125	0.635	0.793	0.106	0.958	0.037	0.123	0.919	0.200	0.227	0.058	0.038	0.004	4.951
Small hotel	0.010	0.288	0.030	0.268	0.114	0.022	0.315	0.020	0.039	0.365	0.089	0.107	0.031	0.020	0.004	1.721
Warehouse	0.349	2.590	0.580	2.966	2.298	0.154	2.446	0.068	0.435	3.580	0.688	0.466	0.049	0.043	0.002	16.716
High-rise apartment	1.521	1.512	0.076	0.652	0.741	0.173	2.506	0.000	0.358	1.163	0.115	0.125	0.016	0.008	0.000	8.967
Mid-rise apartment	0.257	1.094	0.093	0.825	0.862	0.260	1.694	0.022	0.371	1.122	0.318	0.313	0.056	0.032	0.000	7.321
weights by zone	3.242	15.217	2.975	15.025	10.081	1.609	19.286	0.522	2.981	19.366	4.344	4.214	0.569	0.513	0.056	100.000

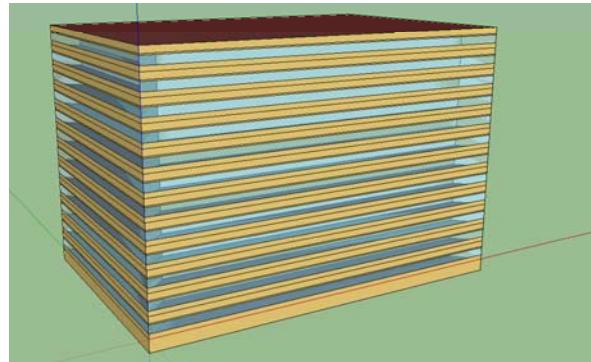
3 Office Prototypes

Small Office



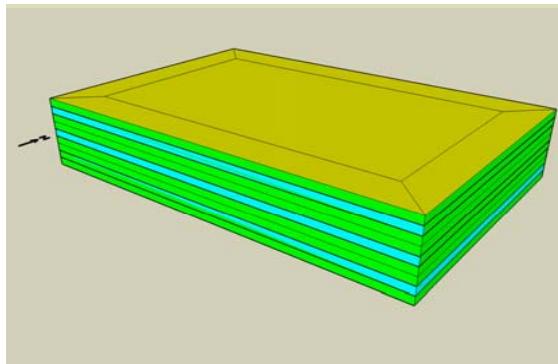
Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
5,500	1	1.5	15%

Large Office



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
498,600	12 (plus basement)	1.5	40%

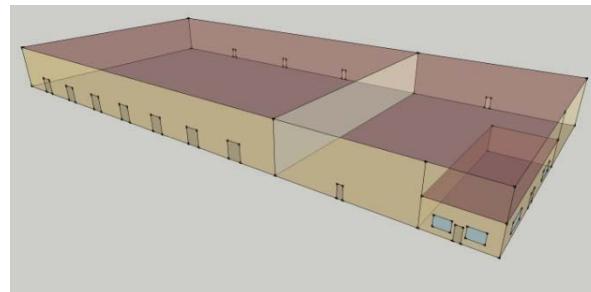
Medium Office



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
53,600	3	1.5	33%

1 Warehouse Prototype

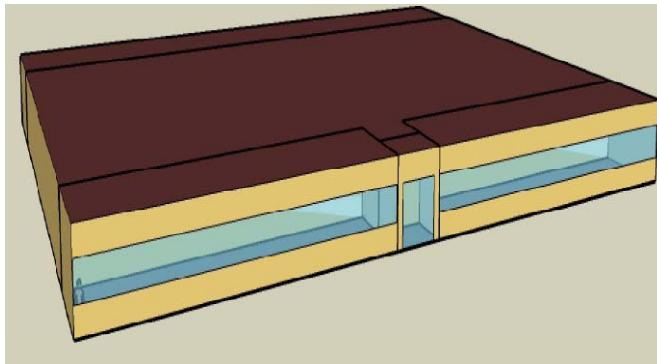
Non-refrigerated warehouse



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
49,500	1	2.2	Office area: 12% Storage Area: 0% Overall: 0.71%

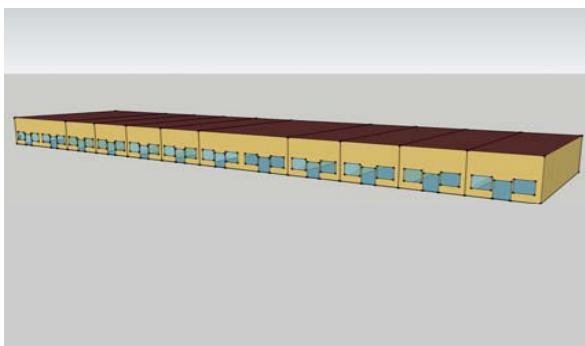
2 Mercantile Prototypes

Stand-alone Retail



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
24,695	1	1.28	7%

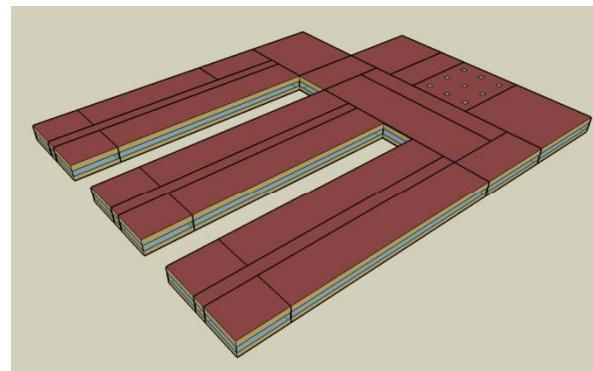
Strip Mall



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
22,500	1	4	11%

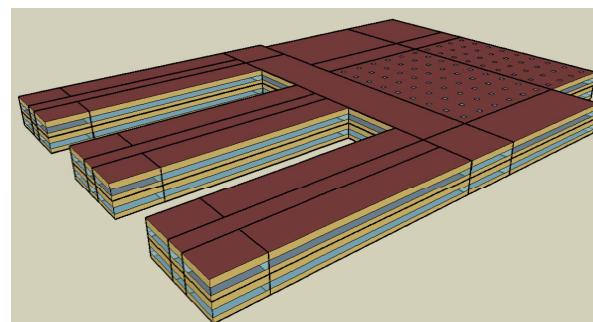
2 Education Prototypes

Primary School



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
74,000	1	NA	35%

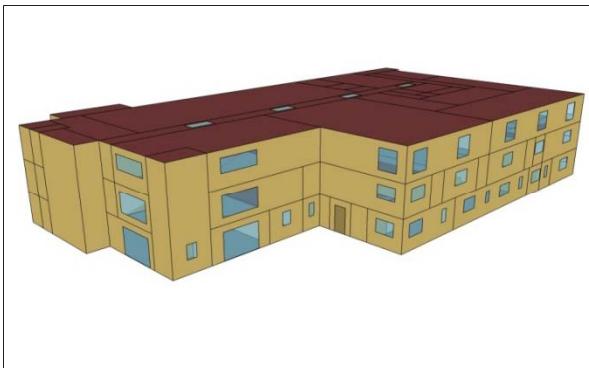
Secondary School



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
210,900	2	NA	33%

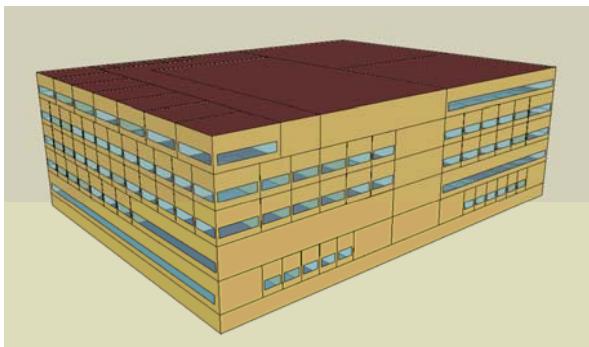
2 Health Care Prototypes

Outpatient Health Care



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
40,950	3	NA	20%

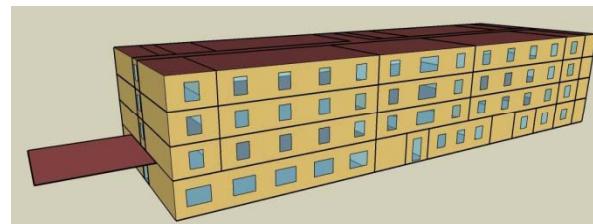
Hospital



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
241,410	5 (plus basement)	1.33	16%

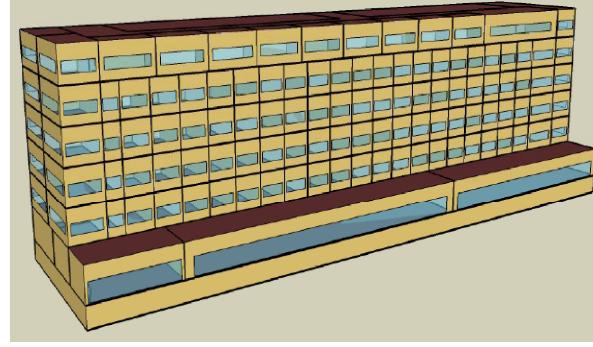
2 Lodging Prototypes

Small Hotel



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
43,200	4	3	11%

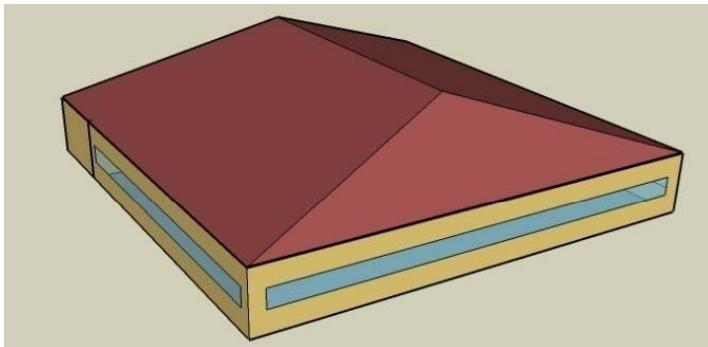
Large Hotel



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
122,132	6 (plus basement)	Ground & basement floor: 3.8 All other floors: 5.1	27%

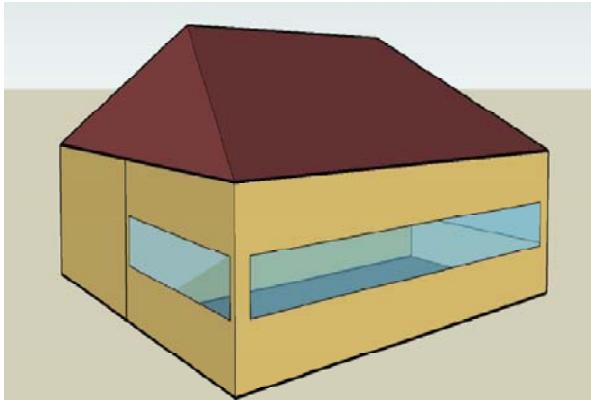
2 Food Service Prototypes

Sit Down Restaurant



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
5,500	1	1	18%

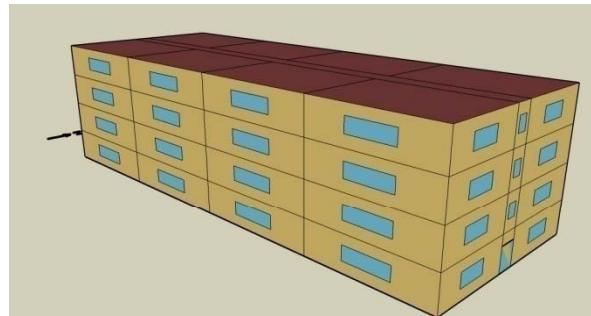
Fast Food



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
2,500	1	1	14%

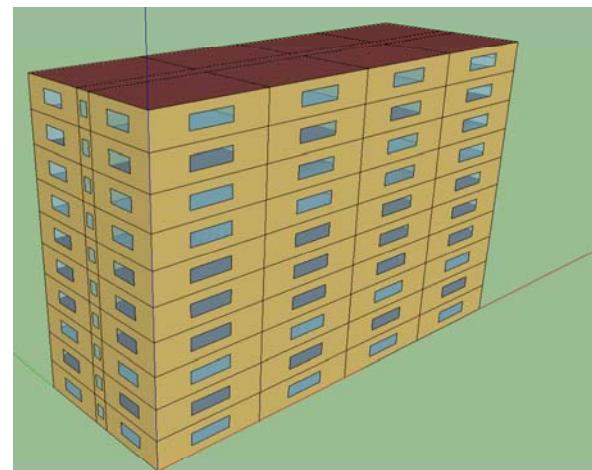
2 Apartment Prototypes

Midrise Apartment



Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
33,700	4	2.74	15%

High-rise Apartment



Floor area (ft ²)	No. of Floors	Aspect Ratio	WWR
84,360	10	2.75	15%

Prototype Construction Types

From 2003 CBECS, AEDG, and ESC

				2003 CBECS (Plus Inputs from AEDG & ESC)	
Principal Building Activity	Building Prototype	Floor area (ft ²)	Number of Floors	Roof	Exterior Wall
Office	Small Office	5,500	1	Attic and Other	Wood-Framed
	Medium Office	53,600	3	Insulation entirely above deck	Steel-Framed
	Large Office	498,600	12 (plus basement)	Insulation entirely above deck	Mass
Mercantile	Stand-alone Retail	24,695	1	Insulation entirely above deck	Mass
	Strip Mall	22,500	1	Insulation entirely above deck	Steel-Framed
Education	Primary school	74,000	1	Insulation entirely above deck	Steel-Framed
	Secondary school	210,900	2	Insulation entirely above deck	Steel-Framed
Health Care	Outpatient health care	40,950	3	Insulation entirely above deck	Steel-Framed
	Hospital	241,410	5 (plus basement)	Insulation entirely above deck	Mass
Lodging	Small hotel/motel	43,200	4	Insulation entirely above deck	Steel-Framed
	Large hotel	122,132	6 (plus basement)	Insulation entirely above deck	Mass
Warehouse	Non-refrigerated warehouse	49,500	1	Metal Building Roof	Metal Building Wall
Food Service	Fast Food	2,500	1	Attic and Other	Wood-Framed
	Sit-down Restaurant	5,500	1	Attic and Other	Steel-Framed
Apartment	Mid-rise apartment	33,700	4	Insulation entirely above deck	Steel-Framed
	High-rise apartment	84,360	10	Insulation entirely above deck	Steel-Framed

Prototype HVAC System Types

Consensus from Mechanical Subcommittee

				Final Selection from MSC			
Principal Building Activity	Building Prototype	Floor area (ft ²)		Heating	Cooling	Primary System	Secondary System
Office	Small Office	5,500		Heat Pump	Unitary DX	Packaged CAV	No
	Medium Office	53,600		Gas furnace	Unitary DX	Packaged VAV w/Reheat	No
	Large Office	498,600		Boiler	Water-cooled (with cooling tower)	VAV w/Reheat	No
Mercantile	Stand-alone Retail	24,695		Gas furnace	Unitary DX	Packaged CAV	No
	Strip Mall	22,500		Gas furnace	Unitary DX	Packaged CAV	No
Education	Primary school	74,000		Gas furnace	Unitary DX	Packaged CAV	No
	Secondary school	210,900		Boiler	Air cooled chiller	VAV w/Reheat	Packaged CAV
Health Care	Outpatient health care	40,950		Boiler	Unitary DX	Packaged VAV w/Reheat	No
	Hospital	241,410		Boiler	Central Chiller, cooling tower	VAV w/Reheat	Central CAV
Lodging	Small hotel/motel	43,200		Electricity	DX	PTAC	No
	Large hotel	122,132		Boiler	Air cooled chiller	Fan-coil Units	VAV w/Reheat
Warehouse	Non-refrigerated warehouse	49,500		Gas furnace	Unitary DX	Unit Heater	Packaged CAV
Food Service	Fast Food	2,500		Gas furnace	Unitary DX	Packaged CAV	No
	Sit-down Restaurant	5,500		Gas furnace	Unitary DX	Packaged CAV	No
Apartment	Mid-rise apartment	33,700		Gas	DX	Split DX system	No
	High-rise apartment	84,360		Boiler	Fluid cooler	WSHP	No

Progress Indicator - Overview

- ▶ To measure progress toward the 30% improvement goal in Standard 90.1-2010
 - Baseline is 90.1-2004 prototypes
 - Incorporate the approved addenda to all 16 prototype buildings and 17 climate zones
 - Update PI and report to SSPC 90.1 at each quarterly meeting
- ▶ Assign final construction weights to each prototype by climate zone
 - National weighted-average EUI and energy cost for each prototype
 - National weighted energy and cost saving percentage
- ▶ PNNL has completed the EnergyPlus Simulation Infrastructure
 - Each set of PI will need run 816 EnergyPlus models
1632 runs = 16 prototypes x 17 locations x 3 Standards x 2 Ventilation Standards
 - Automatic process to read into the modeling inputs and extract the data from modeling results
 - For Washington State, probably 64 runs
64 runs = 16 prototypes x 2 locations x 2 Standards

Progress Indicator - Addenda

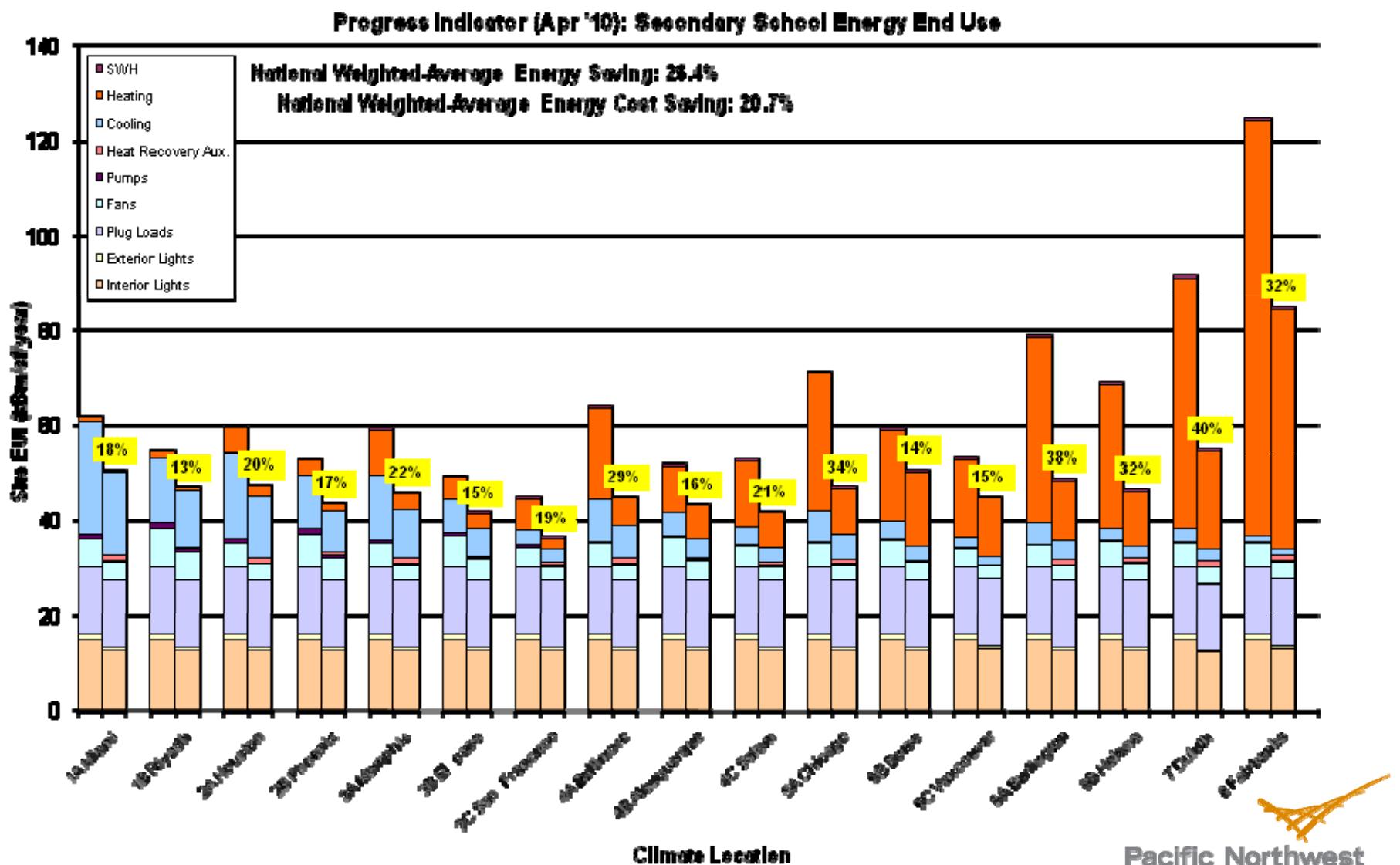
- ▶ 105 addenda since 90.1-2004 publication
 - 44 addenda to 2004
 - 61 addenda to 2007 (BOD-approved through April 2010)

Descriptions	No. of Addenda
Addenda in section 5 through 10 (prescriptive sections)	86
Addenda with no energy saving impacts	36
Addenda with energy savings	50
Savings that can be captured in Progress Indictor	38
Savings that cannot be captured in Progress Indictor	12

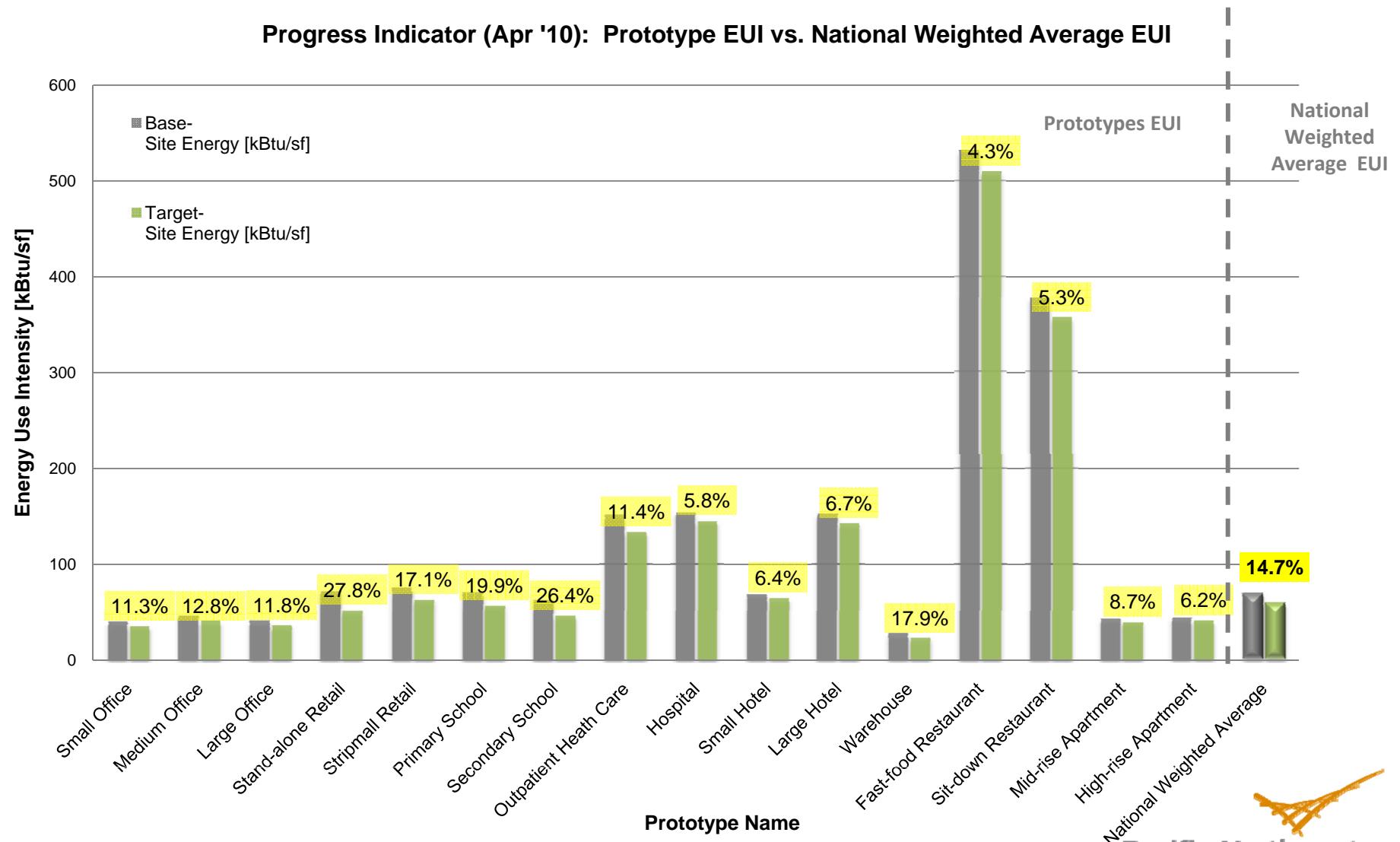


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Results Example: Secondary School



April 2010 PI Summary



April 2010 PI Summary (cont'd)

Building Prototype	Site Energy [kBtu/sf]		Energy Cost [\$/sf]		Site Energy Savings	Energy Cost Savings
	90.1-2004	Apr2010 PI	90.1-2004	Apr2010 PI		
Small office	40.0	35.4	\$1.04	\$0.92	11.3%	11.5%
Medium office	46.7	40.7	\$1.22	\$1.03	12.8%	15.2%
Large office	40.6	35.8	\$1.03	\$0.93	11.8%	10.0%
Standalone retail	71.9	51.9	\$1.70	\$1.26	27.8%	26.1%
Strip mall	75.9	62.9	\$1.78	\$1.45	17.1%	18.5%
Primary school	70.9	56.8	\$1.62	\$1.36	19.9%	16.1%
Secondary school	62.8	46.2	\$1.45	\$1.15	26.4%	20.7%
Outpatient healthcare	151.3	134.0	\$3.58	\$3.16	11.4%	11.8%
Hospital	154.4	145.5	\$3.39	\$3.18	5.8%	6.2%
Small hotel	69.2	64.8	\$1.53	\$1.43	6.4%	6.7%
Large hotel	153.0	142.8	\$2.93	\$2.77	6.7%	5.6%
Warehouse	27.4	22.5	\$0.56	\$0.46	17.9%	16.6%
Fast food restaurant	532.7	509.9	\$10.17	\$9.74	4.3%	4.2%
Sit-down restaurant	377.1	357.2	\$7.49	\$6.95	5.3%	7.2%
Mid-rise apartment	43.5	39.7	\$1.04	\$0.95	8.7%	8.5%
High-rise apartment	44.0	41.3	\$1.11	\$1.05	6.2%	5.8%
National-weighted average	69.8	59.5	\$1.58	\$1.36	14.7%	14.0%

Progress Indicator Summary

Building Type	Building Prototype	October 2009	January 2010	April 2010
Office	Small office	10.4%	11.3%	11.3%
	Medium office	11.6%	13.0%	12.8%
	Large office	9.5%	11.7%	11.8%
Retail	Standalone retail	15.9%	18.2%	27.8%
	Strip mall	9.4%	17.2%	17.1%
Education	Primary school	11.7%	13.0%	19.9%
	Secondary school	10.1%	14.0%	26.4%
Health Care	Outpatient healthcare	11.0%	11.8%	11.4%
	Hospital	NA	5.8%	5.8%
Lodging	Small hotel	5.9%	6.1%	6.4%
	Large hotel	3.1%	6.7%	6.7%
Warehouse	Warehouse	14.9%	14.0%	17.9%
Food Service	Fast food restaurant	0.5%	4.3%	4.3%
	Sit-down restaurant	2.6%	4.9%	5.3%
Apartment	Mid-rise apartment	8.7%	8.7%	8.7%
	High-rise apartment	NA	4.6%	6.2%
National-weighted Average		9.8%	11.4%	14.7%

Time for Questions...

PNNL's Commercial Simulation Team

Bing Liu

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