National Renewable Energy Laboratory
Innovation for Our Energy Future

DOE Commercial Building Benchmark Model Development

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Motivation

- Developing good energy models is a lot of work! – 1,000's of inputs
- Often depend on default values and inputs from other simulations
- What is the answer?

➔Standard benchmark models provide a common set of inputs that people can "trust"

Project Starting Objectives

- “Benchmark Model” Defined
  - Standard building energy model that represents a “typical” building
- Project Goal:
  - Represent ~ 70% of the commercial building stock
  - Manageable number of models
  - Realistic building models
    - Look, construction, systems, operation

Benchmark Models

- 16 building types (+1 in the next release)
- 16 locations
- Three sets of benchmark models
  - New construction
  - Post-1980 construction
  - Pre-1980 construction
- 16 x 16 x 3 = 768 models!
- For simplicity and to ease comparisons:
  - Same geometry and schedules across locations and vintages

Benchmark Models

- Three sets of benchmark models
  - New construction
  - Post-1980 construction
  - Pre-1980 construction

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  - New construction
    - Standard 90.1-2004
    - Typical construction (not Appendix G)
  - Post-1980 construction
    - Same as New Construction except
      - Meets Standard 90.1-1989
      - Some changes in envelope and HVAC types
  - Pre-1980 construction
    - Same as New Construction except
      - Match pre-1980 U-values and HVAC efficiencies
      - Some changes in envelope and HVAC types

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- New versions with 90.1 updates

Benchmark Building Models (16)

	Building Activity	Area ft^2	Floors	Source
Office	Small Office	5,500	1	Small Office AEDG
	Medium Office	53,630	3	2003 CBECS
	Large Office	498,588	12	2003 CBECS
School	Primary School	73,960	1	K-12 AEDG
	Secondary School	210,890	2	K-12 AEDG
Retail	Stand-alone Retail	24,962	1	2003 CBECS
	Strip Mall	22,500	1	2003 CBECS
	Supermarket	45,000	1	2003 CBECS
Food service	Quick Service Restaurant	2,500	1	2003 CBECS
	Full Service Restaurant	5,500	1	2003 CBECS
Lodging	Small Hotel	43,200	4	Highway Lodging AEDG
	Large Hotel	122,120	6	2003 CBECS
Health care	Hospital	241,351	5	2003 CBECS
	Outpatient health care	40,946	3	Health Care AEDG
Storage	Warehouse	52,045	1	Warehouse AEDG
Resi-dential	Midrise Apartment	33,740	4	PNNL

Benchmark Locations

No	Climate Zone	Benchmark City	DOE City
1	1A	Miami FL	Miami FL
2	2A	Houston TX	Houston TX
3	2B	Phoenix AZ	Phoenix AZ
4	3A	Atlanta GA	Memphis TN
5	3B-CA	Los Angeles CA	
6	3B-other	Las Vegas NV	El Paso TX
7	3C	San Francisco CA	San Francisco CA
8	4A	Baltimore MD	Baltimore MD
9	4B	Albuquerque NM	Albuquerque NM
10	4C	Seattle WA	Salem OR
11	5A	Chicago IL	Chicago IL
12	5B	Denver CO	Boise ID
13	6A	Minneapolis MN	Burlington VT
14	6B	Helena MT	Helena MT
15	7	Duluth MN	Duluth MN
16	8	Fairbanks AK	Fairbanks AK

Approach

- Balance of accuracy and practicality
  - Best estimations when there is limited data
- Review and buy in by the modeling community
  - DOE and other researchers
  - ASHRAE review
- Data sources
  - CBECS and construction start data
  - ASHRAE standards
  - AEDG committees
  - Existing research

Envelope

- Construction types
  - Analysis of CBECS and NC[3]
  - AEDG committees
- Thermal properties
  - New Construction ➔Standard 90.1-2004
  - Post-1980 Construction ➔Standard 90.1-1989
    - Represents average of buildings from 1980-2003
  - Pre-1980 Construction ➔1987 Briggs paper
    - 1970 construction for office buildings
    - *Analysis And Categorization Of The Office Building Stock, Topical Report.* GRI-87/0244

Internal Loads

- Interior lighting
  - Standard 90.1-2004 for new construction
  - Standard 90.1-1989 for all others – assumed that most buildings have had a lighting retrofit
- People and plug loads
  - Standard 90.1-1989 (90.1-2004 User's Guide) and judgment
- Exterior lighting (façade only)
  - 90.1-2004 and PNNL analysis
- Schedules
  - AEDG committees and Standard 90.1-1989 (90.1-2004 User's Guide) with adjustments

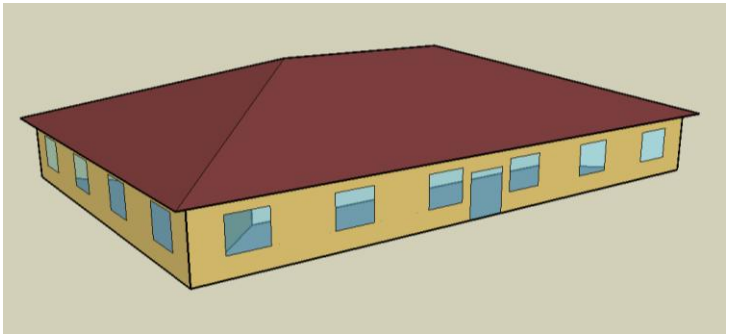
HVAC

- System types
  - CBECS analysis
- System efficiencies
  - Standard 90.1-2004 for new construction
  - Standard 90.1-1989 for post-1980 construction
  - Review of standards for pre-1980 construction and a weighted replacement schedule

Weighting Factors

- Weighting factors show how each benchmark building represents a part of the national building stock
- Data sources
  - CBECS – limited data
  - Construction start data – only new construction
- Solution:
  - New construction benchmarks from construction start data 2000-2007

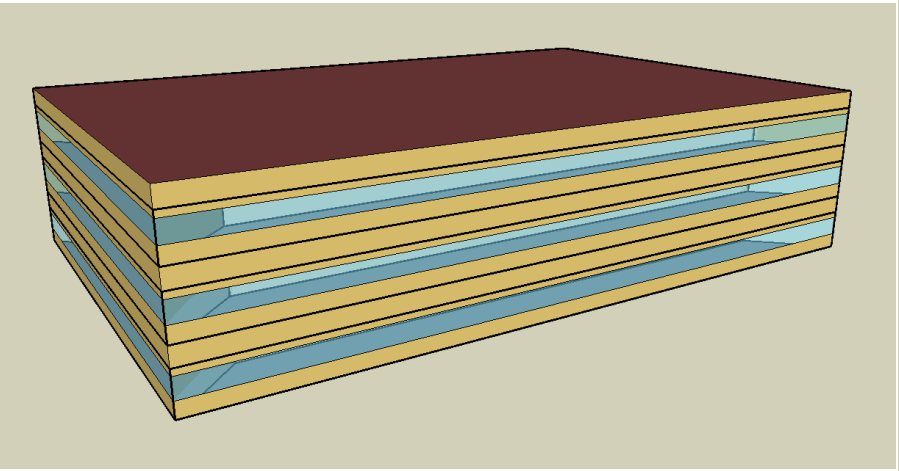
Office Buildings

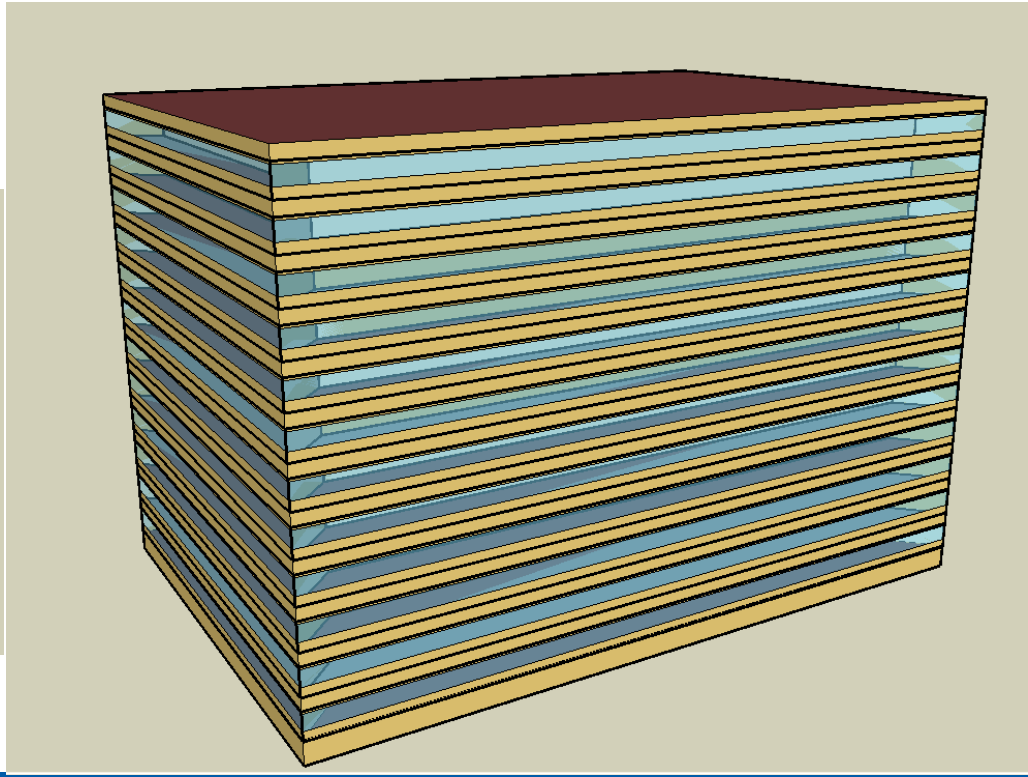


Small Office
1 floor, 5,500 ft^2

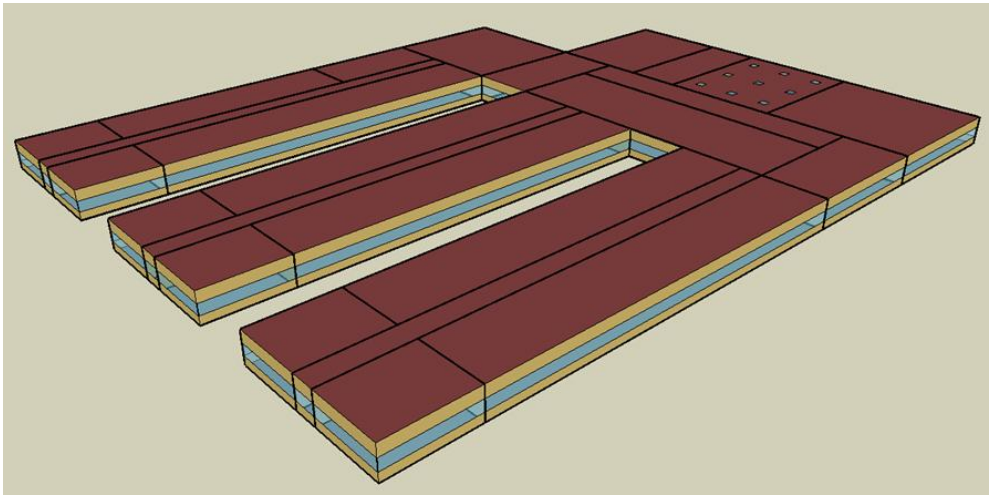
Large Office
12 floors, 498,588 ft^2

Medium Office
3 floor, 53,630 ft^2

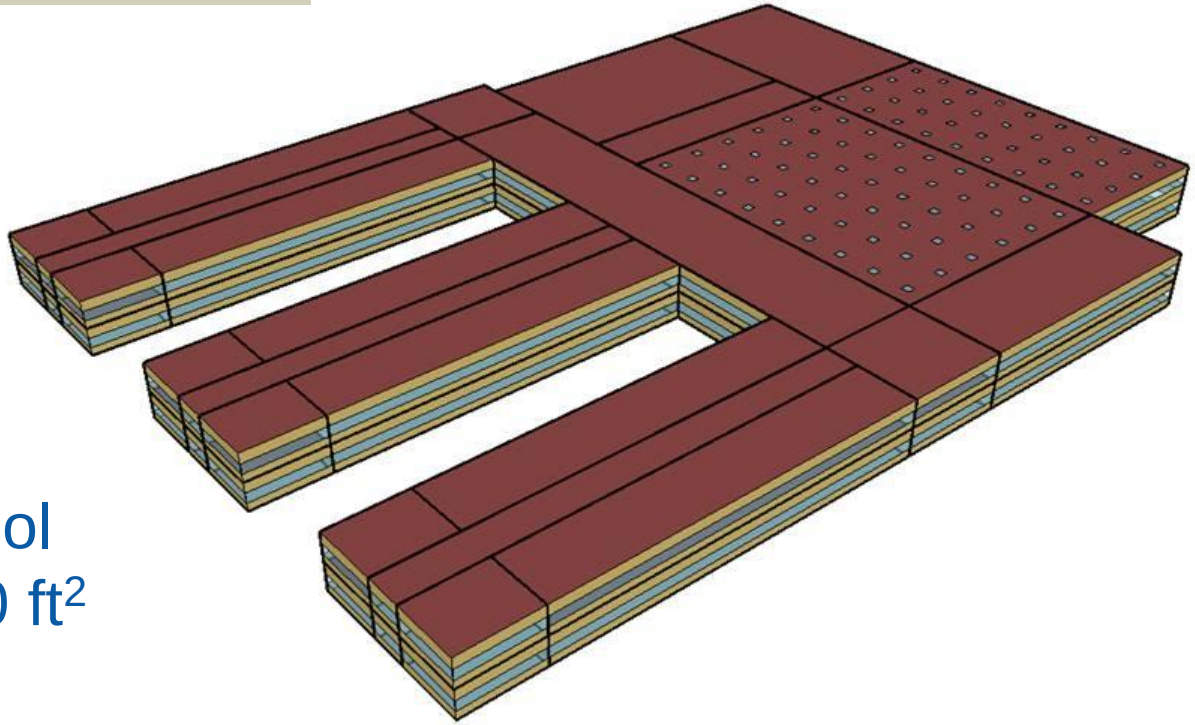




Schools

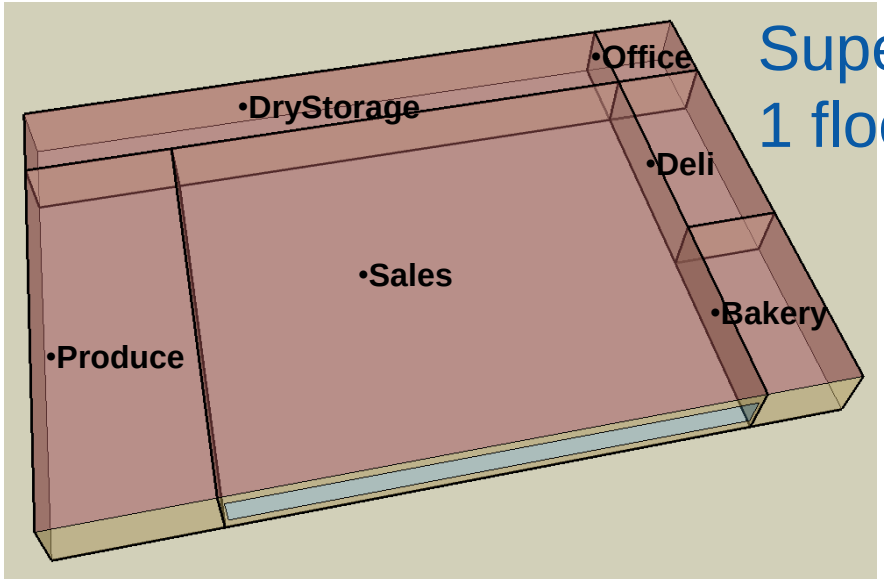


Primary School
1 floor, 73,960 ft^2



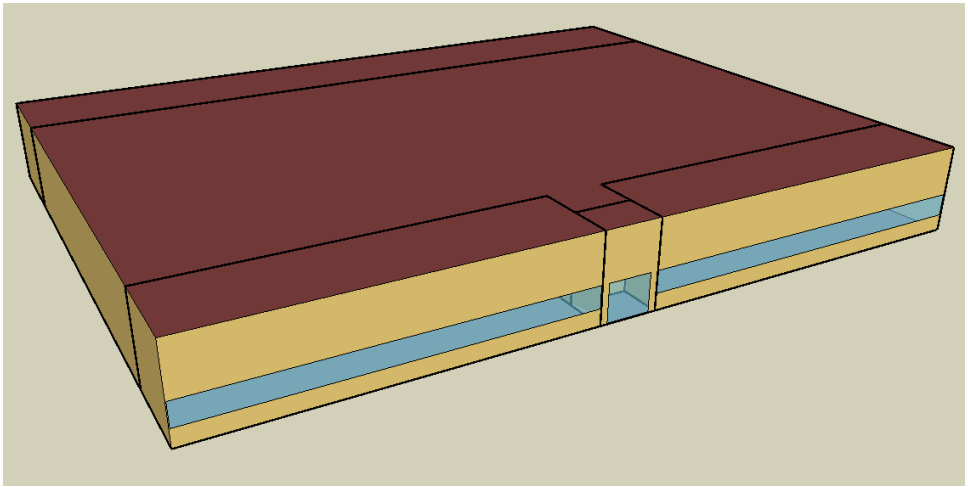
Secondary School
2 floors, 210,890 ft^2

Retail

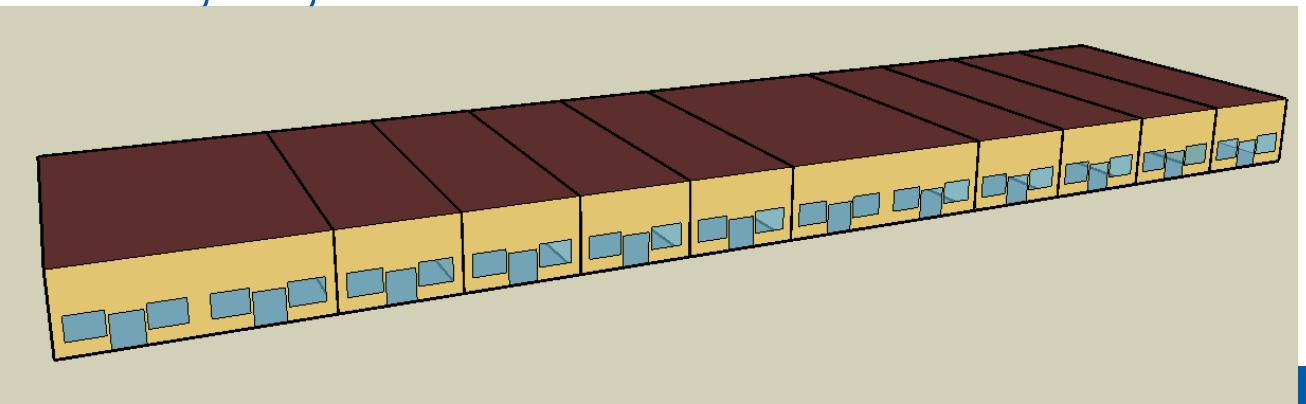


Supermarket
1 floor, 45,000 ft^2

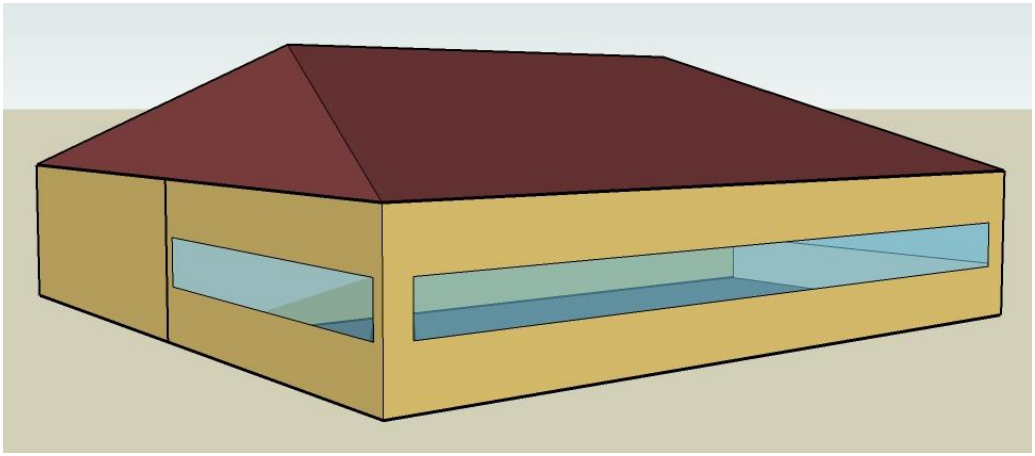
Stand alone retail
1 floor, 25,000 ft^2



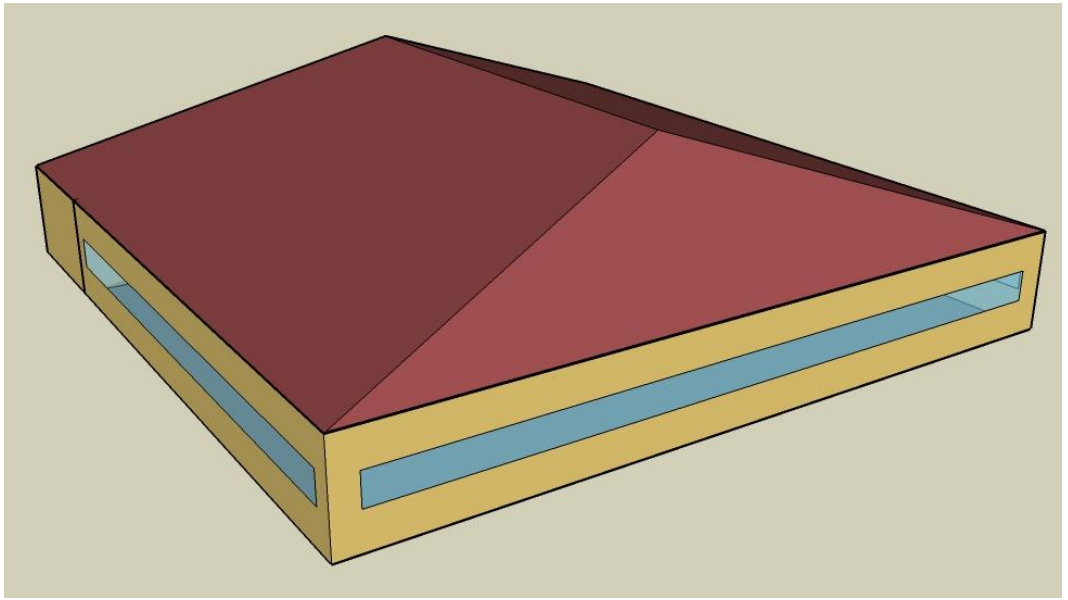
Strip mall
1 floor, 22,500 ft^2



Food Service

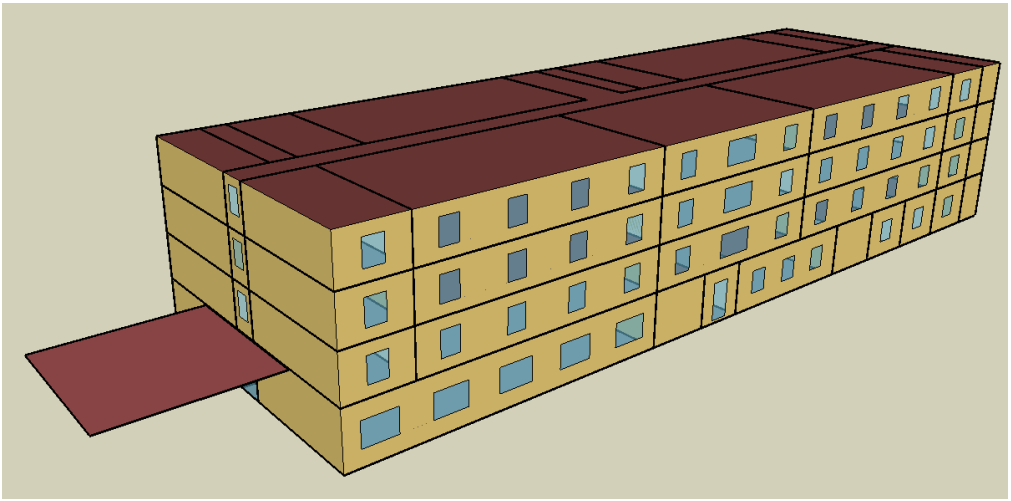


Quick service restaurant
2 zone, 2,500 ft^2

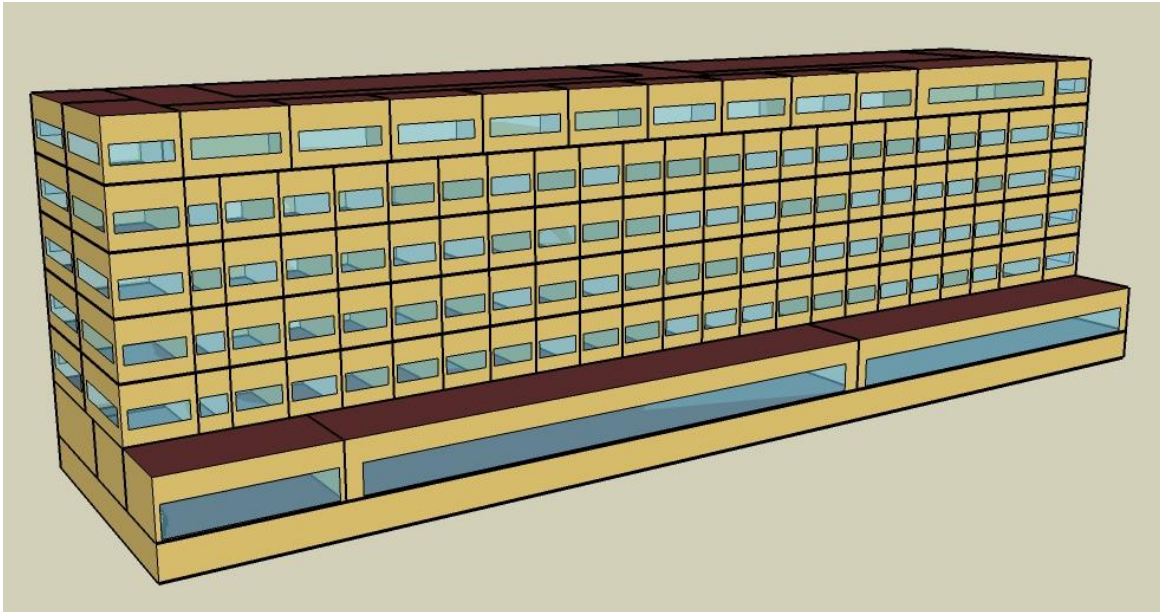


Full service restaurant
2 zone, 5,500 ft^2

Lodging

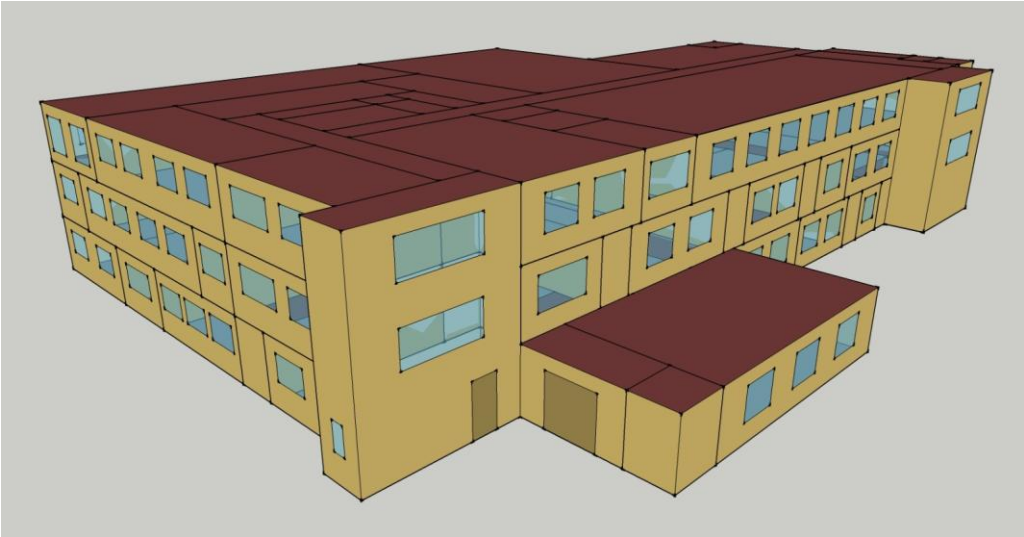


Small hotel
4 floors, 43,200 ft^2

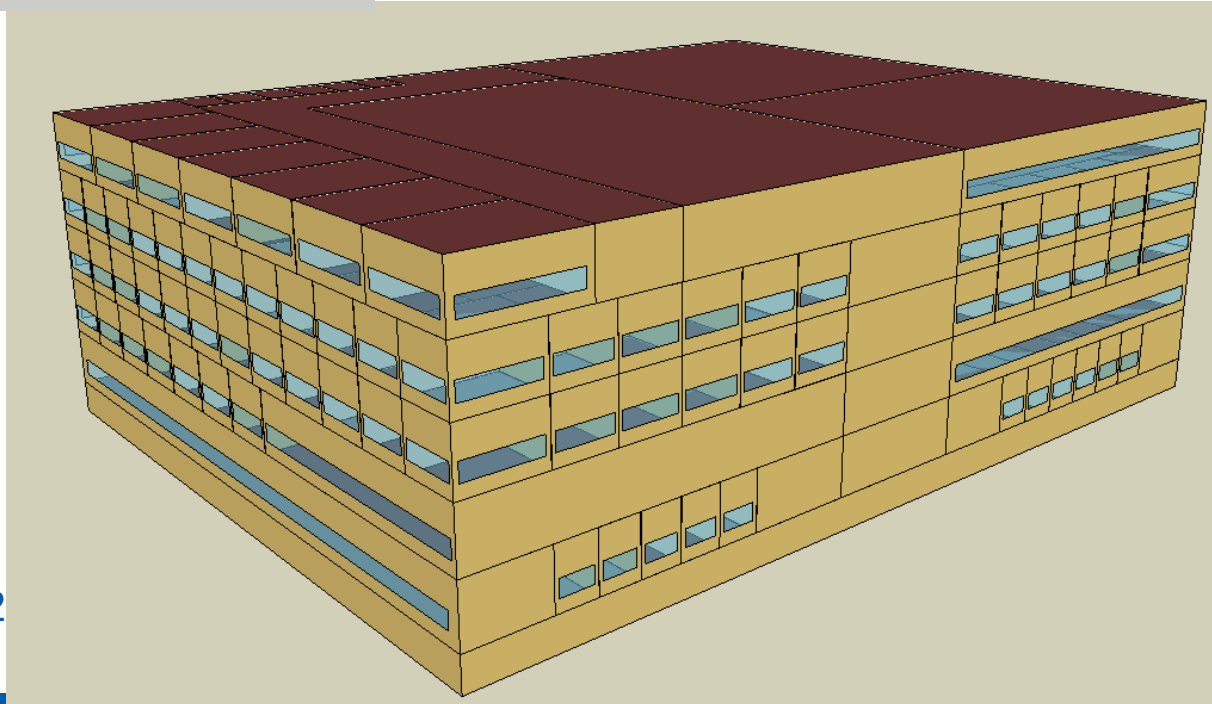


Large hotel
6 floors, 122,120 ft^2

Healthcare

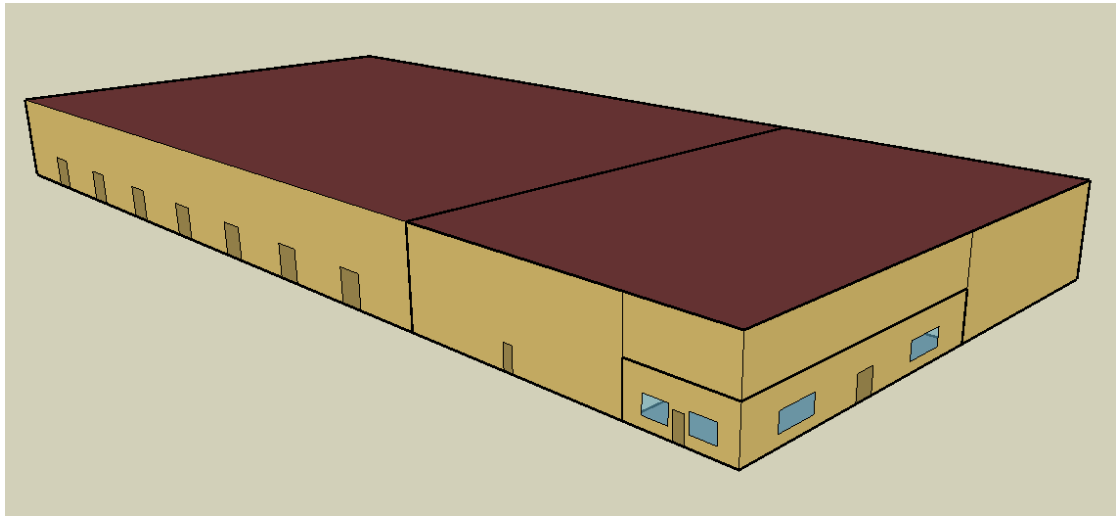


Outpatient Healthcare
3 floors, 40,946 ft^2

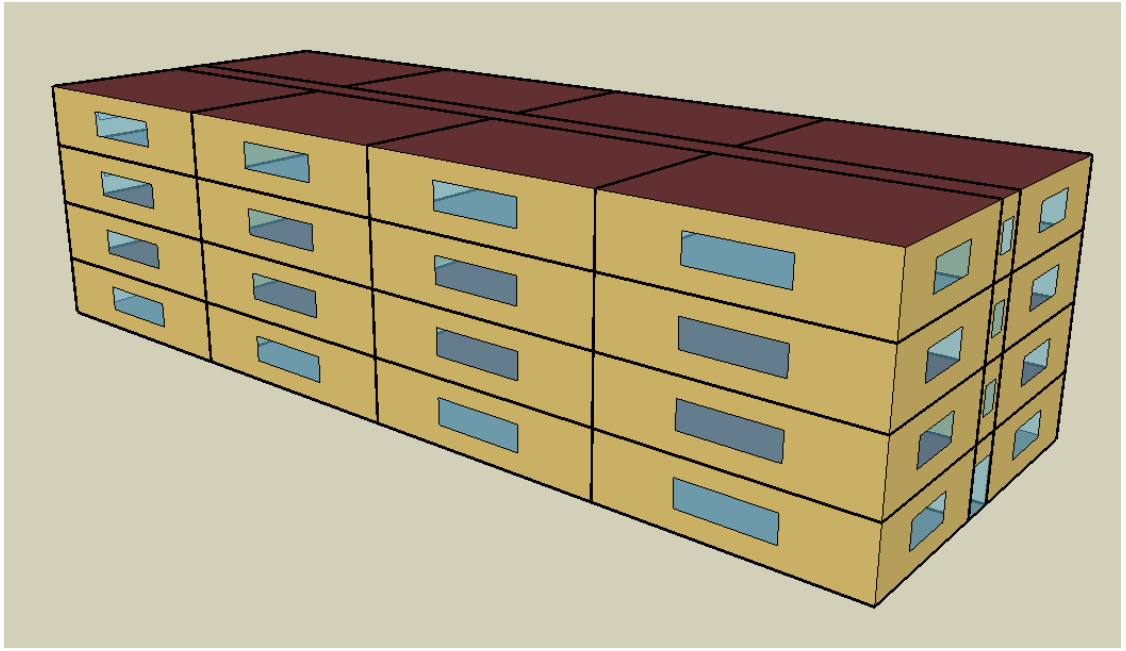


Hospital
5 floors, 241,351 ft^2

Other models



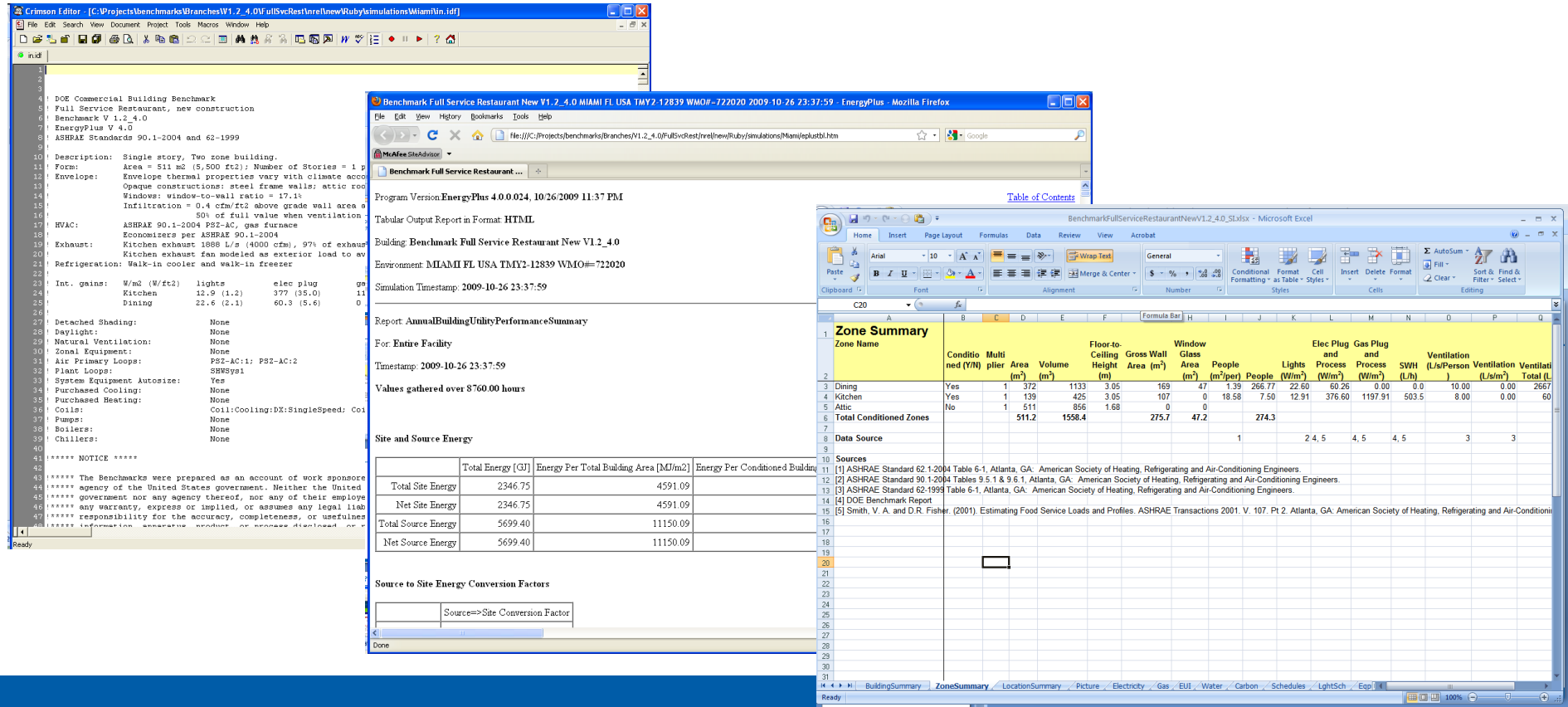
Warehouse
1 floor, 40,946 ft^2



Midrise apartment
4 floors, 241,351 ft^2

What's Available?

- EnergyPlus input and html output files
- Scorecards – spreadsheets with input parameters and output results
- Project report (coming ~ February)



Benchmark Scorecard

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Zone Summary**													
2	**Zone Name**	**Conditioned (Y/N)**	**Multiplier**	**Area (m^2)**	**Volume (m^3)**	**Floor-to-Ceiling Height (m)**	**Gross Wall Area (m^2)**	**Window Glass Area (m^2)**	**People (m^2/per)**	**People**	**Lights (W/m^2)**	**Elec Plug and Process (W/m^2)**	**Gas Plug and Process (W/m^2)**	**SWH (L/h)**
3	Dining	Yes	1	372	1133	3.05	169	47	1.39	266.77	22.60	60.26	0.00	0.0
4	Kitchen	Yes	1	139	425	3.05	107	0	18.58	7.50	12.91	376.60	1197.91	503.5
5	Attic	No	1	511	856	1.68	0	0						
6	**Total Conditioned Zones**			**511.2**	**1558.4**		**275.7**	**47.2**		**274.3**				
7														
8	**Data Source**								1		2	4, 5	4, 5	4, 5
9														
10	**Sources**													
11	[1] ASHRAE Standard 62.1-2004 Table 6-1, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.													
12	[2] ASHRAE Standard 90.1-2004 Tables 9.5.1 & 9.6.1, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.													
13	[3] ASHRAE Standard 62-1999 Table 6-1, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.													
14	[4] DOE Benchmark Report													
15	[5] Smith, V. A. and D.R. Fisher. (2001). Estimating Food Service Loads and Profiles. ASHRAE Transactions 2001. V. 107. Pt 2. Atlanta, GA: American Society of He													
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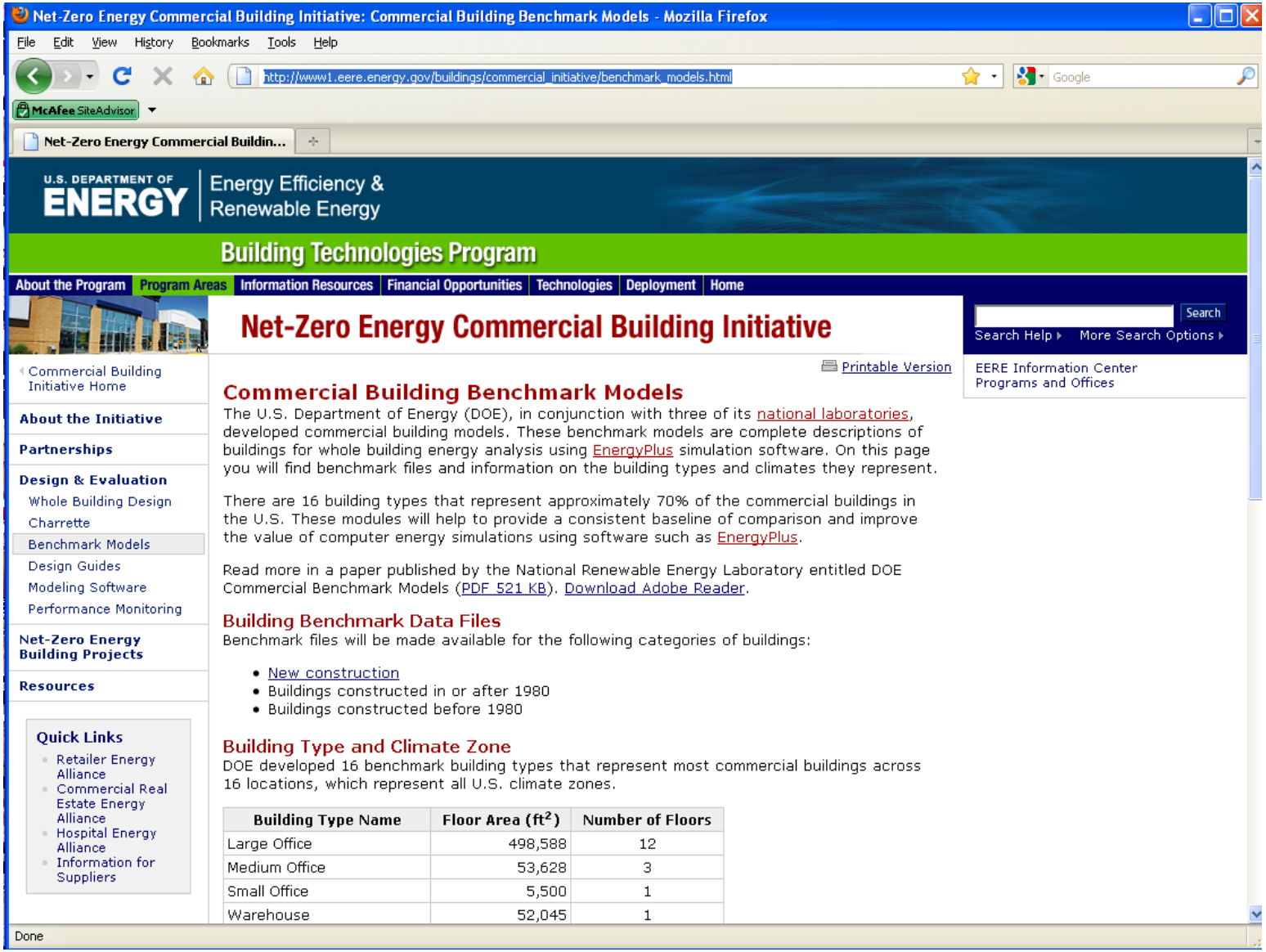
Formula Bar

BuildingSummary | ZoneSummary | LocationSummary | Picture | Electricity | Gas | EUI | Water | Carbon | Schedules | LghtSch | Eqp

Ready

Where Can You Get Them?



http://www1.eere.energy.gov/buildings/commercial_initiative/benchmark_models.html

Thank you