

Model America: A model of every U.S. building

For: CalBEM 2021 – Power Talks

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U.S. Energy and Buildings Overview



Goal of DOE's Building Technologies Office: 30% EUI reduction (energy per sq. ft.) by 2030 compared to 2010 baseline

Building Energy Modeling

building descriptions + weather = estimated building energy consumption, demand, emissions

Market Sizes and Opportunities

- Utility Programs (\$8B EE, \$3B DRMS)
 - Pricing/tariff structures, future-proof business models, Energy as a Service (EaaS), empowering the customer; cost-effective carbon reductions
- Energy Service Companies (ESCOs, \$7B)
- Investment opportunities (\$71-133B)
 - New business models automated financing
- Business relevance
 - What if we put \$4 billion into the county where you live? Could we make building changes, guarantee energy performance, and make \$10 billion profit in 17 years?



5-year vision

Digital Twin of every U.S. building

Methodology: Scalable compute, data, simulation, and empirical validation

1. Quantitatively rank most important building inputs



Sensitivity Analysis



3. Identify and compare data sources for important inputs



Comparison Matrix

4. Establish partnerships and APIs for scalable data retrieval







Computer Vision



Modeling and Simulation Capturing building energy consumption



Demonstrate and stimulate opportunities toward a sustainable built environment

6. Create OpenStudio & EnergyPlus models



DOE Prototype Buildings

7. Make models freely available



Download building vour

Use cases:

- Simulation-informed analysis
- Utility program formulation
- **Business model evaluation**
- **City-scale emissions** reductions
- Sales/marketing leads
- New building design
- Resilience
- Automated financing



Computational tools



Utility-scale impacts

- Partner: EPB Electric Power Board of Chattanooga, TN
- Provided 15-minute whole-building electricity for 178,368 buildings
- Simulation error bar for every building

#	Description	Category	Value	Source
1	Insulate Roof	Envelope	R-16.12 to R-28.57	IECC-2012
2	Reduce Space Infiltration	Envelope	Reduce 25% from vintage	EnergyStar whole-house
3	Adjust Thermostat Setpoint (4F)	HVAC	4°F 2 hrs prior to peak	EPB
4	Smart Thermostat (8F)	HVAC	8°F 4 hrs prior to peak	EPB
5	Change Electric HVAC COP	HVAC	COP to 3.55 (heating) 3.2 (cooling)	IECC-2012
6	Change Lighting Power Density	Lighting	LPD 0.85 W/ft ²	IECC-2012
7	Change to Gas Water Heater	Water	Efficiency 80% (assumes electric)	IECC-2012
8	Change to Gas HVAC	HVAC	Efficiency 80% (assumes electric)	IECC-2012



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Digital Twin: Energy, Demand, Emissions, \$ Savings

Results: Digital Twin of a Utility (every building)

EPB: 178,368 building energy models Validated against 15-minute electricity (colored by modeled energy/ft²)



1	Building Properties for Buildi	ng 2659310000	
	Num Floors	7	
	Square Footage	1,648,094	
	Annual Energy Usage	13,069,609 kWh	
	Annual Aggregated Demand	27,260 kW	
	EUI	8 kWh/ft^2	
	CO2 emissions	12,968,594 lbs	
	Estimated wholesale vs retail cost	671,125 \$	

Savings

	Annual	Annual	Annual
	Energy	Demand	Cost
	Savings	Savings	Savings
1: Env: Insulate Roof 💿	425,721 kWh 3.3%	1,402 kW 5.1%	\$62,161
2: Env: Reduce Space	100,741 kWh	691 kW	\$20,418
Infiltration 🕕	0.8%	2.5%	
3: HVAC: Adjust Thermostat	23,547 kWh	12,089 kW	\$194,305
Setpoint (4F) 1	0.2%	44.3%	
4: HVAC: Smart	-28,720 kWh	12,113 kW	\$189,788
Thermostat (8F) 💿	-0.2%	44.4%	
5: HVAC: Change Electric	119,645 kWh	347 kW	\$16,727
HVAC COP	0.9%	1.3%	
6: Light: Change Lighting	706,276 kWh	848 kW	\$79,657
Power Density ①	5.4%	3.1%	
7: Change to	151,892 kWh	241 kW	\$18,063
Gas Water Heater 💿	1.2%	0.9%	
8: Change to Gas HVAC 🔍	145,468 kWh 1.1%	967 kW 3.5%	\$28,994
9: Combined Electric* Savings Potential (1,2,5,6)	1,352,383 kWh 10.3%	3,288 kW 12.1%	\$178,963
10: Combined Demand*	268,640 kWh	13,321 kW	\$236,844
Savings Potential (4,7,8)	2.1%	48.9%	

Nation-scale...

• Free model of every U.S. building (bit.ly/ModelAmerica)

- OpenStudio (v3.1.0) and EnergyPlus (v9.4)
- State_county.zip (requires free Globus Connect Personal)
- New, Joshua R., Adams, Mark, Bass, Brett, Berres, Anne, and Clinton, Nicholas (2021). "Model America – data and models of every U.S. building." ORNL Constellation, <u>https://doi.ccs.ornl.gov/ui/doi/339</u>, April 14, 2021.
- 125,714,640 buildings, 124,178,694 simulated, 122,930,327 (97.8%) shared
- Dynamic archetypes of models and floor area multipliers for any geographical region
- Automatic Building Energy Modeling (AutoBEM) software
 - Related publications: <u>bit.ly/AutoBEM</u>



Discussion

HPC Tools for Modeling and Simulation Capturing building energy consumption

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CPU Cores	% HPC	Wall-clock Time (mins)	# Buildings Annual Sim	Data Size (zipped)
114,688	40	121.57	917,504	14.9 GB
140,544	50	109.59	1,124,352	18.3 GB
168,704	60	122.1	1,349,632	22.0 GB
193,920	69	121.6	1,551,360	25.3 GB
224,896	80	79.7-122.3	1,799,168	29.3 GB

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Computer Vision – street-level imagery

3D Building Model Generation



Acknowledgements

- EPB/ORNL partnership
- U.S. Department of Energy
 - EERE/Building Technologies Office
 - Office of Electricity
 - National Nuclear Security Administration
- Oak Ridge National Laboratory









Computer Vision – street-level imagery

CV DEMO

Façade Type







Windows (blue) Façade (green) Street/open (black) Other building (red)





Window-to-wall ratio



Model output



Market Sizes and Opportunities

- ~125M U.S. buildings
 - Building ~1% new per year; retrofits for 99%
- Market breakout (~\$25B changing 0.3% of buildings/yr)
 - Energy Service Companies (ESCOs)
 - \$7.5-\$9B/yr (CAGR 13%)
 - Utilities (\$10B/yr)
 - Energy efficiency programs (\$8B/yr)
 - Demand response (\$1.6B/yr, CAGR 16%)
 - Cities Sustainability Efforts
 - \$8.8B/yr (CAGR 24%)
- Investment opportunities
 - \$71-\$133B

