Automatic Building Energy Modeling (AutoBEM) software in action
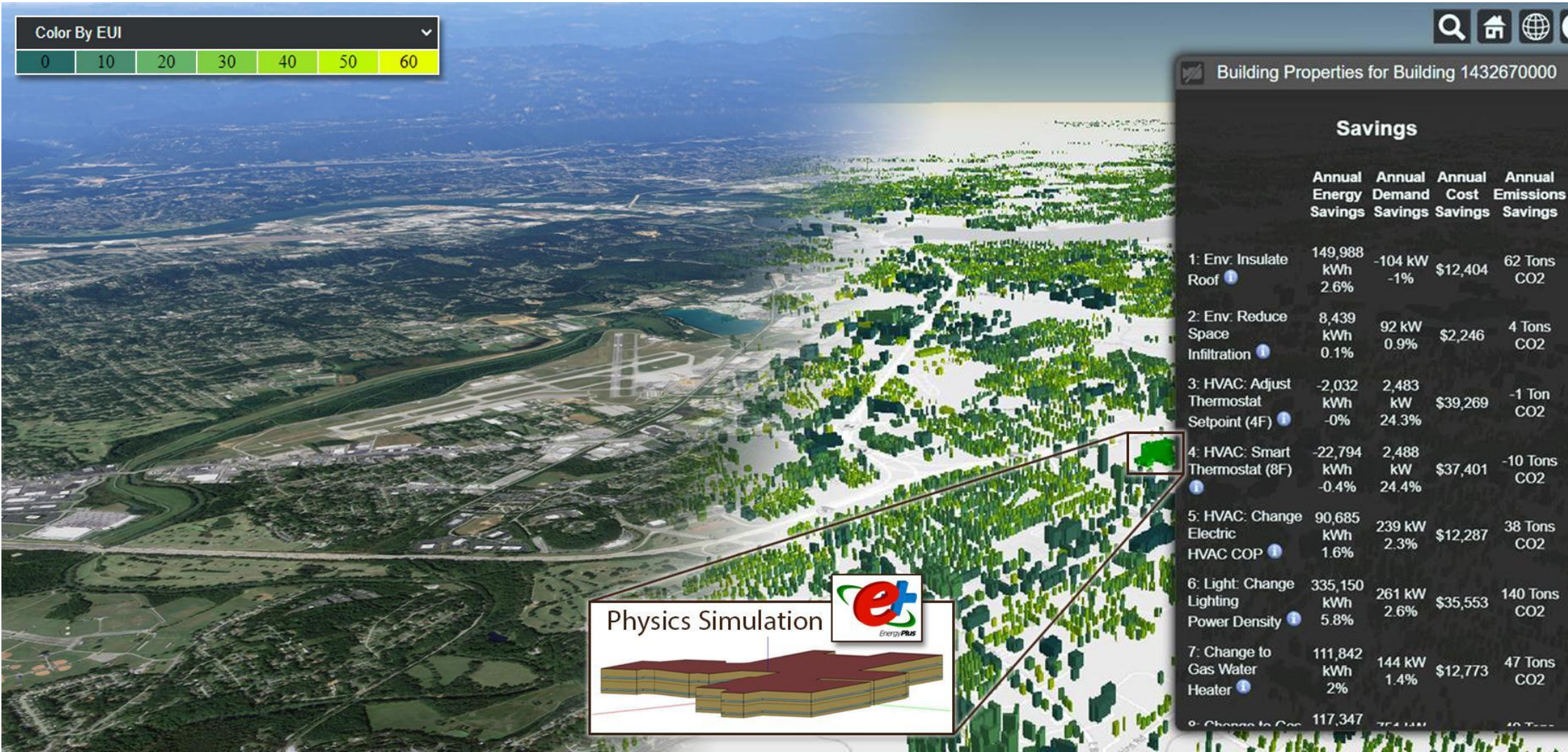
For: CalBEM 2023 – Power Talks

Presented by:
Joshua New, Ph.D., C.E.M., PMP, CMVP, CSM, IREE
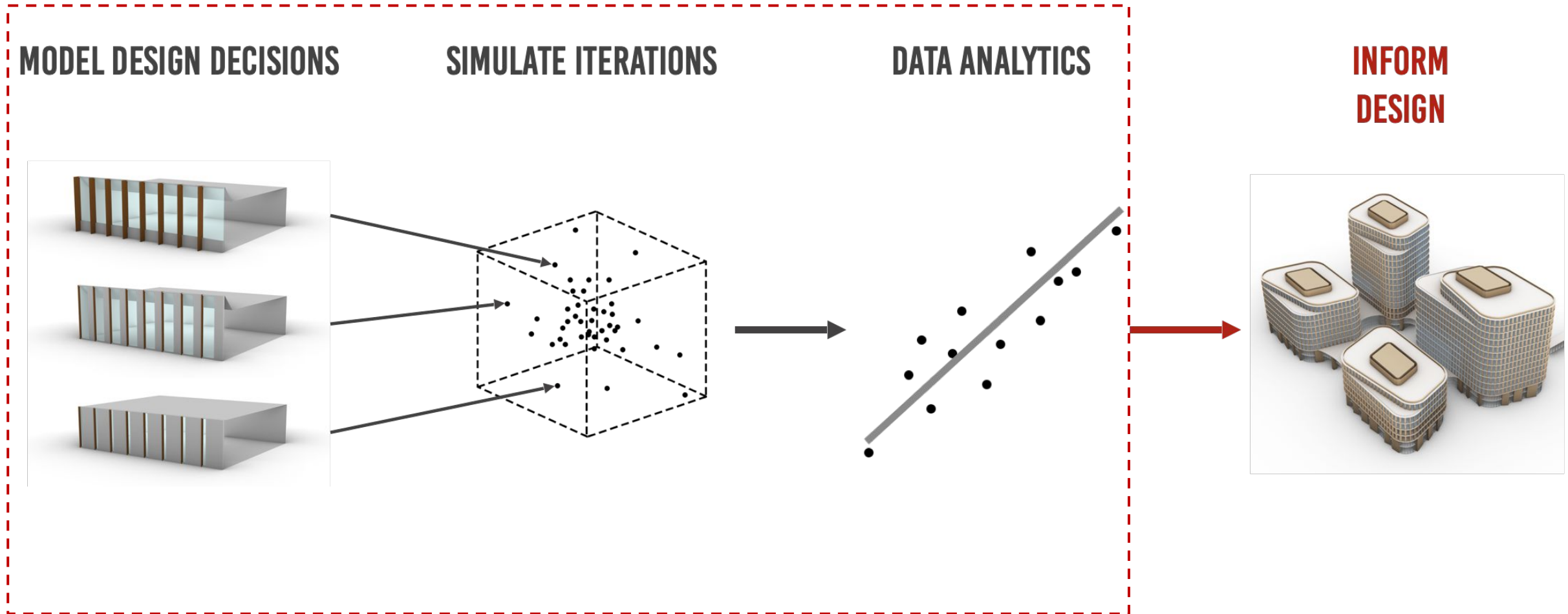Distinguished R&D Staff Member, Oak Ridge National Laboratory

Date: 10/18/23

Results (Publications – bit.ly/AutoBEM; Models – bit.ly/ModelAmerica)

- Digital twin of every U.S. building (125.7M data, 122.9M models; 141.5M in-process)
  - Estimates energy (kBtu), demand (kW), emissions (CO_{2-eq}) and cost ($) savings
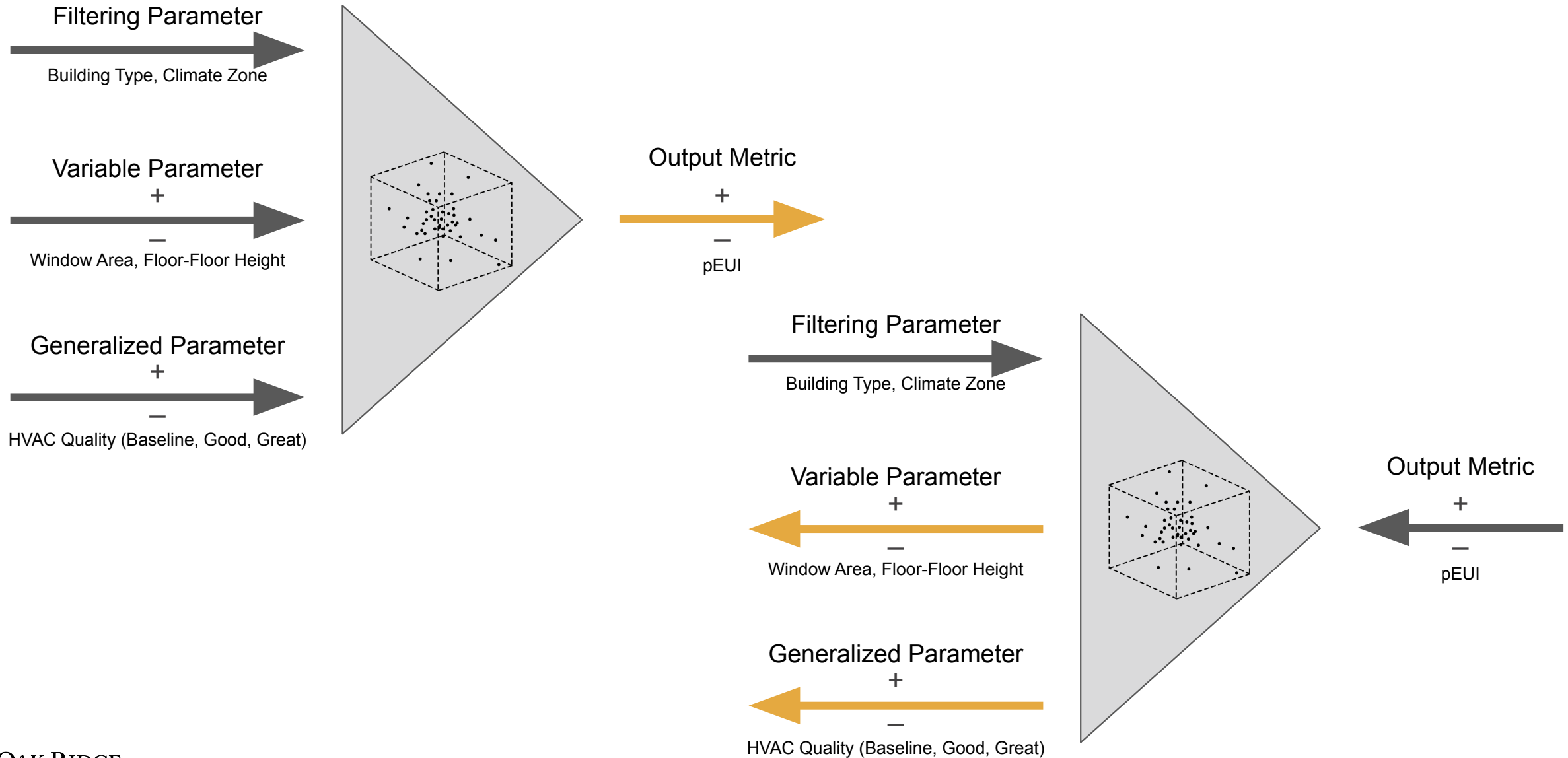
Universal Design Space Exploration

Pre-simulated analysis that encapsulates a common problem

MODEL DESIGN DECISIONS   SIMULATE ITERATIONS   DATA ANALYTICS   INFORM DESIGN

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UDSE: Define performance, not inputs

Filtering Parameter
Building Type, Climate Zone

Variable Parameter
+
−
Window Area, Floor-Floor Height

Generalized Parameter
+
−
HVAC Quality (Baseline, Good, Great)

Output Metric
+
−
pEUI

Filtering Parameter
Building Type, Climate Zone

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Market Value for High Performance Computing

- 1,068,813 buildings/hour – generated, simulated, results stored

- Building energy modelers - $150/hr

- Model levels and cost at Architectural, Engineering, Const. (AEC) firm

| Model Quality	Typical Time	Cost
Basic	2 days	$2,400
Functional	1 week	$6,000
Detailed	2 weeks	$12,000

- AutoBEM on HPC - $6.4 billion and 20,554 person-years worth of work… completed in 1 hour on supercomputers

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Prototype App: Real-time Analytics

AutoBEM Chattanooga

- Validation
  - 15-Minute electricity use
  - 178,000 building electrical meters
  - Chattanooga, TN

- Technological Evolution
  - Data
  - Algorithms

- Analysis
  - Energy saving technologies
  - Demand saving technologies
  - Renewable technologies
  - Microgrids

- AutoBEM can ingest known building properties automatically

bit.ly/virtual_epb
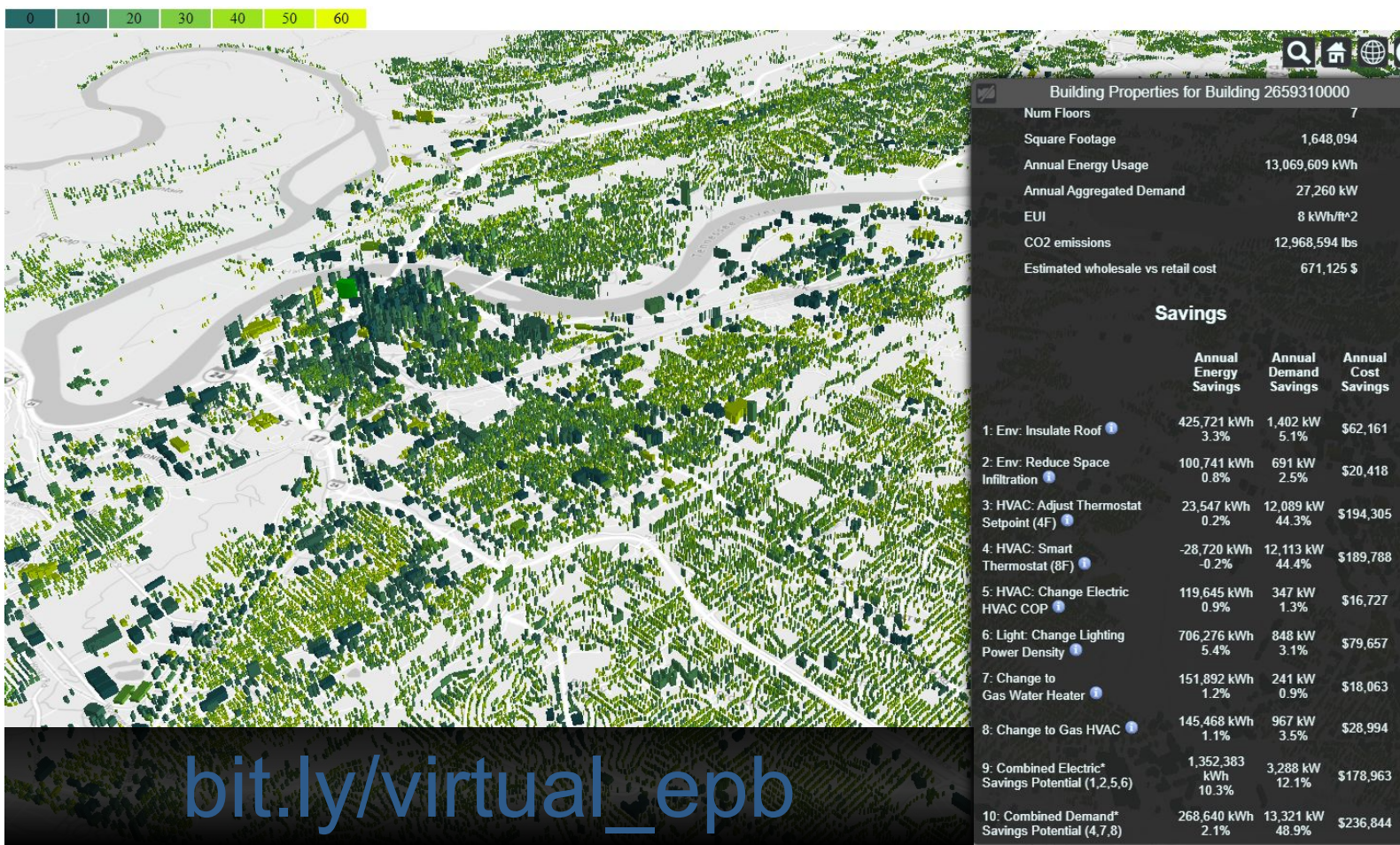
Digital Twin of Chattanooga, TN, shows energy, demand, and cost savings of individual measures and packages of EE or DR measures.

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Dynamic Archetypes

- Model with median EUI selected for each building type/vintage combination

- Dynamically construct floor space multiplier (all buildings / median-EUI bldg.)

- 29,230 Boulder, CO buildings represented by 60 models

	AutoBEM Original	Dynamic Archetypes
Total Electricity (TWh)	1.29	1.36
Total Natural Gas (TWh)	1.77	1.92
Total Energy (TWh)	3.06	3.27

https://github.com/ORNL-BTRIC/AutoBEM-DynamicArchetypes

- 589,586 Clark County (Las Vegas) bldgs. via 129 archetypes

  – New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Model America - Clark County (Vegas) extract from ORNL's AutoBEM (Version 1.1) [Data set]." Zenodo, doi.org/10.5281/zenodo.4552901, Feb. 16, 2021. [Data]

  – New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Clark County (Vegas) Archetypes from ORNL's AutoBEM [Data set]." Zenodo, doi.org/10.5281/zenodo.4552901, Mar. 21, 2021. [Data]
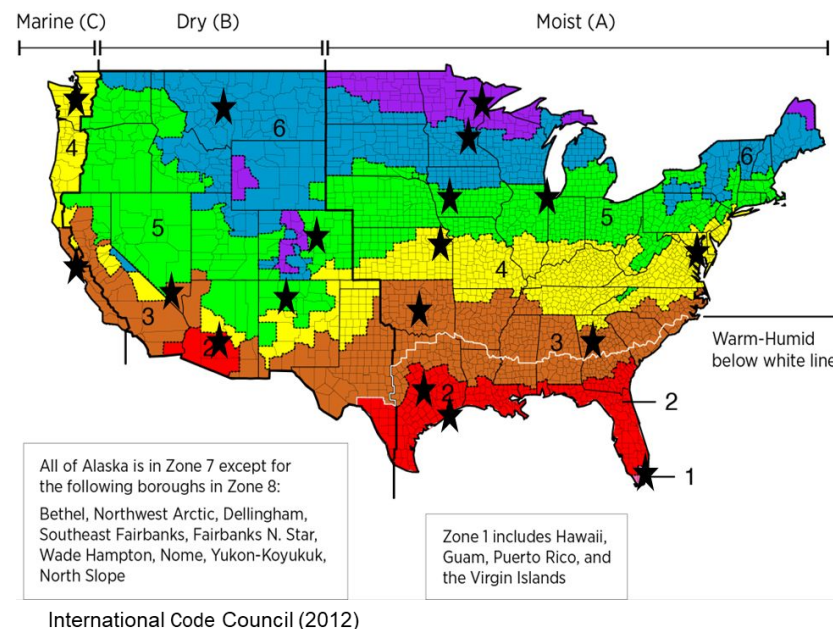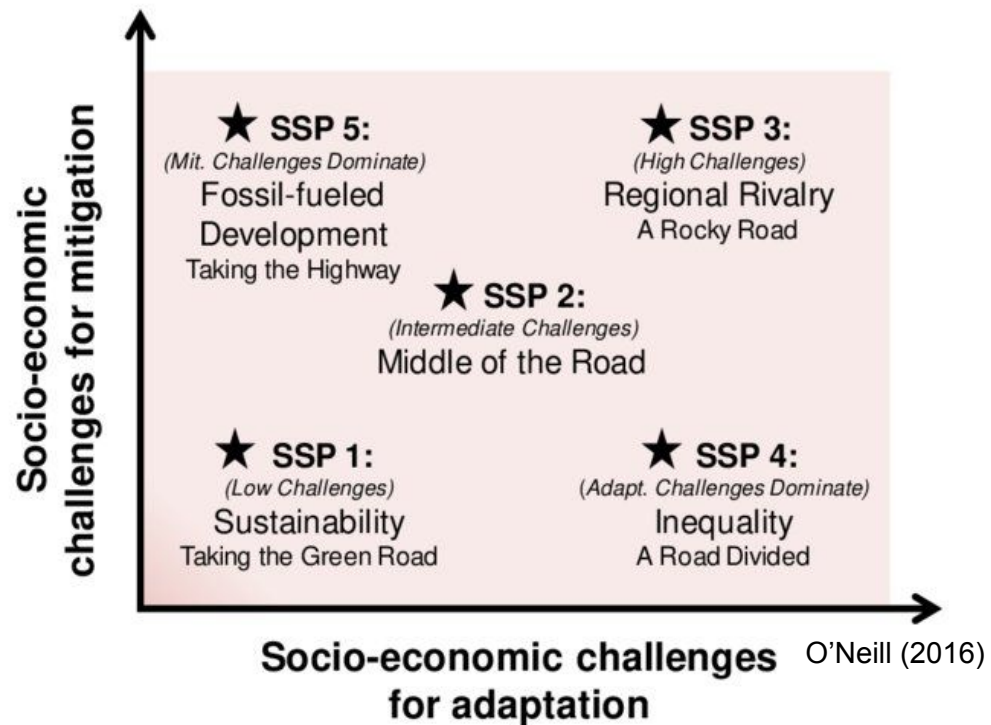
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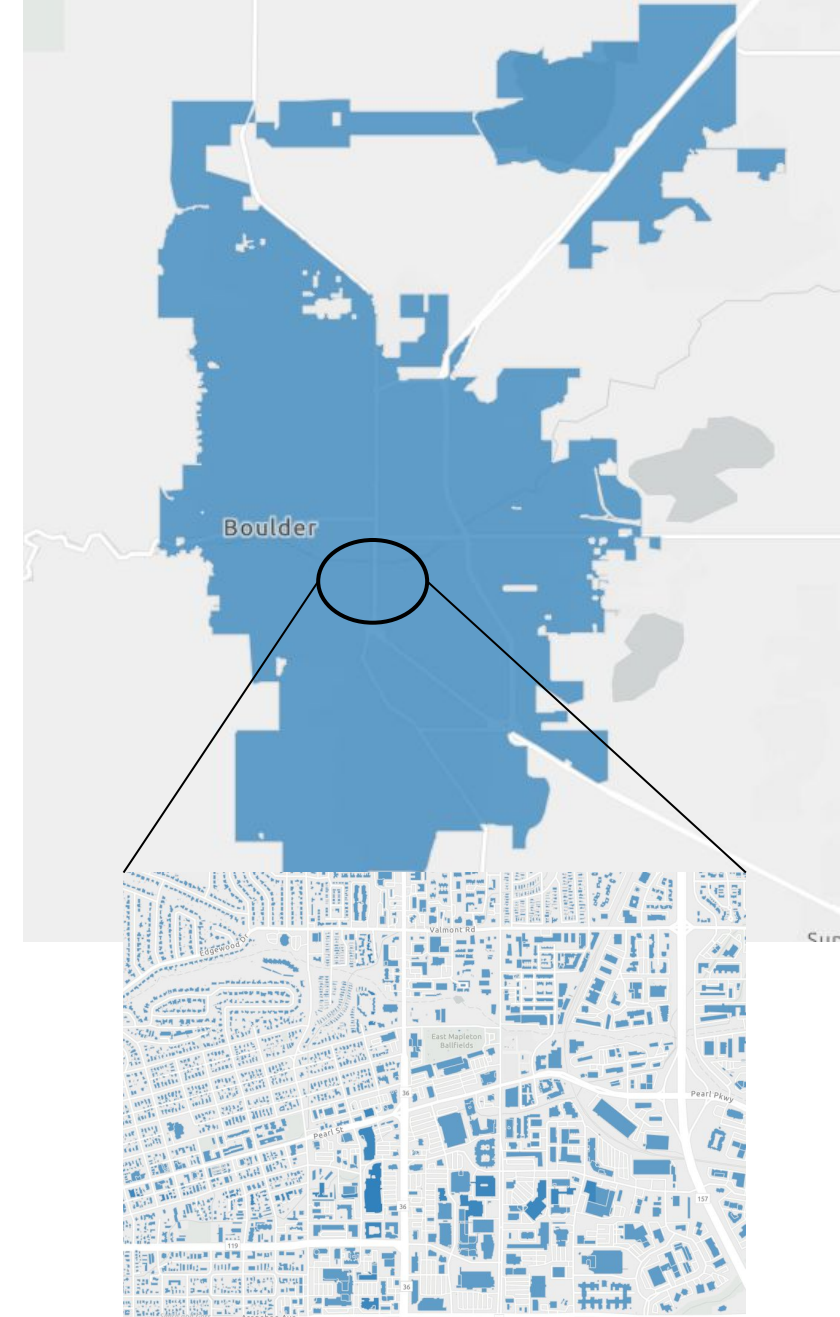
Developing fTMY Weather Files

- Future Typical Meteorological Year (fTMY)

- ASHRAE cities, county-specific (free EPWs)
  - SSP 5, RCP 8.5 from 2020-2100 (every 2 decades)

- 6 Climate Models from around the globe

- 9 Weather Variables
  - Air Temp
  - Longwave
  - Shortwave
  - Vapor Pressure
  - Vapor Pressure Deficit
  - Relative Humidity
  - Precipitation
  - Wind
  - Pressure

- More info? Google "fTMY" or "zenodo fTMY" for data
- Code - https://github.com/klimaat/rnlyss/blob/master/rnlyss/tmy.py
- Downscaled data – https://doi.org/10.21951/SWA9505V3/1887469

O'Neill (2016)

International Code Council (2012)

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Maricopa County Case Study

- Phoenix, AZ – potential 5°F increase in 2100,
  16% more electricity use, and 23% more demand

bit.ly/virtual_phoenix

Building Data

UBID	8559FW99+VF7-3-2-2-2
Building Type	SINGLE FAMILY RESIDENTIAL
Year Built	1949
Num Floors	1
Square Footage	2,477
Height (ft)	12

Total Energy Projections

	Annual Energy	Annual Cost	Annual Emissions
TMY3	58,234 kBTU	21,647 $	6.2 Tons CO2
fTMY 2020-2040	56,276 kBTU	20,942 $	6 Tons CO2
fTMY 2040-2060	58,949 kBTU	22,178 $	6.3 Tons CO2
fTMY 2060-2080	59,629 kBTU	22,706 $	6.4 Tons CO2
fTMY 2080-2100	63,832 kBTU	24,699 $	6.8 Tons CO2

Electricity Projections

	Annual Energy	Annual Cost	Annual Emissions
TMY3	47,950 kBTU	21,482 $	5.1 Tons CO2
fTMY 2020-2040	46,391 kBTU	20,783 $	5 Tons CO2
fTMY 2040-2060	49,154 kBTU	22,021 $	5.3 Tons CO2
fTMY 2060-2080	50,349 kBTU	22,556 $	5.4 Tons CO2

Scenario	Average Dry Bulb Temperature (°F)
TMY	23.8
fTMY 2020-2040	24.1
fTMY 2040-2060	25.8
fTMY 2060-2080	26.6
fTMY 2080-2100	29.1

Scenario	Total Energy	Electricity	Natural Gas
TMY	0.24 Quads	0.20 Quads	0.04 Quads
fTMY 2020-2040	-1.0%	-1.0%	-1.1%
fTMY 2040-2060	3.4%	4.6%	-3.2%
fTMY 2060-2080	4.6%	6.9%	-8.1%
fTMY 2080-2100	11.6%	15.9%	-12.3%

Scenario	Total Costs	Total Emissions
TMY	$ 8.5 Billion	26 Million Tons CO2
fTMY 2020-2040	-1.0%	-1.0%
fTMY 2040-2060	4.0%	3.4%
fTMY 2060-2080	5.85%	4.6%
fTMY 2080-2100	14.0%	11.6%

Scenario	July Total Energy
TMY	0.02 Quads
fTMY 2020-2040	1.9%
fTMY 2040-2060	11.1%
fTMY 2060-2080	14.3%
fTMY 2080-2100	23.0%

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Environmental Insights Explorer (Google)

- Model America (version 1) to MAv2 improvements
  - More, newer buildings
  - Height (< 1-meter vertical resolution)
  - Building type (mapped from 150+ classifications)
  - Multi-use building classification
- Accuracy (no calibration or adjustment)
  - For city-scale annual total bldg energy, average error rate 2.3% (5% max)
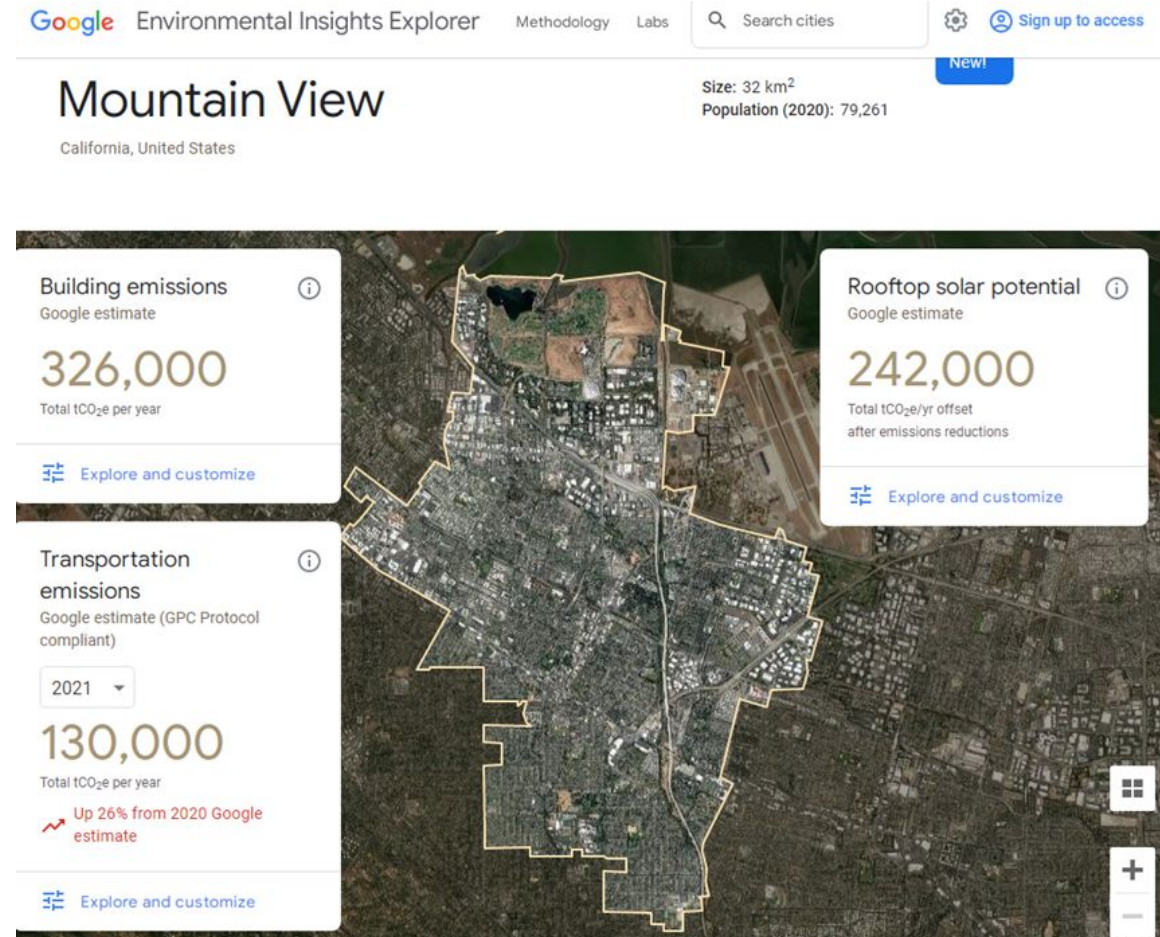
Hartford, CT	
EIE	-26%
AutoBEM	-1%

Boulder, CO	
EIE	-41%
AutoBEM	-1%

Washington DC	
EIE	-46%
AutoBEM	5%

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Analysis (2 years: ~50 NDAs; FY23 – 87% proposal success, 13 projects)

Supercomputing for building analysis (1M bldgs/hr)

Dynamic archetypes for area representation

Boulder

29,230 buildings to 60 models with floor area multipliers (~7% error)
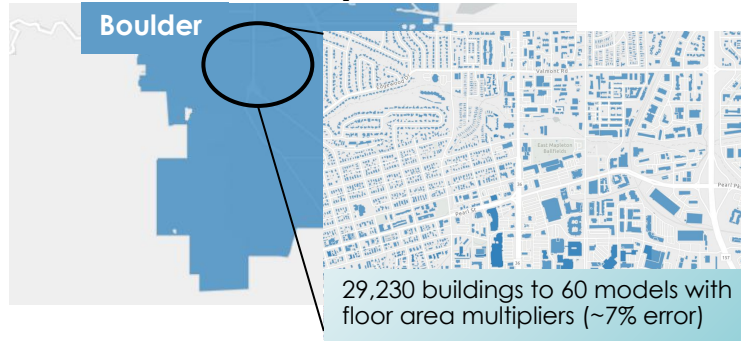
Climate Change – IPCC weather files for buildings

Marine (C)   Dry (B)   Moist (A)

Warm-Humid below white line

All of Alaska is in Zone 7 except for the following boroughs in Zone 8: Bethel, Northwest Arctic, Dellingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

Argonne NATIONAL LABORATORY

Sandia National Laboratories
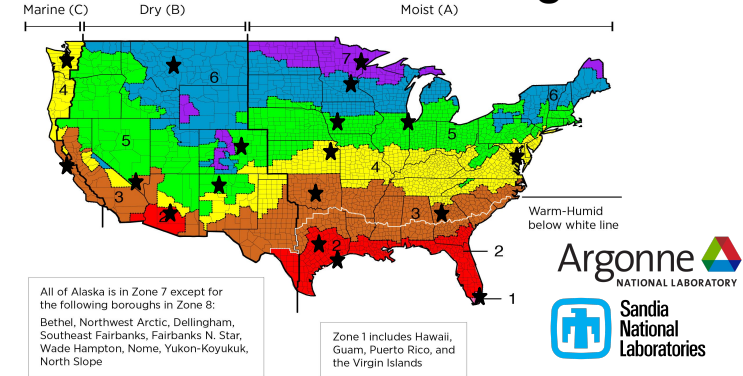
AI for real-time EUI during building design

EUI : 72.82 kBTU/sf

$6.4B and 20,500 person-years of work in 1 hour

SMITHGROUP

Utility-scale savings used operationally

Annual Demand Savings

Vintage
- 90.1-2004
- 90.1-2007
- 90.1-2010
- 90.1-2013
- DOE-Ref-1980-2004
- DOE-Ref-Pre-1980

DualFuel   SmartThermo4 ECM   SmartWH
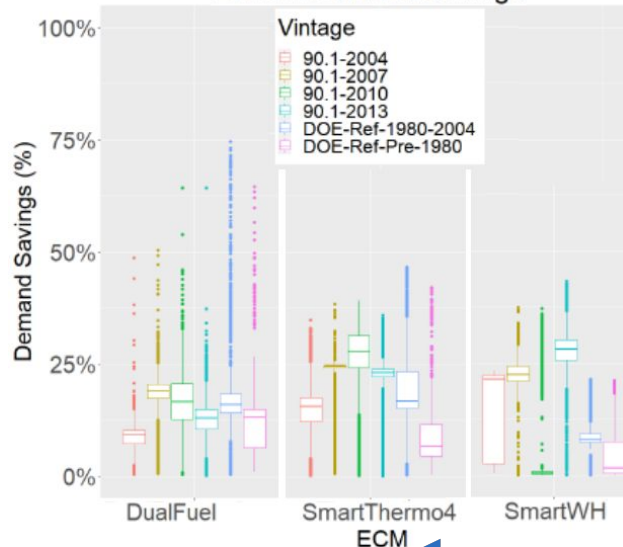
Web-based visualization of climate change impacts

https://evenstar.ornl.gov/autobem/phoenix/

Buildings carbon footprint for 40,000 cities

	DC		
	Electricity	Natural Gas	Total
EIE	-44%	-73%	-46%
AutoBEM	-9%	23%	5%

Error <5% at city-scale

Google

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epb

LIGHTBOX

BEM is dead. Long live BEM!

https://gshp.ornl.gov - for ground-source heat pumps

On-demand metrics for any building (GSHP today, tomorrow?)

Natural Gas Price ($/MMBtu)	Electricity Price ($/kWh)	Water Price ($/kgal)	GHE Unit Price ($/ft)
$ 15	$ 0.2	$ 3.48	$ 10

GSHP SYSTEM CONFIGURATION

Total GHE Length (ft)	167,450
Capacity (ton)	894
Length per Ton of Capacity (ft/ton)	187

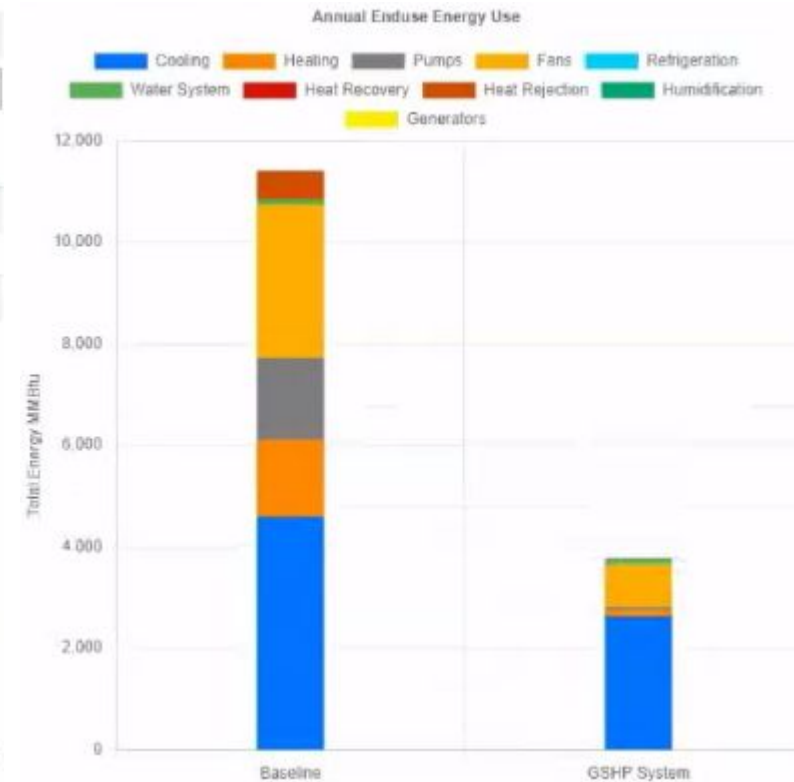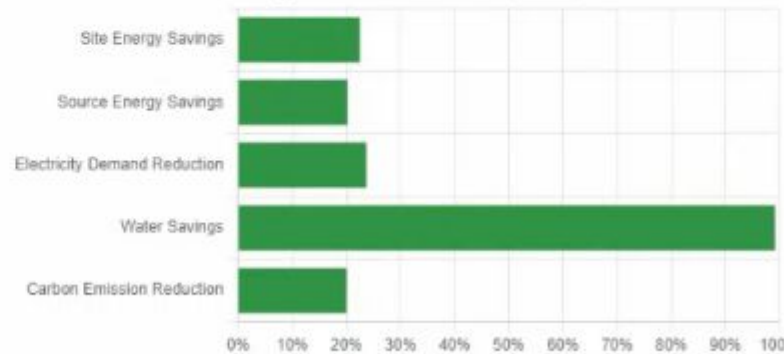**ECONOMICS**

Cost Premium of GSHP System	$2,344,306
Simple Payback Period (Year)	6.1
Annual Return of Investment	4.4%

BENEFITS (ANNUAL)

Category	Values	Percentage
Electricity Savings [kWh]	1,794,754	19%
Natural Gas Savings [MMBtu]	1,519	94%
Site Energy Savings [MMBtu]	7,638	22%
Source Energy Savings [MMBtu]	21,026	20%
Carbon Emissions Reduction [klb]	3,223	20%
Peak Electricity Demand Reduction [kW]	583	24%
Water Savings [kgal]	5,764	99%

YOU SAVE: $381,730 — **PER YEAR ON UTILITY 20% SAVINGS**

Energy and Environmental Benefits (Annual)

Annual Enduse Energy Use

End-use breakdown and dynamics can feed typically black box load models

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