# Public Tools to Improve Building Energy Efficiency

**Tianzhen Hong, PhD**
Building Technology and Urban Systems Division
Lawrence Berkeley National Laboratory

**Josh Wentz**
Director of Product, Lucid
Architect of BenchmarkMyBuilding.com

Statewide
Energy
Efficiency
Collaborative

# Summary

|  | | |
|---|---|---|
| **Team** | Lawrence Berkeley National Laboratory (LBNL)  focused on engines | Lucid, makers of BuildingOS.com  focused on user interface |
| **Software Tools** | City Building Energy Saver (CityBES) | BenchmarkMyBuilding.com |
|  | Retrofit Analysis Software  Energy Conservation Measure (ECM) Database  OpenStudio  EnergyPlus  ENERGY STAR® TargetFinder™  DOE BUILDINGS PERFORMANCE DATABASE | buildingOS  **10,000**+ buildings, **1B**+ ft$^2$  across universities, corporations, real estate, government, cities, states  **150**+ integrations  with building hardware & software systems  **700**+ customers  primarily building owners & operators |

Statewide Energy Efficiency Collaborative

# City Building Energy Saver

(CityBES) by Lawrence Berkeley National Lab

# DOE WORKSHOP: Energy Transformation in Cities

How can the national labs help cities?

- Data management

- Prioritization

- Policy evaluation

- District-scale technical assistance

- Estimating NEBs

Washington, D.C. • January 5-6, 2017
Boston • Boulder • Cambridge • Chicago • Denver • Detroit • DC • Knoxville • LA • NYC • Oakland • Phoenix • Portland • SF • Seattle
American Planning Association • Energy Foundation • Kendeda • Kresge • NASEO • NRDC • NBI • Rockefeller • USDN • USGBC
ANL • LBNL • NREL • ORNL • PNNL
White House: OMB • NEC • OSTP
Office of the Vice President
DOE: BTO • EERE • EPSA • OSP • SETO • VTO • WIP

BERKELEY LAB
Lawrence Berkeley National Laboratory

# DOE WORKSHOP: Energy Transformation in Cities

**Seattle**: Modeling effect of a gas-to-electricity mandate without building fuel data

**Boston**: Hired MIT Lincoln Labs to run DER-CAM to find promising micro-grid locations

**San Francisco**, CA: Made tool for citizens to spec home solar installations, don't know who uses.

**NYC**: Made their own high rise typologies, modeled in eQuest.

**Washington DC**: Prioritizing district energy systems locations to reduce 100 peak hour use.

ACEEE City Scorecard

# WHY CITIES?

- Cities drive our economy and dominate energy and environmental challenges.
- Not new end-uses or sectors, but new partnership opportunities with local governments
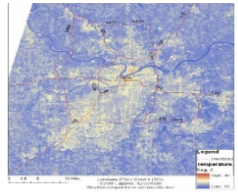
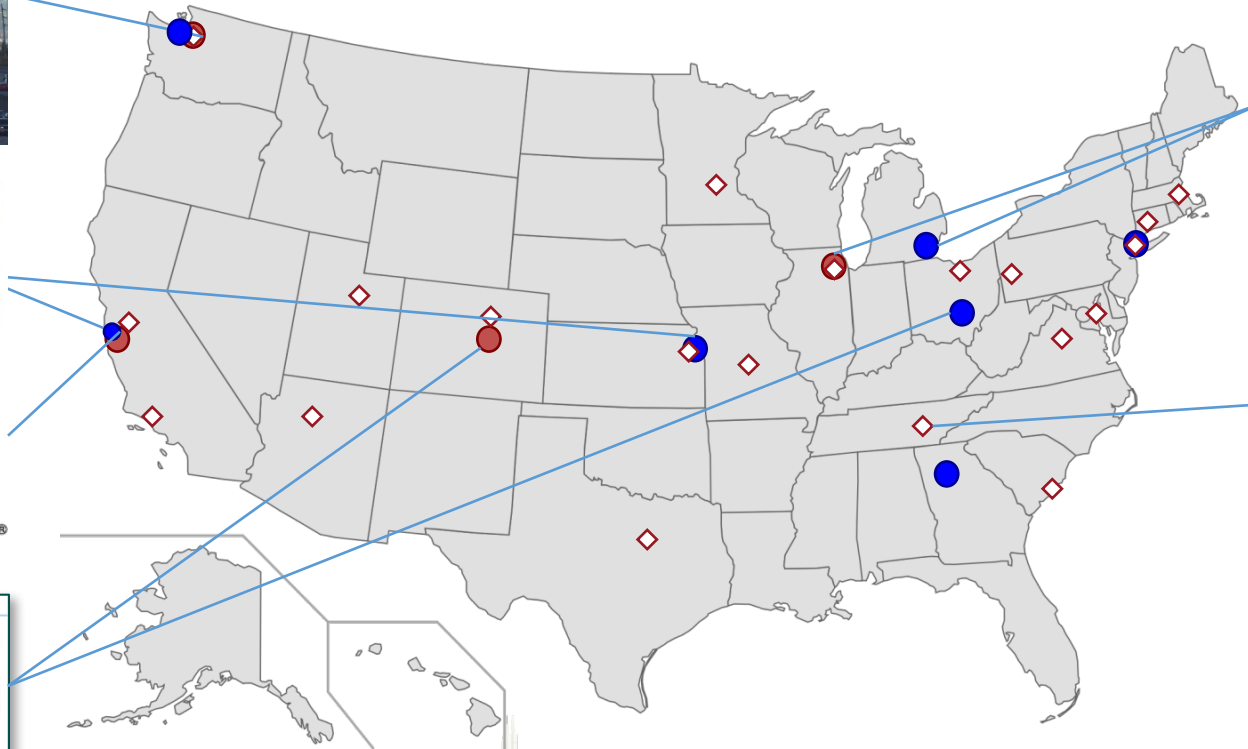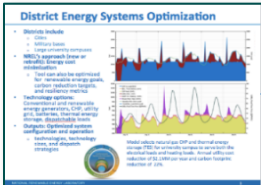**70% GHG**

**70% Energy**

**80% GDP**
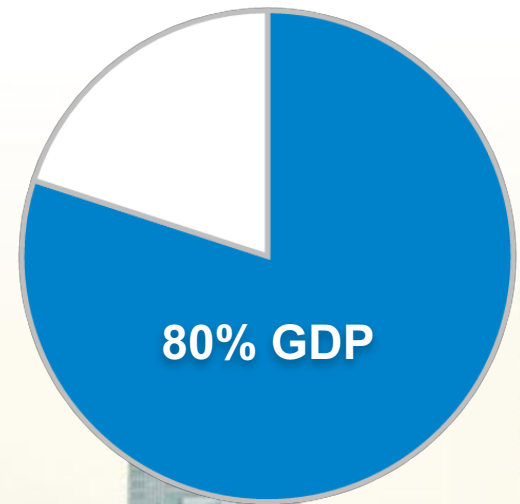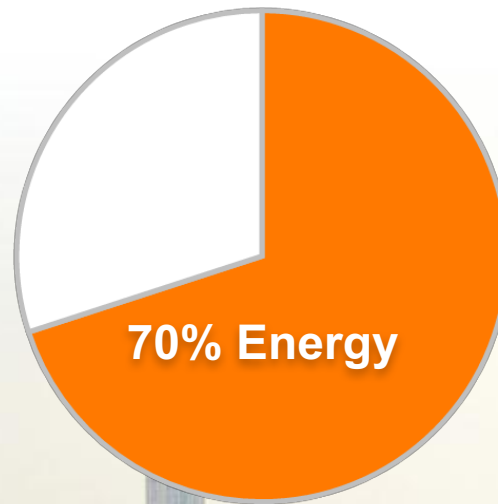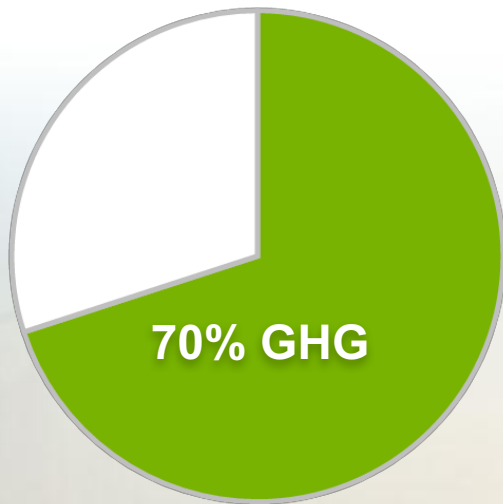
# IMAGINE A CITY…

…that consumes 50% less total energy per person while improving economic vitality and quality of life and increasing resilience and sustainability

# WHAT ARE WE LEARNING?



**URBAN ENERGY SCIENCE/ENGINEERING**
Argonne Partnership with the City of Chicago

Coupled Computational Models

Data Integration and Analysis Infrastructure

Plenario, a Powerful City-Data Tool, Debuts

Urban and Green Space Sensing

**Urban-CAT: Urban Climate Adaption Tool**
Partnership: City of Knoxville, TN

- **Issue:** Mid-size cities house ~50% of urban dwellers and typically lack the resources to address climate-related vulnerabilities.
- **Goal:** Create a tool with simple interface that can answer:
  1. What are storm water runoff patterns for different combinations of climate and population projections?
  2. How to best characterize infrastructure vulnerability and risk?
  3. How to prioritize green infrastructure locations (available parcels, flood history, etc.)?
  4. What are the benefits and costs of green infrastructure options under present and future conditions?

**District Energy Systems Optimization**

SAN FRANCISCO
2030 DISTRICT®

**NREL**

**City-Level Energy Decision Making: Data Use in Energy Planning, Implementation, and Evaluation in U.S. Cities**

Alexandra Aznar, Megan Day, Elizabeth Doris, and Shivani Mathur
*National Renewable Energy Laboratory*

Paul Donohoo-Vallett
*U.S. Department of Energy*

● Multi-Lab Summit   ● Individual Lab Interactions   ◇ C-LEAP Discussions
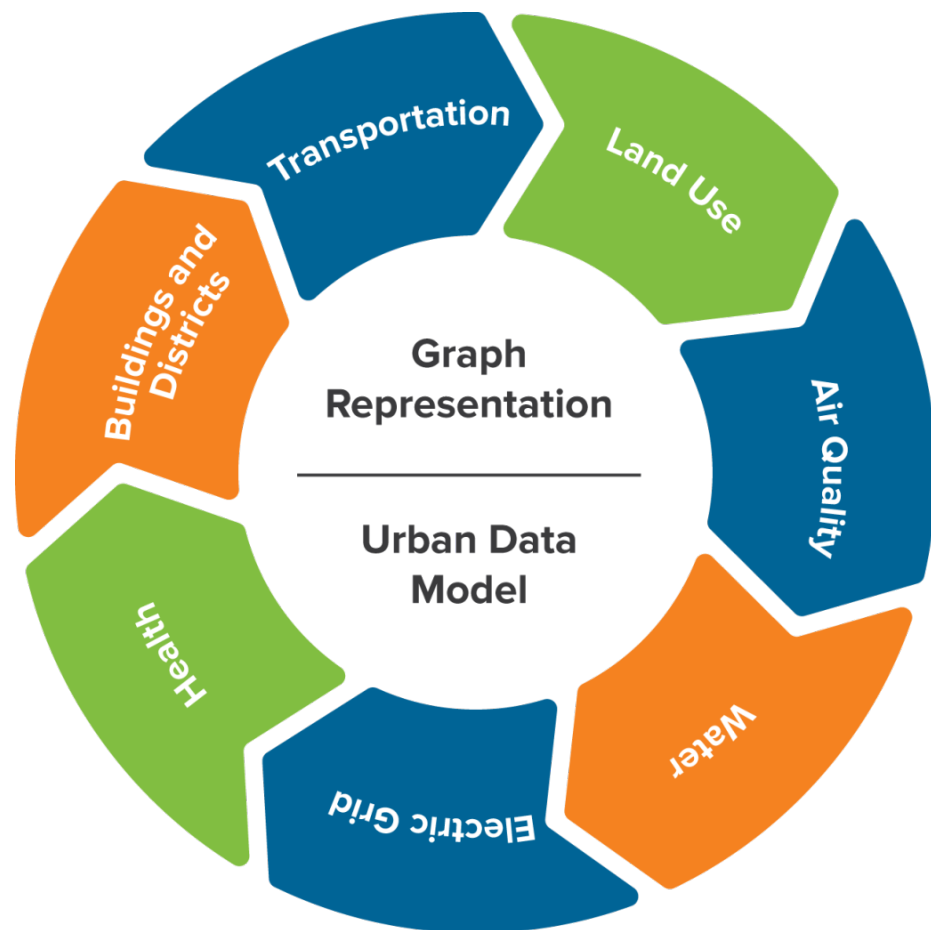
# WHY NOW?

- $40T in new urban infrastructure over the next 2 decades

- Aggressive energy targets

- Economic revitalization

# HOW?

- **Develop science-based, validated tools**
  - Integrated measurement, data and analysis for city-scale, multi-sector models of energy, climate, land use

- **Develop, evaluate and demonstrate new technology**

- **Establish partnerships**
  - City and community leaders
  - Industry & NGOs
  - DOE resources and capabilities



Graph Representation
—
Urban Data Model

Transportation · Land Use · Air Quality · Water · Electric Grid · Health · Buildings and Districts
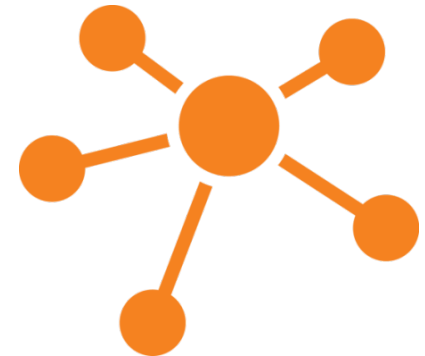
# WHAT?

- Cities as integrated, dynamic systems vs. places

- Resources and tools for energy planning and analysis — from buildings to transportation to grid
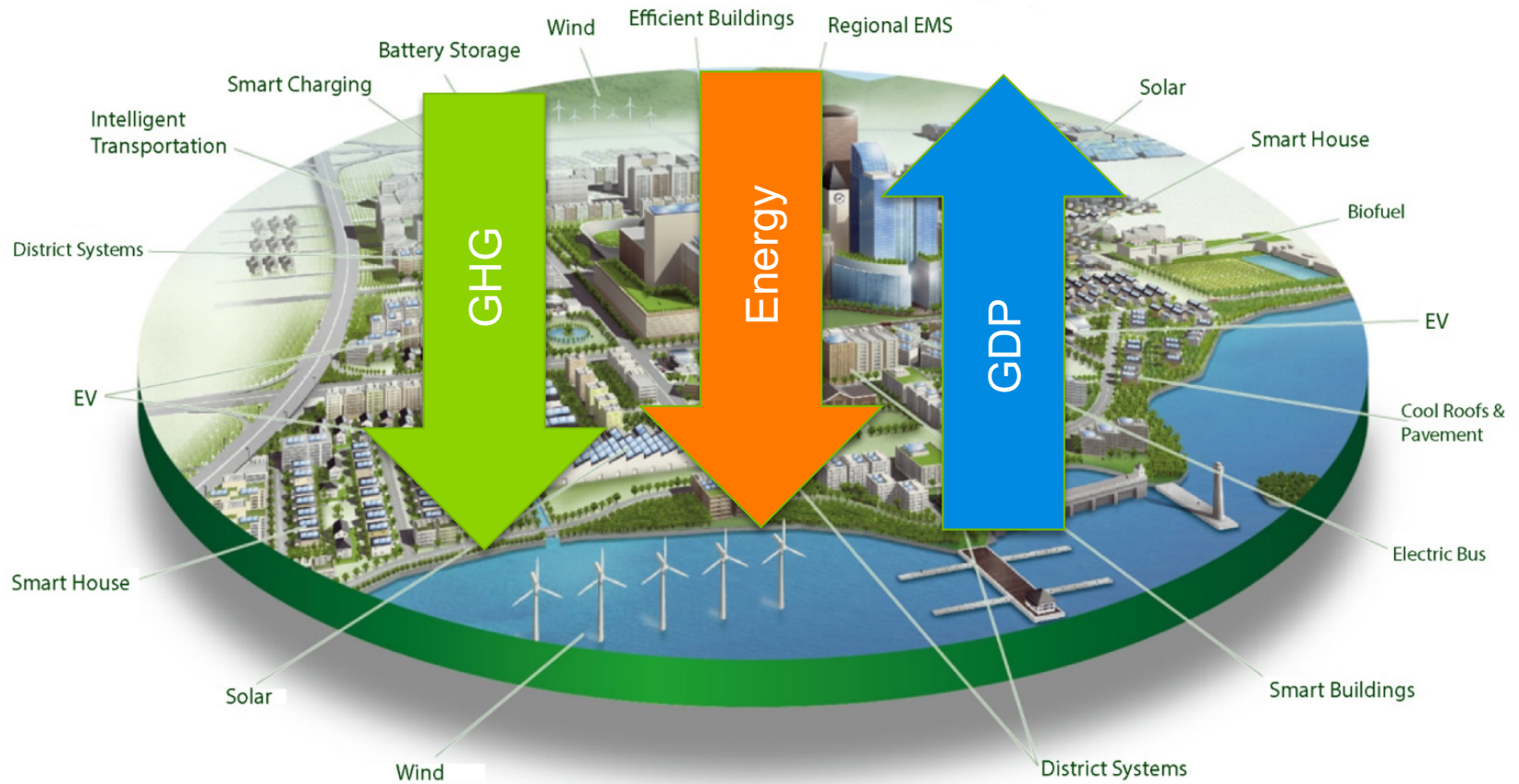
**Data**

**Tools**

**Models**

# SUCCESS

- Develop, deploy, and validate new integrated technologies at scale, predict impacts on efficiency and sustainability, facilitate evaluation

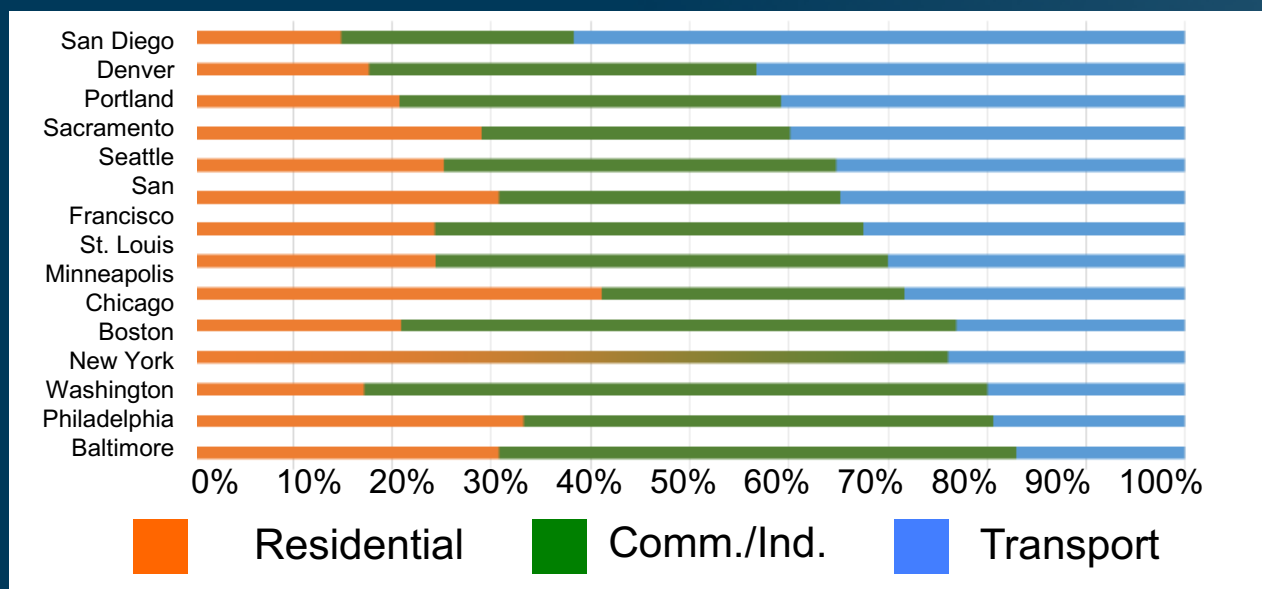- Optimize investments based on data-driven cost/benefit analysis across sectors

# SUCCESS (CONT.)
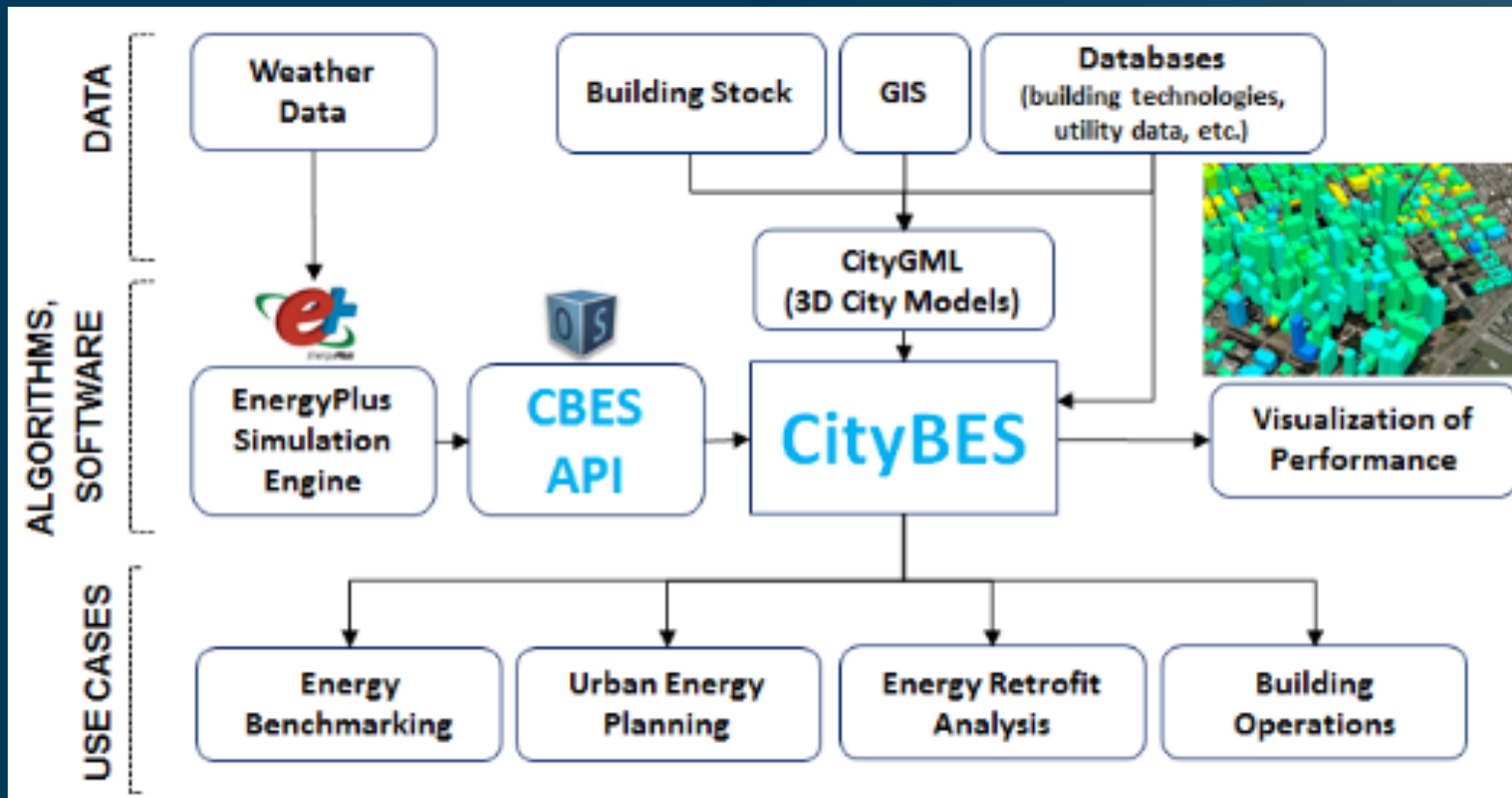
# WHY CITY BUILDINGS

- 30-70% city total primary energy

- Need deep retrofit and scale up

- Opportunity for integration



City Energy Profiles

GOAL: 50% primary energy reduction in city building stock by 2030

# CityBES: A DATA AND COMPUTING PLATFORM



- Supports city/utility scale EE
- Open access web app
- Built upon CityGML
- Cloud computing architecture
- Large scale on-demand simulation
- Modeling, simulation, visualization

# CityBES – Visualize cities' building performance
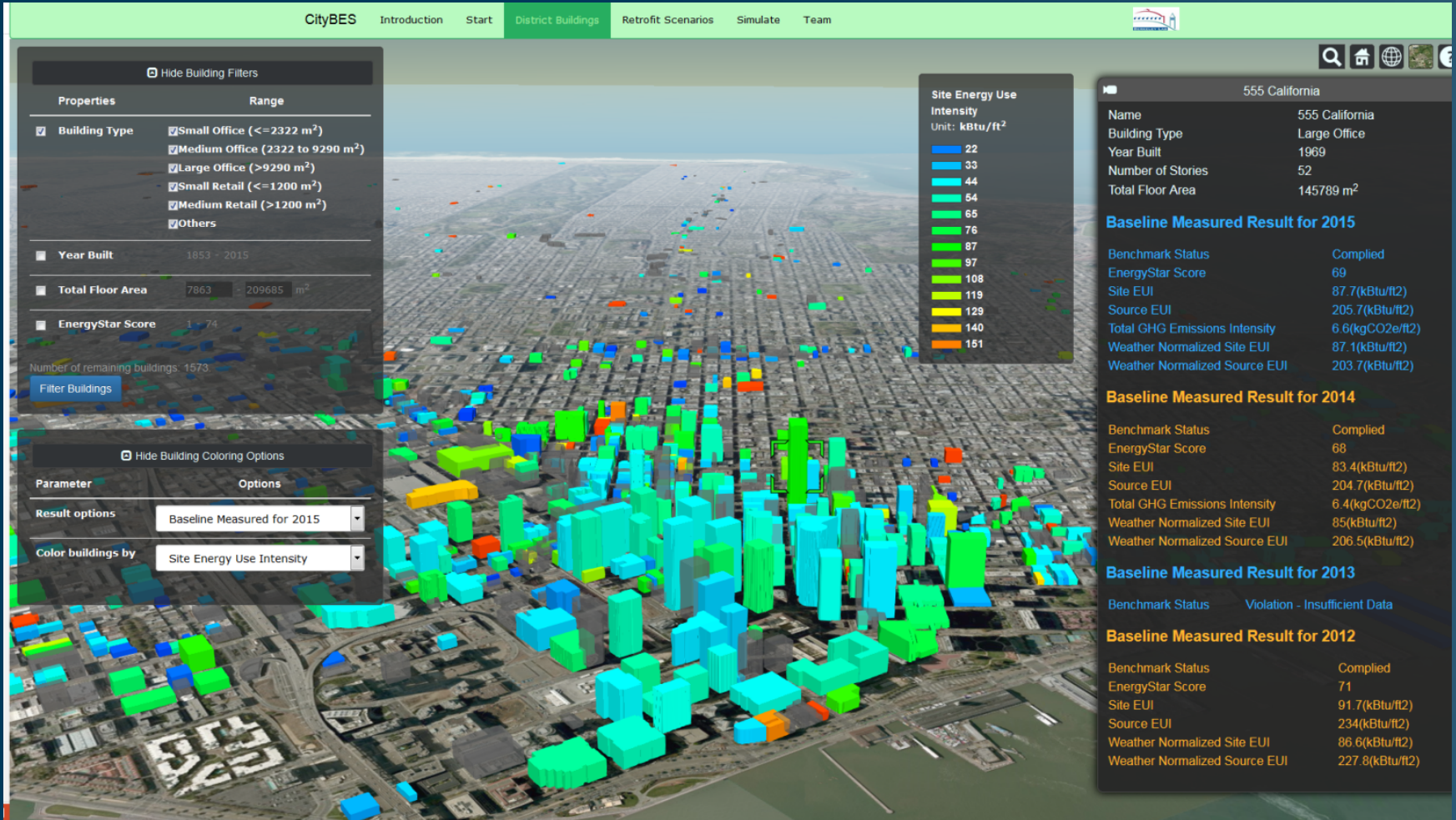


Visualizing the San Francisco energy ordinance dataset with 1,573 buildings: (1) filtering buildings by type, size, vintage, and (2) color-coding by EUI, $CO_2$ emission, ENERGY STAR score, compliance status.

# CityBES – Building Retrofit Analysis

540 small/medium commercial buildings in San Francisco, 5 common ECMs
Together save 22-48% of site energy per building
LED upgrades, air economizer additions most cost effective
Long payback for HVAC upgrade in mild climate
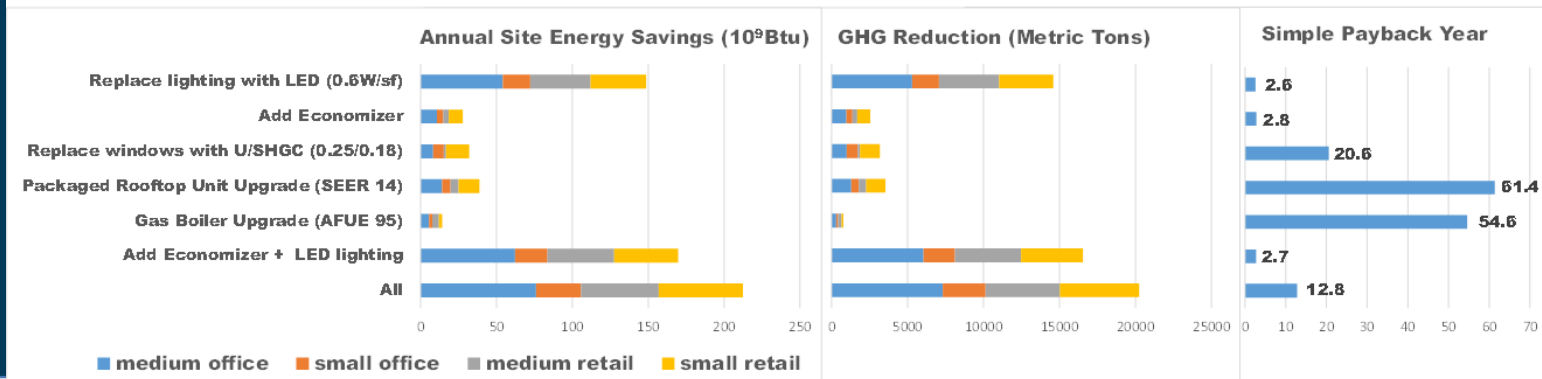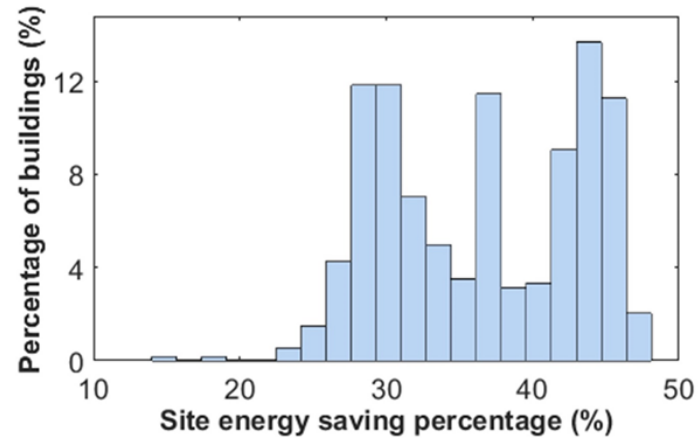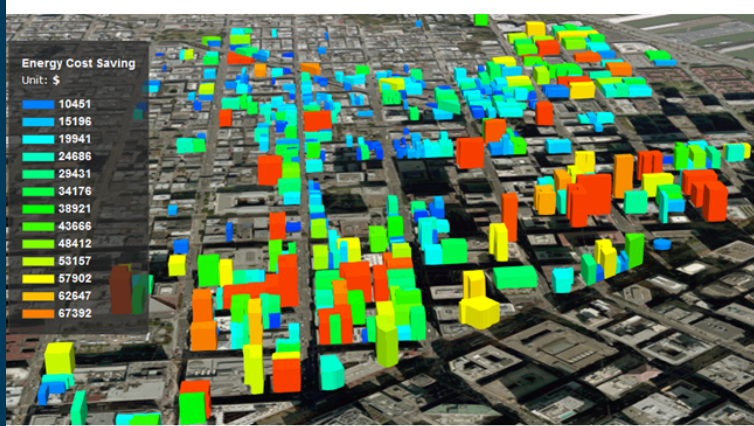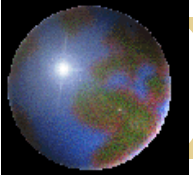
CBES (**CBES.lbl.gov**) is an energy retrofit analysis toolkit for small- and medium-size commercial buildings.
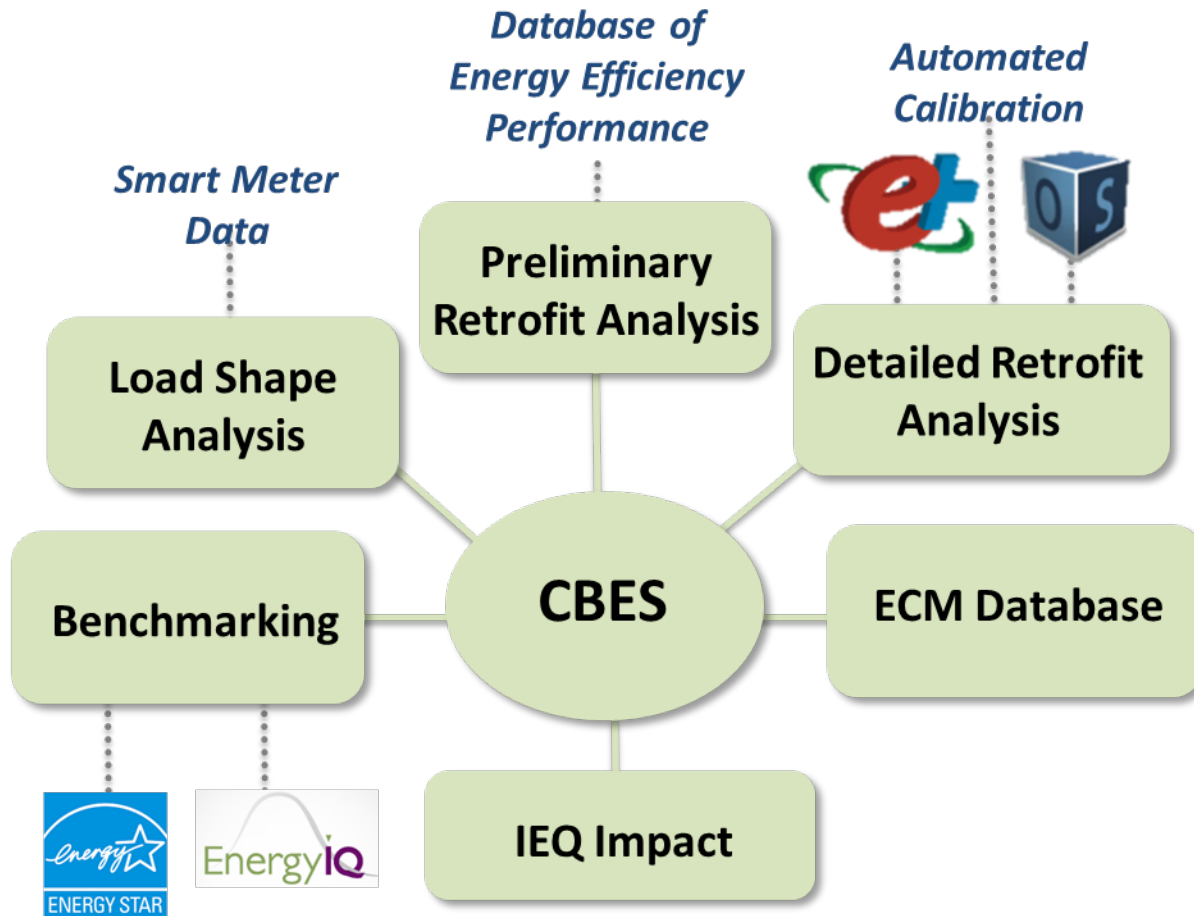
# CityGML

International OGC standard for representation and exchange of 3D city models

Started 2002, v.2.0 in 2012

Multi-resolution model

Customization and extensibility

Examples of CityGML objects

Terrain, Building, Transport network, Vegetation, Urban furniture, Water bodies, Land use, Groupings

CityGML for 3d city models

Disaster management — Kreis Recklinghausen
Radio network planning — T-Mobile
Noise immission mapping — Stapelfeldt GmbH
Police simulator — Rheinmetall Defence Electronics
Business development & tourism — Google
Navigation
Facility management
Urban planning
Architecture — Architekturwerkstatt SenStadt Berlin

LoD0   LoD1   LoD2   LoD3   LoD4

# CLIMATE ACTION CHAMPIONS
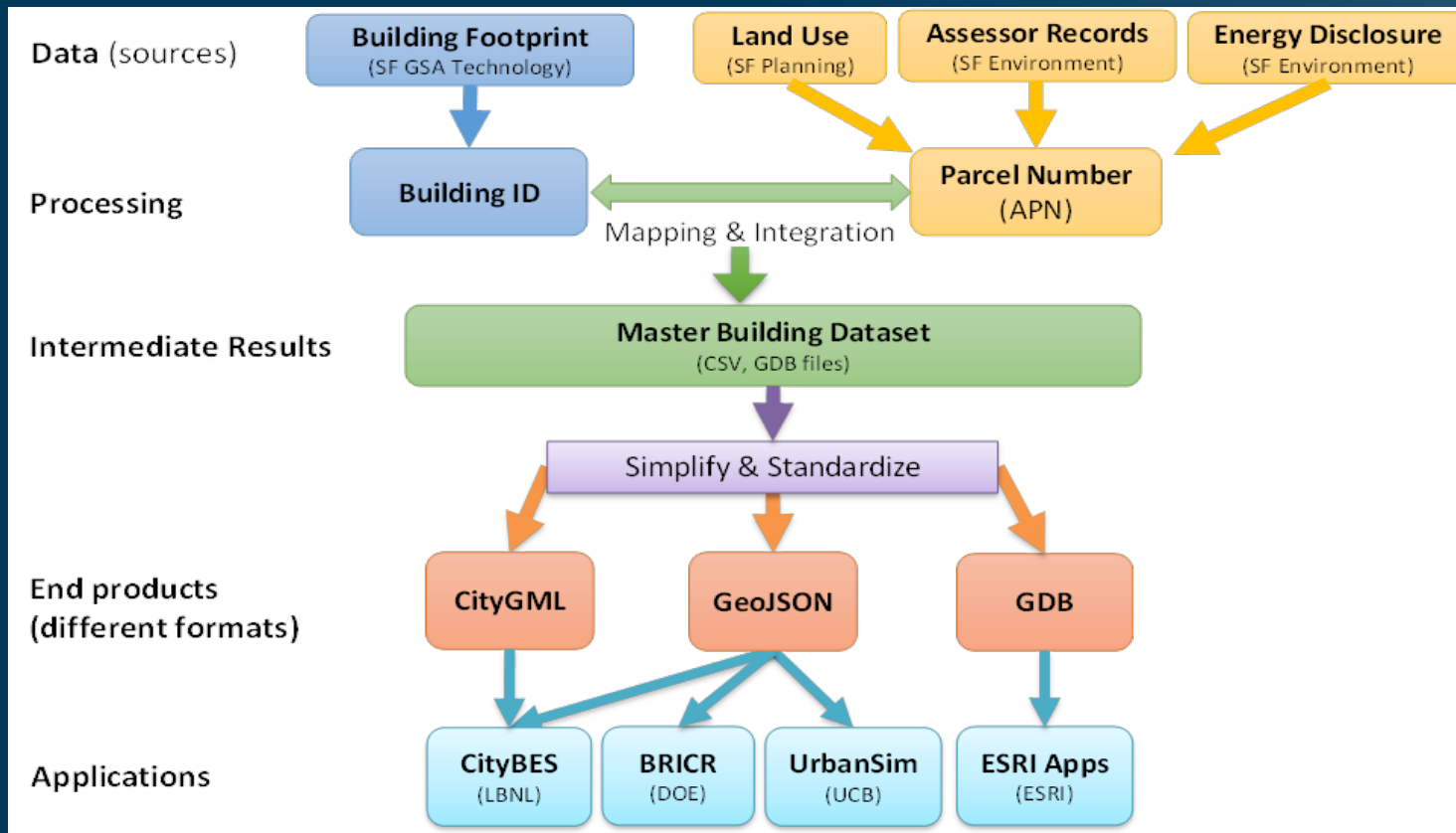


- Translate diverse city data sets into inter-operable, standardized format
- Collaborate with City of San Francisco

# Acknowledgements

- Berkeley Lab's Laboratory Directed Research and Development (LDRD) Program

- Department of Energy: Building Technologies Office, Office of Science

- City of San Francisco

- LBNL team: Mary Ann Piette, Yixing Chen, Xuan Luo

- DOE Labs: ANL, ORNL, NREL, PNNL

# BenchmarkMyBuilding.com

free & public tool by Lucid & LBNL

# Why Was Free Benchmarking Tool Developed?

## Our Goals

Leverage Existing Data:
- Energy Star Portfolio Manager
- Building Performance Database

Expansion of CBES:
- Provide national scope and infrastructure to integrate model-based retrofit and ECM engine into BuildingOS.com

Make Benchmarking More Accessible:
- Easy entry point to benchmarking portfolio
- Provide valuable information with basic input data
- Demonstrate dollar savings that are available by improving efficiency

# How Was BenchmarkMyBuilding.com Developed?

**Collaborative Approach**

LBNL provided Lucid detailed understanding of DOE tool architecture, APIs, ECMs, facility types, characteristics, underlying analysis in CBES, PM, and BPD

LBNL provided Lucid design guidance and technical assistance to integrate desired benchmarking and ECM analysis capabilities into BuildingOS.com (coding examples, testing and verification process, user presentation).

Lucid leveraged Energy Star Target Finder & DOE BPD to create a public benchmarking web tool

LBNL expanded CBES functionality for applicability beyond CA climates and measures.

**Key Issues**

Architecture: Ensuring compatibility with cloud-based SaaS infrastructure

User Experience: Ability for users to understand the information and transform the information into actions

# Unique Industry Benchmarking Tool

Leverage the most powerful building performance databases to find out where your building ranks.

- Three inputs for a basic benchmark report
- Add consumption and spend data for advanced comparisons
- Engaging and easy to understand outputs
- Access most complete building performance databases created in partnership with Lawrence Berkeley National Labs:
    - Energy Star Buildings Database
    - DOE Building Performance Database

# Intuitive benchmark reports to show where you stand

See how you compare in relative and absolute terms to similar buildings across the country.

- Compare against the median and top-percentile (Energy Star):
  - Building energy costs, total and per square foot
  - Annual energy consumption
  - Site Energy Use Intensity (EUI)
  - Median building profile
- Position against the absolute scores of similar buildings (DOE):
  - Site Energy Use Intensity



Your building's annual energy costs
compared to similar buildings in the 75th percentile

↑ 13% higher

| You | $78,650 |
| | $2.04/ft² |
| Median | $53,830 |
| | $1.80/ft² |
| 75th percentile | |
| 90th percentile | |

Energy cost benchmarks
Agency Energy Star Targ...

Site Energy Use Intensity (EUI)
for similar buildings and climate conditions

Site Energy Use Intensity (kBTU/ft²)

Great

Peer group data for 50,000-100,000 ft² office buildings with Warm/Marine...
U.S. Department of Energy Building Performance Database, in collaborati...
National Laboratory.

**buildingOS_**

Utility Bills

Weather Data

**150+** integrations

**10,000+** buildings across nation & world track their data with BuildingOS.com

# Demos

CityBES.lbl.gov

BenchmarkMyBuilding.com

# Questions?
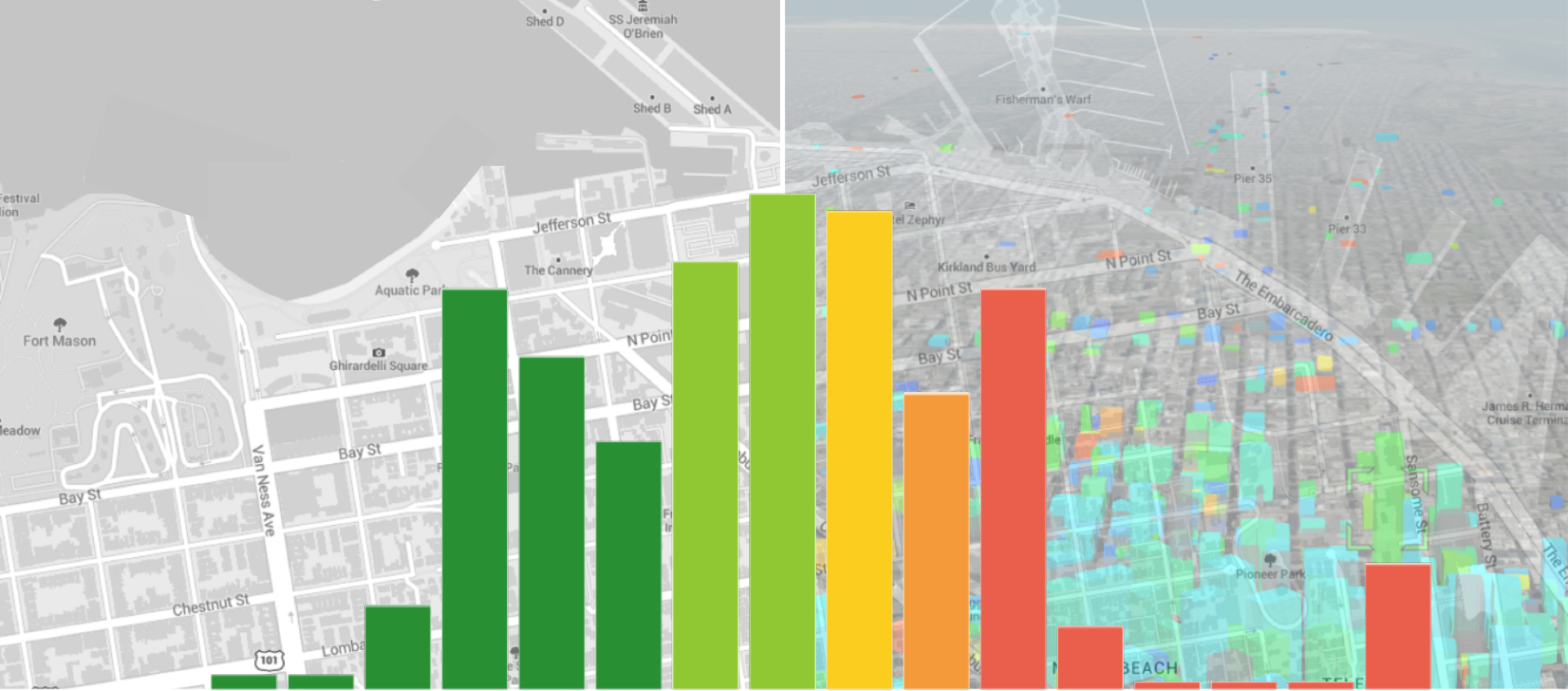
# Public Tools to Improve Building Energy Efficiency

**Tianzhen Hong, PhD**
Building Technology and Urban Systems Division
Lawrence Berkeley National Laboratory

**Josh Wentz**
Director of Product, Lucid
Architect of BenchmarkMyBuilding.com

Statewide
Energy
Efficiency
Collaborative

# Appendix Slides

# BenchmarkMyBuilding.com inputs

Free easy-to-use public benchmarking web tool to motivate the 'why' to act

Benchmark My Building web form:

**1** Enter your building's details

**Building address** ⓘ

📍 304 12th Street, Oakland, CA 94607

**Building type** ⓘ

Office ⌄

**Building size** ⓘ

35,000     square feet

**2** Personalize your report (optional)

Include *all* energy sources for your building, such as electricity, natural gas, fuel oil, steam, chilled water, etc.

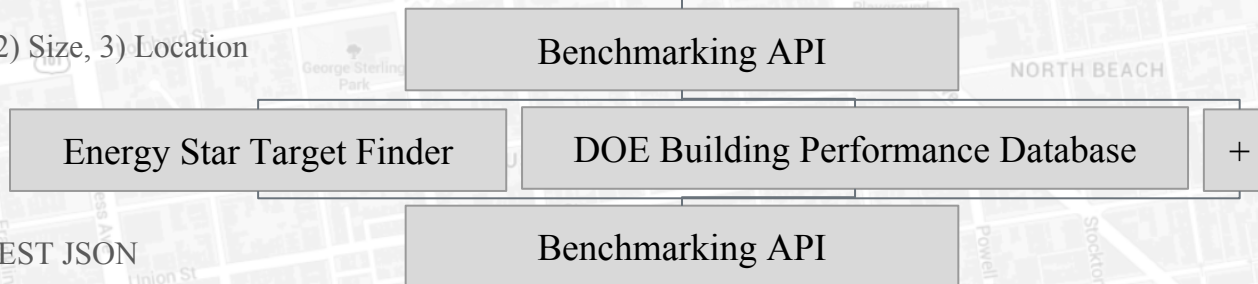**Annual building energy cost** (optional)

$ 78,650     USD

**Annual building energy consumption** (optional)

1,599,000     kBTU

Help me enter consumption by energy source

3 INPUTS 1) Type, 2) Size, 3) Location

| Benchmarking API |

2 ENGINES

| Energy Star Target Finder | DOE Building Performance Database | + |

Future Potential: Asset Score, BOMA

15+ OUTPUTS in REST JSON

| Benchmarking API |

32

# BenchmarkMyBuilding.com outputs

## Median Benchmarks
### from 3 inputs, type, size, location

**data-driven OUTPUTS**

## Personalized Benchmarks
### from all 5 inputs, annual cost & consumption



Median annual energy cost is

## $53,830

for similar office buildings of 30,000 ft2 in Oakland, CA

Benchmarks for a 35,000 ft2 office building in Oakland, CA 94607 provided by the U.S. Environmental Protection Agency's ENERGY STAR® Target Finder, a statistical model based on the Commercial Buildings Energy Consumption Survey (CBECS).

**ENERGY STAR**

7k buildings
from CBECS
representative of 57M

**DOE BUILDINGS PERFORMANCE DATABASE**

230k+ commercial buildings
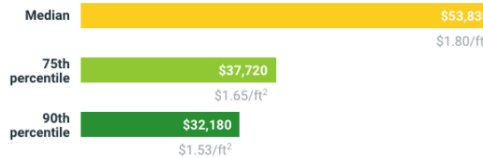of metered & utility data

Similar buildings spend

## $60,798 - $93,500 less

on energy annually compared to your building

Benchmarks for a 35,000 ft2 office building in Oakland, CA 94607 provided by the U.S. Environmental Protection Agency's ENERGY STAR® Target Finder, a statistical model based on the Commercial Buildings Energy Consumption Survey (CBECS).
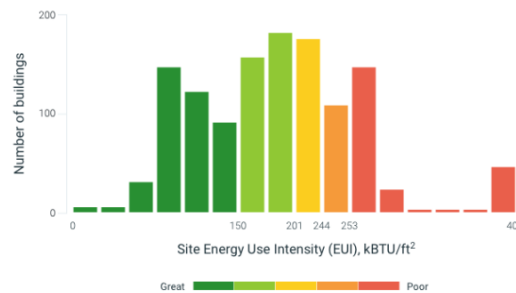
### Annual energy costs
for a 35,000 ft² office building in Oakland, CA

| | |
|---|---|
| Median | $53,83_ |
| | $1.80/ft |
| 75th percentile | $37,720 |
| | $1.65/ft² |
| 90th percentile | $32,180 |
| | $1.53/ft² |

Benchmarks for a 35,000 ft2 office building in Oakland, CA 94607 provided by the U.S. Environmental Prote_ ENERGY STAR® Target Finder, a statistical model based on the Commercial Buildings Energy Consumption_

We've found 2,345 buildings in your peer group
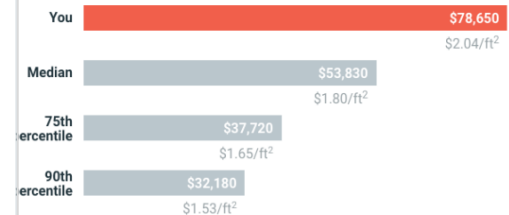Here's how they rank in the U.S. Department of Energy's database



Peer group data for 50,000-100,000 ft² office buildings with Warm/Marine climate conditions provided by U.S. Department of Energy Building Performance Database, compiled by Lawrence Berkeley National Laboratory.

### Your building's annual energy costs
compared to similar buildings in the 75th percentile

## ↑13% higher

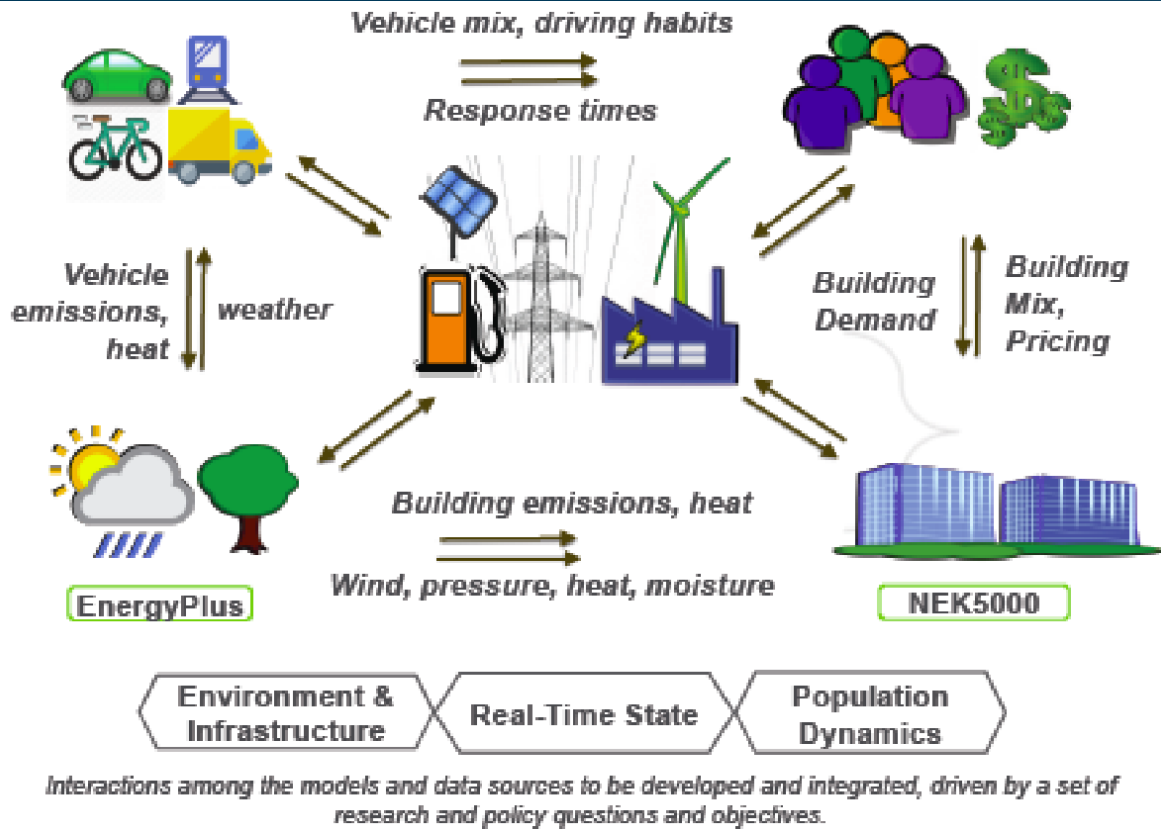| | |
|---|---|
| You | $78,650 |
| | $2.04/ft² |
| Median | $53,830 |
| | $1.80/ft² |
| 75th percentile | $37,720 |
| | $1.65/ft² |
| 90th percentile | $32,180 |
| | $1.53/ft² |

Energy cost benchmarks for 35,000 ft2 office buildings in Oakland, CA 94607 provided by U.S. Environmental Protection Agency Energy Star Target Finder®.

1. Bridges gap between finance & engineering
2. Transfers Data: Owner > City > DOE > BenchmarkMyBuilding Tool

# Multiscale Coupled Urban Systems – An Exascale Computing Project



Vehicle mix, driving habits

Response times

Vehicle emissions, heat — weather

Building Demand

Building Mix, Pricing

Building emissions, heat

Wind, pressure, heat, moisture

**EnergyPlus**

**NEK5000**

Environment & Infrastructure — Real-Time State — Population Dynamics

*Interactions among the models and data sources to be developed and integrated, driven by a set of research and policy questions and objectives.*

- **Application Area:** *Coupled computational models integrating urban systems such as atmosphere, buildings, transportation, and social/economics.*

- **Challenge Problem**: *Support urban design and operations, at multiple scales (district, building, vehicles) through coupled models capturing interdependencies between urban systems and activities.*

- **USDOE Office of Science**

- **Five national labs: ANL, LBNL, ORNL, NREL, PNNL**

*This work will provide insights to:*
- ❑ Impacts of greenhouse gases (GHG) on local climate
- ❑ Resulting impacts on city function
- ❑ Incorporation of renewables into city energy portfolio
- ❑ Resilience of physical infrastructure
- ❑ Economic protection, resilience, and enhancement

# Challenges

1.  ## Data
    A big data problem integrating diverse sources with different temporal and spatial resolutions, quality, and structure/format.

2.  ## Modeling
    Integration of multiple domain models with different scales and resolutions.

3.  ## Simulation
    An exascale computing problem.