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Seminar 29
Urban-Scale Building Energy Modeling, Part 5

Retrofitting District-Scale Buildings to Cut Energy Use By 50%: A Case Study

Learning Objectives

1. Provide the amount of energy consumed by buildings and cities
2. Provide a method to develop a customized building energy use baseline estimation tool by using a data-driven approach
3. Describe how façade features could influence certain building energy use in a specific climate condition and a particular building geometry
4. Demonstrate how district-scale energy retrofit analysis can be performed using existing urban modeling tools

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Acknowledgements

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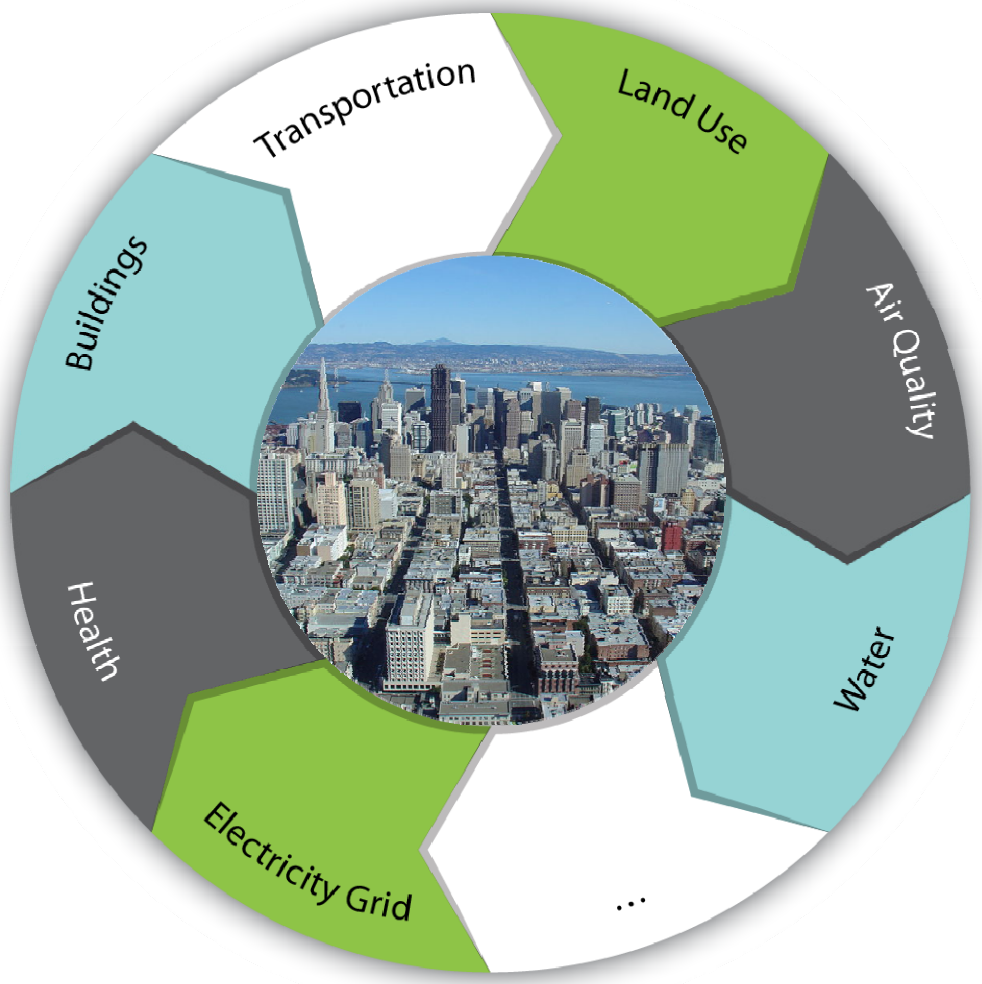
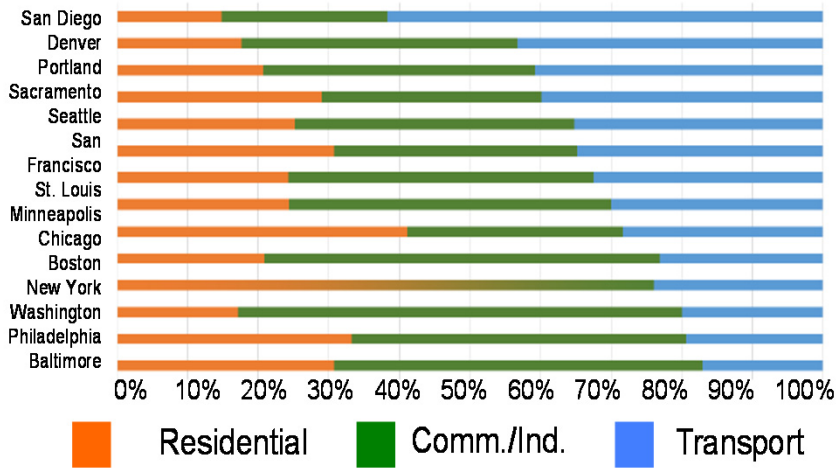
- This work was also supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.
- City of San Francisco, Department of the Environment and Department of Technology, provides the building datasets and support in the development of the San Francisco CityGML city models.

How to reduce 50% energy use in city building stock?

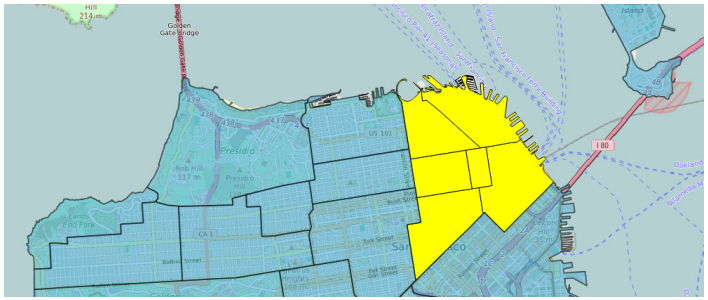


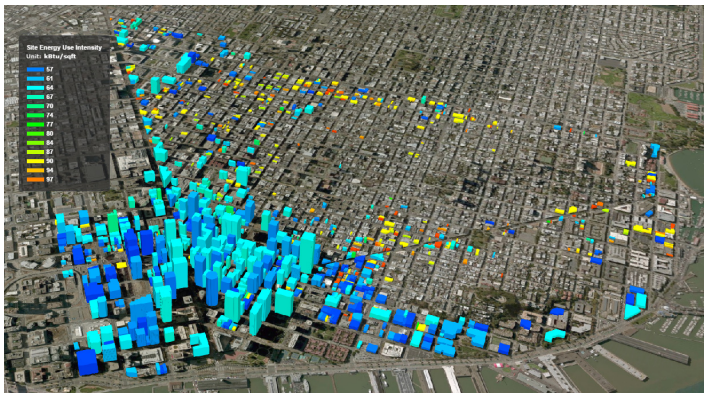
- Buildings in cities consume 30% to 70% of primary energy
- Cities have different building energy use profiles
- The building sector has the most potential to save energy



City Energy Profiles

Case Study – Northeast San Francisco





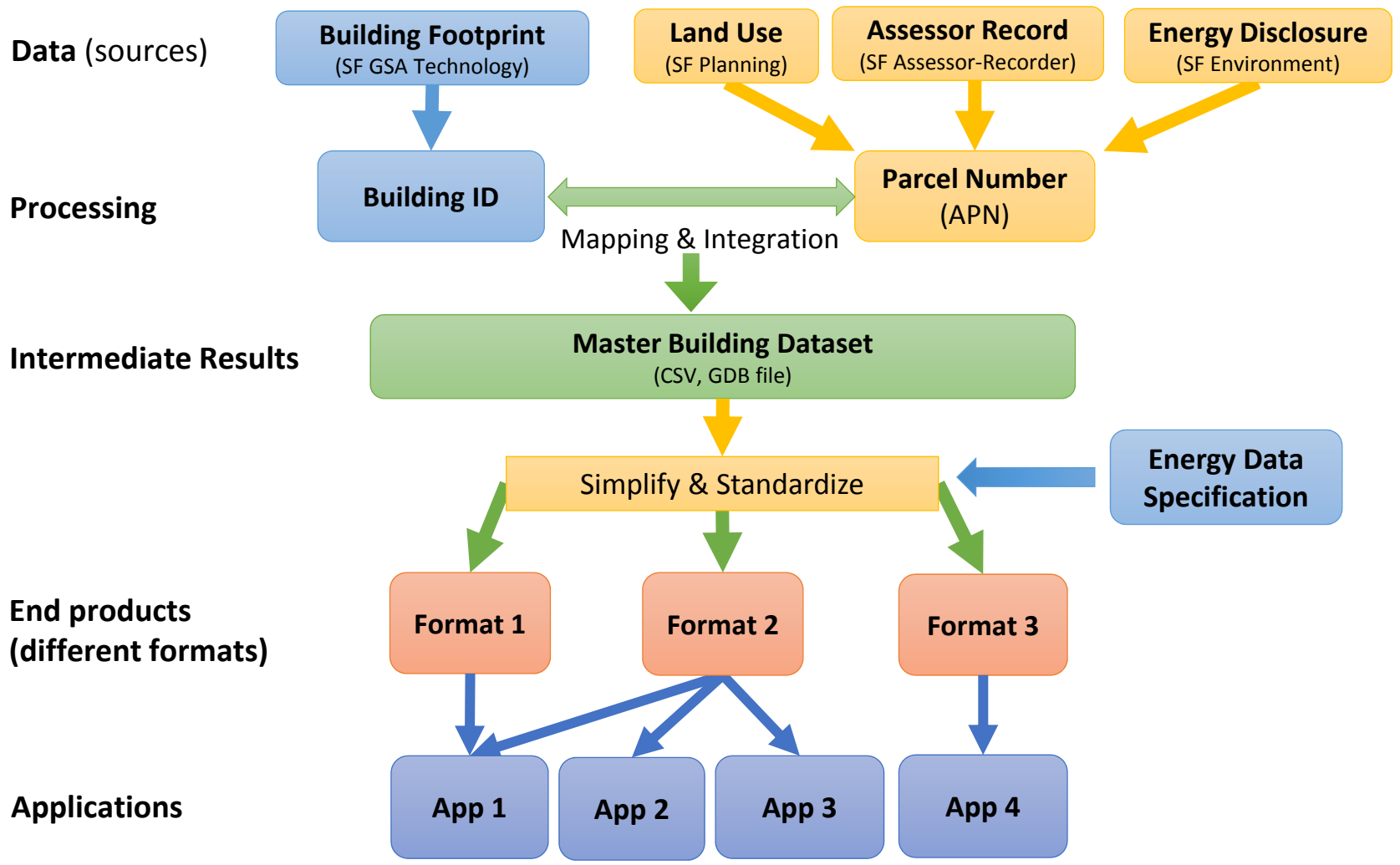
San Francisco mild climate: ASHRAE Climate Zone 3C
Monthly mean air temperature:

- Highest in September at 62.7 °F (17.1 °C)
- Lowest in January at 51.3 °F (10.7 °C)

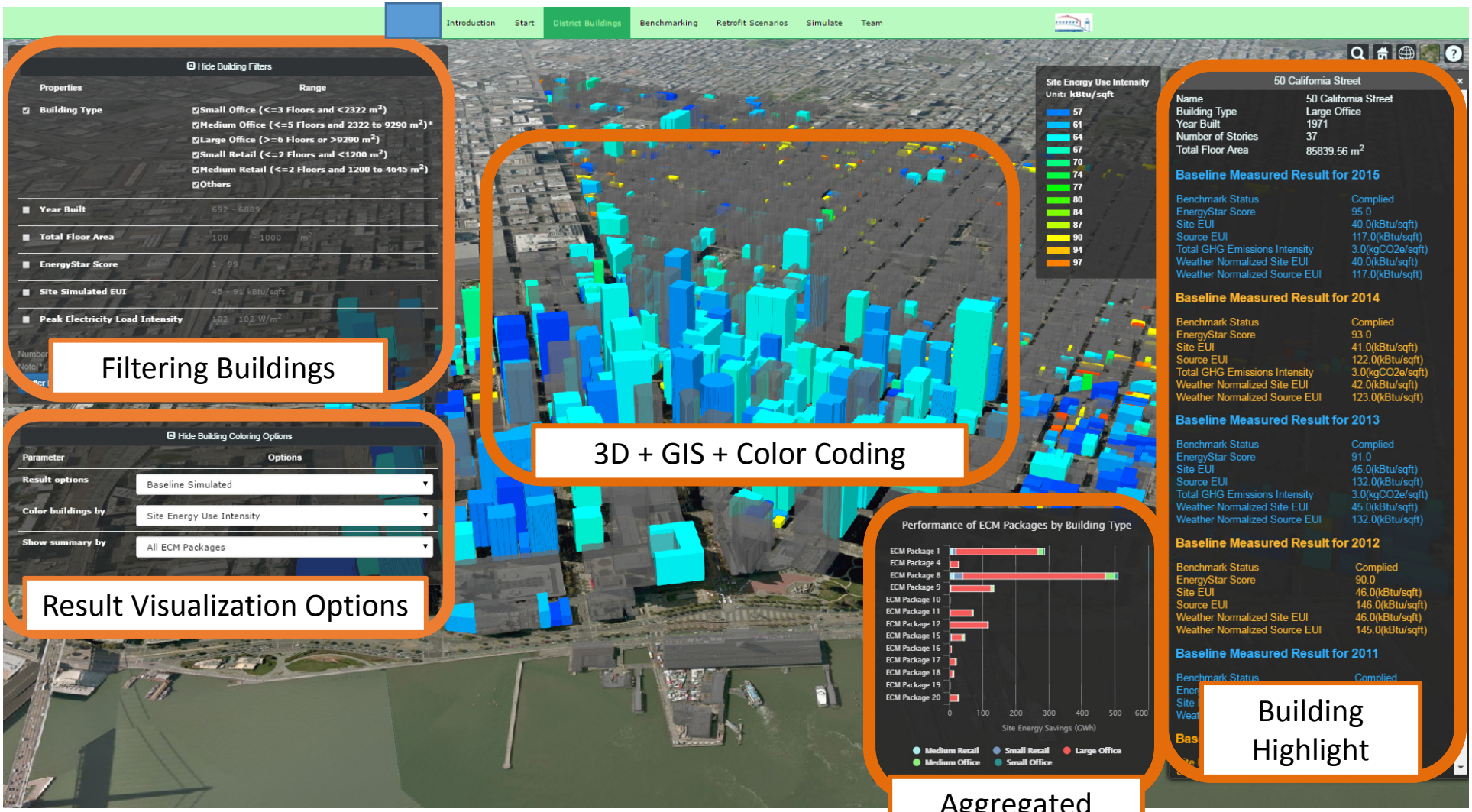
Six planning districts in Northeast San Francisco
Downtown, Financial District, Chinatown,
Russian Hill, Nob Hill, & North Beach
Totally **8,665** buildings, **940** Case Study Buildings

Building Type	Building Count	Total Floor area (10^3 m^2)
Small office	173	148
Medium office	149	478
Large office	279	5,787
Small retail	291	148
Medium retail	48	89
Total	**940**	**6,649**

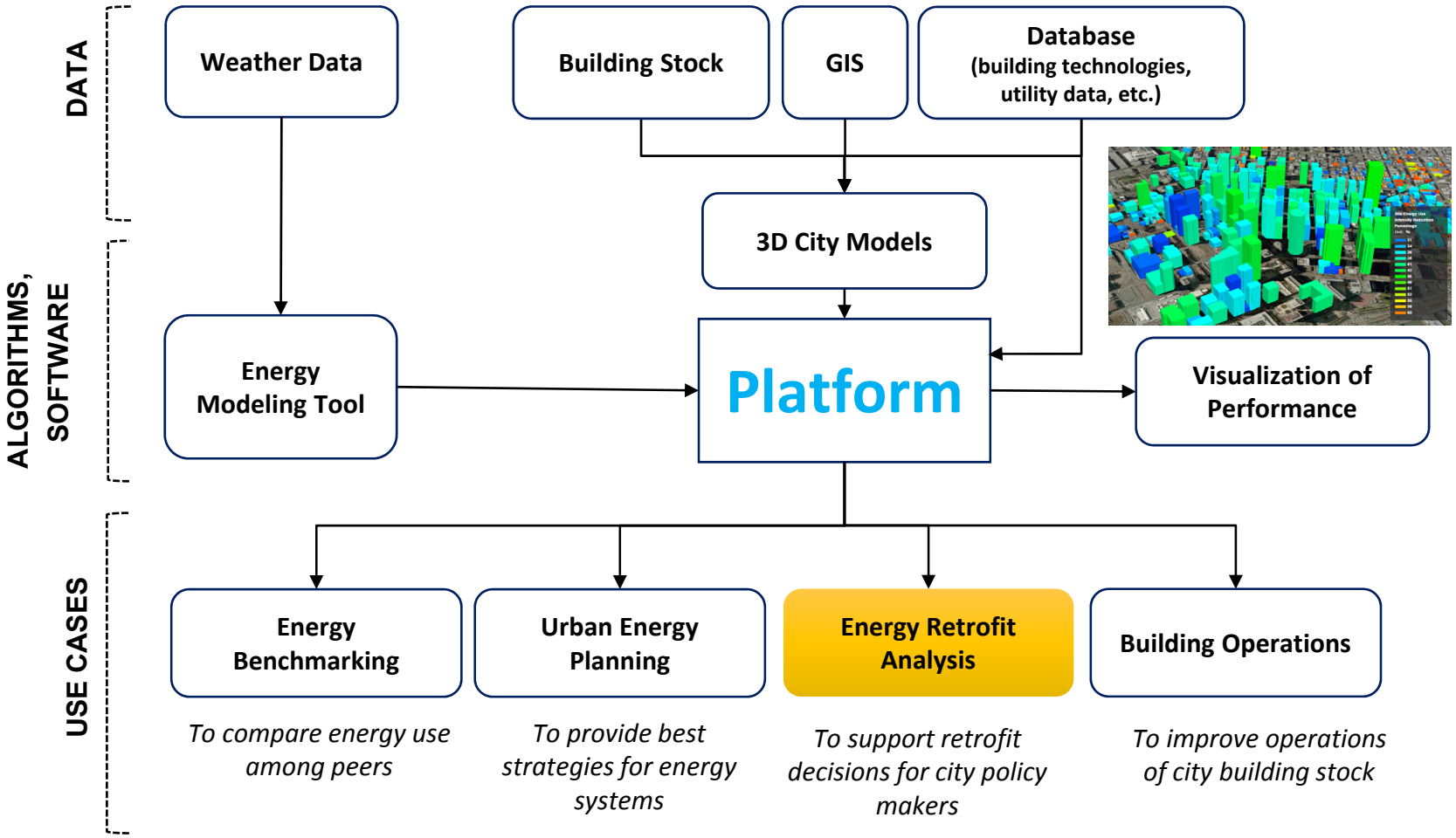
Creation of City Building Stock Dataset



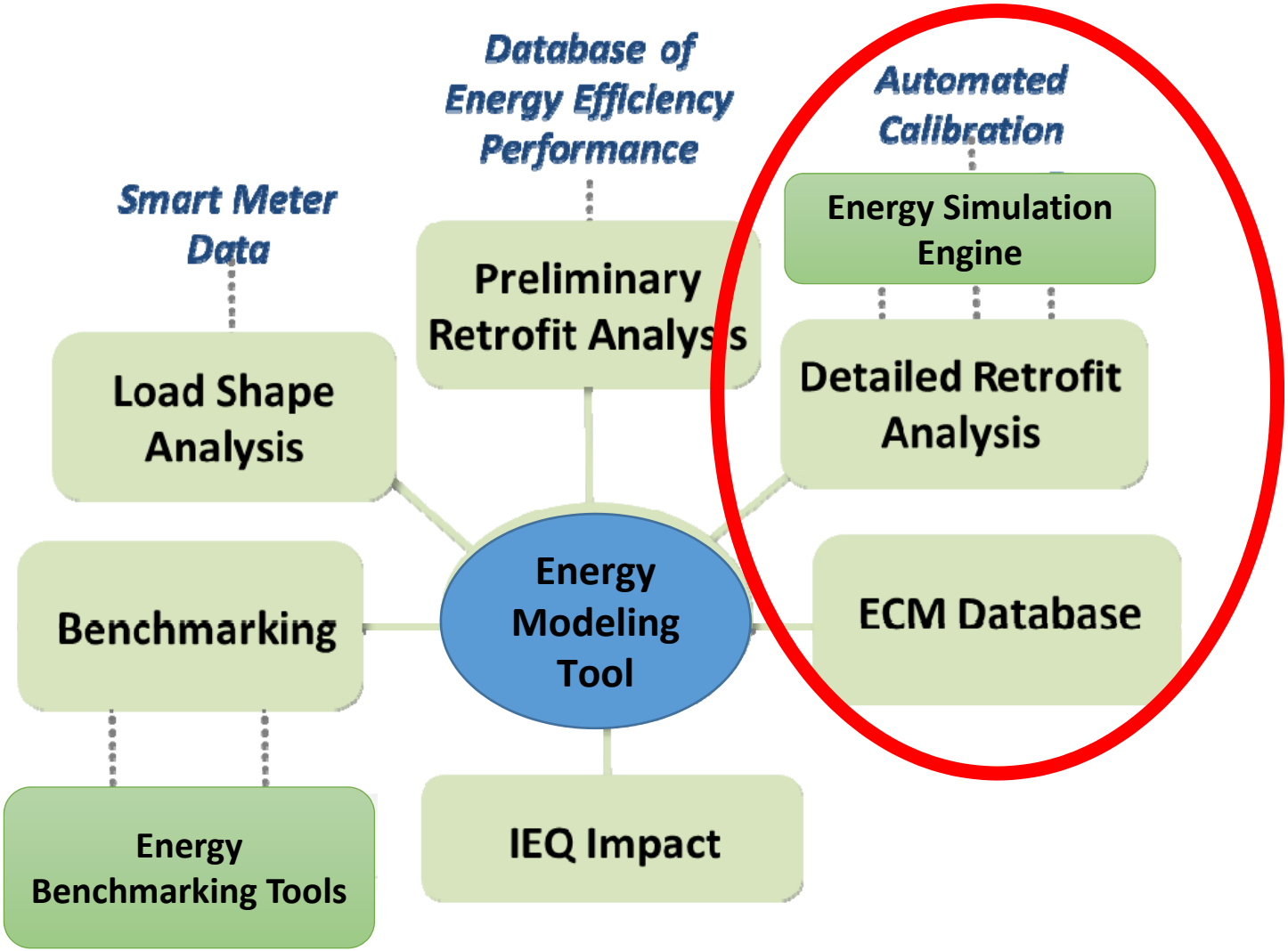
Automatic Generation of Urban Building Energy Models



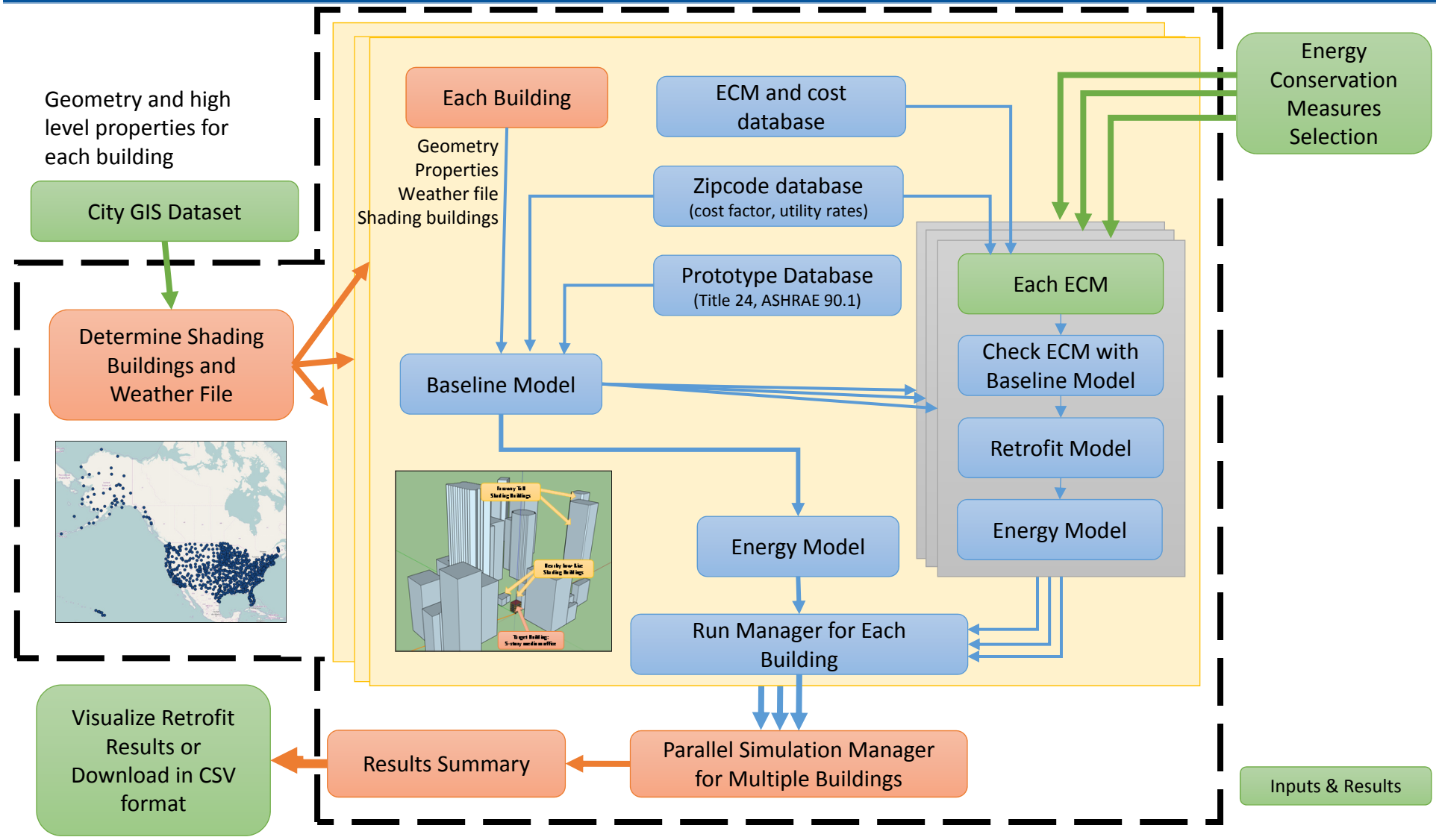
Software Architecture of the Platform



The Energy Modeling Tool

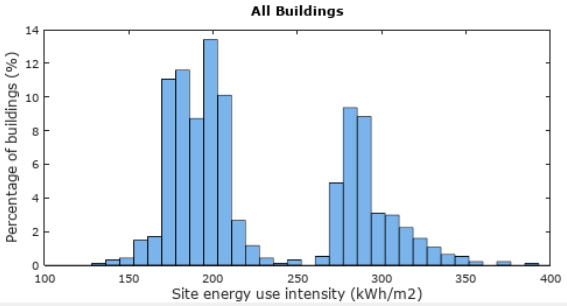


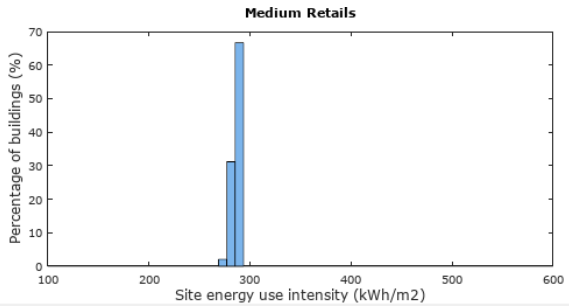
Urban Building Energy Modeling Workflow

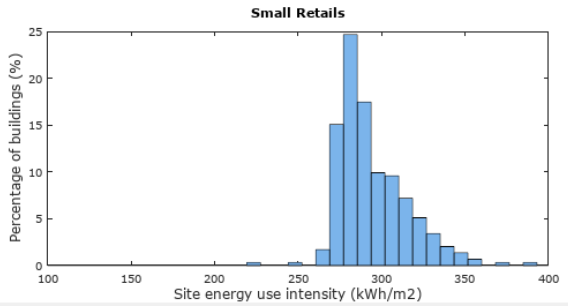


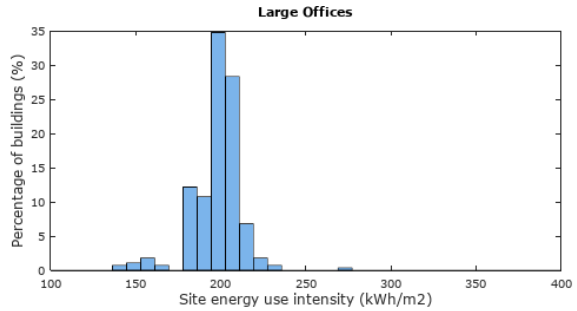
Baseline Results – 940 Buildings

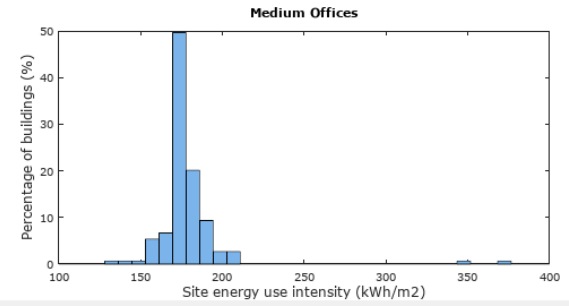
Building Type	Building Count	Total Floor area (10^3 m^2)	Simulated site energy use (10^3 GJ)
Small office	173	148	99
Medium office	149	478	301
Large office	279	5,787	4,008
Small retail	291	148	156
Medium retail	48	89	91
Total	**940**	**6,649**	**4,655**

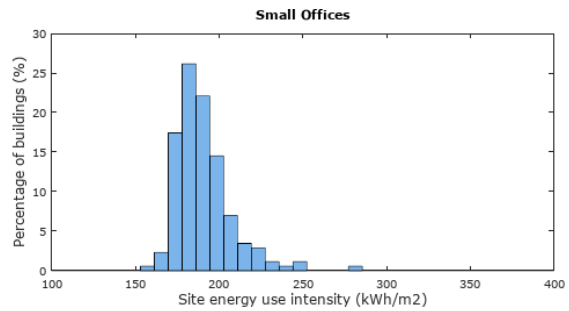










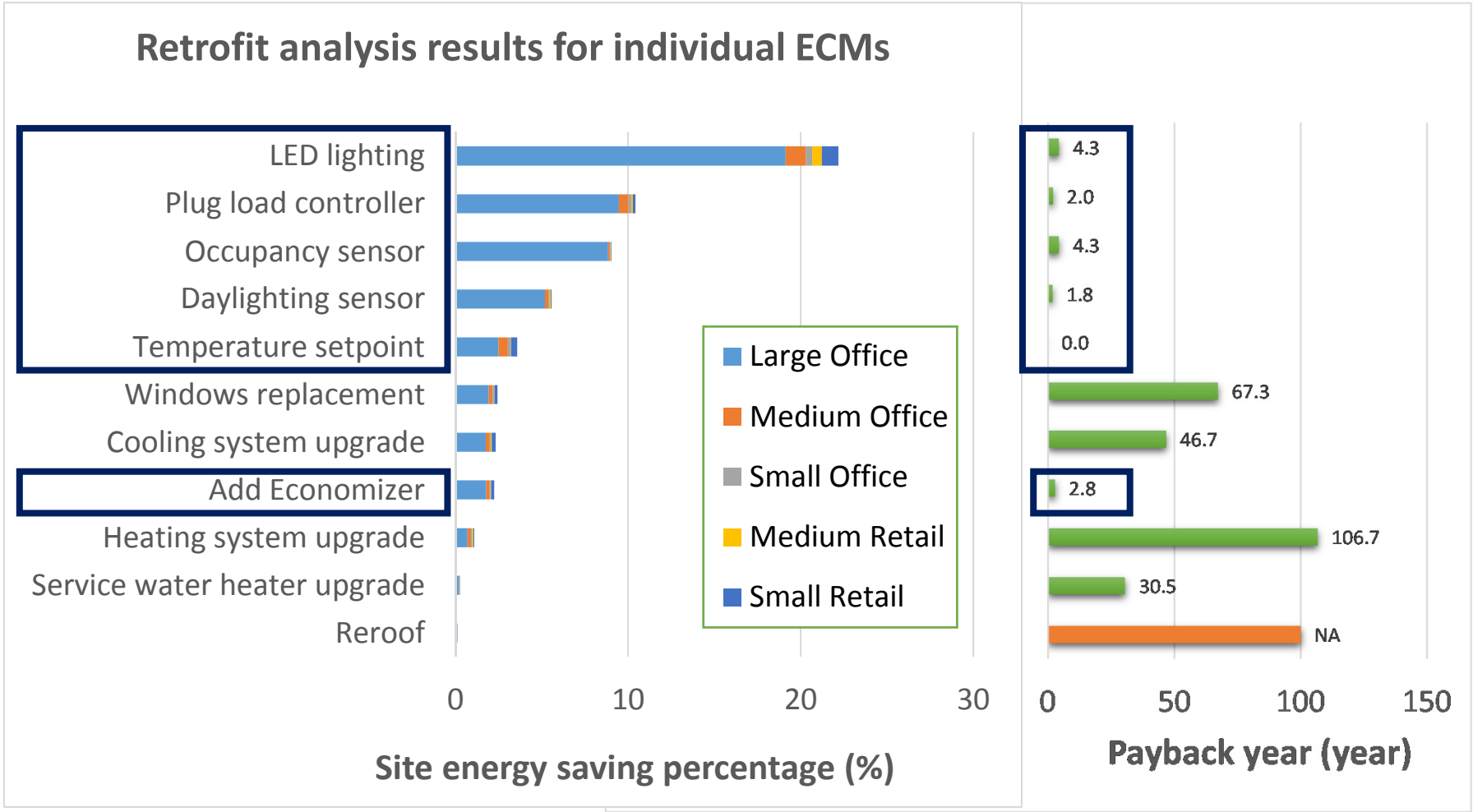


Energy Conservation Measures (ECMs)

ID	ECM Category	ECM Name
ECM 1	Lighting	Replace existing lighting with LED upgrade (0.6W/sf)
ECM 2	Lighting - Controls	Install daylighting sensors for interior lighting control
ECM 3	Lighting - Controls	Install Wall-Mounted Occupancy Sensors
ECM 4	Plug Loads	Use Plug Load Controller (30% efficient from Baseline)
ECM 5	Envelope - Window	Replace fixed-window to U-factor (0.25) and SHGC (0.18)
ECM 6	Envelope - Roof	Reroof and Roof with Insulation (R24.83)
ECM 7	Service Hot Water	Efficiency Upgrade of the Gas Storage Water Heater (0.93)
ECM 8	HVAC - Economizer	Add Economizer
ECM 9	HVAC - Operation	Widen zone temperature deadband (cooling: +2 ^{o}F; heating: -2 ^{o}F)
ECM 10*	HVAC - Cooling	Replace constant speed pumps to variable speed pumps
ECM 11*	HVAC - Cooling	Replace to high efficiency chillers (COP: 6.2)
ECM 12*	HVAC - Cooling	Single zone rooftop unit efficiency upgrade (SEER 14)
ECM 13*	HVAC - Cooling	Packaged Rooftop VAV Unit Efficiency Upgrade (SEER 14)
ECM 14*	HVAC - Heating	Gas Furnace Efficiency Upgrade (AFUE 95)
ECM 15*	HVAC - Heating	Gas Boiler Efficiency Upgrade (AFUE 95)

*Note: The “HVAC – Cooling” and “HVAC – Heating” measures depend on building type and vintage.
E.g., ECMs 10 & 11 only apply to large office with center cooling plant; ECM 14 is used for small-sized office and retail buildings.

Individual ECM Results



Retrofit Packages

Economical Retrofit Package

Include ECMs with payback years less than 5.

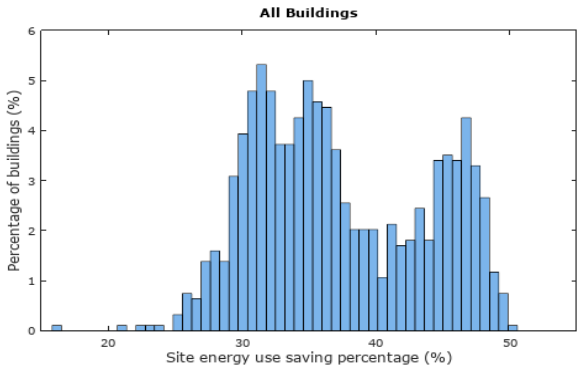
ID	ECM Category	Saving (%)	Payback (years)	ECM Name
ECM 1	Lighting	22.2	4.3	Replace existing lighting with LED upgrade (0.6W/sf)
ECM 4	Plug Loads	10.4	2.0	Use Plug Load Controller (30% efficient from Baseline)
ECM 3	Lighting - Controls	9.0	4.3	Install Wall-Mounted Occupancy Sensors
ECM 2	Lighting - Controls	5.6	1.8	Install daylighting sensors for interior lighting control
ECM 9	HVAC - Operation	3.6	0.0	Widen temperature deadband(cooling:+2^{o}F;heating:-2^{o}F)
ECM 8	HVAC - Economizer	2.2	2.8	Add Economizer
	Individual ECMs savings add up	**53.0**		

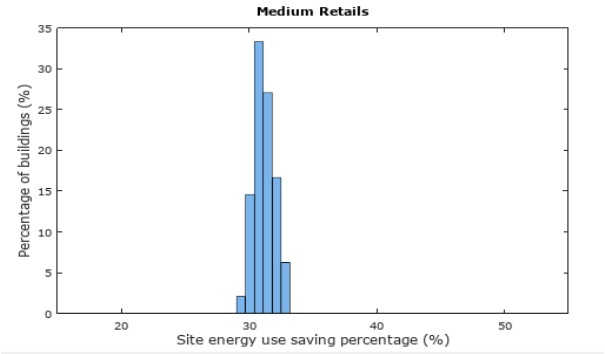
Deep Retrofit Package

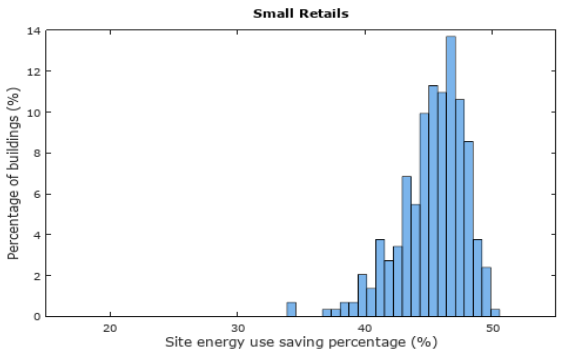
Include all ECMs except the ***Reroof*** measure, as the ***Reroof*** measure don't have cost savings.

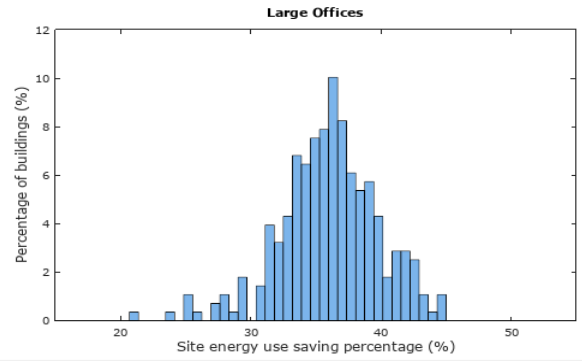
Economical Retrofit Package Results

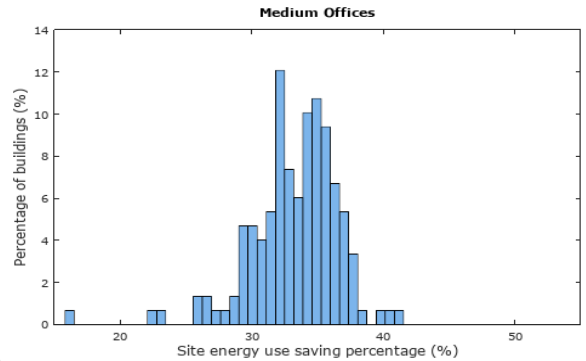
Building Type	Large Office	Medium Office	Small Office	Medium Retail	Small Retail	Total
Total Site Energy Saving Percentage (%)	32.66	2.19	0.66	0.61	1.54	**37.66**
Median Saving (%)	36.14	33.68	30.78	31.13	45.74	**36.04**
Average Payback (years)	4.26	5.24	5.29	2.74	2.94	**4.26**

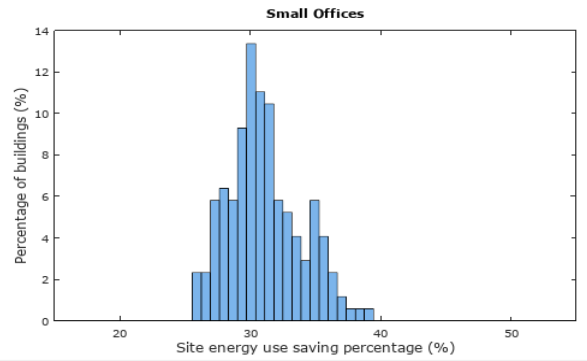






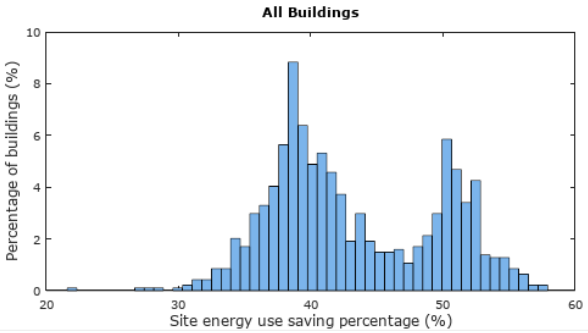


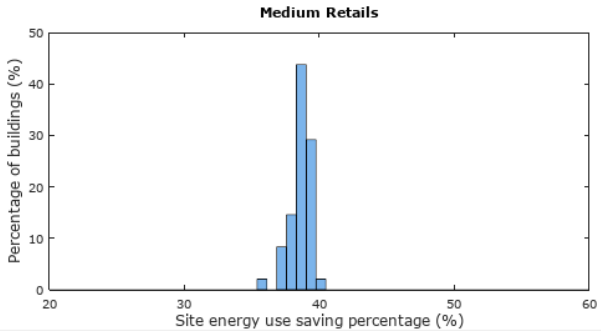


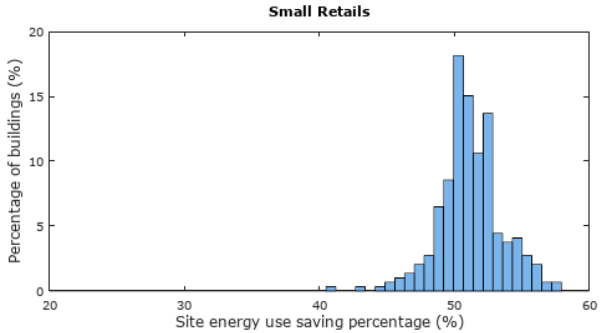


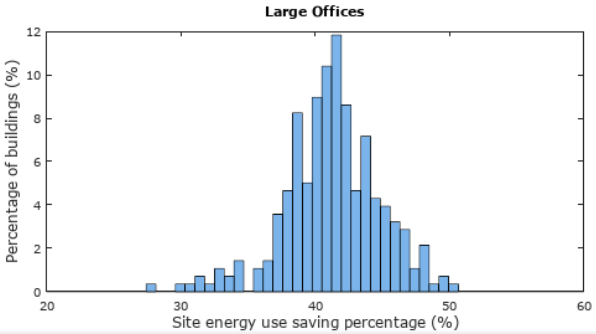
Deep Retrofit Package Results

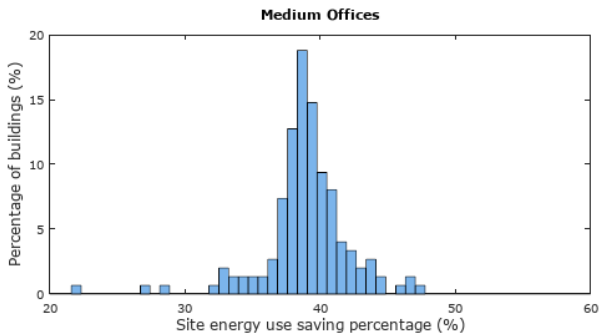
Building Type	Large Office	Medium Office	Small Office	Medium Retail	Small Retail	Total
Total Site Energy Saving Percentage (%)	36.83	2.51	0.80	0.76	1.73	**42.63**
Median Saving (%)	41.34	38.96	36.94	38.75	51.02	**41.49**
Average Payback (years)	7.55	16.82	17.12	10.07	6.97	**8.31**

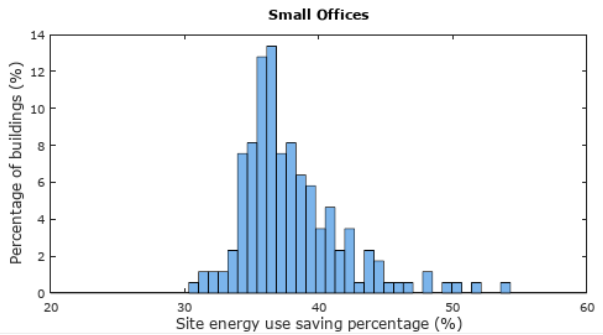












Discussion / Next Steps

- Automatic portfolio level building energy model calibration using public data (e.g., energy ordinance or disclosure data from city)
- Multiscale Coupled Urban Systems (Exascale Computing Project) :Couple Buildings, micro-climate, transportation, and social-economic models.
- Onsite renewable
- More building types
- District heating and cooling system
- Inter-building effect

Conclusions

- Best Individual ECM: Replacing lighting with LED saves the most energy of **22.2%** of the total annual site energy consumption.
- Six ECMs have payback year less than **5** years, including LED Lighting, plug load controller, occupancy sensor, daylighting sensor, widen temperature setpoint, and add economizer.
- Changing envelope, upgrading heating or cooling equipment, or upgrade service hot water have longer payback year as well as less energy savings, due to the **mild climate** of San Francisco.
- Economical retrofit package can save **28%** to **48%** (median **36%**) of the site energy use, with an average payback years of **4.26**.
- Deep retrofit package can save **35%** to **53%** (median **42%**) of the site energy use, with an average payback years of **8.31**.

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QUESTIONS?

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