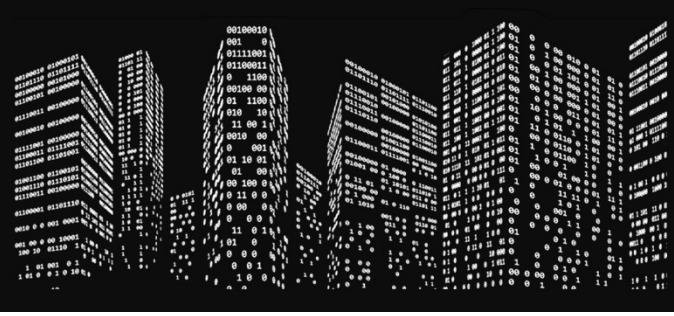
Urban Energy Analytics

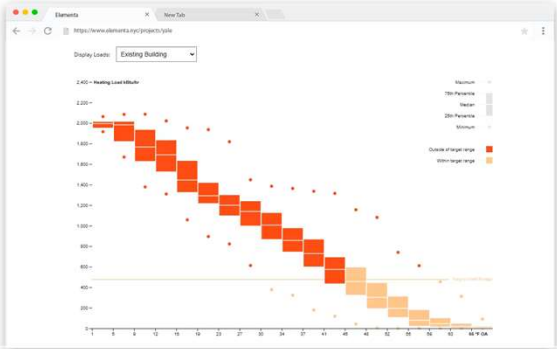
Data-driven design for the built environment.

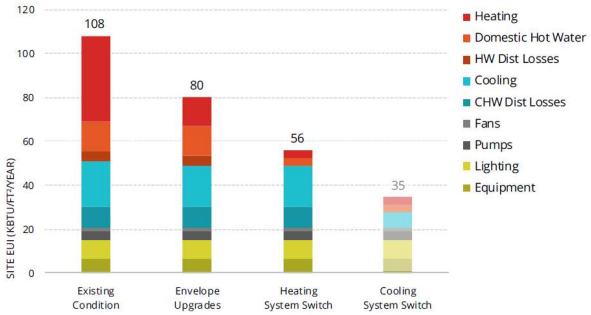


Shreshth Nagpal
Principal | Design Analytics

INTEGRAL | ELEMENTA

1





2

4 Climate Action

TAKE URGENT ACTION TO MITIGATE CLIMATE CHANGE AND PROACTIVELY ADAPT TO ITS IMPACTS

OBJECTIVE 4.1
ACHIEVE CARBON NEUTRALITY FOR YALE UNIVERSITY BY OR BEFORE 2050

Goal: GHG Emissions Reduction Commitment
By 2020, meet or exceed the 2005 commitment to reduce greenhouse gas emissions by 43% below 2005 levels.

Goal: Carbon Neutrality Strategy
By 2019, develop a strategy to achieve carbon neutrality by or before 2050.

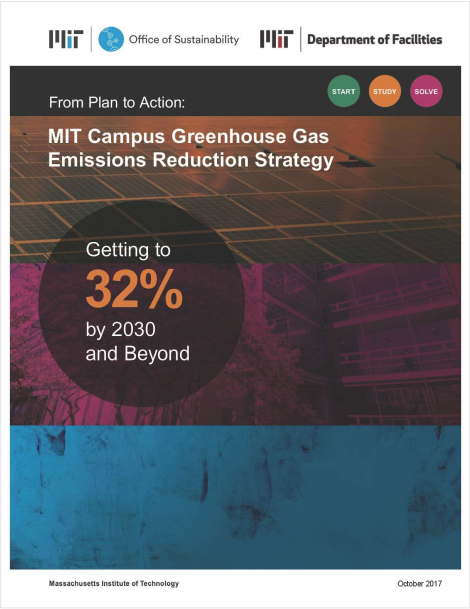
OBJECTIVE 4.2
DEVELOP, TEST, AND SHARE CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES IN SUPPORT OF OVERALL REGIONAL RESILIENCE

Goal: Campus Resilience Plan
By 2019, create a campus resilience plan that aligns with local and regional adaptation approaches for resiliency.

3

4

5



Total Campus GHG Emissions By Source, 2016 (MTC02e)

Fleet Vehicles	1,007
Fugitive Gases	3,423
Leased Buildings	5,759
MIT Owned Buildings	187,848

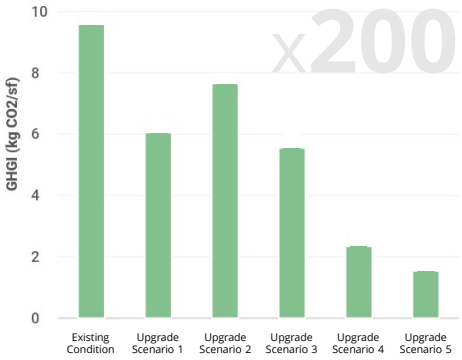
The 2016 GHG emissions inventory represents the third year of comprehensive inventory assessment for the Institute and was audited by the MIT Office of Treasury. The total change in emissions is a reduction of 15,390 MTCO2e from 2014 to 2016. The reduction in GHG emissions was primarily achieved through:

- **Implementation of energy efficiency measures in existing buildings**, including investments in new construction and renovation, lighting, building retro- and monitoring based-commissioning, mechanical system upgrades, and utility system insulation.
- Use of less carbon-intensive fuels in the central utility plant.
- Reduced demand from buildings partially or fully offline for renovation.
- Modest reductions attributed to weather variation.
- Improvements in carbon-intensity of grid-purchased electricity.

6

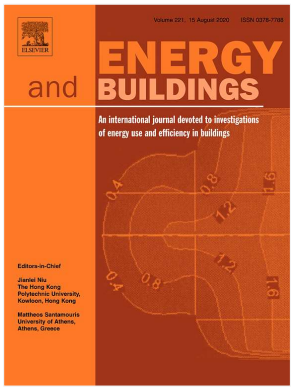
THE PROBLEM

How can we quickly evaluate building specific strategies, with limited data, to help us develop early-stage prioritization plans?

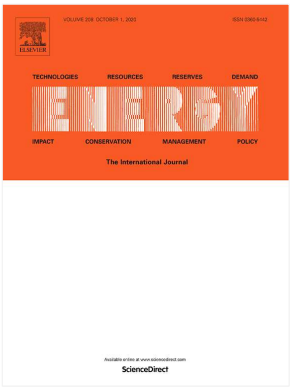


THE PROBLEM

NEEDED SOLUTION

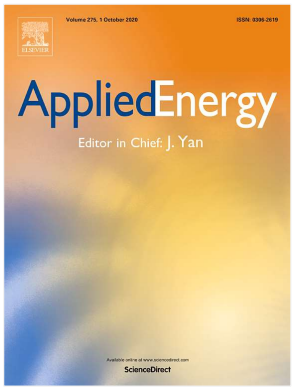


S Nagpal, C Reinhart, A comparison of two modeling approaches for establishing and implementing energy use reduction targets for a university campus, **Energy and Buildings** 173 (2018), 103-116



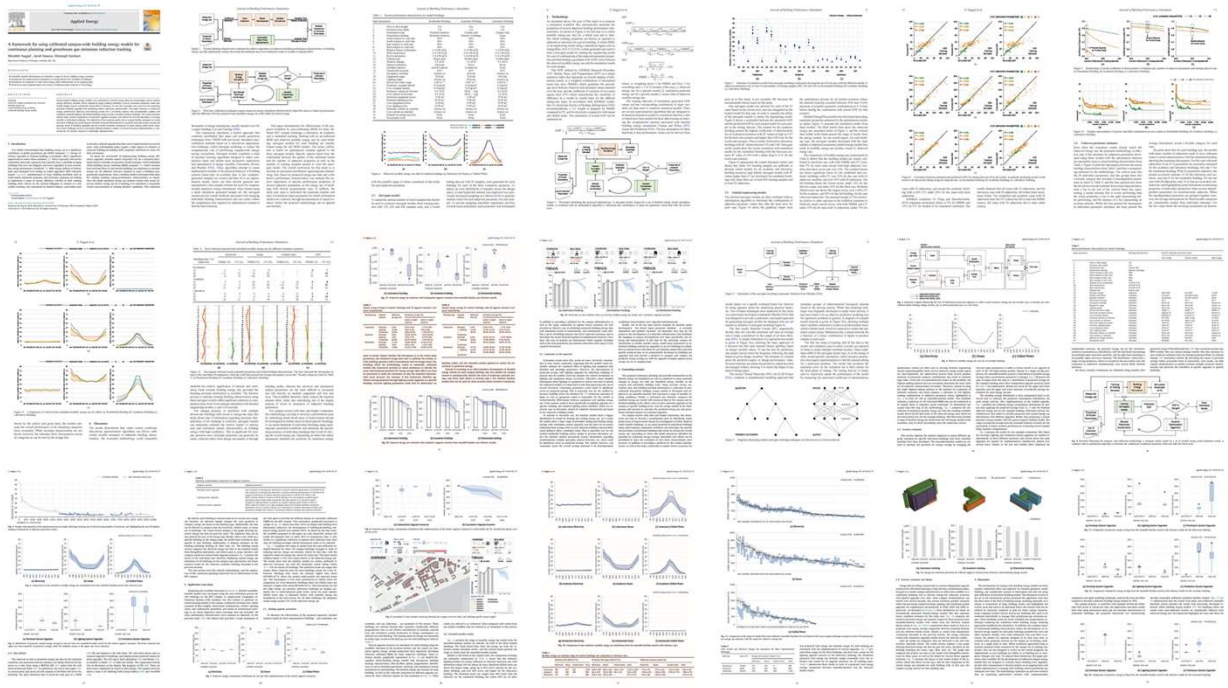
S Duchesne, **S Nagpal**, M Kummert, C Reinhart, Balancing demand and supply: Linking neighborhood level building load calculations with detailed district energy network analysis models, **Energy** 150 (2018), 913-925

S Nagpal, C Mueller, A Aijazi, C Reinhart, A methodology for auto-calibrating urban building energy models using surrogate modeling techniques, **Journal of Building Performance Simulation** 12 (2018), 1-16



S Nagpal, J Hanson, C Reinhart, A framework for using calibrated campus-wide building energy models for continuous planning and GHG emissions tracking, **Applied Energy** 241 (2019), 82-97

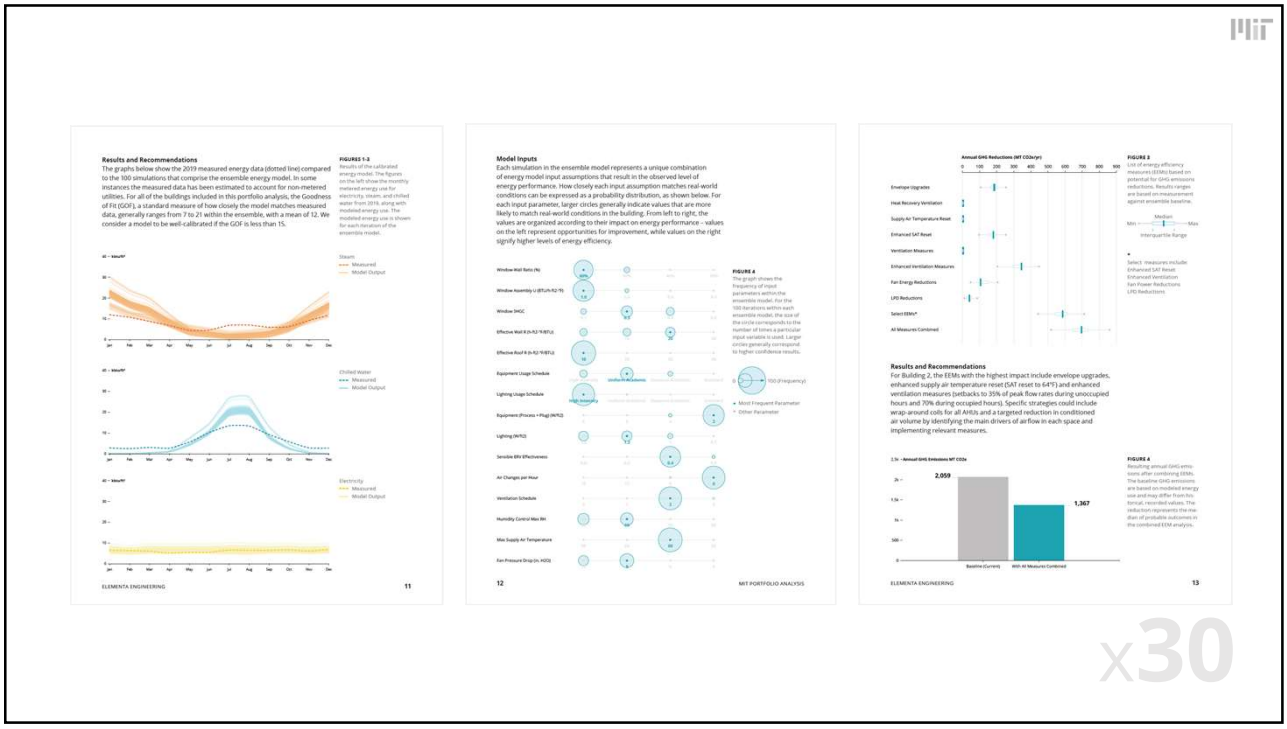
9



10

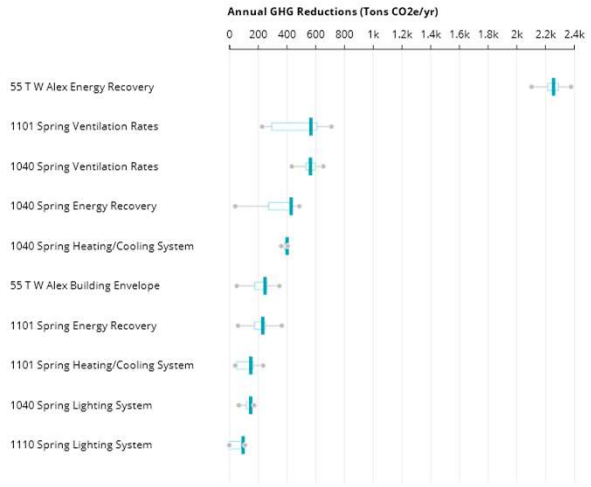

CASE STUDIES

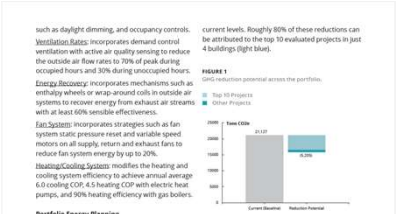
11


Results and Recommendations
Model Inputs
Annual GHG Reductions (MT CO2e/yr)
Results and Recommendations
ELEMENTA ENGINEERING
MIT PORTFOLIO ANALYSIS
x30

12

13





such as daylight dimming, and occupancy controls.

Ventilation Rates: Incorporates demand control ventilation with active air quality sensing to reduce the outside air flow rates to 70% of peak during occupied hours and 30% during unoccupied hours.

Energy Recovery: Incorporates mechanisms such as enthalpy wheels or wrap-around coils in outside air systems to recover energy from exhaust air streams with at least 60% sensible effectiveness.

Fan System: Incorporates strategies such as fan system static pressure reset and variable speed motors on all supply, return and exhaust fans to reduce fan system energy by up to 20%.

Heating/Cooling System: modifies the heating and cooling system efficiency to achieve annual average 6.0 cooling COP, 4.5 heating COP with electric heat pumps, and 90% heating efficiency with gas boilers.

Portfolio Energy Planning

Our portfolio energy planning approach is designed to identify projects that offer the largest emissions reduction potential across the building stock. Each building is evaluated for the above broad upgrades to the envelope, lighting, ventilation and mechanical systems. When an existing building already incorporates the studied measure, the evaluation does not show any savings and is ignored by the model.

In certain cases, an evaluated upgrade may offer emissions reduction potential for a building but may not be feasible due to programmatic or other reasons. It is also possible that a measure may have already been implemented in the building, but its metered utility date does not yet capture that upgrade. In such instances, that particular project recommendation may be ignored.

Emissions Reduction Potential

Based on our analysis, there is significant potential for GHG emissions reduction in the buildings included in this study. With all evaluated strategies combined, portfolio-wide emissions can potentially reduce by over 5,000 Tons-CO2e/yr, or 25% from current levels. Roughly 80% of these reductions can be attributed to the top 10 evaluated projects in just 4 buildings (light blue).

FIGURE 1

GHG reduction potential across the portfolio.

Top 10 Projects
Other Projects

TABLE 1

Median GHG reduction potential for each studied building.

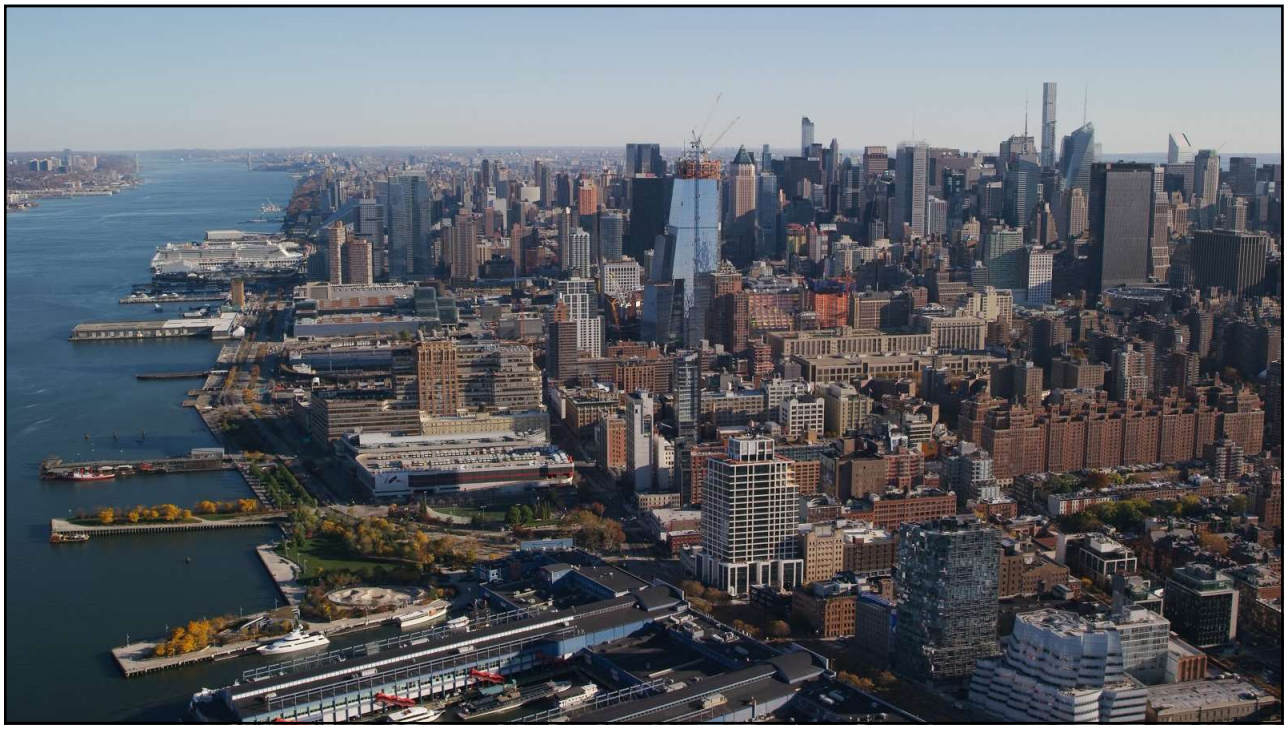
BUILDING NAME	CURRENT (TONS-CO2e)	REDUCTION (TONS-CO2e)	REDUCTION (%)
1040 Spring St	4,860	1,194	25%
55 T.W. Alex Dr	9,167	2,562	28%
1101 Spring St*	1,937	835	43%
1110 Spring St	1,011	253	25%
1015 Spring St	511	10	<2%
1000 Spring St	231	6	<2%
1733-35 Conn Ave	174	35	20%
FL. Assist	49	7	14%
100 Comm St*	85	18	21%
2 Maughan Drive*	2,693	176	7%
1729-31 Conn Ave	94	44	47%
Bromont*	315	66	21%
TOTAL	**21,127**	**5,250**	**25%**

* 2020 utility data used for model calibration. 2019 utility data was used for all other buildings.

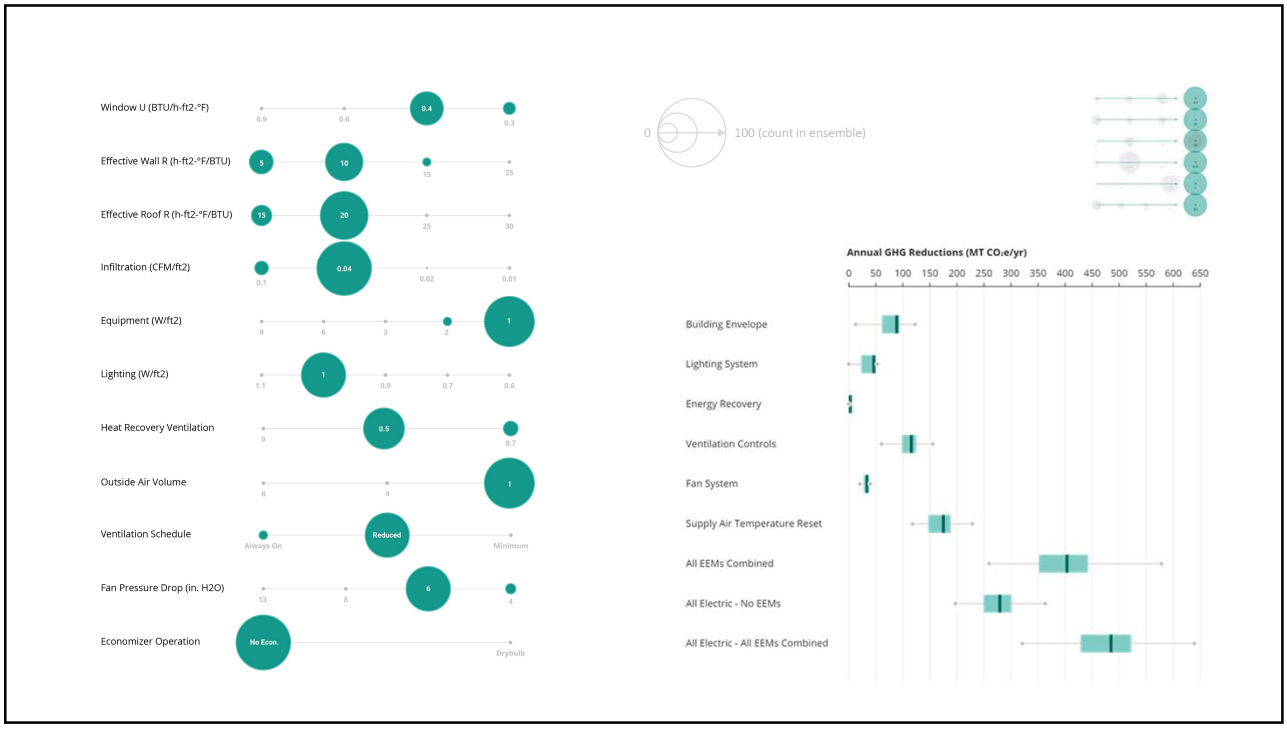
ELEMENTA ENGINEERING 5

ELEMENTA ENGINEERING 11

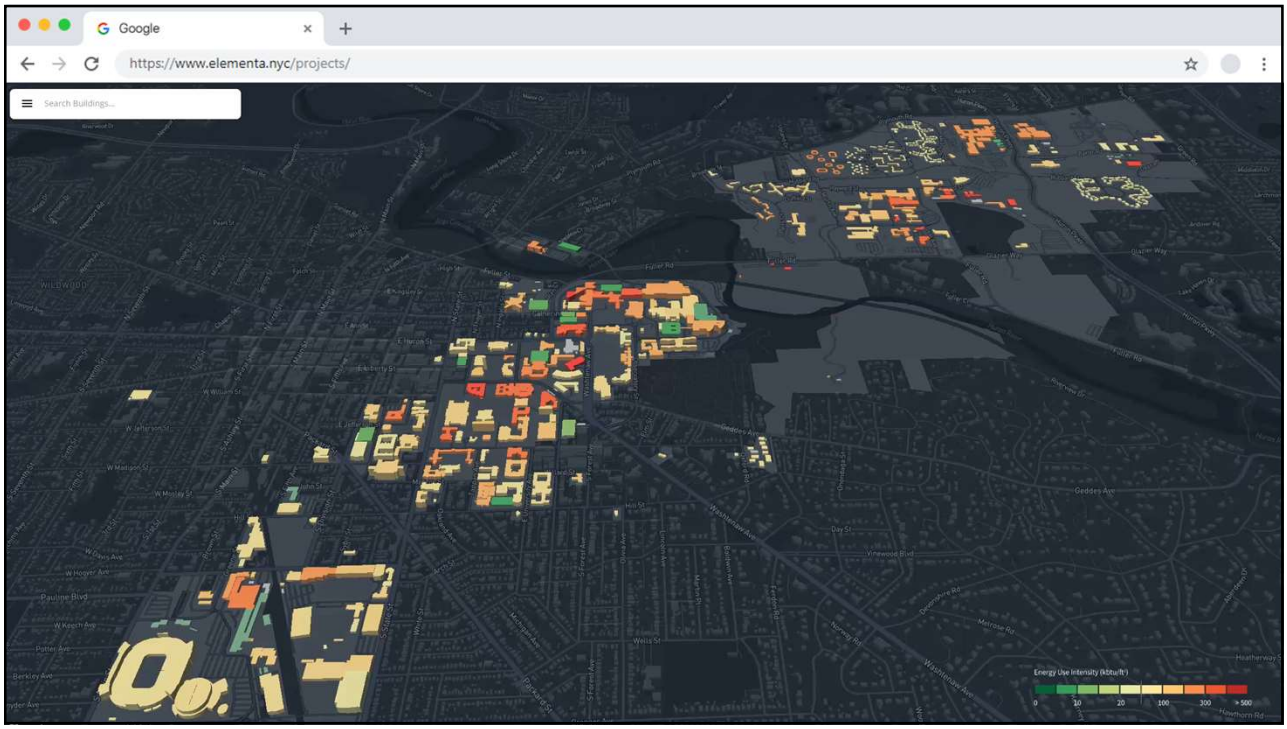
14



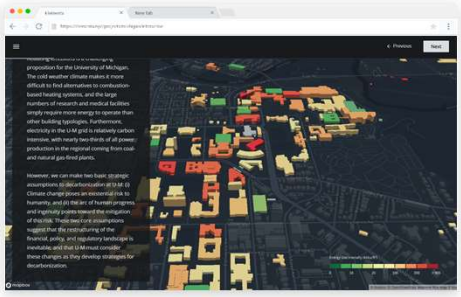
15

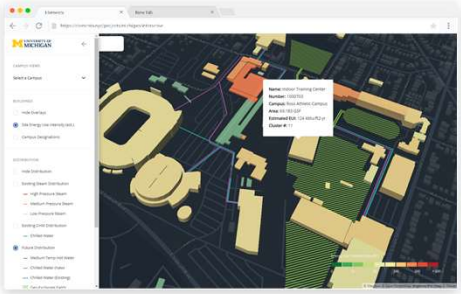

Window U (BTU/h-ft2-°F)
0.9
0.6
0.4
0.3
Effective Wall R (h-ft2-°F/BTU)
5
10
15
25
Effective Roof R (h-ft2-°F/BTU)
15
20
25
30
Infiltration (CFM/ft2)
0.1
0.04
0.02
0.01
Equipment (W/ft2)
9
6
3
2
1
Lighting (W/ft2)
1.1
1
0.9
0.7
0.6
Heat Recovery Ventilation
0
0.5
0.7
Outside Air Volume
8
4
1
Ventilation Schedule
Always On
Reduced
Minimum
Fan Pressure Drop (in. H2O)
13
8
6
4
Economizer Operation
No Econ.
Drybulb
0
100 (count in ensemble)
Annual GHG Reductions (MT CO₂e/yr)
0 50 100 150 200 250 300 350 400 450 500 550 600 650
Building Envelope
Lighting System
Energy Recovery
Ventilation Controls
Fan System
Supply Air Temperature Reset
All EEMs Combined
All Electric - No EEMs
All Electric - All EEMs Combined

16

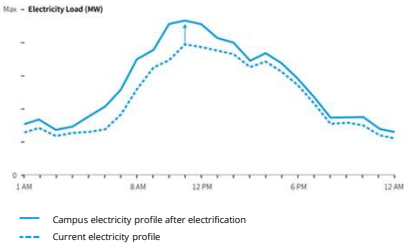


17

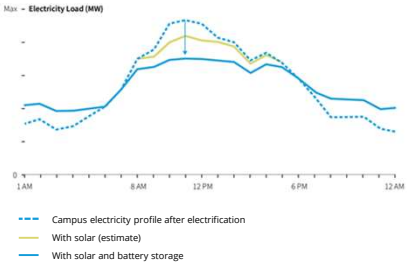




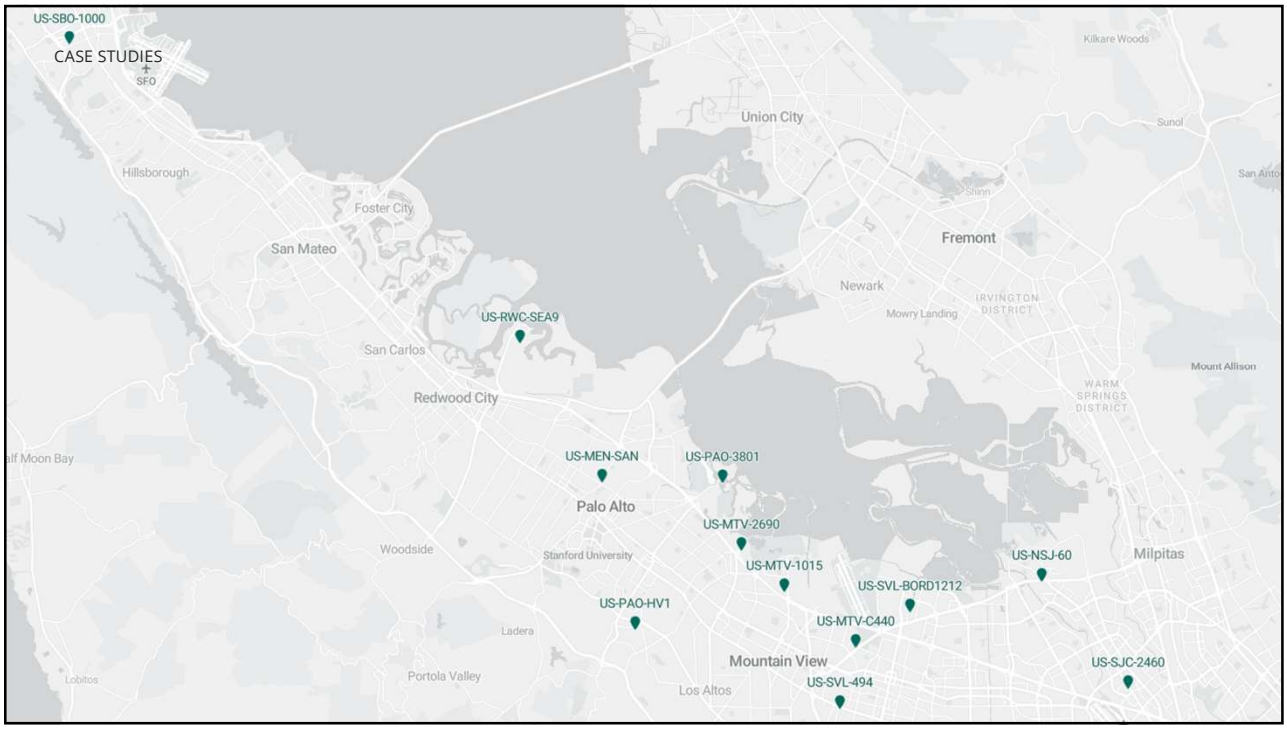
WINTERTIME DEMAND INCREASE



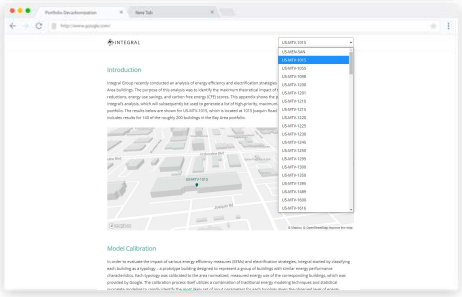
PEAK DEMAND REDUCTION

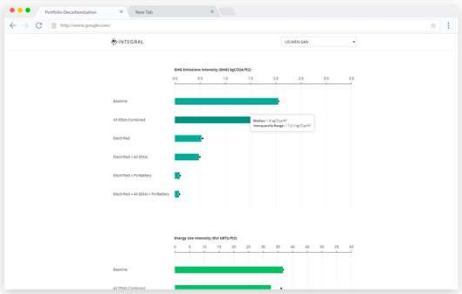


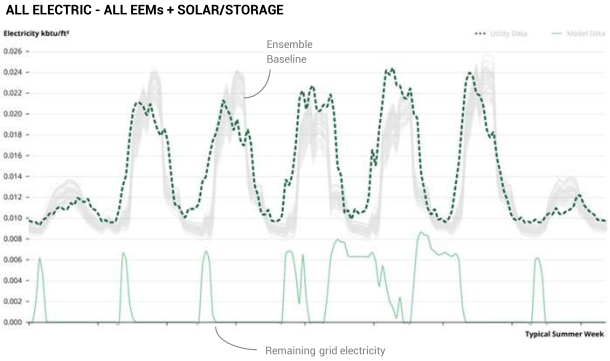
18


US-SBO-1000
CASE STUDIES
SFO
Hillsborough
Foster City
San Mateo
US-RWC-SEA9
San Carlos
Redwood City
Union City
Fremont
Newark
Mowry Landing
IRVINGTON DISTRICT
Kilkare Woods
Sunol
Mount Allison
WARM SPRINGS DISTRICT
US-MEN-SAN
US-PAO-3801
Palo Alto
US-MTV-2690
Stanford University
Woodside
US-MTV-1015
US-NSJ-60
Milpitas
US-SVL-BORD1212
US-PAO-HV1
US-MTV-C440
Ladera
Mountain View
US-SJC-2460
Portola Valley
Los Altos
US-SVL-494
Lobitos

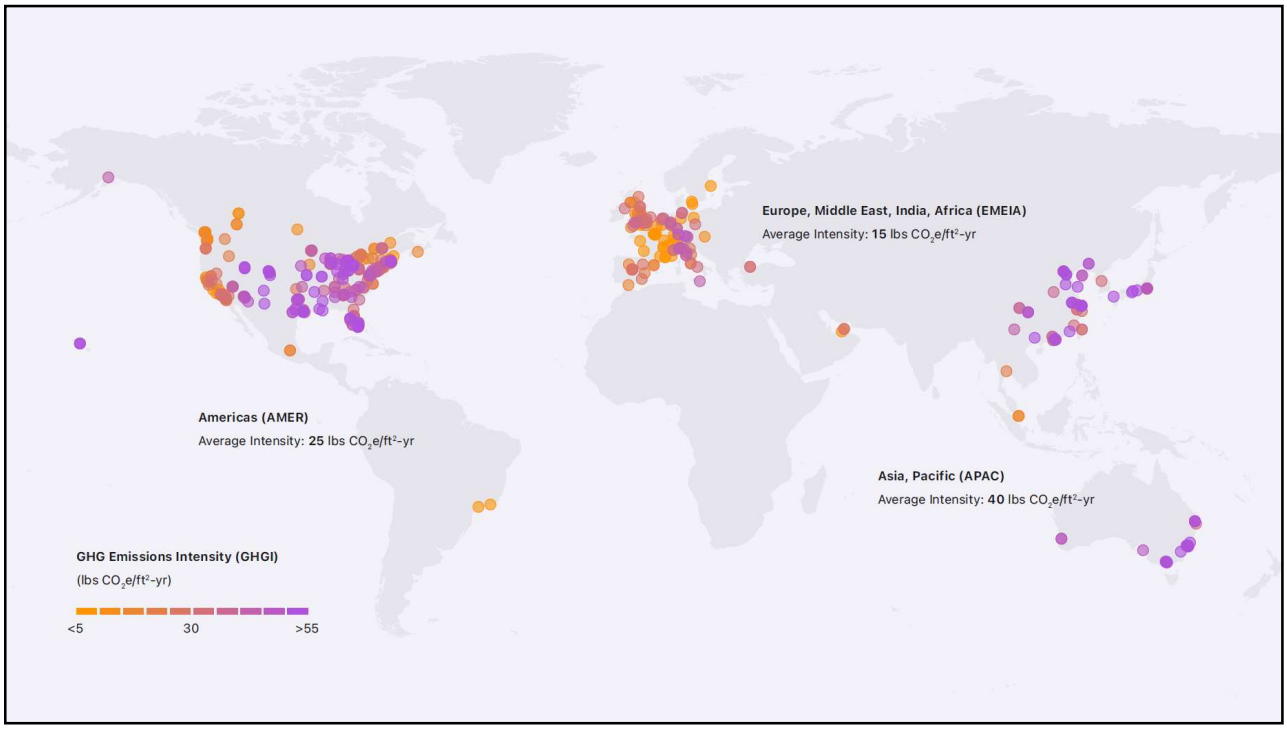
19



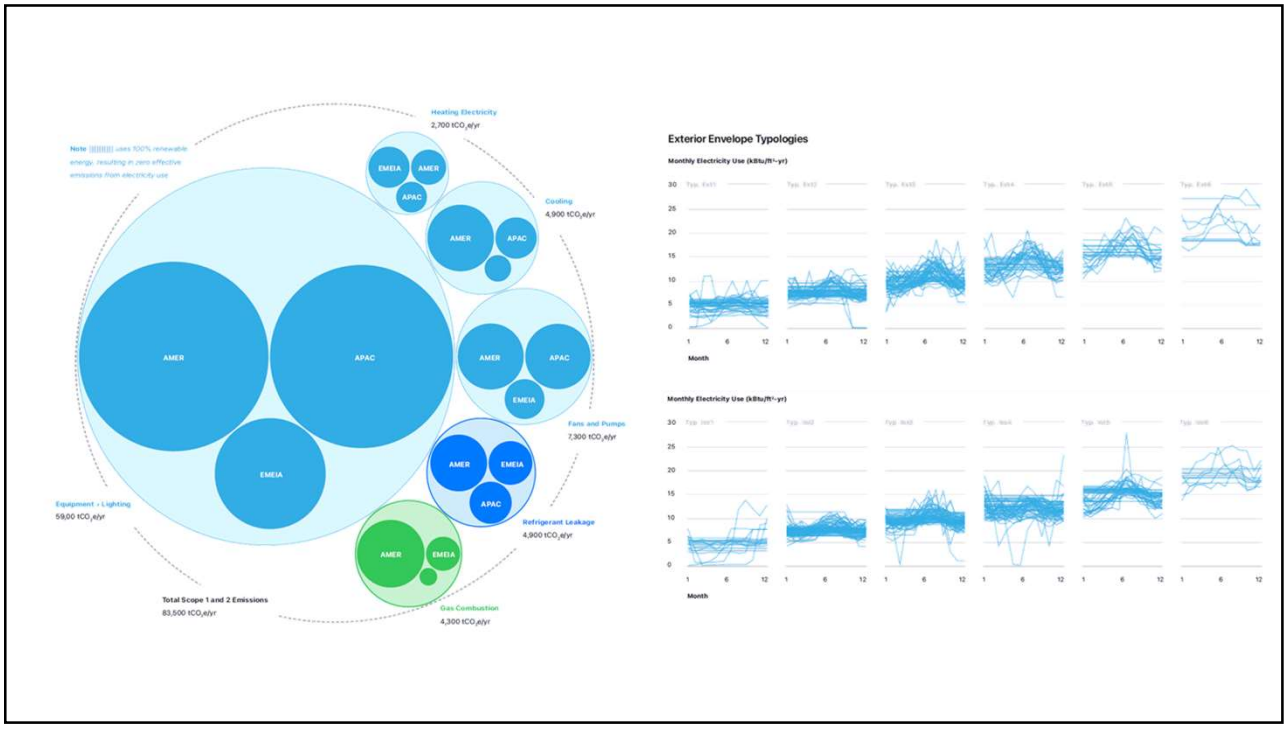



ALL ELECTRIC - ALL EEMs + SOLAR/STORAGE
Electricity kbtu/ft²
Utility Data
Model Data
Ensemble Baseline
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Typical Summer Week
Remaining grid electricity

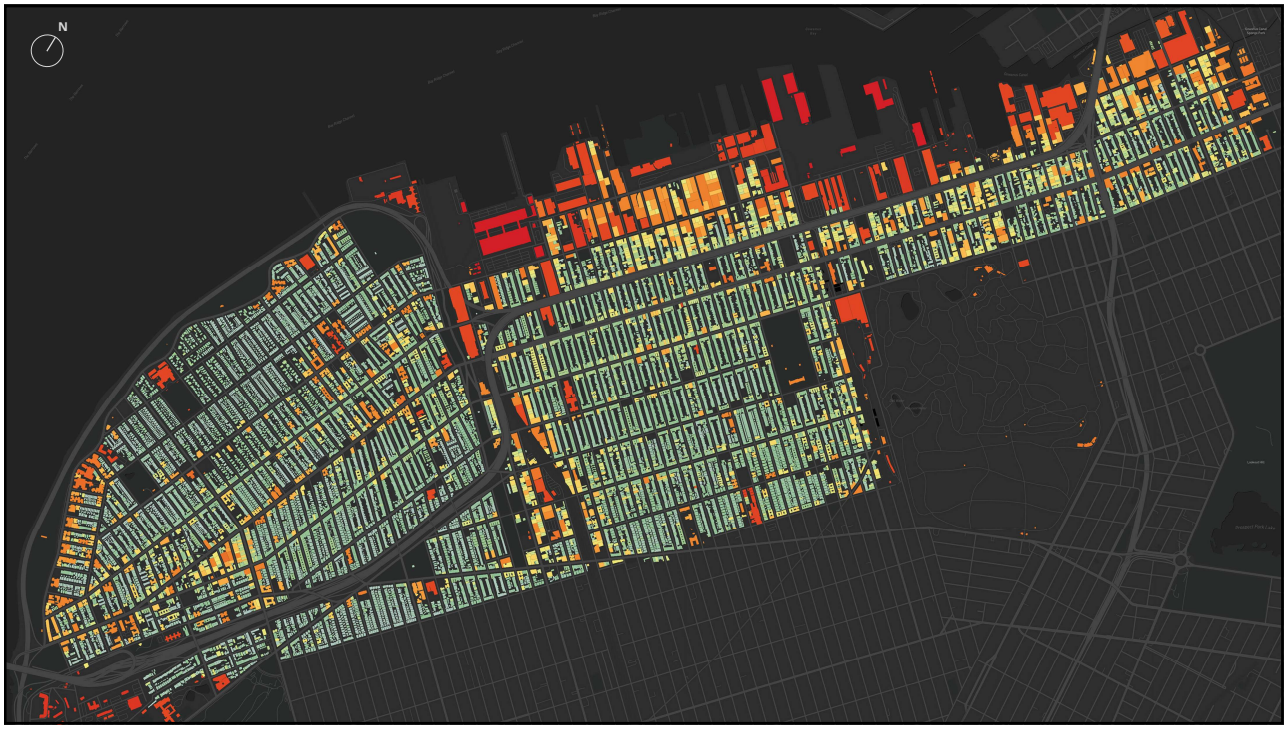
20


Europe, Middle East, India, Africa (EMEIA)
Average Intensity: 15 lbs CO_2e/ft^2-yr
Americas (AMER)
Average Intensity: 25 lbs CO_2e/ft^2-yr
Asia, Pacific (APAC)
Average Intensity: 40 lbs CO_2e/ft^2-yr
GHG Emissions Intensity (GHGI)
(lbs CO_2e/ft^2-yr)
<5
30
>55

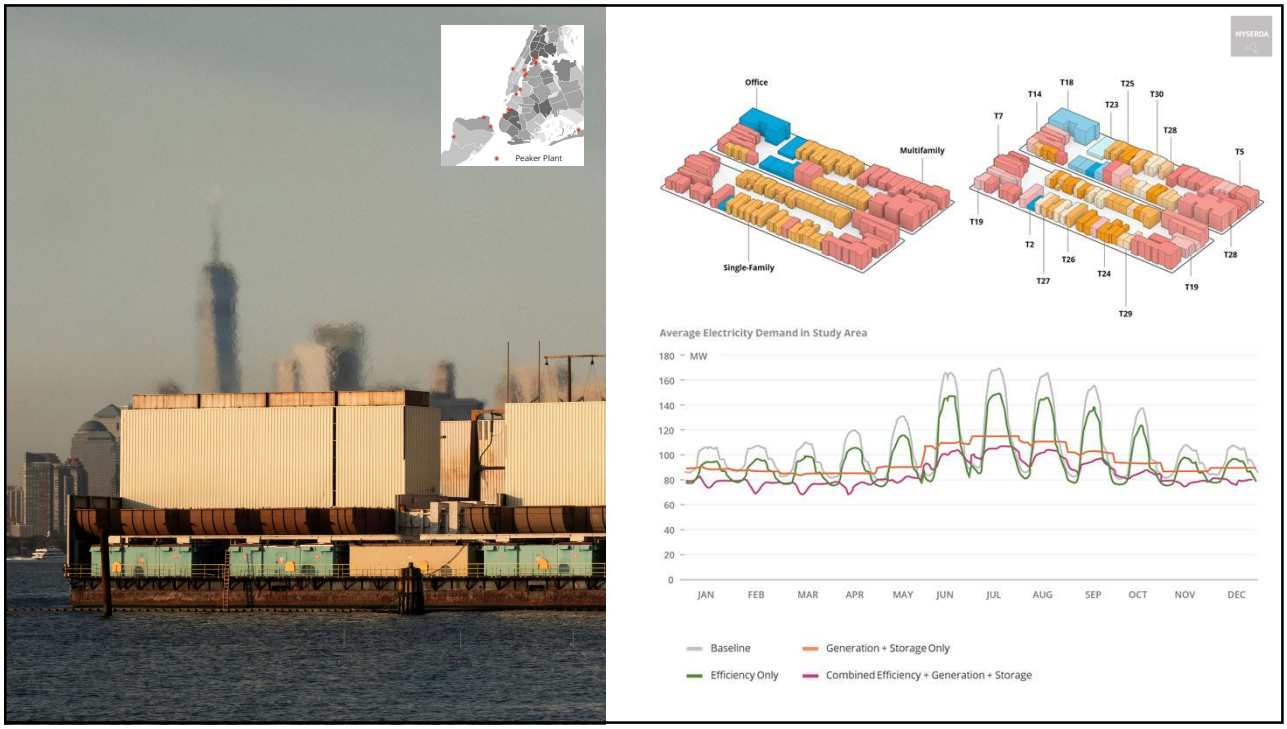
21


Heating Electricity
2,700 tCO_2e/yr
Cooling
4,900 tCO_2e/yr
Fans and Pumps
7,300 tCO_2e/yr
Refrigerant Leakage
4,900 tCO_2e/yr
Gas Combustion
4,300 tCO_2e/yr
Equipment - Lighting
59,00 tCO_2e/yr
Total Scope 1 and 2 Emissions
83,500 tCO_2e/yr
AMER
APAC
EMEIA
Exterior Envelope Typologies
Monthly Electricity Use (kBtu/ft²-yr)
Month

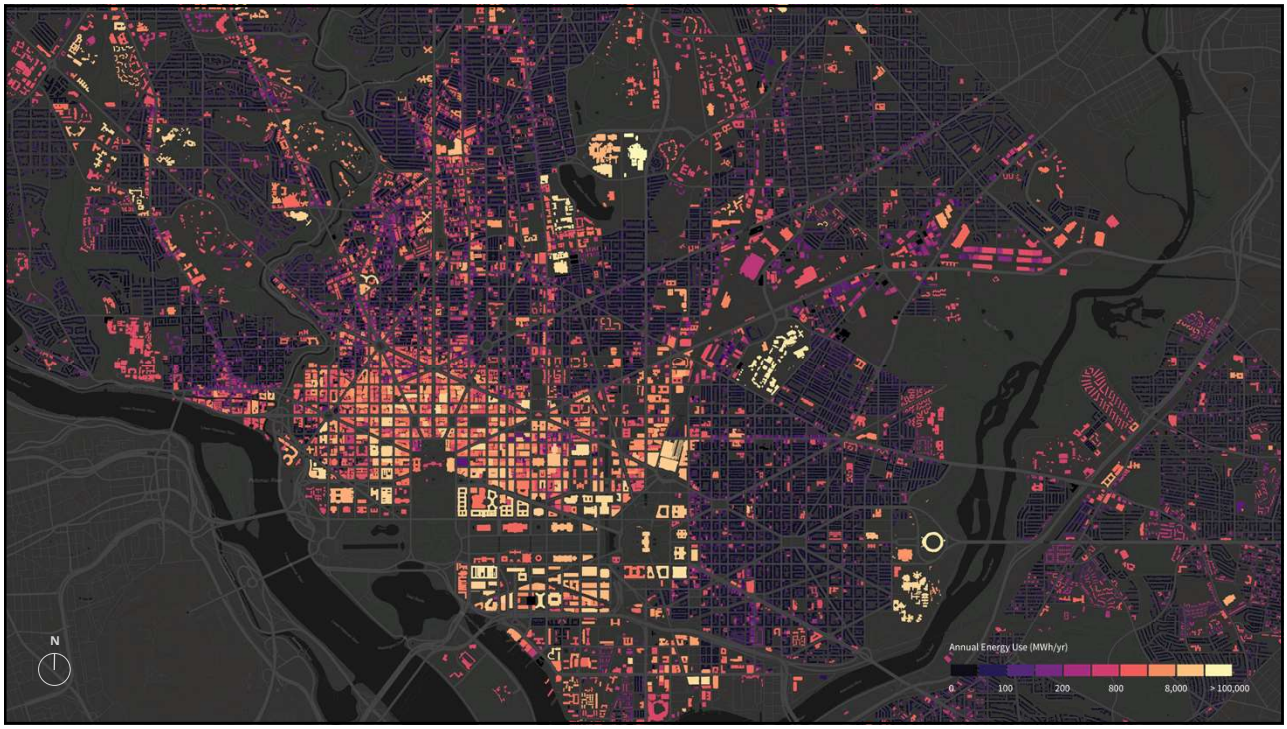
22


N

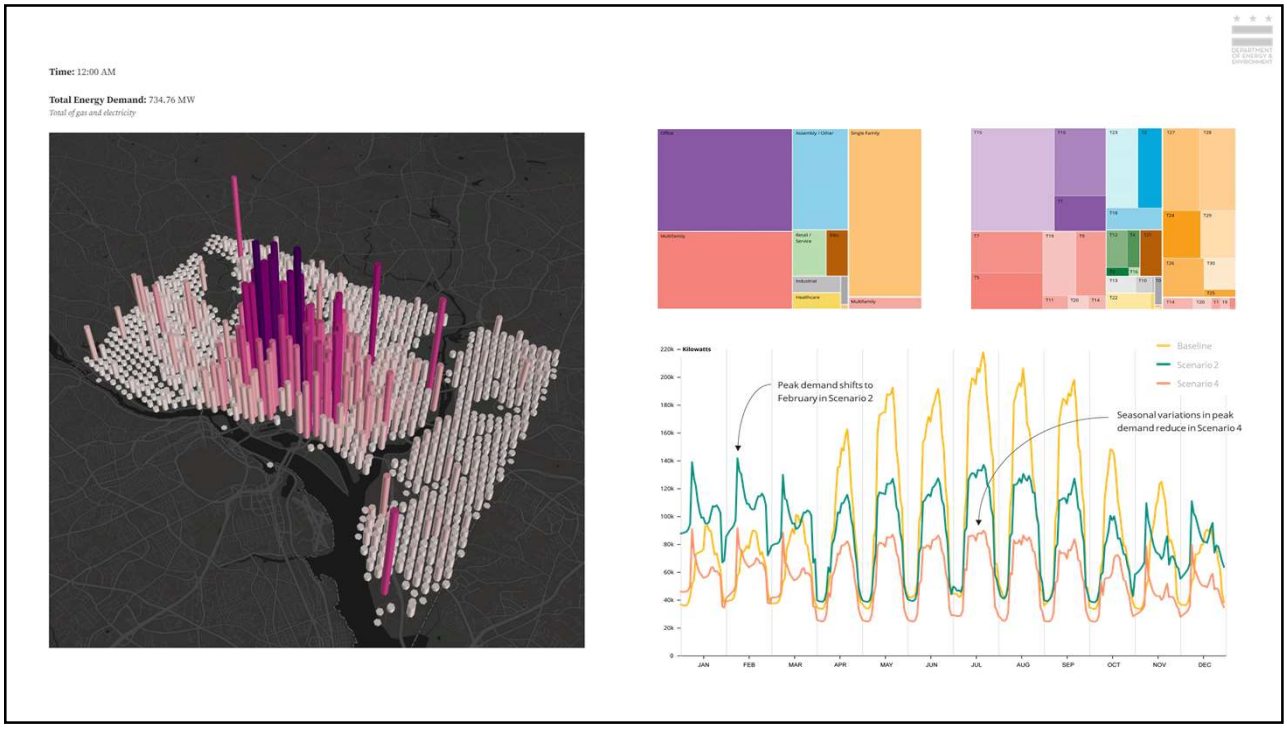
23


Peaker Plant
NYSERDA
Office
Multifamily
Single-Family
T7
T14
T18
T23
T25
T30
T28
T5
T19
T2
T27
T26
T24
T29
T28
T19
Average Electricity Demand in Study Area
MW
180
160
140
120
100
80
60
40
20
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Baseline
Generation + Storage Only
Efficiency Only
Combined Efficiency + Generation + Storage

24


N
Annual Energy Use (MWh/yr)
0
100
200
800
8,000
> 100,000

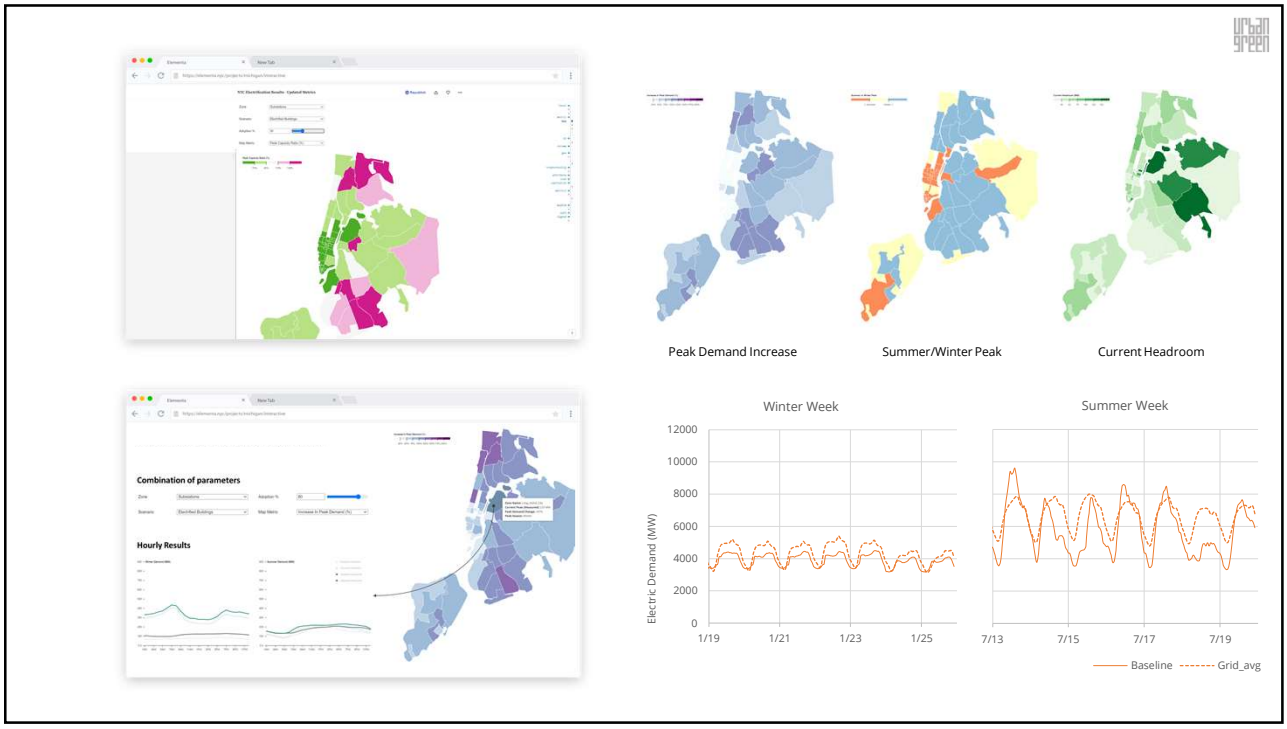
25


Time: 12:00 AM
Total Energy Demand: 734.76 MW
Total of gas and electricity
Office
Assembly / Other
Single Family
Multifamily
Retail / Service
Industrial
Healthcare
Multifamily
220k — Kilowatts
200k
180k
160k
140k
120k
100k
80k
60k
40k
20k
0
Baseline
Scenario 2
Scenario 4
Peak demand shifts to February in Scenario 2
Seasonal variations in peak demand reduce in Scenario 4
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

26


N

27


Combination of parameters
Hourly Results
Peak Demand Increase
Summer/Winter Peak
Current Headroom
Winter Week
Summer Week
Electric Demand (MW)
12000
10000
8000
6000
4000
2000
0
1/19
1/21
1/23
1/25
7/13
7/15
7/17
7/19
Baseline
Grid_avg

28

next
~~THE~~ PROBLEM

How can ~~we~~ anyone quickly evaluate building specific strategies, with limited data, to help ~~us~~ develop early-stage prioritization plans?

Massachusetts Institute of Technology
Climate Action Implementation Plan

University of Michigan
Thermal Energy Electrification Plan

United Therapeutics Corporation
ESG Carbon Strategy

Confidential NYC Portfolio
Policy and Regulatory Assessment

Confidential Bay Area Portfolio
Carbon Free Energy Strategy

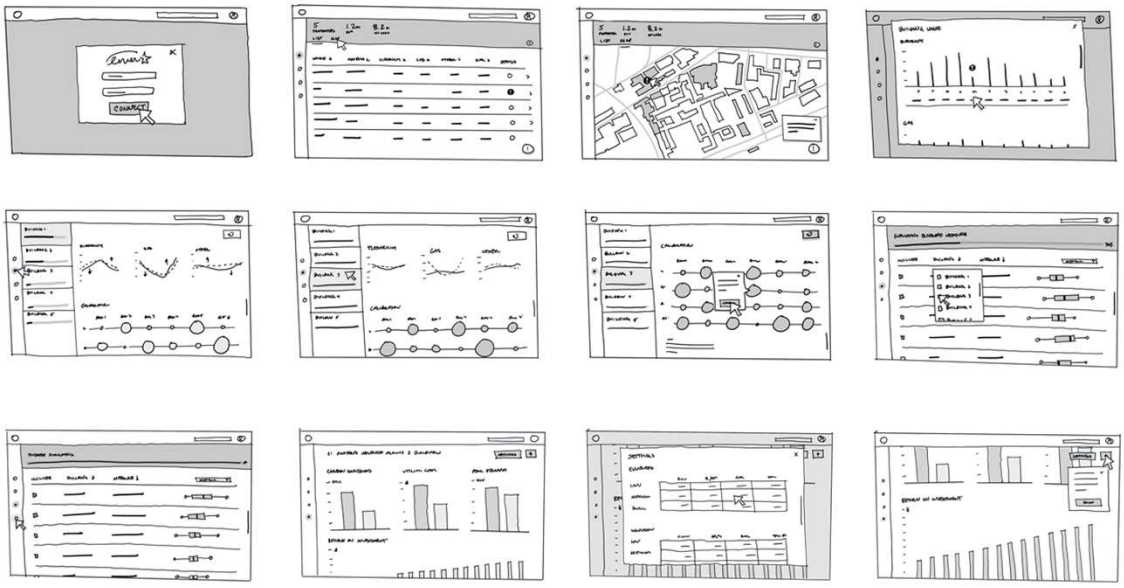
Confidential Global Portfolio
Portfolio Decarbonization Plan

Brooklyn Sunset Park
Community DER Study

District of Columbia
Electrification Policy Roadmap

New York City
Electrification Impact Assessment

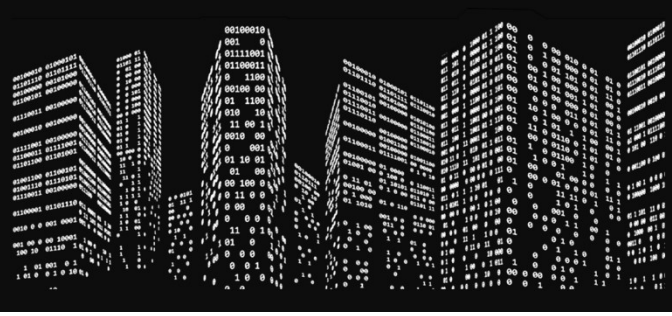
29



30

Urban Energy Analytics

Data-driven design for the built environment.



Shreshth Nagpal
snagpal@elementaengineering.com

INTEGRAL | ELEMENTA