A comparison between two urban-scale methods for the assessment of heat energy demand and photovoltaic potential in New York City, USA

Presentation for:

European International Conference on Transforming Urban Systems (EICTUS)

University of Strasbourg, France

Presented by:
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Center for Sustainable Energy Technology
Univ. of Applied Sciences
Stuttgart, Schellingstrabe, Germany

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June 26-28, 2019

ORNL is managed by UT-Battelle
for the US Department of Energy

OAK RIDGE National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

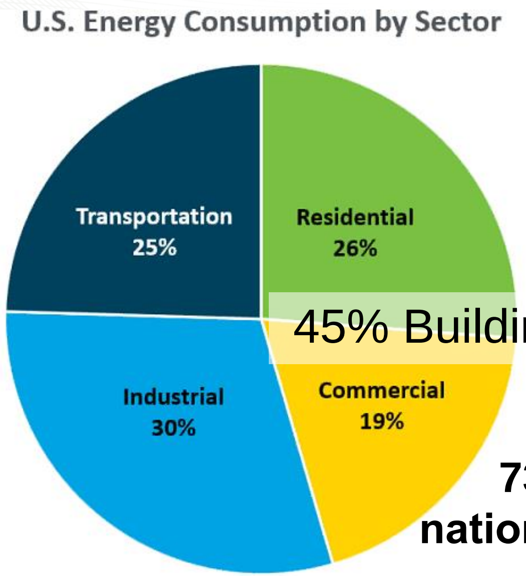
Joshua New, Ph.D., C.E.M., PMP, CMVP, CSM

- **Career**
  - 2009+ Oak Ridge National Laboratory, R&D staff
    - ETSD, Building Technology Research & Integration Center (BTRIC), Building Envelope & Urban Systems Research Group (BEUSR)
    - Urban Dynamics Institute, Resiliency Team member
  - 2012+ The University of Tennessee, Joint Faculty
- **Education**
  - The University of TN, (2004-2009), Knoxville; Ph.D. Comp. Sci.
  - Jacksonville State University, AL (1997-2001, 2001-2004)
    M.S. Systems&Software Design, double-B.S. Computer Science and Mathematics, Physics minor
- **Professional Involvement**
  - IEEE, Senior Member (top 8%)
  - ASHRAE, defines international building codes
    - TC1.5, Computer Applications, Voting member and officer
    - TC4.2, Climatic Information, Voting member and officer
    - SSPC169, Weather Data for Building Design Standards (24% of page count of building code), Voting member
    - TC4.7, Energy Calculations, Voting member and officer
    - SSPC140 and ASHRAE Guideline 14 involvement

Certifications
- AEE, Lifetime Member
  - Certified Energy Manager
  - Certified Measurement & Verification Professional
- PMI, Member
  - Project Management Professional
- Certified Scrum Master

Artificial Intelligence
- President's National S&T Council's Machine Learning and Artificial Intelligence Subcommittee's Artificial Intelligence Consortium

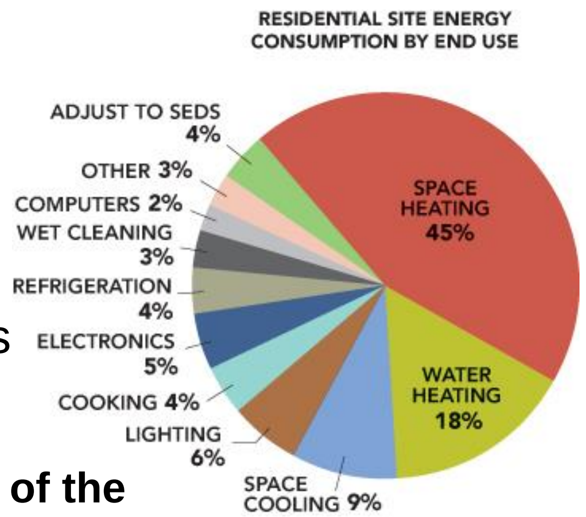
Energy Consumption and Production

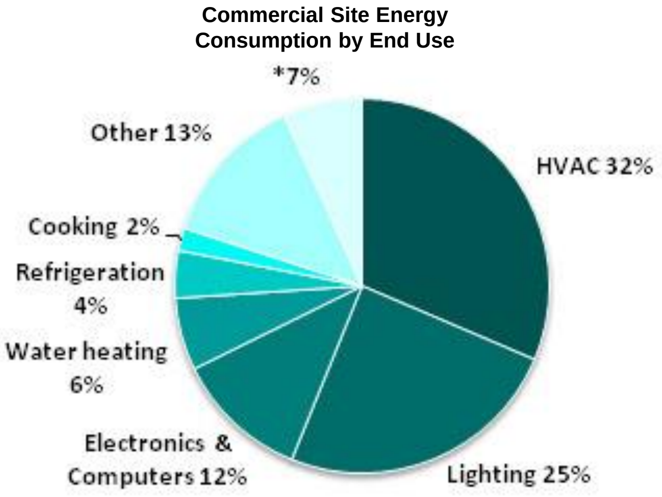


45% Buildings

73% of the nation's electricity

Source: U.S. Energy Information Administration, January 2016 to January 2017, *Monthly Energy Review – Table 2.1*.





124 million U.S. buildings
$380 billion/yr energy bills

Goal of the DOE
Building Technologies Office:
30% energy reduction per sq. ft.
by 2030 compared to 2010 baseline

Building Energy Modeling – building descriptions + weather = estimated building energy consumption

$9B/yr – ESCO; $7B/yr – utility EE
$14B/yr – DR management systems
0.3% modified, BEM < 10% of those

Building Energy Modeling

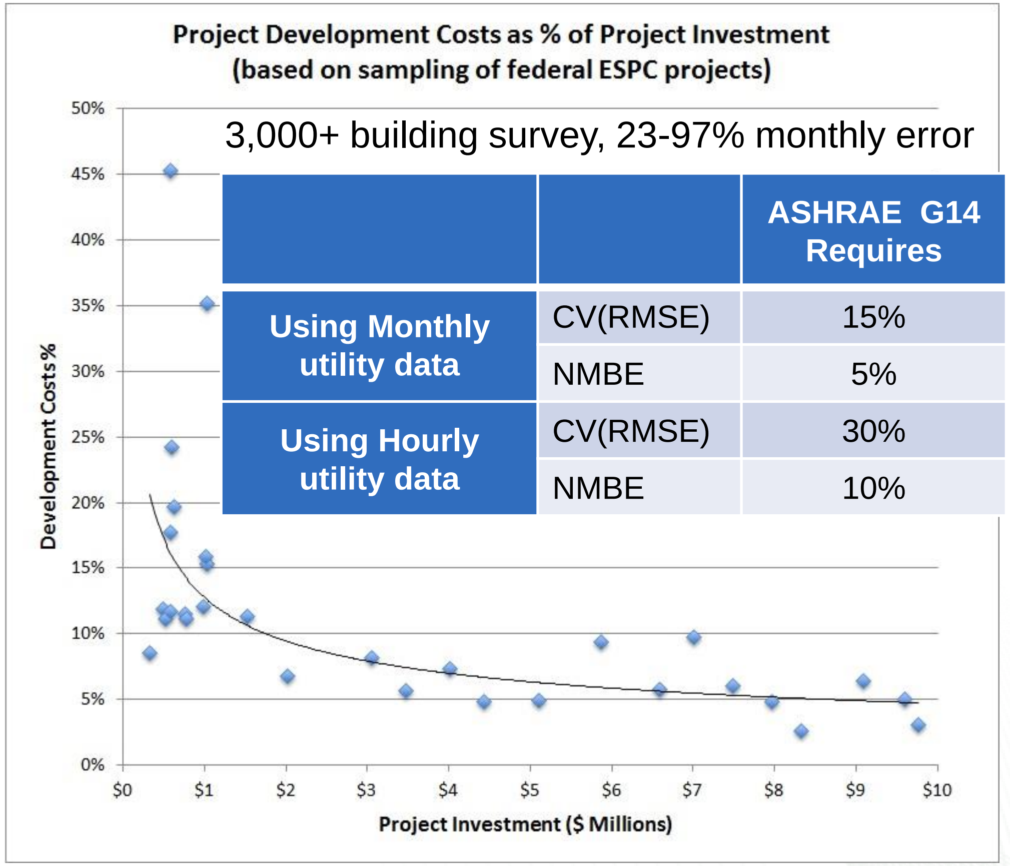
Optimal Return on Investment (for building energy savings)

Simulation Engine and Analysis Platform

U.S. Dept. of Energy
$93M, 1995–?

EnergyPlus **OpenStudio**

Free, open-source (GitHub),
free support community (unmethours.com)



3,000+ building survey, 23-97% monthly error

		ASHRAE G14 Requires
Using Monthly utility data	CV(RMSE)	15%
	NMBE	5%
Using Hourly utility data	CV(RMSE)	30%
	NMBE	10%

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HPC scalability for desktop software

Titan is the world's fastest buildings energy model (BEM) simulator

>500k building simulations in <1 hour

130M US buildings could be simulated in 2 weeks

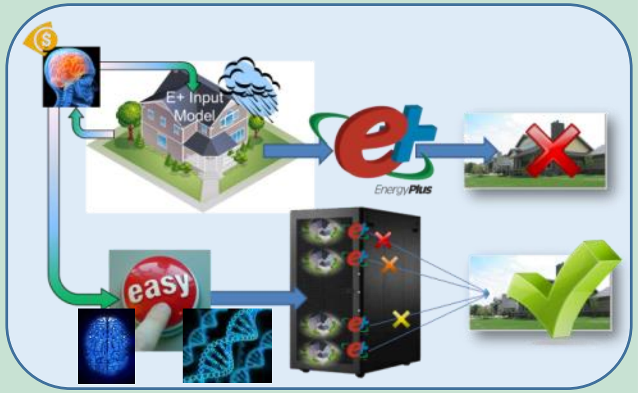
8M simulations of DOE prototypes (270 TB)

CPU Cores	Wall-clock Time (mm:ss)	Data Size	EnergyPlus Simulations
16	18:14	5 GB	64
32	18:19	11 GB	128
64	18:34	22 GB	256
128	18:22	44 GB	512
256	20:30	88 GB	1,024
512	20:43	176 GB	2,048
1,024	21:03	351 GB	4,096
2,048	21:11	703 GB	8,192
4,096	20:00	1.4 TB	16,384
8,192	26:14	2.8 TB	32,768
16,384	26:11	5.6 TB	65,536
32,768	31:29	11.5 TB	131,072
65,536	44:52	23 TB	262,144
131,072	68:08	45 TB	524,288

Calibration Performance – automated M&V

National HPC Resources → **Applied Research** → **Industry and building owners**

High Performance Computing
- Different calibration algorithms
- Machine learning – big data mining
- Large-scale calibration tests



Features
- Calibrate any model to data
- Calibrates to the data you have (monthly utility bills to submetering)
- Runs on a laptop and in the cloud

- 35 Publications:
  `http://bit.ly/autotune_science`
- Open source (GitHub):
  `http://bit.ly/autotune_code`

Results

		ASHRAE G14 Requires	Autotune Results
Monthly utility data	CVR	15%	1.20%
	NMBE	5%	0.35%
Hourly utility data	CVR	30%	3.65%
	NMBE	10%	0.35%

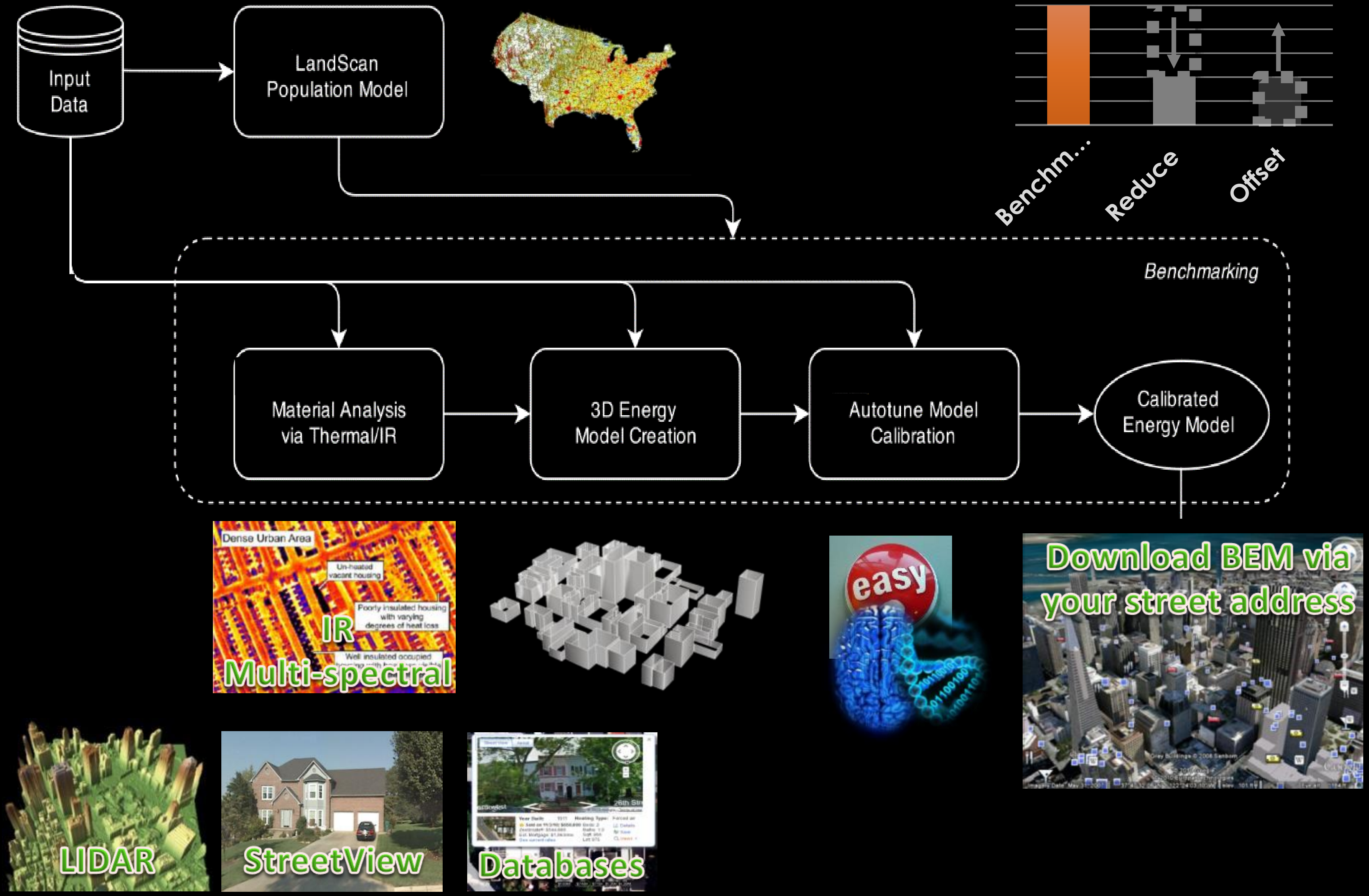
Results of 20,000+ Autotune calibrations (15 types, 47-282 tuned inputs each)

Other error metrics

Residential home	Tuned input avg. error
Within 30¢/day (actual use $4.97/day)	Hourly – 8% Monthly – 15%
	3 bldgs, 8-79 inputs

Leveraging HPC resources to calibrate models for optimized building efficiency decisions

Model America 2020 – BEM for every U.S. building



Acknowledgements

- U.S. Department of Energy
- National Nuclear Security Administration
- Oak Ridge National Laboratory
- Building Technologies Office
- Office of Electricity

What matters and how much?

- 100+ page internal report NDA/OUO
  - New, Joshua R., Hambrick, Joshua, and Copeland, William A. (2017). "Assessment of Value Propositions for Virtual Utility Districts: Case Study for the Electric Power Board of Chattanooga, TN." ORNL internal report ORNL/TM-2017/512, December 15, 2017, 107 pages.
- Sensitivity analysis for all building types
  - 80% of commercial buildings - 16 climate zones, 16 building types, averaging 5.75 vintages
  - 281-4,617 building descriptors (e.g. thermostat, insulation level) were modified

	Small Office	Outpatient	Large Office	Medium Office	Hospital	Warehouse	Small Hotel	Large hotel
Inputs	458	3483	1072	760	1955	333	1823	887
	Strip Mall	Retail	Quick Service Restaurant	Full Service Restaurant	Mid Rise Apt	High Rise Apt	Secondary School	Primary School
Inputs	800	438	281	286	1464	4617	1621	1051

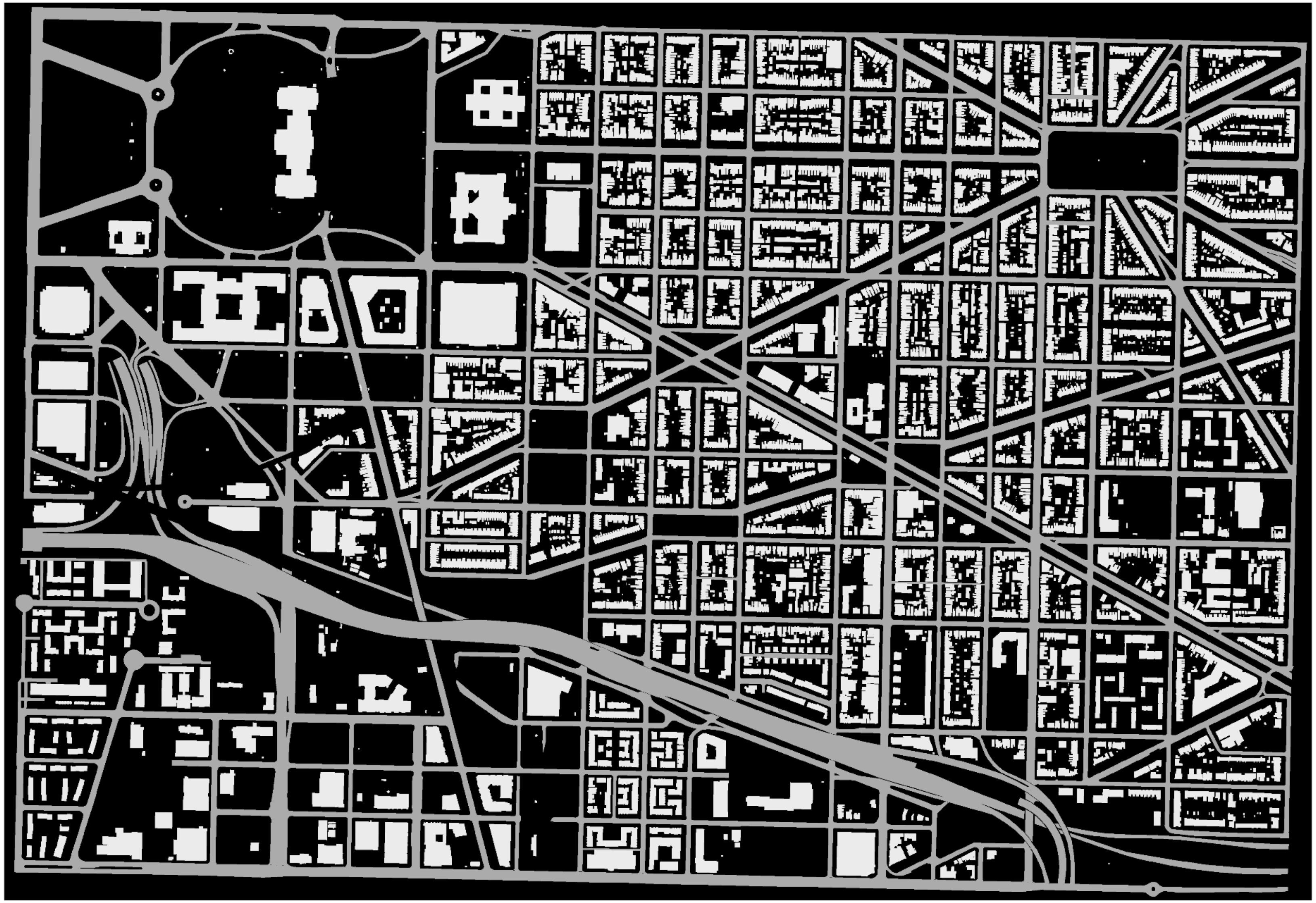
  - Fractional Factorial (FrF2) resolution IV statistical design of experiments
- Summarize 768 lists of impactful variables
  - 254,544 annual simulations were completed on the nation's fastest supercomputer (Titan)
  - 216 Excel spreadsheets were created listing the energy and demand impacts of each building property
- Quantify Most Important Building Parameters
  - Top 10 annual <u>energy (kWh)</u> and <u>demand/peak-shaving (kW)</u> variables for each of the 16 building types

Data Sources

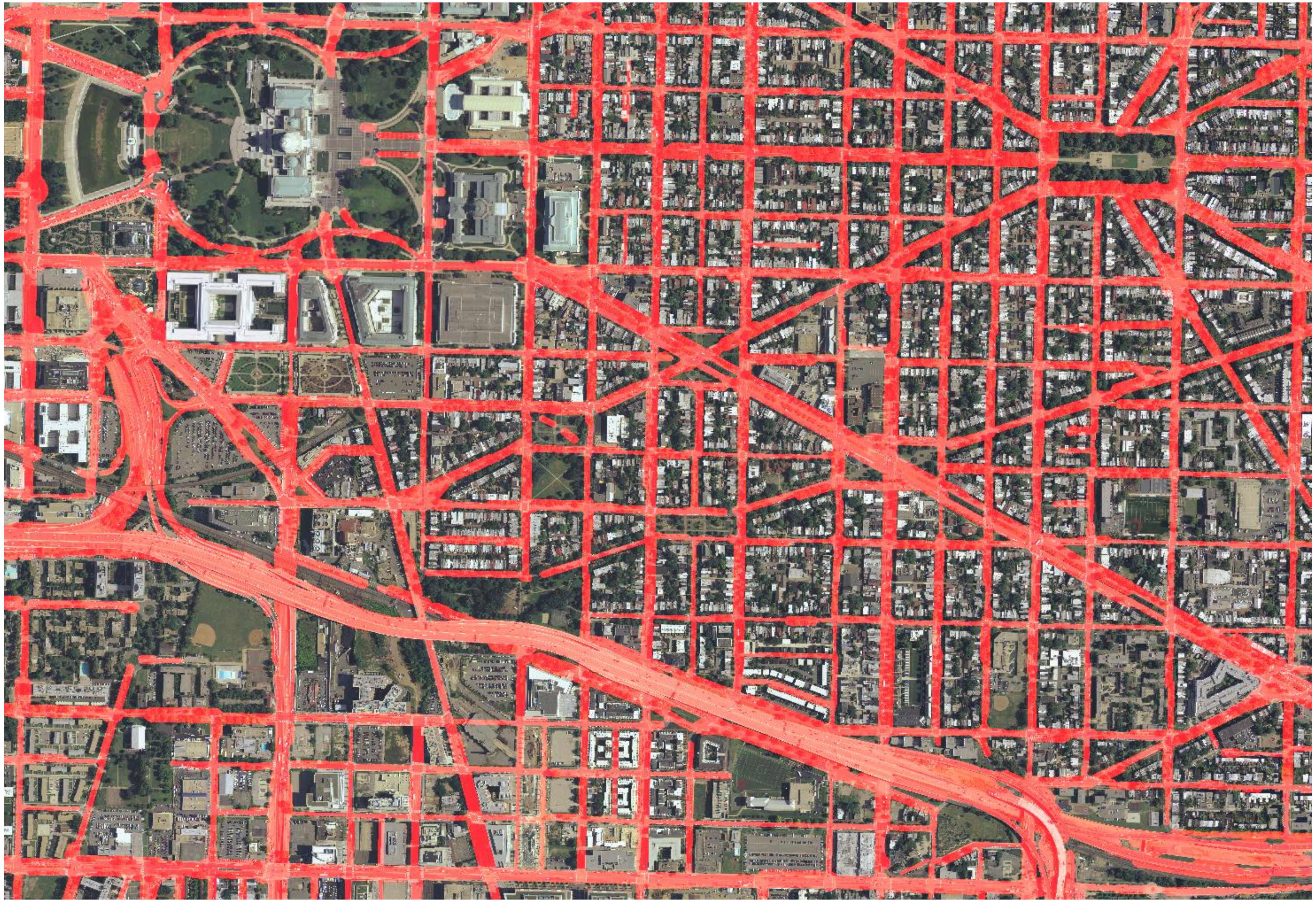
- Database and image sources for urban model generation
  - Satellite and airborne imagery
  - Cartographic data
  - Ground level images
  - Elevation data
  - Building information databases
  - 3D building model databases

	Short Title
Summary	Satellite imagery, including panchromatic and multispectral images
Data type	Image
Company	
Website	
Temporal resolution	Cities - 3-11 times per week
Spatial resolution	0.3 m
Measure accuracy	
Cost	$11 per sq. km
Format	GeoTiff
Mapping to building input variables	Building footprints
Mapping to area properties	Vegetated areas, road surface, buildings, parking lots
Mapping to material properties	Road pavement materials (e.g., concrete, asphalt), parking lots (e.g., gravel, soil)
Coverage of US	Over 10 million km^2 of coverage of the contiguous US
Orientation	Aerial
Existing internal software	N/A
Existing expertise	Remote sensing data analysis tool
Restrictions	N/A
Comments	

Manual Segmentation of DC



Automatic Road Extraction



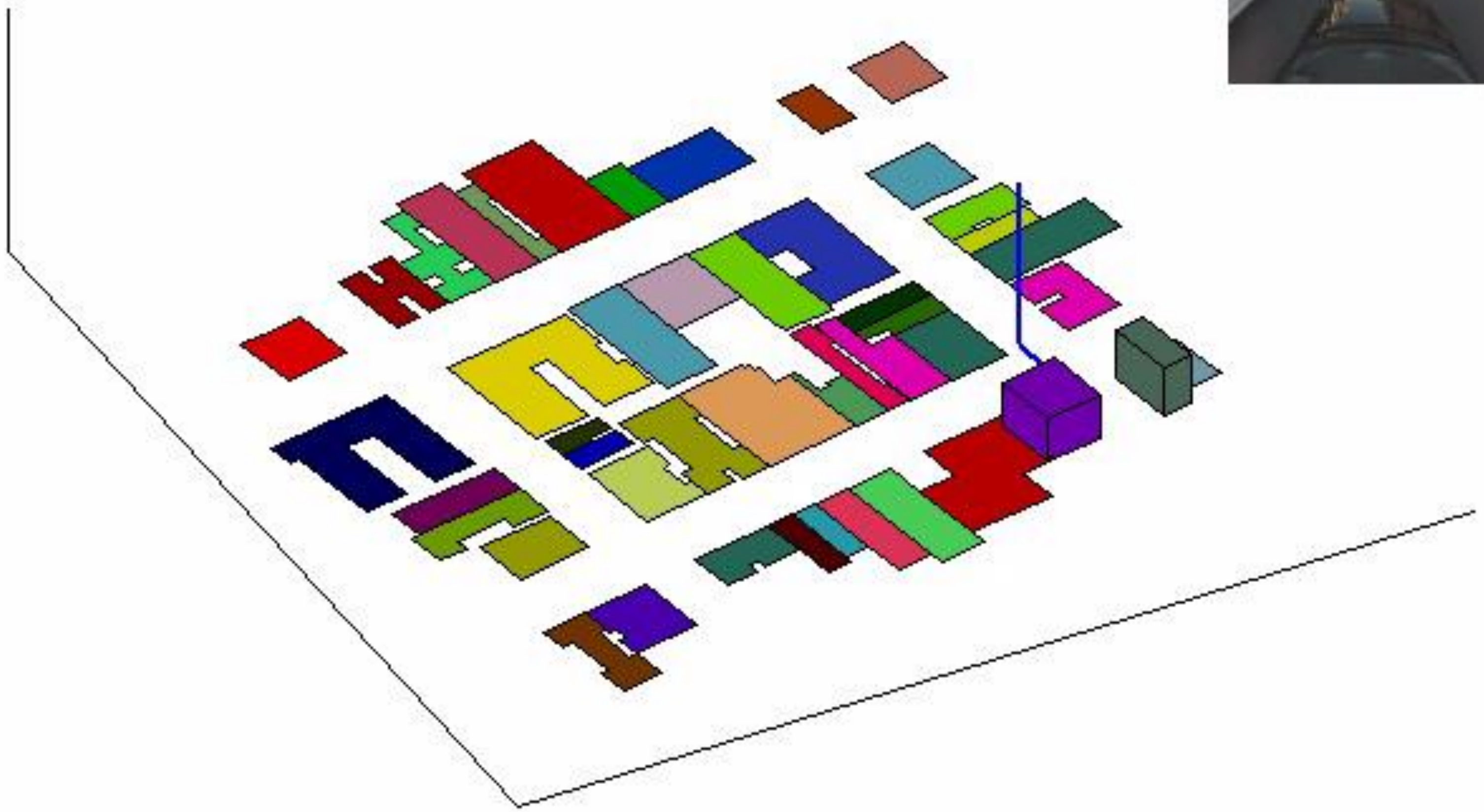
Automatic Building Footprint Extraction

Algorithm: Deep Learning extended and using GPUs for fast building footprint and area extraction over large geographical areas.

Multi-company Competition Precision/Recall – 30/35; Current Precision/Recall – 60+/60+

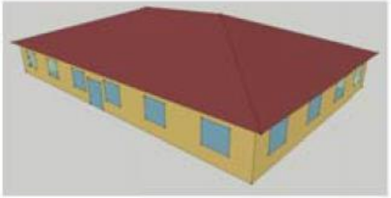
Processing Street-Level Imagery – Jiangye Yuan

3D Building Model Generation

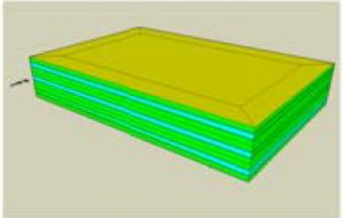


Prototype Buildings

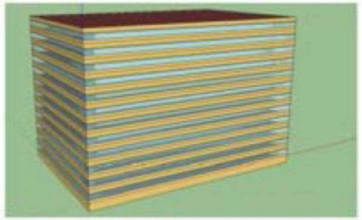
Small Office



Medium Office

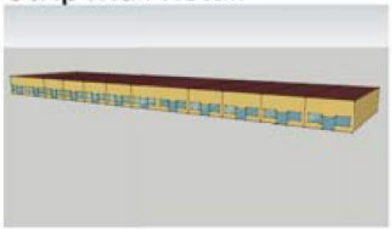


Large Office

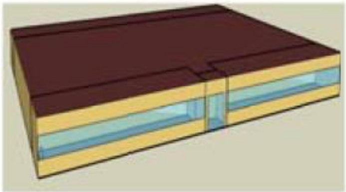


Warehouse

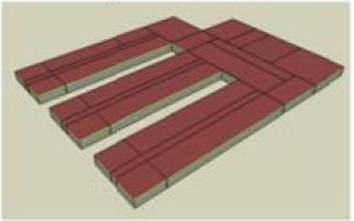
Strip Mall Retail



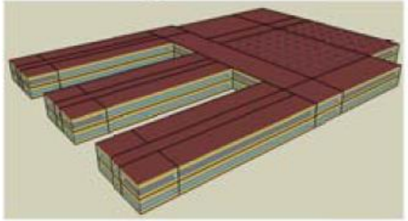
Standalone Retail



Primary School

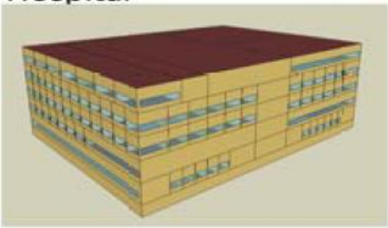


Secondary School

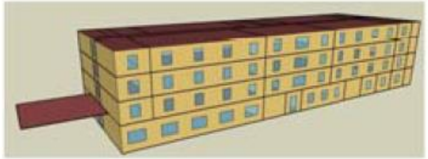


Outpatient Healthcare

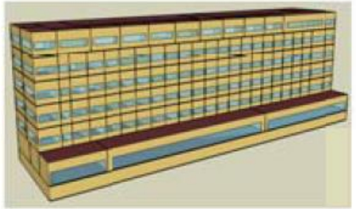
Hospital



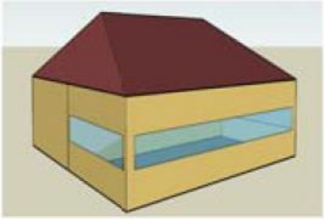
Small Hotel



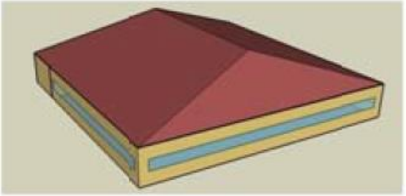
Large Hotel



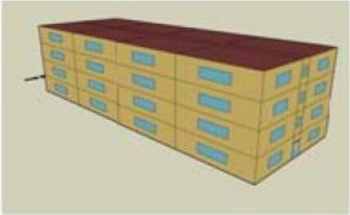
Quick-service Restaurant



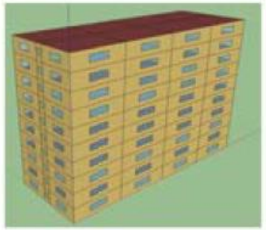
Full-service Restaurant



Mid-rise Apartment

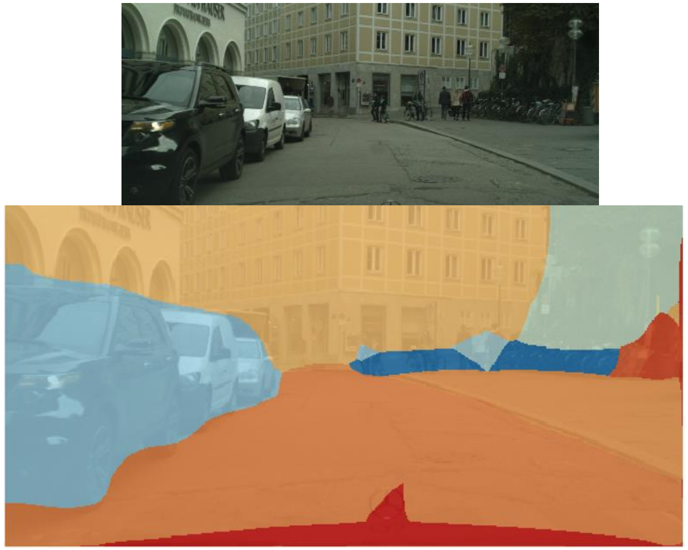


High-rise Apartment

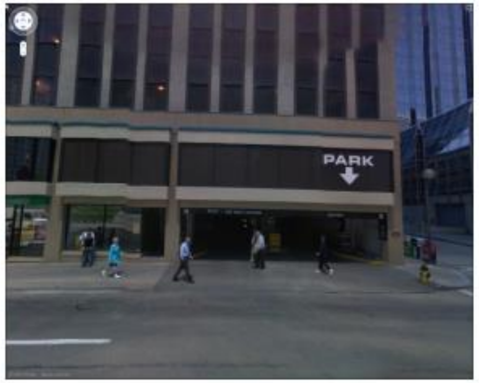


Street-level imagery (Lexie Yang)

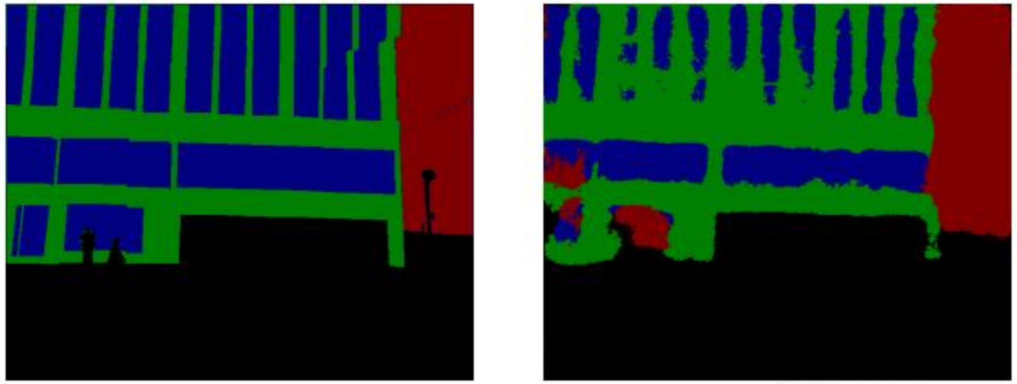
Façade Type



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

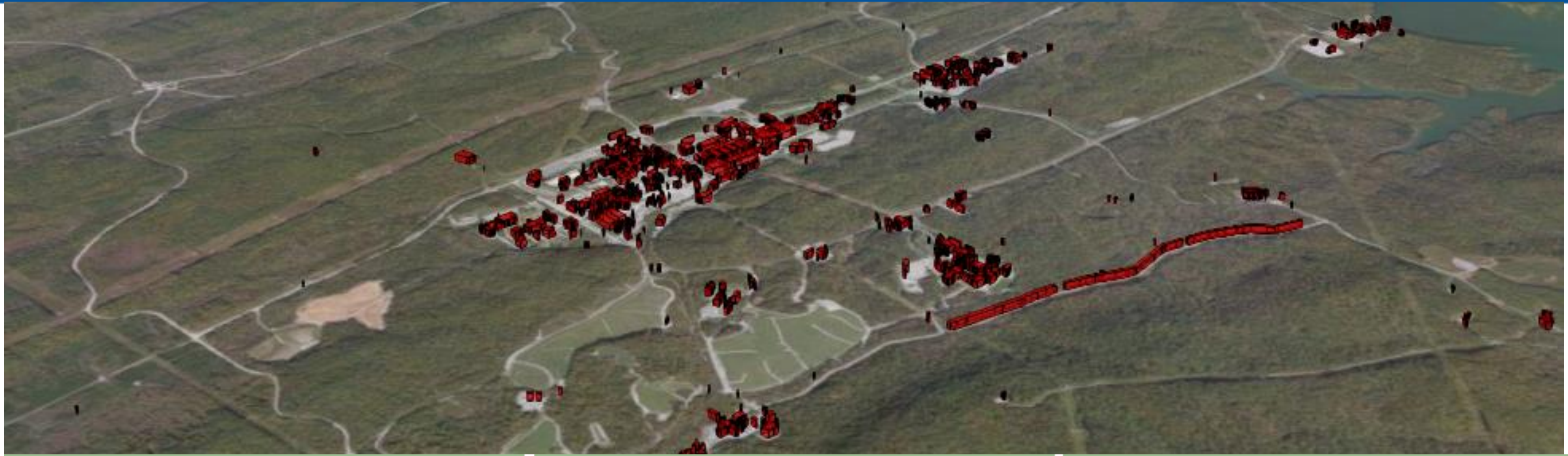


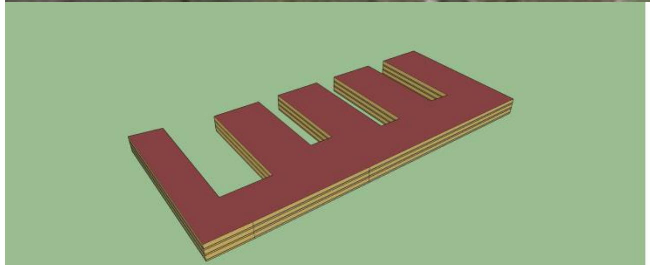
Window-to-wall ratio



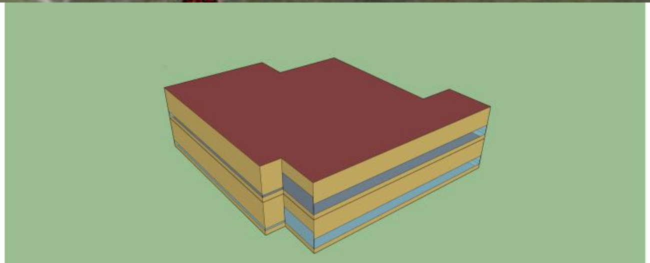
Input image Ground truth Model output

Oak Ridge National Laboratory

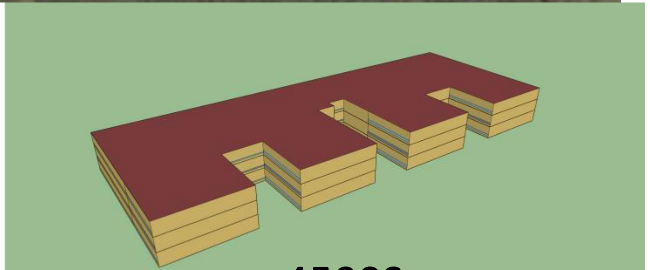




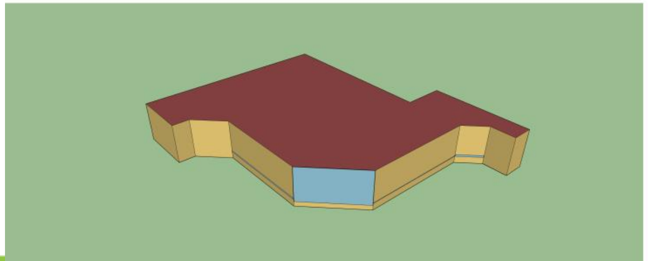
4500N



4020



4500S



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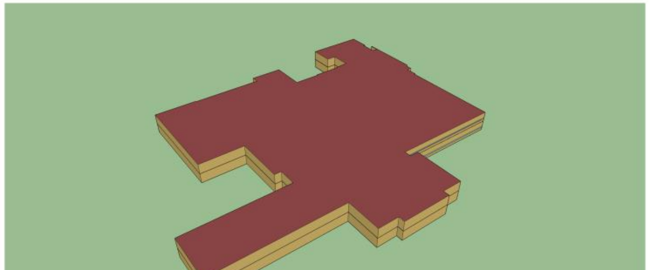
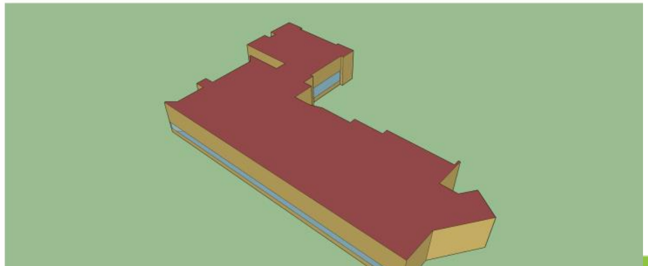


6000



6008

Oak Ridge National Laboratory (interactive)

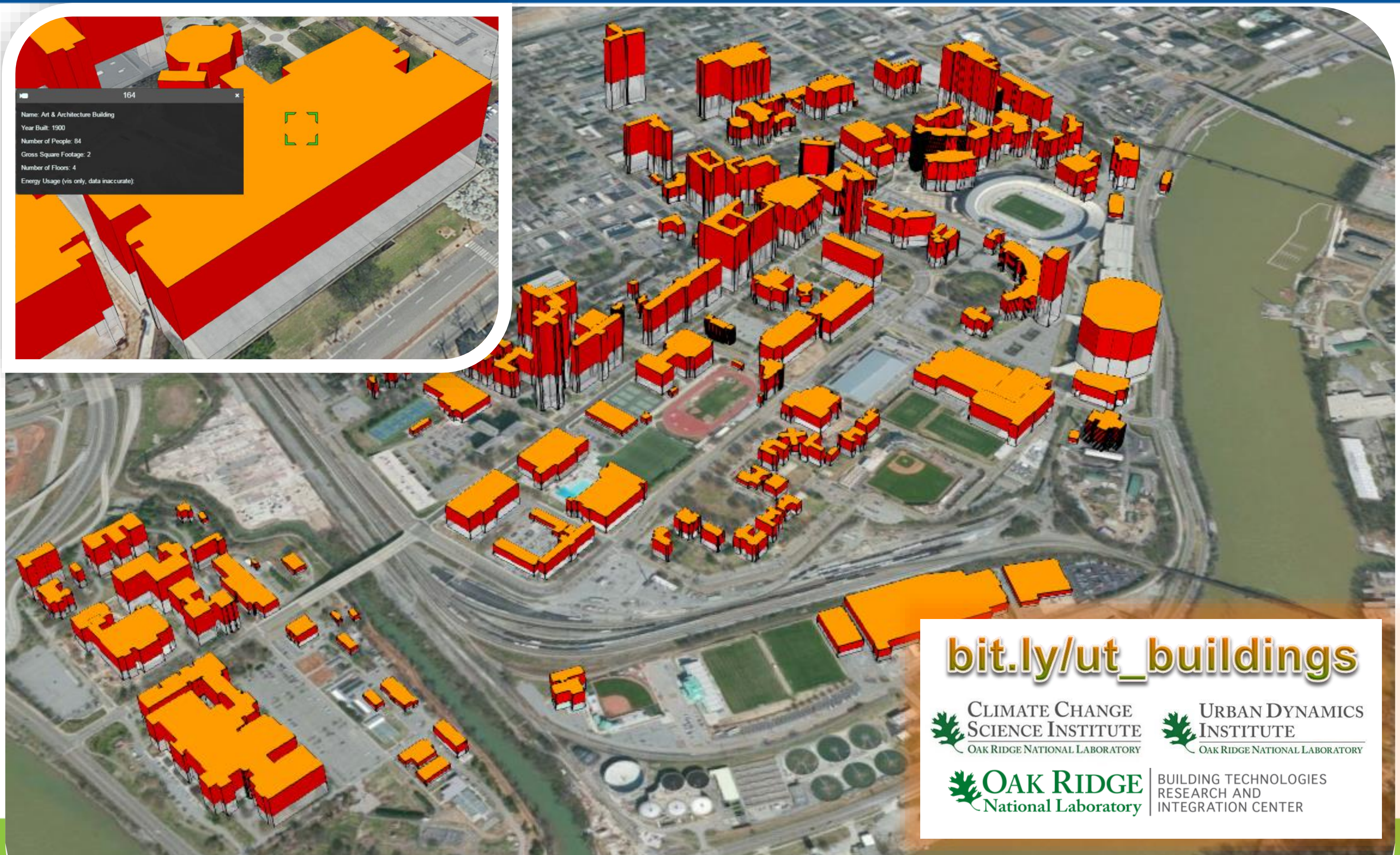
bit.ly/ornl_buildings

Climate Change Science Institute
Oak Ridge National Laboratory

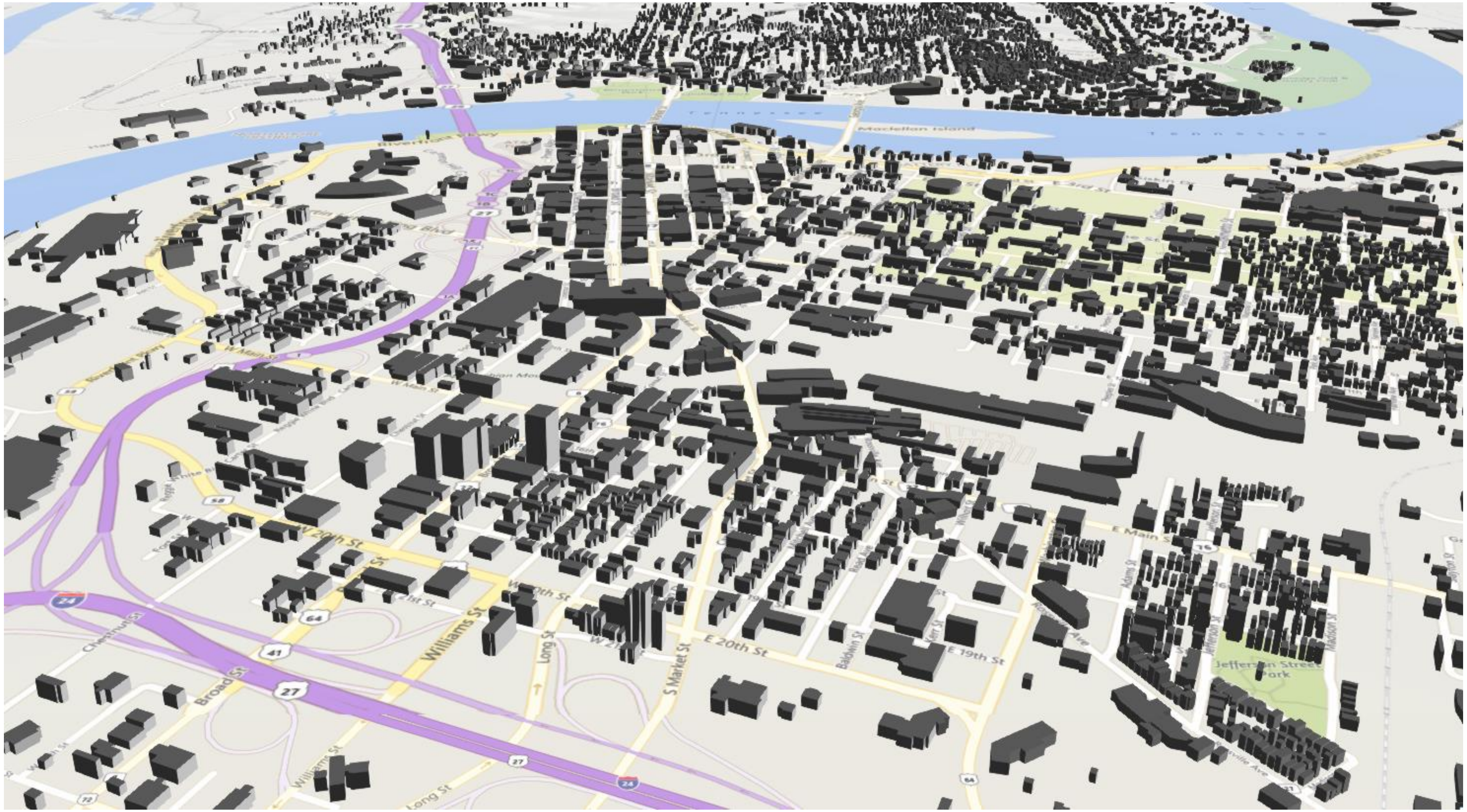
Urban Dynamics Institute
Oak Ridge National Laboratory

Oak Ridge National Laboratory
Building Technologies Research and Integration Center

The University of Tennessee (2 days)



Chattanooga, TN (100,000+ buildings)



The AutoBEM technology "axe"

135,481 building models have been created and matched to EPB's PremiseID

Limitations: limited building types, not calibrated, will improve quarterly

QA/QC: will show how close our simulations are to 15-min data

2.3 million EnergyPlus building energy models using AutoBEM technology, Titan, cloud, and local servers to produce and analyze 13 TB of simulation data.

1. Generate baseline building – OpenStudio (1.5-3h Amazon, 30h internal)
2. Run ECM measures – OS Measure (30 mins AWS, 2h internal), Custom (1m AWS, 5m intl.)
3. Copy data to Titan – 1 min (1.2GB tar.gz)
4. Submit to Titan – 0-2 hours in queue
5. EnergyPlus simulation time – 30-45 mins (5mins/sim = 1.4 years to simulate EPB on 1 core)
6. Data transfer – 40 mins (160GB tar.gz)
7. Uncompress – 10-15 mins
8. Reformat data – 20-30 mins
9. Analysis – 5-10 mins

Time for creation, annual simulation, and analyzing "all" EPB buildings

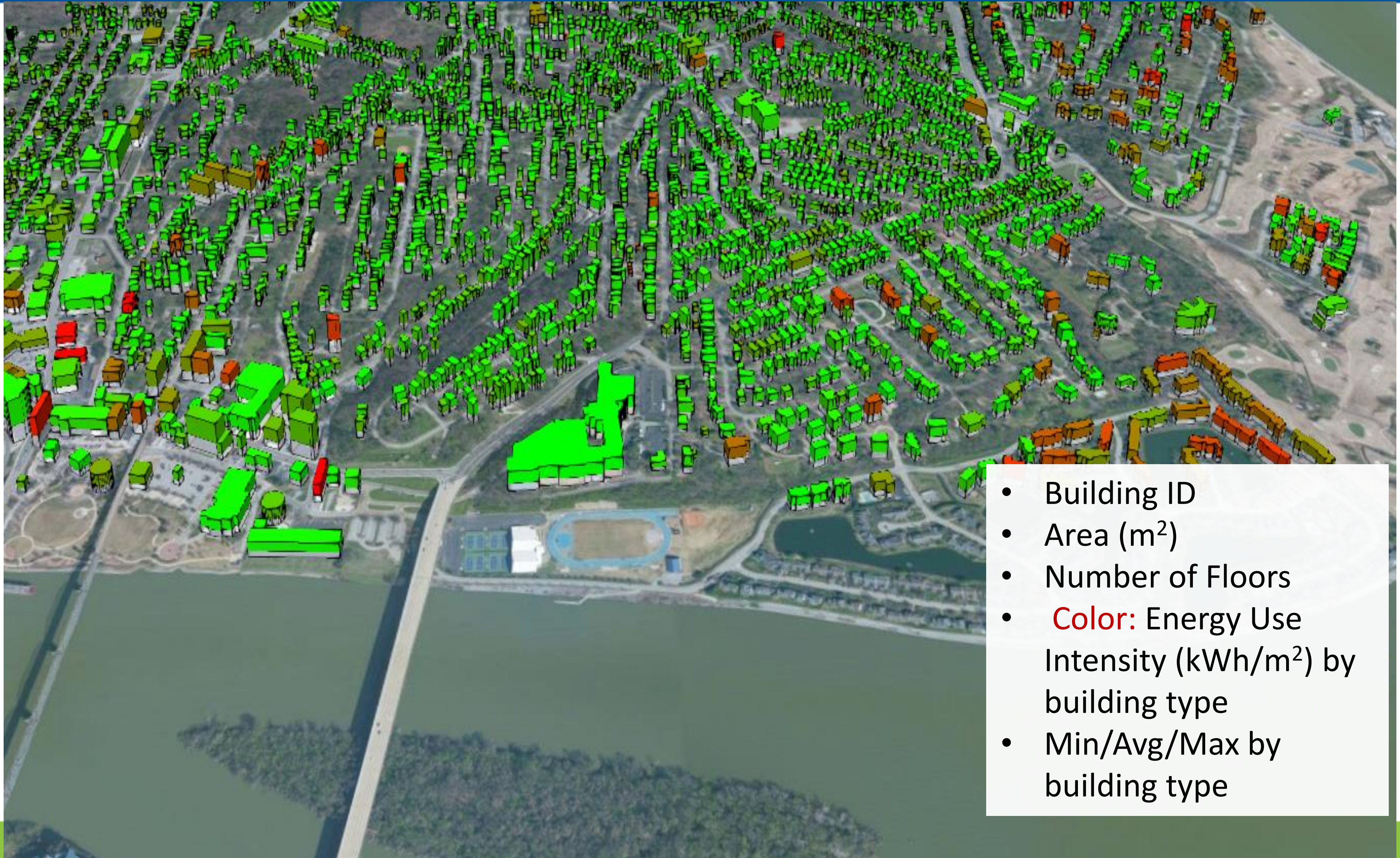
6.5 hours (6.1h –36.5h)

Use Case - Scenarios

- ***Preliminary*** building-specific estimates of energy, demand, and cost savings totaling **$11-$35 million per year** based on 9 scenarios prioritized by EPB.

1. **Peak Rate Structure**
    1. Scenario #1a, Peak contributions for each building
    2. Scenario #1b, Cost difference, in terms of dollars per year, for all building
2. **Demand Side Management**
    1. Scenario #2a, Monthly peak demand savings, annual energy savings, and dollar savings based on rate structure for all buildings.
    2. Scenario #2b, Location-specific deferral of infrastructure cost savings potential
3. **Emissions**
    1. Scenario #3a, Emissions footprints for each building
4. **Energy Efficiency**
    1. Scenario #4a, Optimal retrofit list of independent ECMs
    2. Scenario #4b, Optimal retrofit package of dependent ECMs
5. **Customer Education**
    1. Scenario #5a, Percentile ranking of each building's EUI by building type and vintage
    2. Scenario #5b, Monthly peak demand savings, annual energy savings, and dollar savings based on rate structure for all buildings compared to AMY weather file scenario.

1a – Peak contribution percentile by type



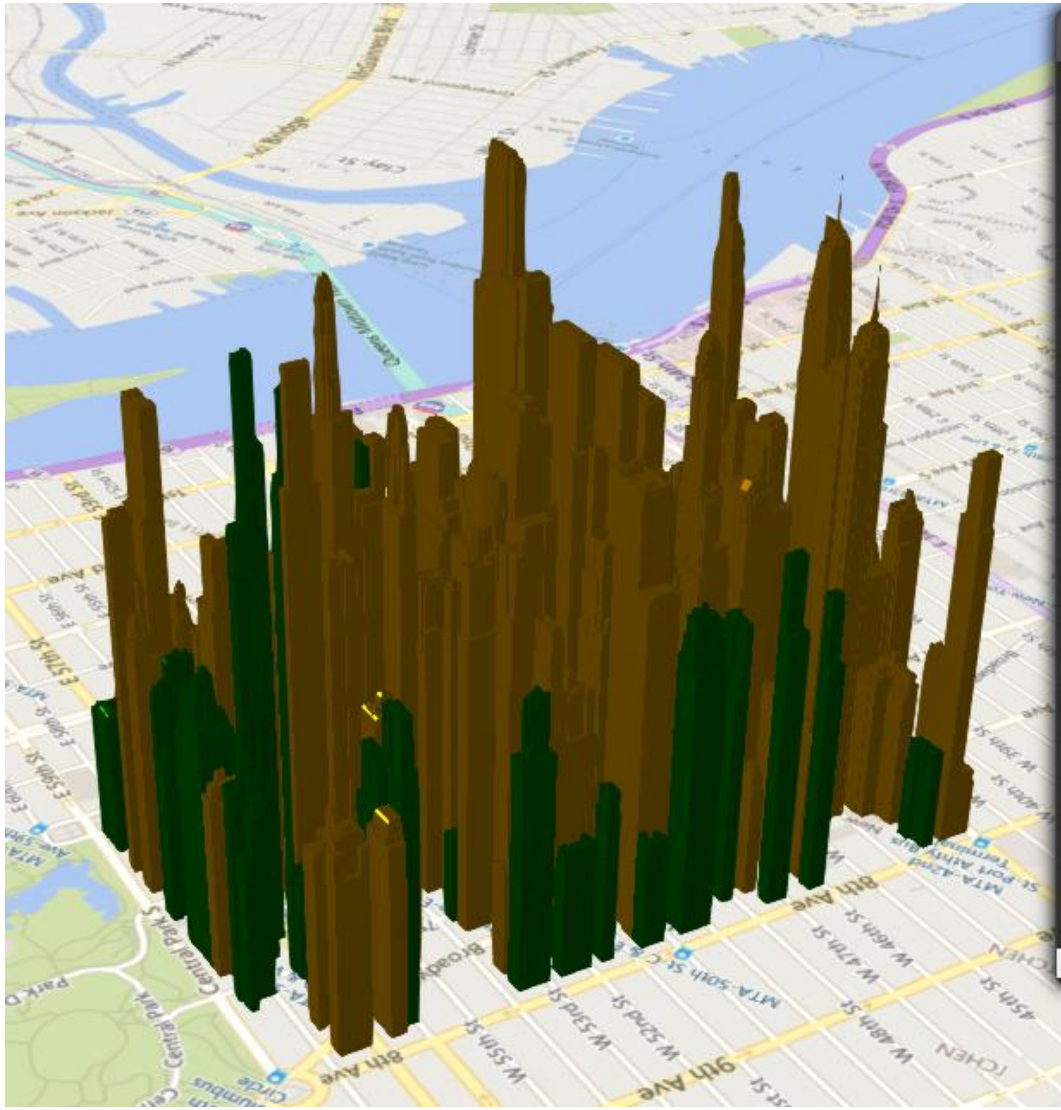
- Building ID
- Area (m^2)
- Number of Floors
- Color: Energy Use Intensity (kWh/m^2) by building type
- Min/Avg/Max by building type

Virtual EPB – interactive results

60246

ID	60246
DOE Building Type	SmallOffice
Num Floors	3
Percentile	87.70 %
Estimated wholesale vs retail cost	$ 9797.07
CO2 emissions	222052.32 lbs/year
Smart Thermostat - 4F cost savings	$ 1316.61
Smart Thermostat - 8F cost savings	$ 2325.84
TMY->AMY Smart Thermostat - 4F cost savings	$ 204.99
TMY->AMY Smart Thermostat - 8F cost savings	$ 103.41
HVAC Efficiency ECM	$ 1291.79
Gas HVAC ECM	$ 4276.69
Gas Water Heater ECM	$ 725.58
Heat Pump Water Heater ECM	$ 476.95
Insulation ECM	$ 736.27
Infiltration ECM	$ 1577.50
Lighting ECM	$ 2898.95

Virtual NYC – interactive results



Bldg_12210017046

ECM	Annual Electricity/Savings	Jan Demand/Savings	Feb Demand/Sa
Baseline	41282530.14 kWh	8463.14 kW	8426.13 kW
Change Elec Base COP	0.09 kWh	155.27 kW	3232.78 kW
Change Lighting Power Density	2796916.23 kWh	975.65 kW	3597.39 kW
Change Roof Insulation	688072.96 kWh	267.15 kW	3348.45 kW
Change to Elec Water Heater	-24140.75 kWh	152.50 kW	3230.01 kW
Change to Gas Water Heater	0.09 kWh	155.27 kW	3232.78 kW
Change Space Infiltration	411236.67 kWh	176.59 kW	3436.11 kW
Smart Thermostat 4 Degree	14573.47 kWh	155.27 kW	4155.11 kW

Virtual NYC – interactive results

Savings across 152 buildings

E=energy (MWh), D=demand (kW), [min,avg,max]

1. **Smart thermostat 2.2C (4F) pre-condition**
   E=[-72, 1.4, 525] D=[-938, 918, 13907]
2. **Natural gas water heater (80% efficient)**
   E=[0, 0, 0] D=[0, 772, 13907]
3. **Heat pump water heater (COP 2.2)**
   E=[-184, -16.4, -2] D=[-30, 768, 13853]
4. **HVAC Efficiency (COP$_H$ 3.55 and COP$_C$ 3.3)**
   E=[0, 0,0] D=[0, 772, 13908]
5. **Lighting Efficiency (0.85 W/ft^2)**
   E=[77, 784, 6757] D=[23, 999, 14410]
6. **Infiltration (reduce 25%)**
   E=[40, 774, 4648] D=[-0.8, 840, 14020]
7. **Insulation (R16.12 to R28.57)**
   E=[12, 204, 1600] D=[1.9, 817, 13928]

building_id	Elec_savings (kWh)	Jan (kW)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12210000247	-25559.37	5852.94	4309.38	5366.97	6592.65	4262.77	870.72	457.84	431.46	2406.69	6587.84	6630.63	6242.57
12210000469	-721.30	25.08	89.07	156.48	6.73	26.60	168.46	150.48	4.51	7.44	6.22	6.39	12.52
12210000518	-2701.65	7.76	1762.35	3394.86	22.85	550.36	2560.03	2263.61	2697.12	709.85	75.10	74.33	0.00
12210000994	-8481.05	1055.41	905.72	990.42	1474.41	848.47	196.65	194.14	3.66	548.06	1276.96	1252.69	887.56
12210001156	-5736.16	1196.35	1000.11	1101.04	1673.10	954.47	222.70	215.54	216.98	671.15	1469.96	1418.45	973.81
12210001197	546.94	77.19	407.63	1004.80	8.67	143.51	888.66	830.73	901.23	227.86	8.38	69.38	0.00
12210001252	-42452.78	7440.43	5315.70	6722.96	8265.02	6113.35	511.76	625.95	1.15	4142.70	8232.69	7282.54	6572.38
12210001490	-905.68	8.48	39.99	177.69	8.06	30.01	16.00	155.19	158.46	81.12	3.35	0.64	3.88
12210002001	-16751.35	2353.22	1774.32	2166.91	3481.47	2139.86	229.42	419.27	3.45	1610.13	3238.90	2776.87	1857.80
12210002031	-1226.89	1.96	145.84	444.87	-0.66	9.45	-496.24	63.75	116.22	-111.25	10.52	49.65	0.00
12210002047	-692.42	22.52	99.76	370.75	9.39	64.11	347.40	349.46	382.89	179.84	11.41	3.25	0.00
12210002150	30.35	60.50	255.99	806.49	3.48	66.73	812.78	689.28	5.88	147.68	3.96	77.14	0.00
12210002629	-3701.09	882.04	839.96	797.77	1059.83	717.52	153.35	140.93	1.94	482.84	970.80	1050.46	741.97
12210003200	-28557.61	2563.00	2406.68	2510.02	2962.48	2202.89	357.32	419.56	410.43	1519.44	2886.95	3028.13	2298.47
12210003292	-1583.51	4.30	1311.22	2826.54	9.47	448.83	2200.25	1916.39	2278.23	611.96	56.75	85.90	0.00
12210003302	-5519.82	119.63	2140.16	4235.07	33.48	608.39	2922.95	2597.64	2876.36	866.10	103.19	9.61	0.00
12210003314	-5708.34	4.91	2444.18	3982.02	0.71	264.42	1733.69	315.91	49.63	393.20	12.85	158.36	0.00
12210003317	-3372.72	111.52	510.91	1173.94	9.19	255.62	1086.71	950.19	1091.03	408.28	31.76	9.90	0.00
12210003333	-1604.88	1.96	84.76	221.98	5.28	6.44	21.88	212.90	20.55	82.06	2.34	5.21	0.15
12210003346	-2131.77	5.41	1474.50	3019.75	11.03	474.57	2247.52	1996.23	2414.45	577.55	42.52	74.95	0.00
12210003350	-891.15	54.48	119.26	163.76	6.54	16.33	187.35	170.99	3.96	9.51	5.52	7.50	9.59
12210003354	-17125.51	4898.93	4556.63	4387.42	5461.75	3512.42	38.73	682.57	661.52	2552.29	5508.01	5809.67	4086.09
12210003361	-1214.74	9.77	58.91	210.65	0.63	6.87	-5.49	191.78	204.65	97.66	2.19	1.29	0.45
12210003379	759.09	63.94	308.85	797.63	4.71	97.05	791.79	701.29	669.47	6.47	4.73	63.31	0.00
12210003383	2626.09	118.49	681.87	1367.29	25.09	224.15	1207.86	1043.81	2.29	341.70	64.43	95.22	0.00
12210003661	-42.89	7.47	88.91	223.08	6.93	15.57	232.71	212.10	5.81	1.05	10.39	4.12	0.09
12210003791	-676.58	1.83	108.79	273.89	4.62	-0.71	266.11	11.88	10.69	51.54	12.46	30.17	0.21
12210004115	2116.15	22.16	265.01	744.60	3.08	96.42	759.76	510.54	57.95	57.73	6.83	49.82	0.00
12210004205	1070.38	82.79	545.31	1222.73	3.25	160.14	1072.99	873.94	14.49	48.06	8.56	99.29	0.00
12210004223	380.10	38.15	95.93	354.41	15.05	76.17	337.95	319.08	361.81	192.99	36.14	1.04	0.00
12210004406	-2142.06	123.81	557.33	1385.46	15.95	278.12	1199.00	1104.96	1282.00	403.57	12.01	11.16	0.00

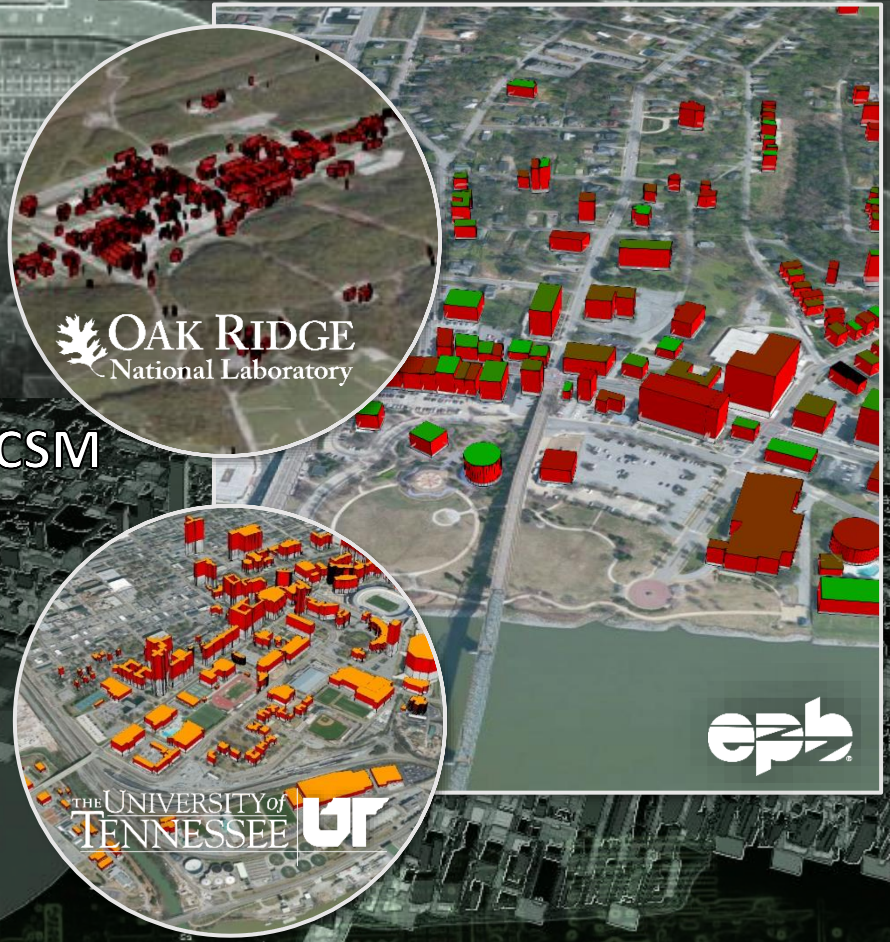
Discussion

HPC Tools for
Modeling and Simulation
Capturing building energy consumption

Ahmed Hussein
Center for Sustainable Energy Technology
Univ. of Applied Sciences
Stuttgart, Schellingstrabe, Germany

Joshua New, Ph.D., CEM, PMP, CMVP, CSM
BTRIC, Software Tools & Models
Oak Ridge National Laboratory

newjr@ornl.gov



Hussein, Ahmed, M.Sc., B.Sc.

Career

- 2017- Center for Sustainable Energy Technology - zafh.net
  - Urban development and planning research group, institute of applied research. Urban modeling and simulation with innovative district heating/cooling
  - Active contribution to Annex 70 collaborative network and the H2020 Eu-funded project of FLEXYNETS
- 2016-2017 The Cooperative University of Mannheim
  - Electrochemical hydrogen compression and separation
  - Studying the degradation of PEM-fuel cell components in automotive applications and e-mobility
- 2013-2014 The German Aerospace Center
  - Innovative thermal management of HT-PEM fuel cell stacks in automotive applications
- 2012-2013 MT-Energie GmbH and Hinneburg GmbH
  - Anaerobic digestion of biodegradable wastes for sustainable biogas production
  - Development of patented biological reactors for the production of biohydrogen

Education

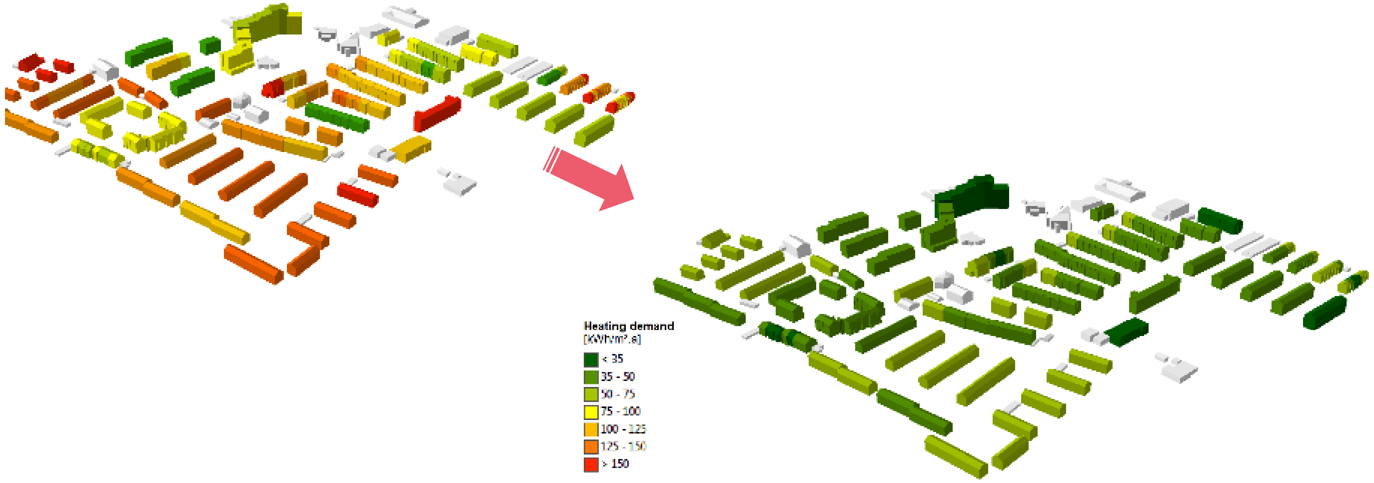
- The University of Applied Sciences Offenburg, Germany, (2011-2014), M.Sc. Energy Conversion and Management
- Alexandria University, Egypt, (2005-2010), B.Sc. Mechanical Engineering

Professional Involvement

- SAE active member
- Active reviewer for more than 10 journals, e.g. Energy and Buildings, JUEE, etc.
- Part-time ocean life and climate conservationist (Project AWARE foundation, Coral Reef Alliance, World Wildlife Federation WWF)

SimStadt – 3D Urban Energy Simulation Platform

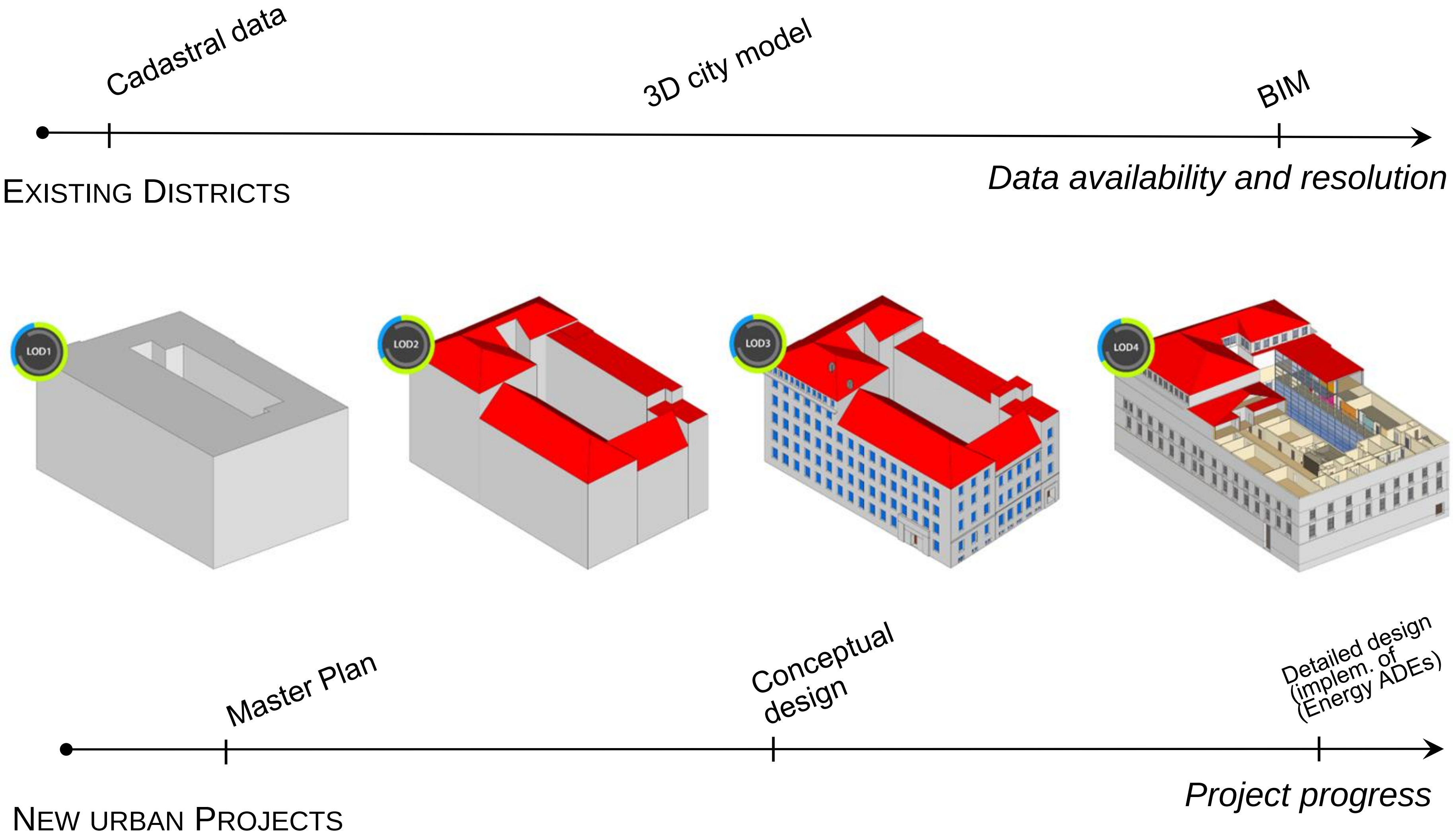
- Designed to serve city planners, engineering bureaus and energy suppliers
- Based on the open standard format of CityGML with <u>modular features</u>
- Capable of performing photovoltaic/solar potential analysis, heat demand/environmental analysis with/without refurbishment strategy and district heating network analysis for city districts, whole cities and regions
- Extensible to include future planning and operation scenarios



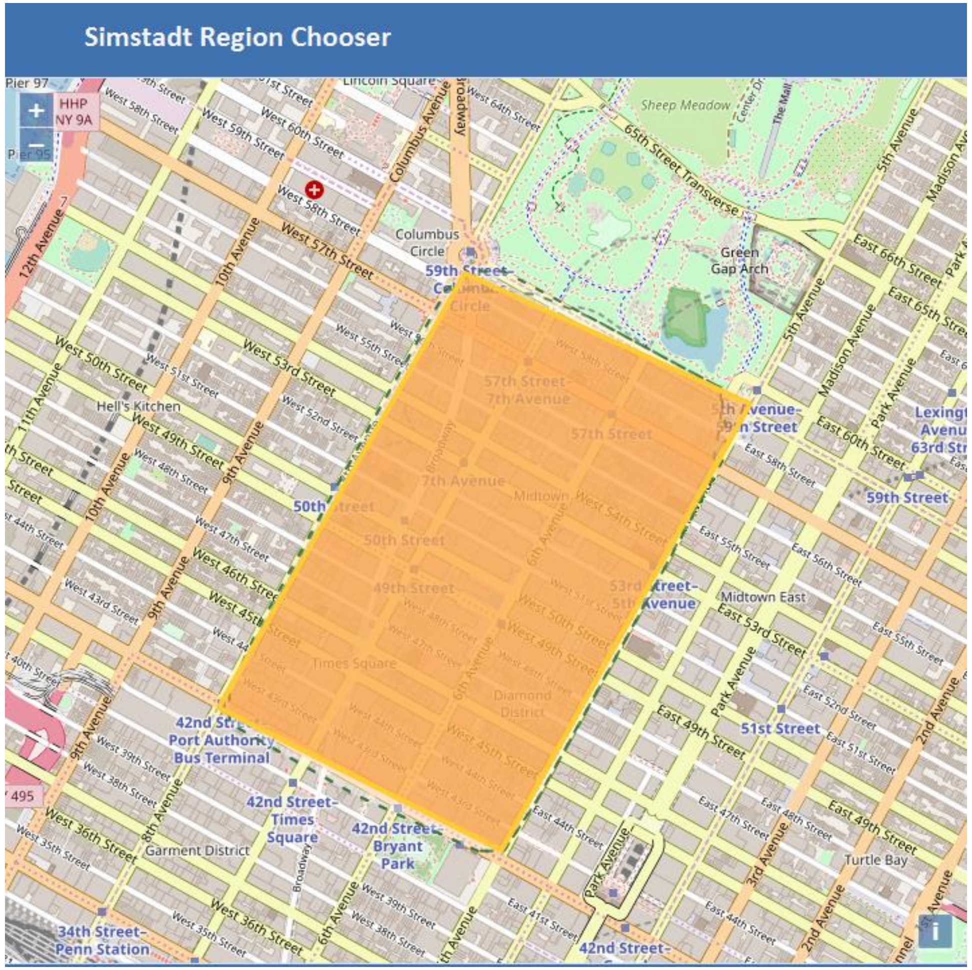
Heat Demand Calculation and Visualization

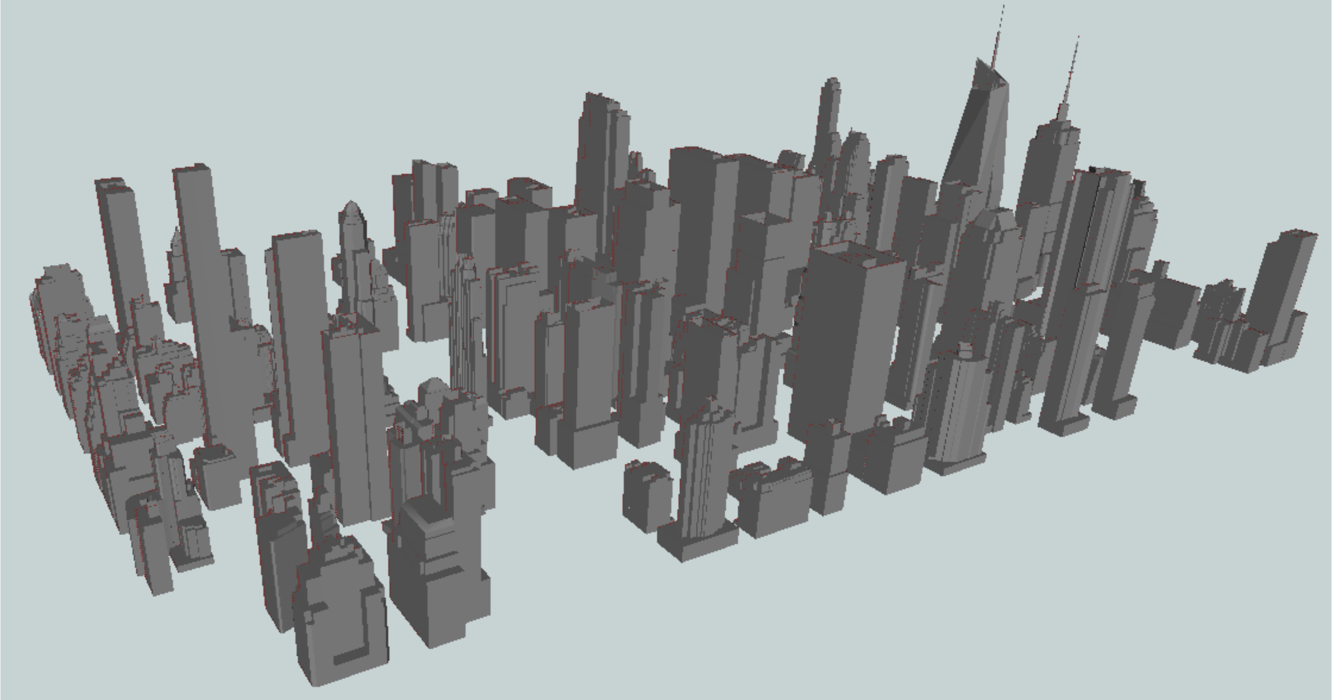
- Monthly energy balance according to DIN V 18599 (ISO 13790)
- Low data requirements: 3D city model, building age and building function
- Results: heat demand and energy reference area per building / city district, heat density map etc.

Levels of Detail in Virtual 3D City Models

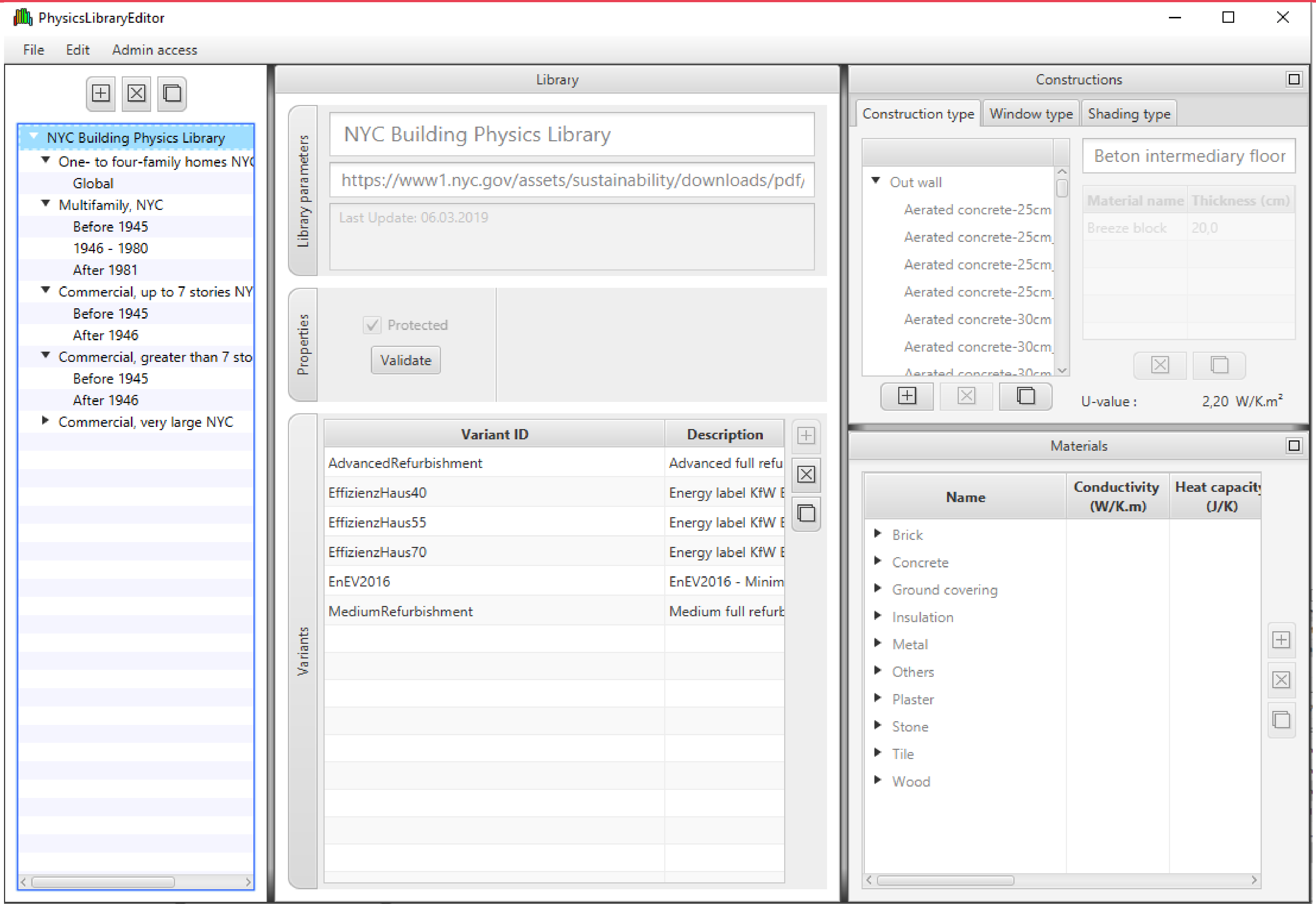


Region Chooser Tool for CityGML files’ Export

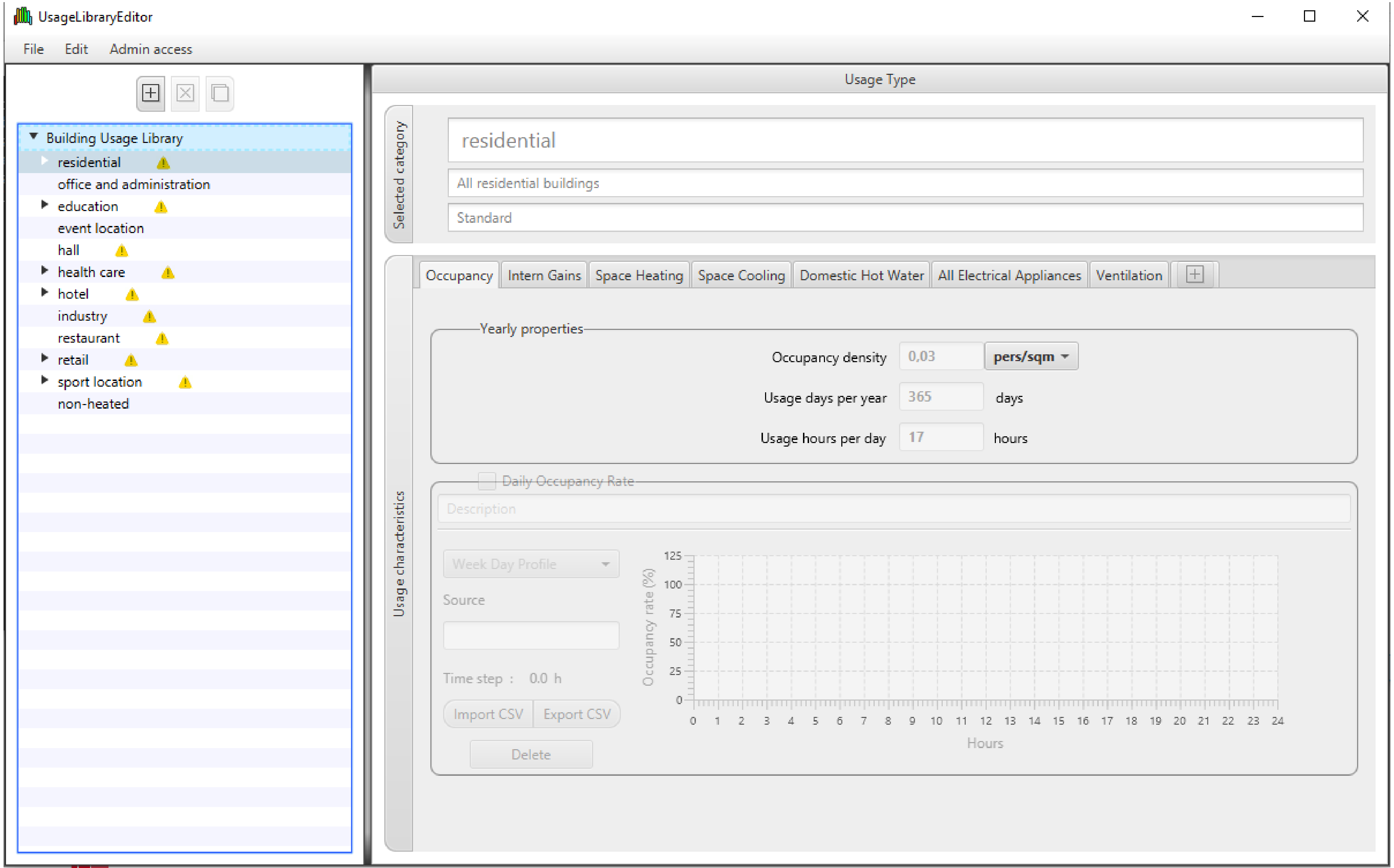




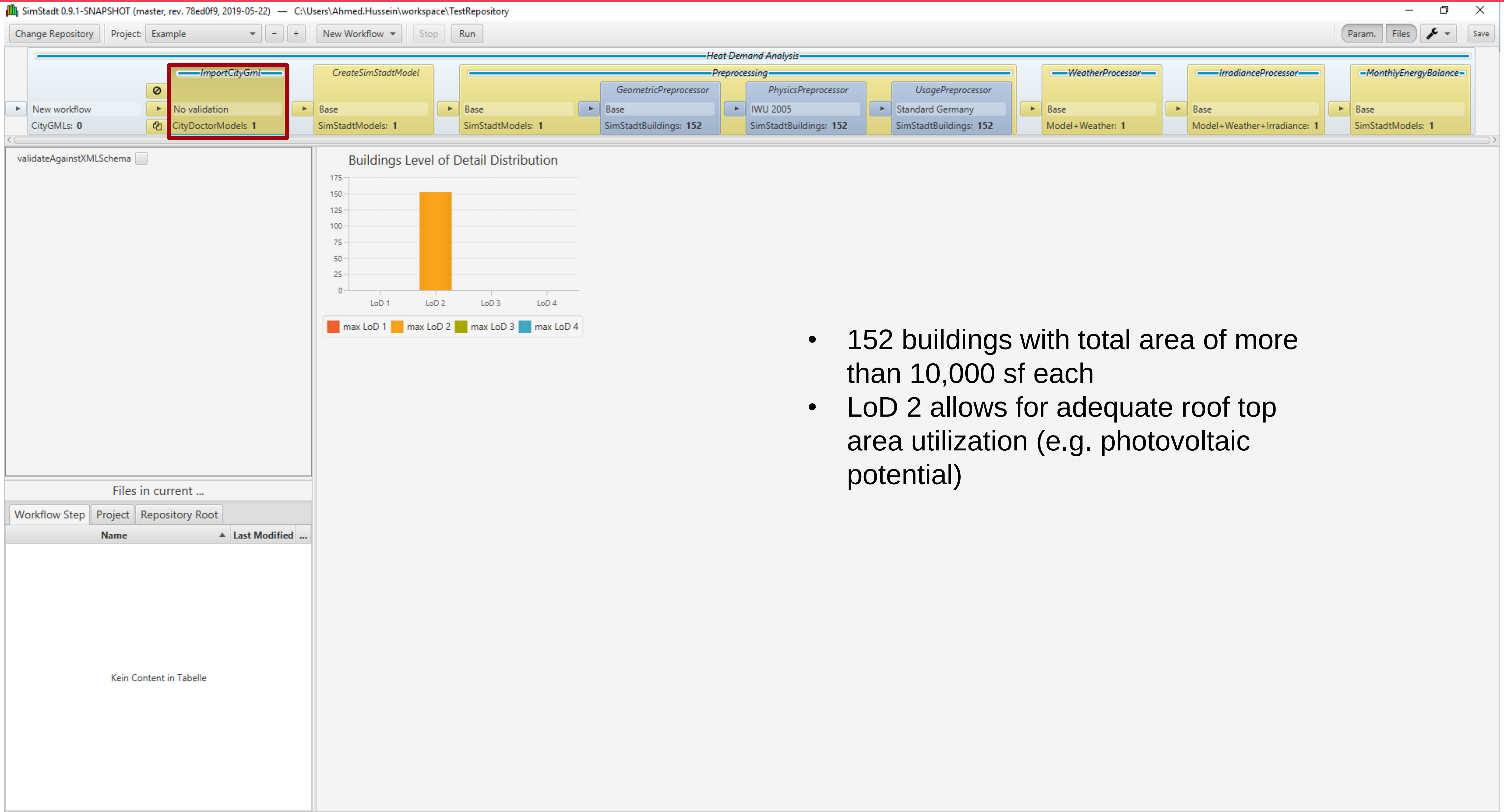
Assigning Building Physics Library



Assigning Usage Library

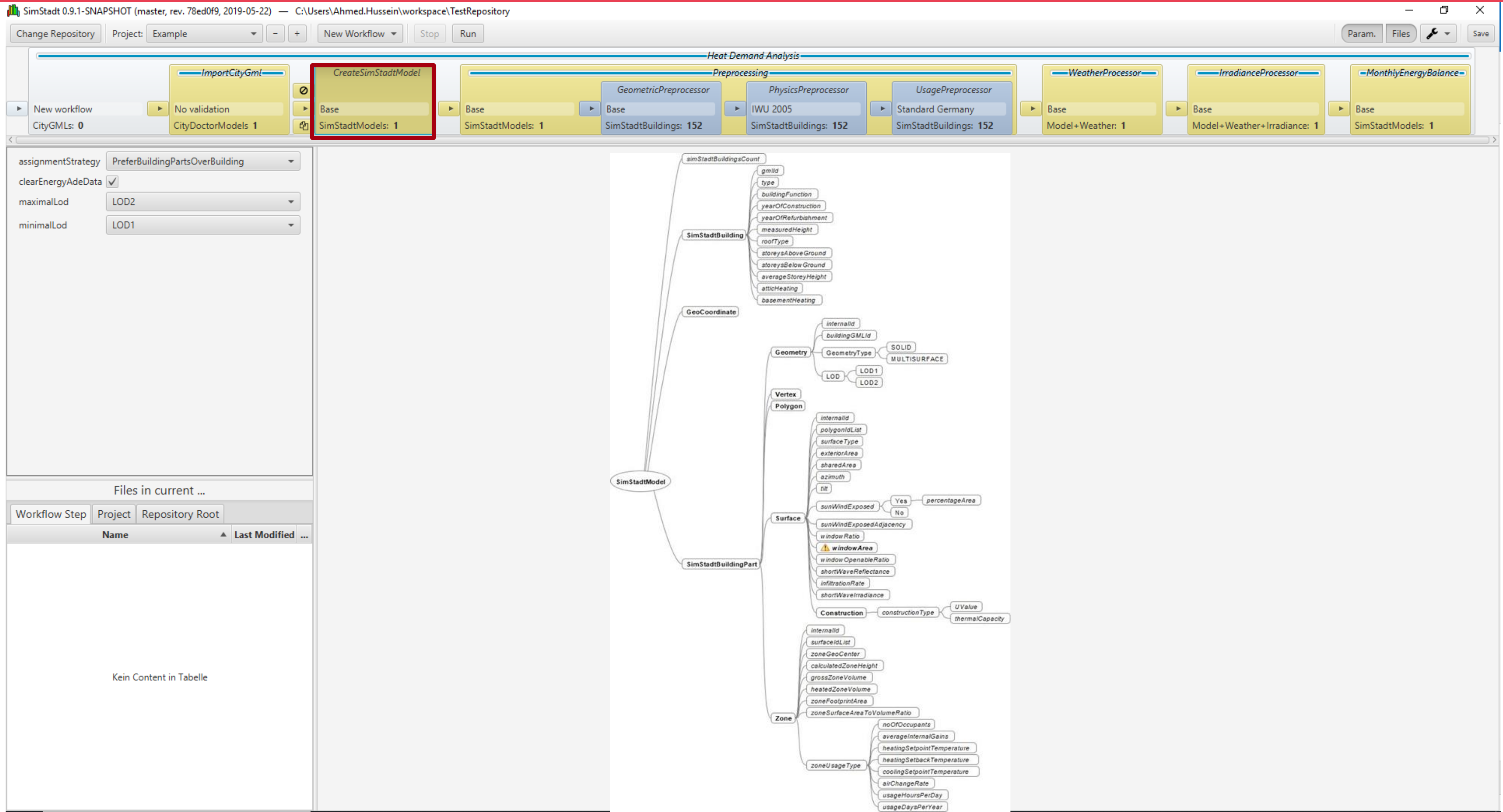


Analyzing the GML File

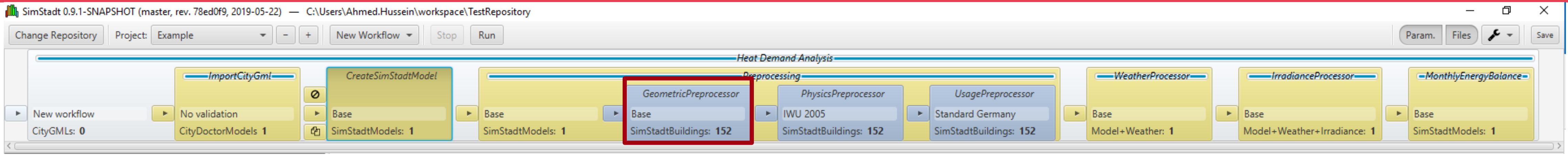


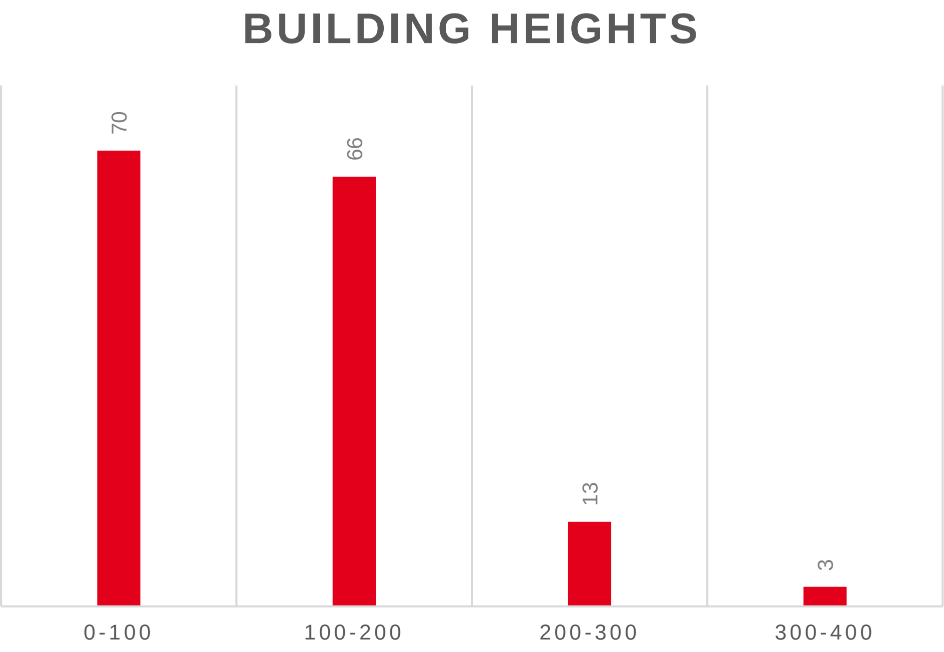
- 152 buildings with total area of more than 10,000 sf each
- LoD 2 allows for adequate roof top area utilization (e.g. photovoltaic potential)

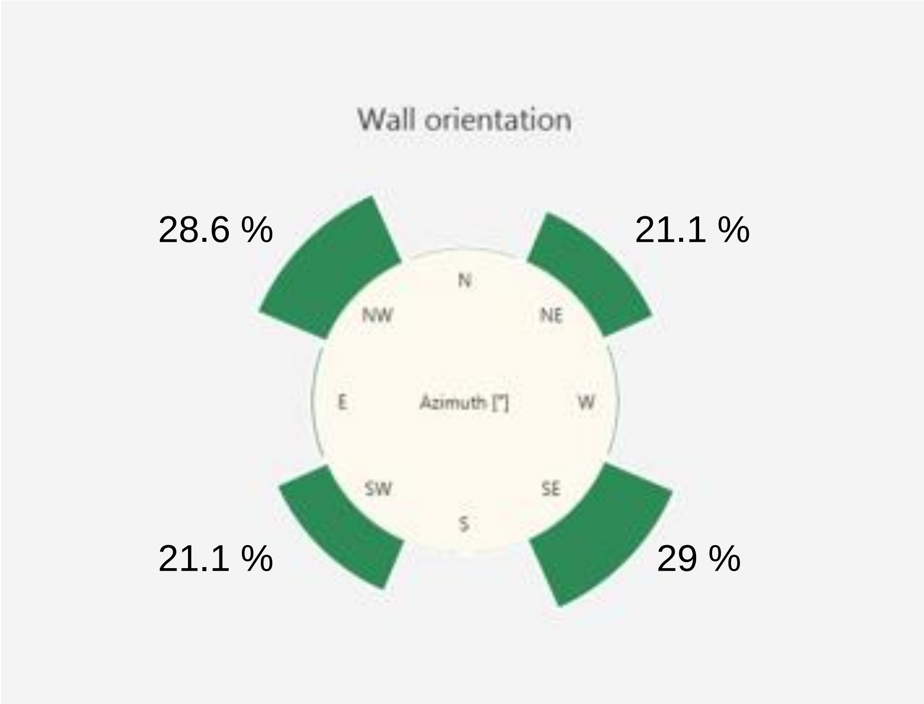
Creating the SimStadt Model



Geometric Preprocessing

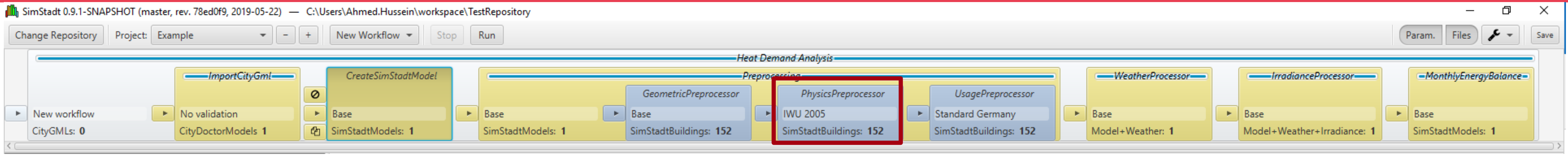


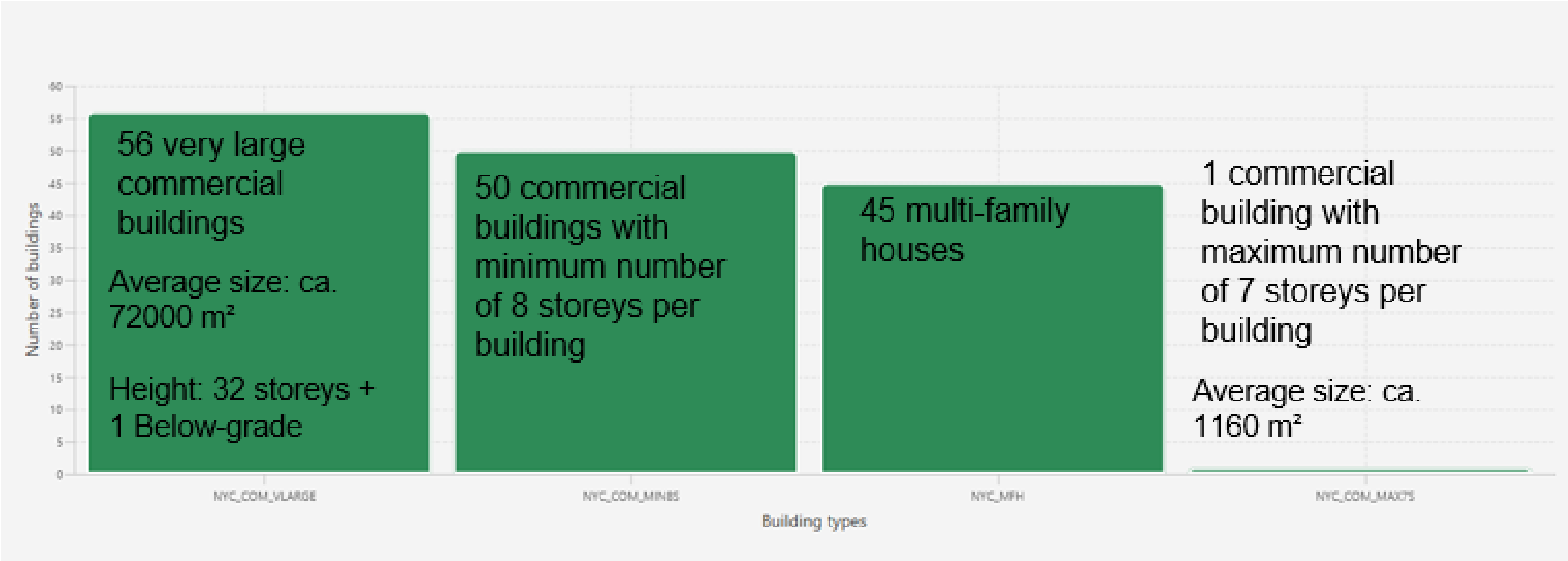




- 46 % of building heights range from 0-100 m and 43 % range from 100-200 m

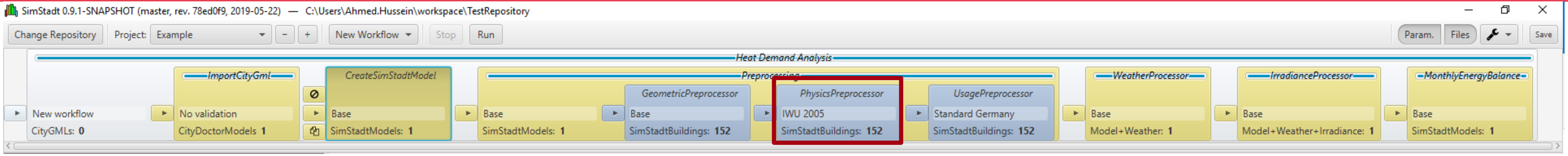
Building Physics Preprocessing

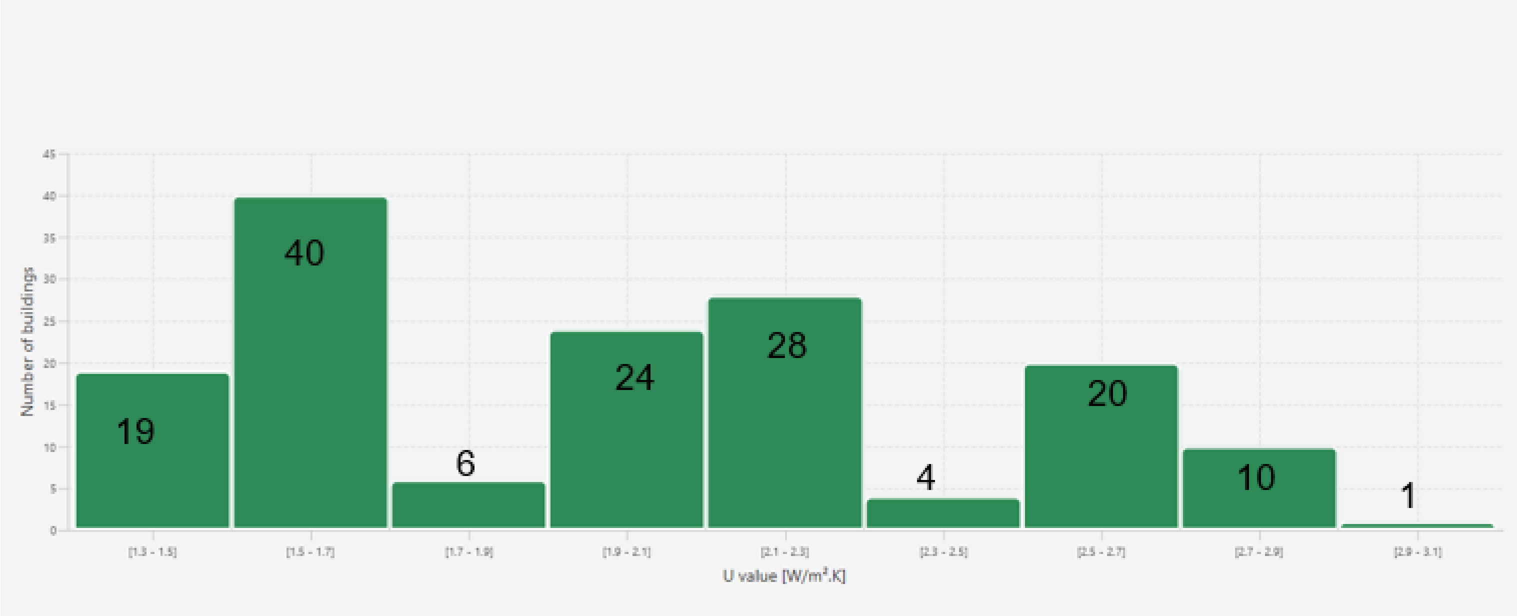




- 31 % of buildings were built between 1920-1940
- 24 % of buildings were built between 1960-1980
- 18 % of buildings were built between 1980-2000

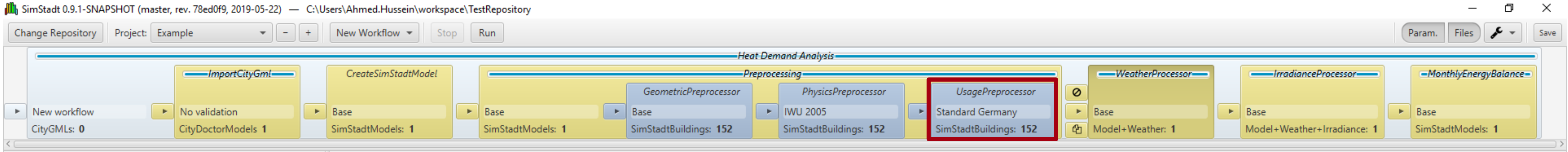
Building Physics Preprocessing – Building U-value

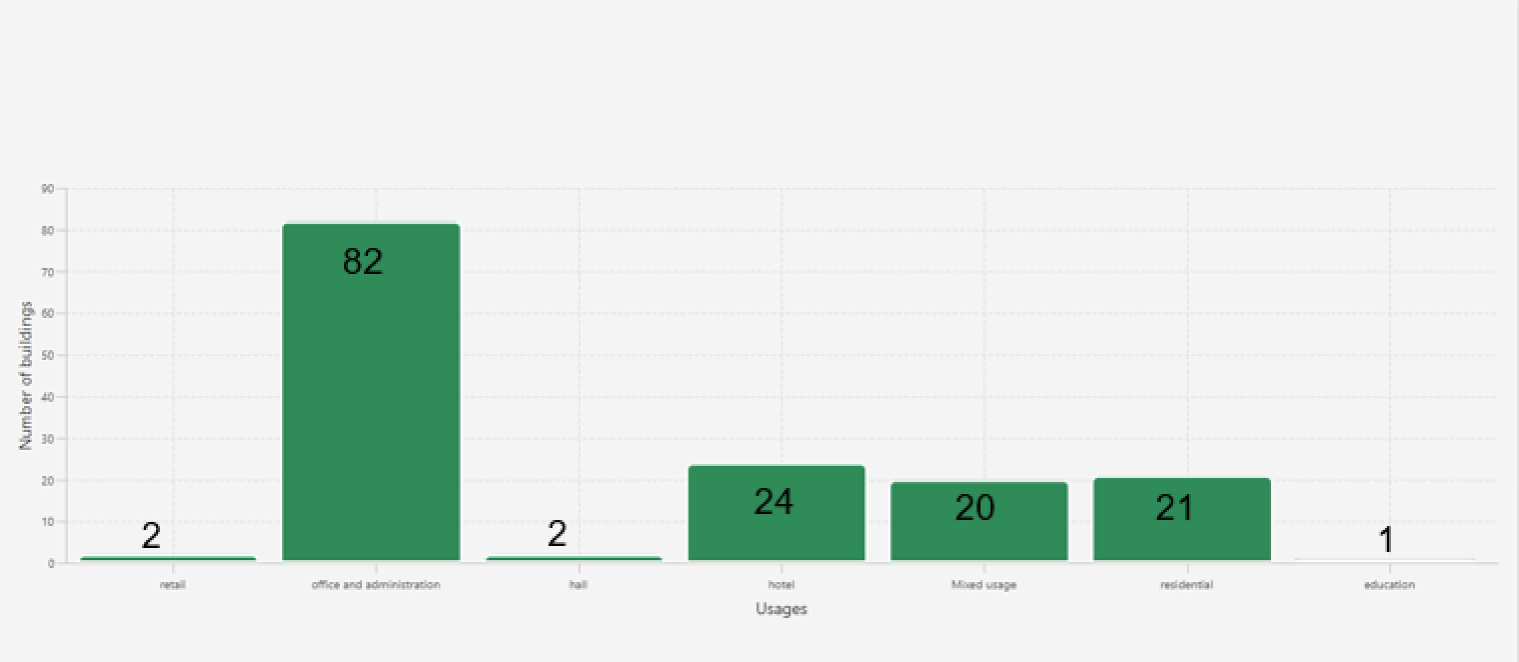




- 34 % of buildings have a U-value higher than or equal 1.9 W/m².K

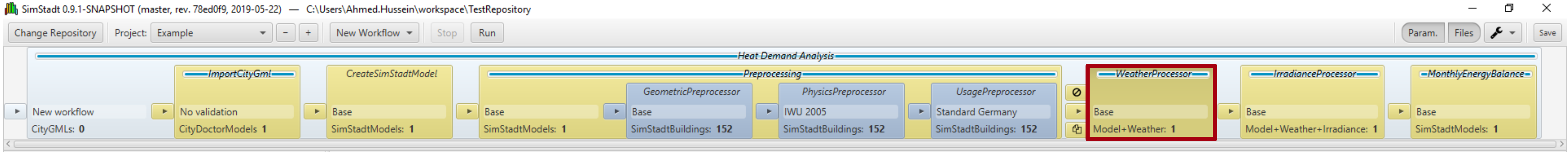
Usage Preprocessing

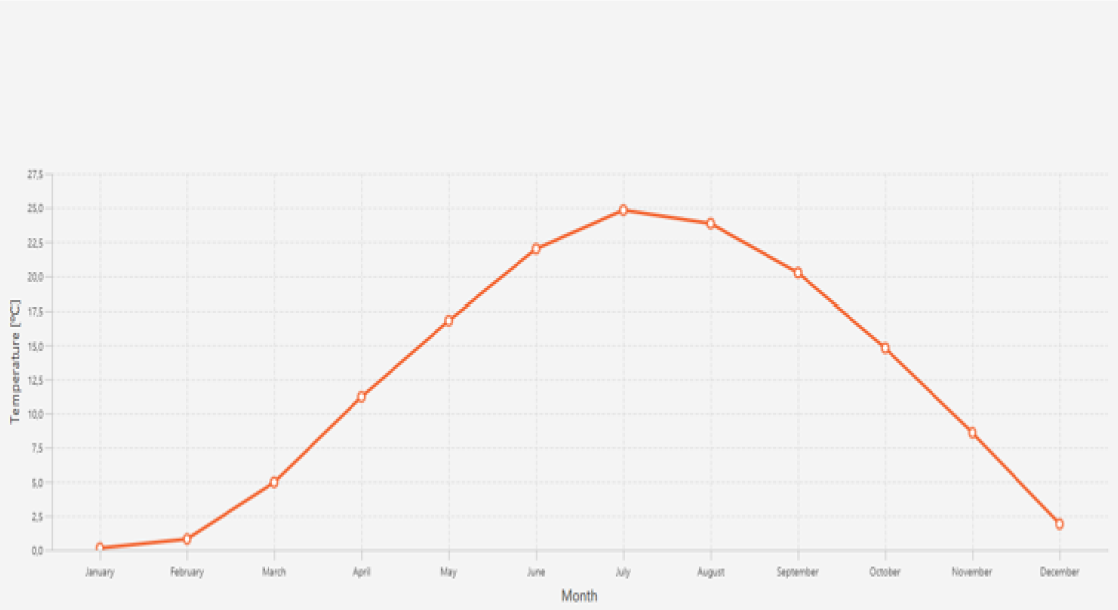


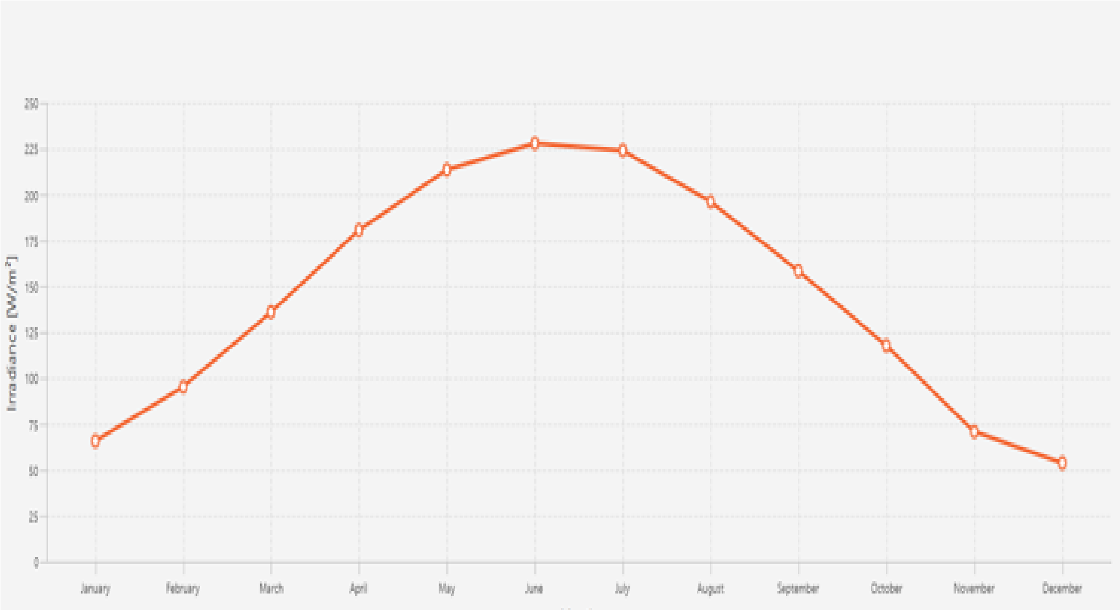


- 54 % of buildings are office and administration buildings

Weather Processing



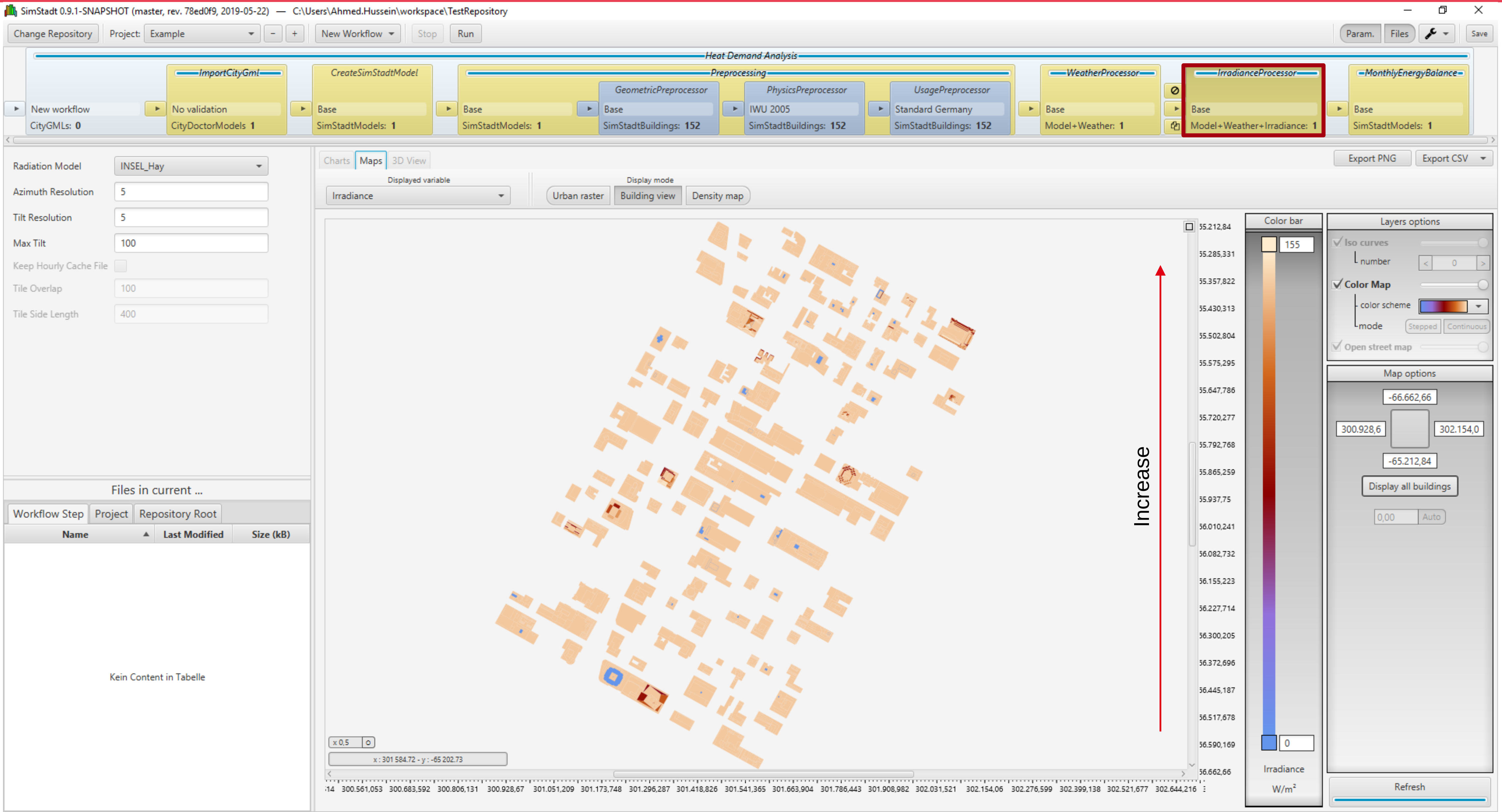




Maximum temperature recorded on July @ 25 °C

Maximum irradiance recorded on June @ 225 W/m²

Irradiance Processing



Hochschule für Technik Stuttgart

Monthly Energy Balance - Heating

- Color: Specific annual energy consumption (kWh/m².a)

Increase

Photovoltaic Potential

- Total PV potential yield = 16.89 GWh/a

Comparison

Software		
	SimStadt	**AutoBEM**
Data used for simulation	3D CityGML XML-based data developed with LiDAR remote sensing	3D CityGML XML-based data developed with LiDAR remote sensing
Simulation time	Average 1 min. per 150 buildings. Also depending on how much attributes are being processed	Average 7 mins. And 47 secs per building
Energy Balance Assessment	DIN V 18599-10 within integrative approach using average monthly climate data and air temperature dependency with regressive interrelation	The standard used was determined from "YearBuilt" and sorted into one of 6 categories: DOE-Ref-Pre-1980 DOE-Ref-1980-2004 90.1-2004 90.1-2007 90.1-2010 90.1-2013
Source of building usages and year of construction	PLUTO data dictionary provided by the Department of City Planning (DCP)	PLUTO data dictionary provided by the Department of City Planning (DCP)
Source of weather data	INSEL weather database (Hourly interpolated values from a database with long term monthly average values for the air temperature TMY3)	TMY2 of NYC
Source of building types	One City Built to Last, technical working group report developed by the city of New York	< 50,000 sf is small > 50,000 sf, < 3 floors is med > 3 floors, is large If res. > comm., high rise apart.

ECMs		
	SimStadt	**AutoBEM**
Increase roof insulation by 50 % in very large commercial buildings	Reduction on annual heat consumption by 2.4 %	Total savings of 1.3 % (average demand saving across 12 months: 25.4 %), from 0.034-0.065 depending on roof type
LPD reduction by 25 % in office and administration buildings	Reduction on annual heat consumption by 3 %	Total savings of 6.1 % (average demand savings across 12 months: 19.6 %)
Increasing cooling setpoint temperature by 6 K in residential buildings plus reducing infiltration losses by 60 % in residential buildings	Annual heat demand reduction by 12 % and annual cool demand reduction by 63 %	
ONLY reducing infiltration losses by 60 % in residential buildings		Total savings of 13.1 % (average demand savings across 12 months: 24 %)