Seminar 57 – Multiscale Building Energy Modeling

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Building Modeling and District System Optimization at Scale

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Learning Objectives

- Provide an overview of Urban Building Energy Model (UBEM) techniques and data sources

- Describe the use of regional building modeling as a forecasting tool

- Demonstrate the ability of 3D mapping techniques to provide wide-area geometrical information over urban and foliated scenes with evaluation of critical infrastructure (e.g. power line damage and flooding)

- Describe an approach for community-scale modeling using detailed whole-building energy models with use cases for district system optimization

Acknowledgements

Outline/Agenda

- Background

- Major Features

- Implementation and User Interface

- Demonstration Projects

- Conclusion

Background

SMPL Tool
(**S**ystem **M**aster **PL**anning Tool)

NZP / **N**et **Z**ero **P**lanner

⟷

District Zero

US Army Corps of Engineers
Construction Engineering Research Laboratory

Big Ladder Software LLC

US Department of Defense

Everyone else!
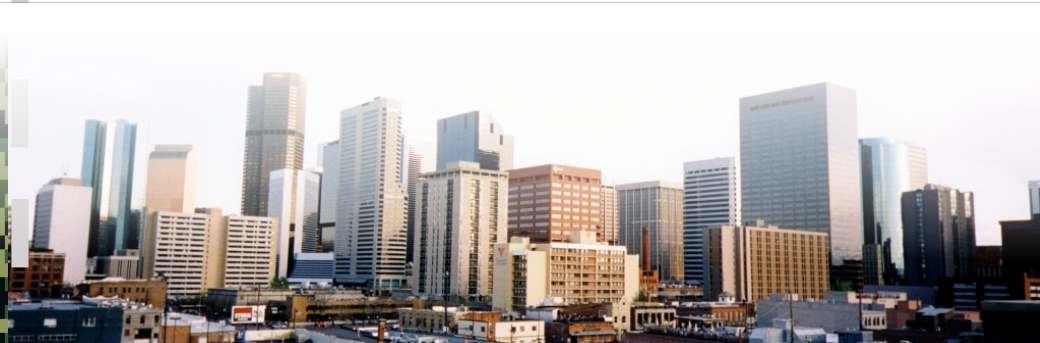
Background

- Funded by DoD: 2011 – 2016
- Energy master planning
  - Army energy managers
  - Used on 60+ DoD installations
- Army bases and installations
  - 10,000 – 50,000 residents
  - Sparse building density
  - Standardized building designs
- Collaborative R+D: 2017 –

Federal Energy Drivers

- EPAct 2005
  - 30% site energy vs. ASHRAE 90.1-2004

- EISA 2007
  - By 2010: 55% source energy
  - By 2020: 80% source energy
  - By 2030: net zero energy

- 2017 –
  - Resiliency, security, reliability

Major Features

Detailed Prototype Modeling
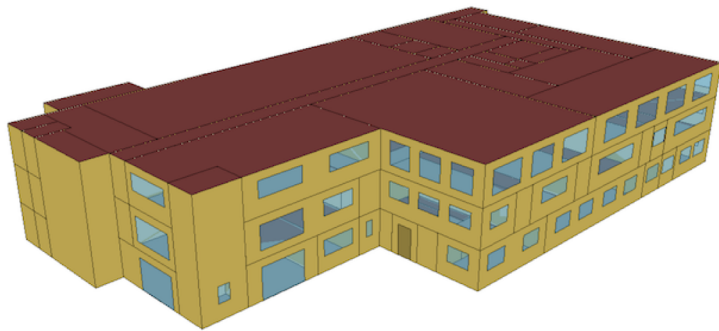
District/Cluster Optimization

Energy + Water + Waste
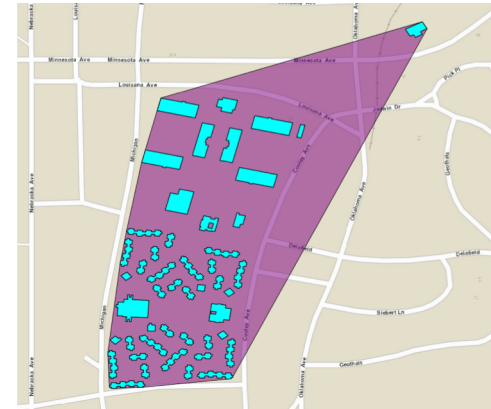
Multi-Criteria Decision Analysis
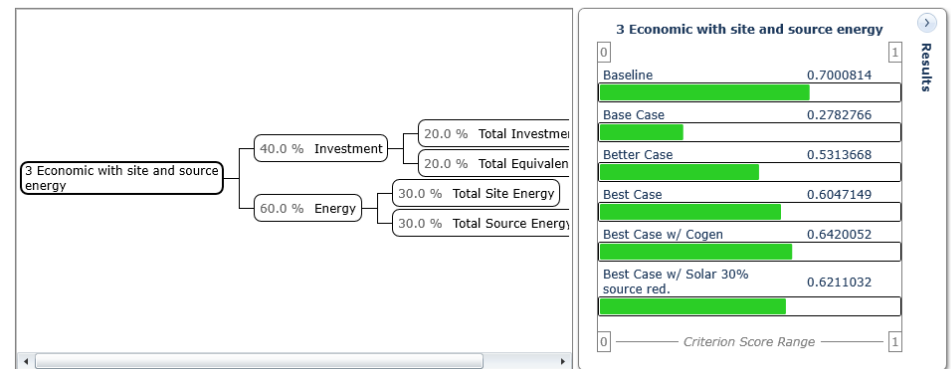
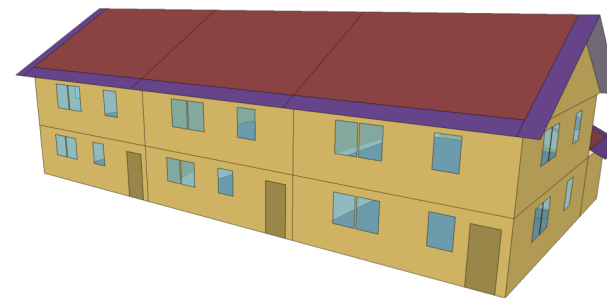# Software Architecture

GIS View of Facilities

Table View of Facilities

Commercial Prototype Models
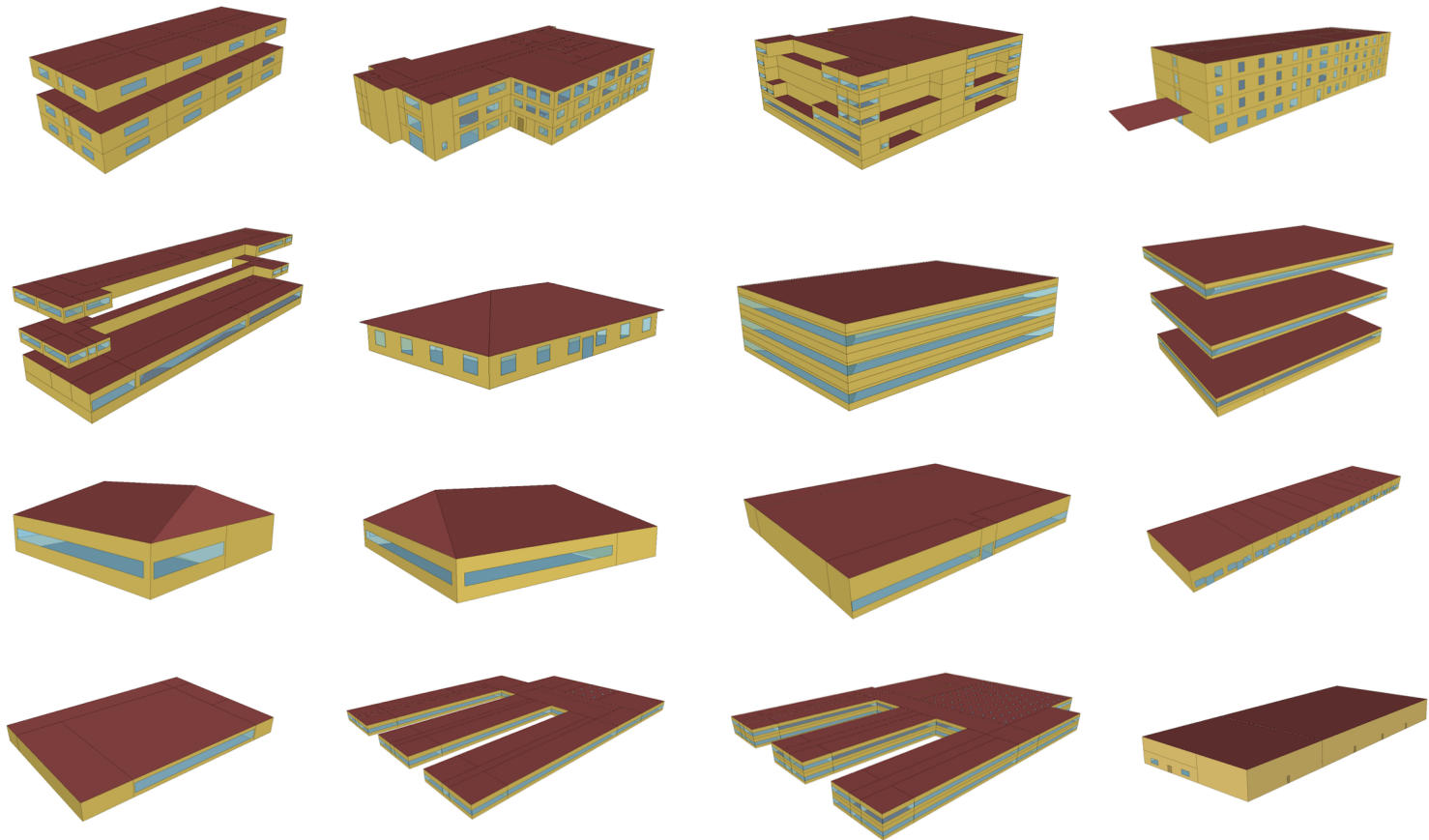
US Army Prototype Models
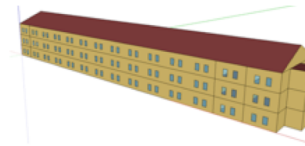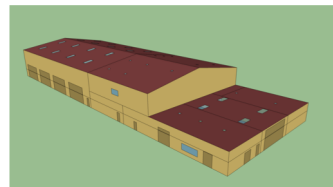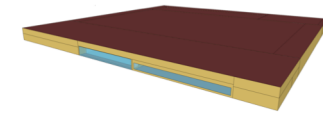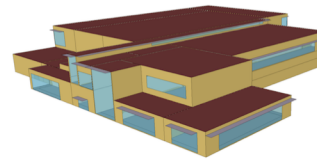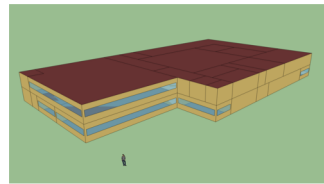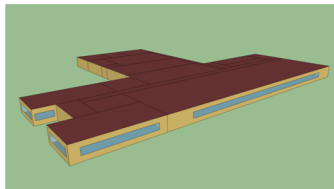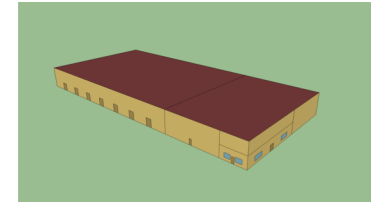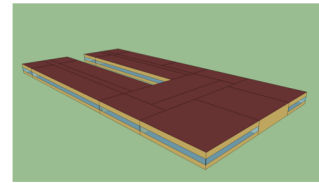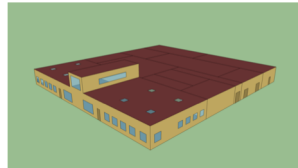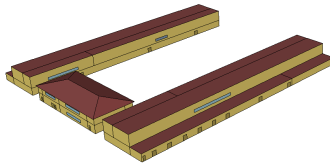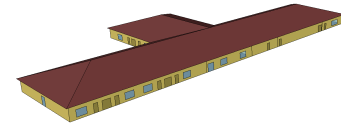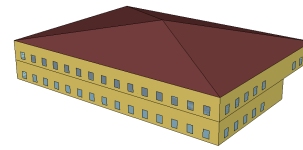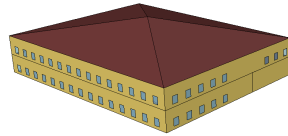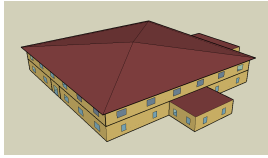
Residential Prototype Models
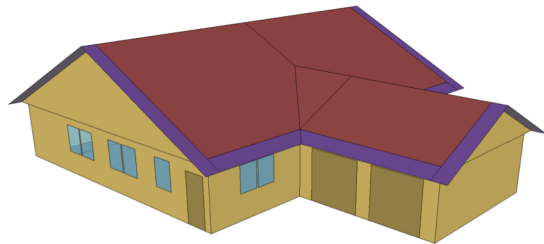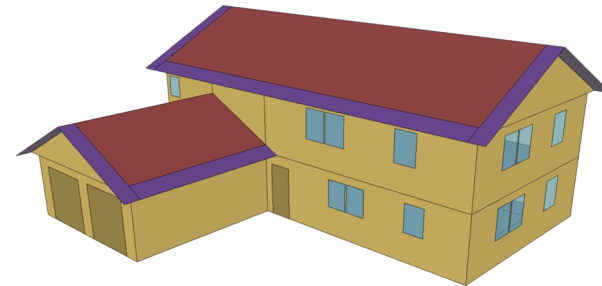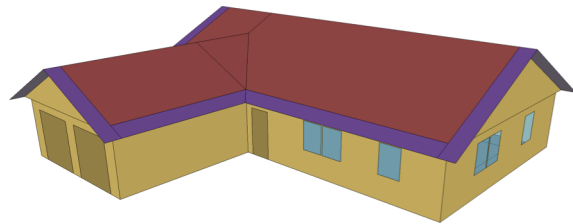
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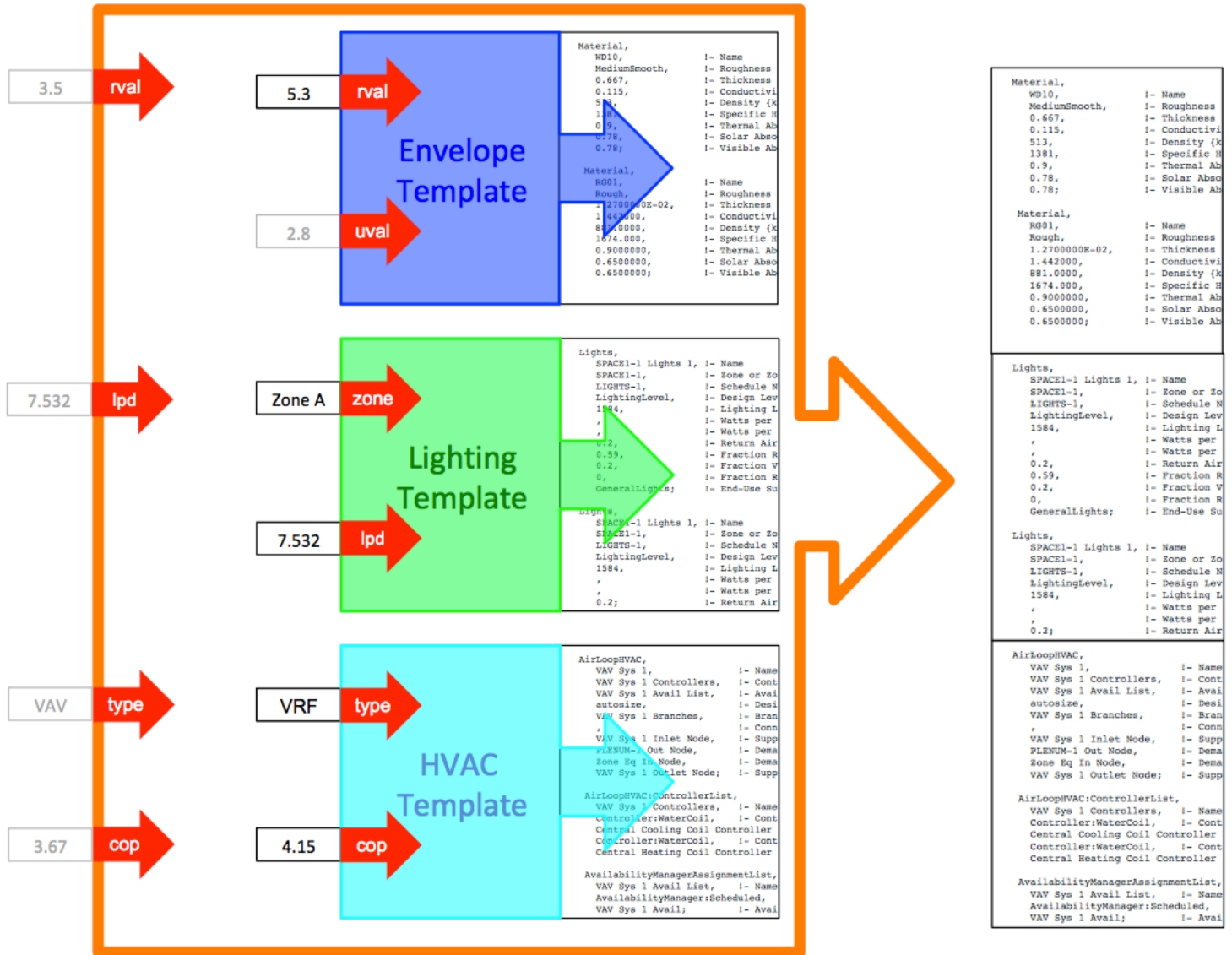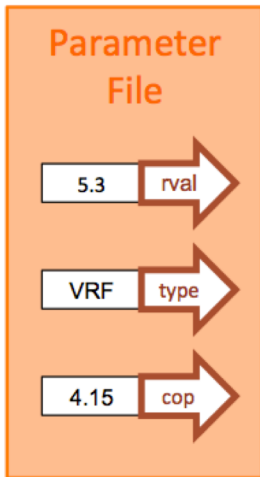
Flexible Template Library

Zone Loads

- **Classroom**
- **Corridor**
- **Fitness**
- **Kitchen**
- **Lobby**
- **Office**
- **Residence**
- **Restroom**
- **Retail**
- **Storage**
- **and more...**

Zone HVAC

- **Air-Source HP**
- **Baseboard Heat**
- **Chilled Beam**
- **DOAS Terminal**
- **Fan Coil Unit**
- **PTAC**
- **Radiant Slab**
- **VAV Terminal**
- **VRF Terminal**
- **Window AC**
- **and more...**

Systems

- **CAV**
- **Chilled Water**
- **DHW**
- **DOAS**
- **Dual Duct**
- **Ground HX**
- **Heat Rejection**
- **Hot Water**
- **VAV**
- **VRF**
- **and more...**

Parameter Values for Baseline Models

Parameter Values for Efficiency Packages

Building Energy Results

Building Energy Results

Load Profile Aggregation
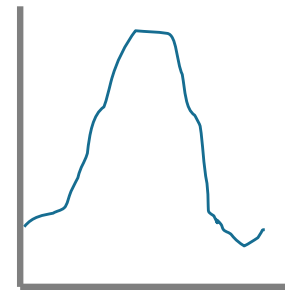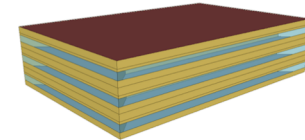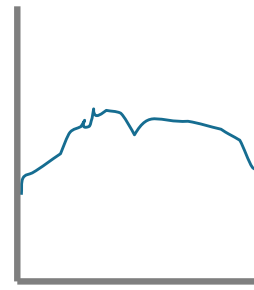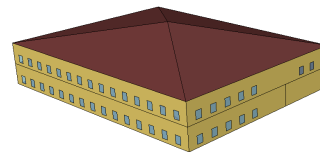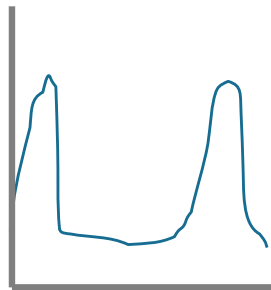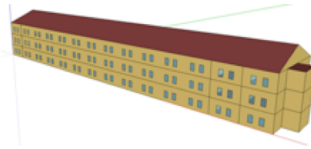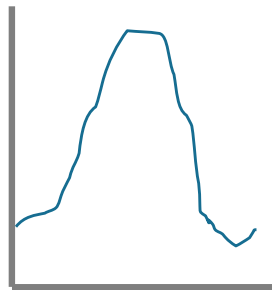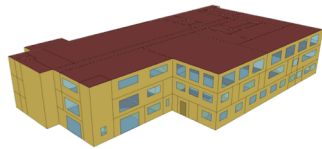
Load Duration Curve
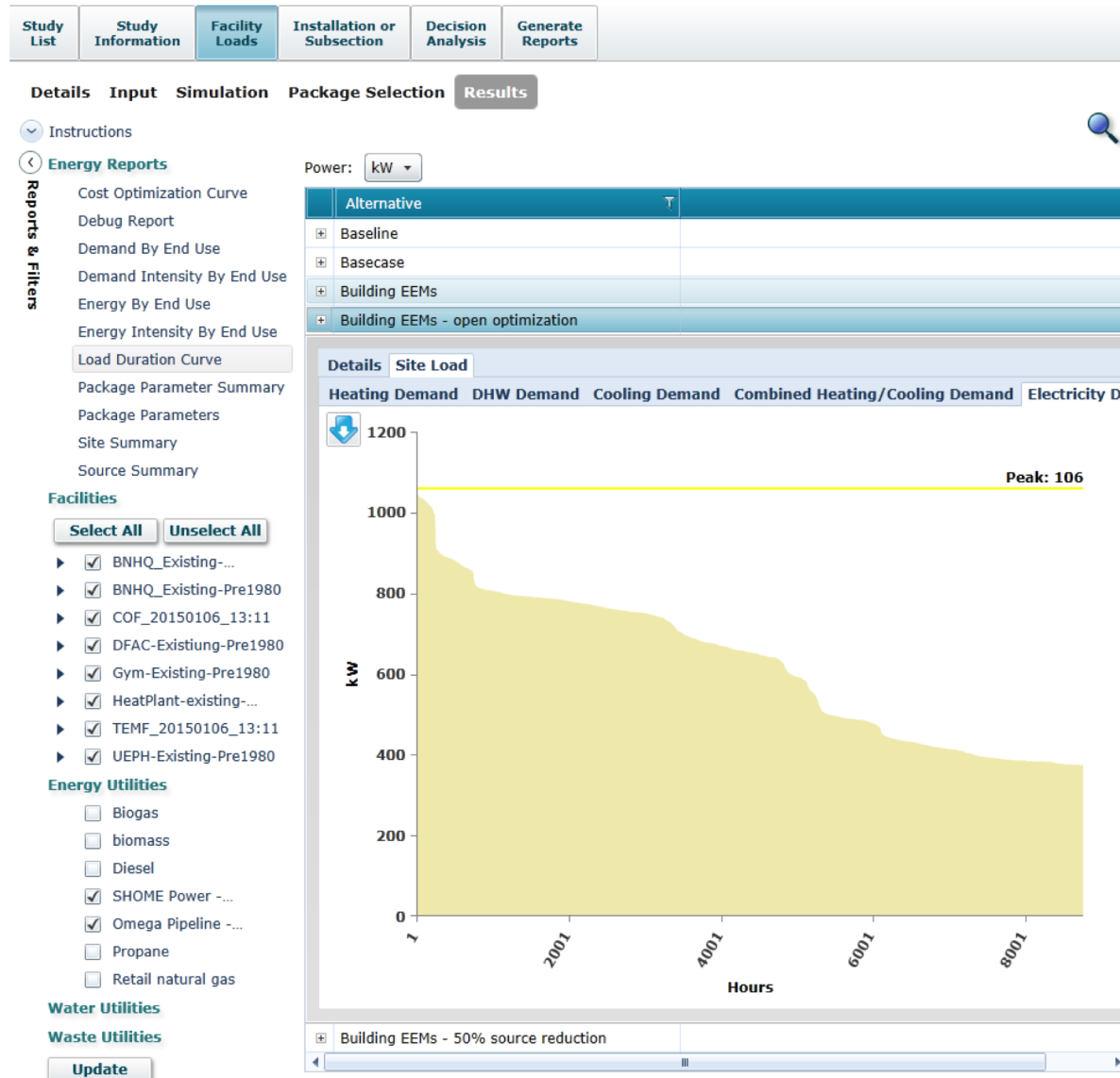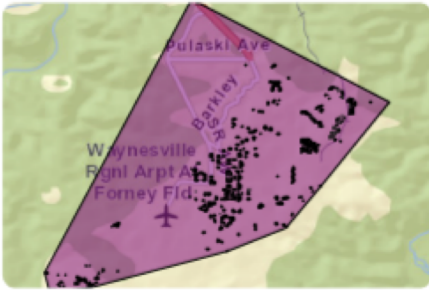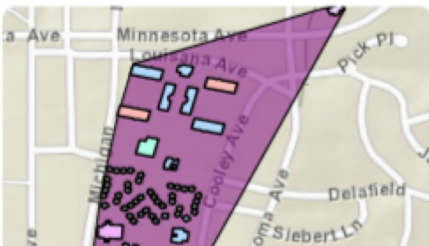
District/Cluster Selection

Page 1 of 1

Search

Remaining Buildings
N/A
Number of Buidlings: 403
Ground Coverage: 311,912,512 sqft
Total Electrical Load: 65,161,264 kWh/Yr
Total Space Heating Load: 29,428,604 kWh/Yr
Total DHW Load: 24,905,866 kWh/Yr
Total Cooling Load: 41,729,232 kWh/Yr
Total Heating Load Density: 0.17 kWh/Yr/sqft
Total Cooling Load Density: 0.13 kWh/Yr/sqft

View
Delete

South Cluster
N/A
Number of Buidlings: 23
Ground Coverage: 6,570,904 sqft
Total Electrical Load: 7,428,096 kWh/Yr
Total Space Heating Load: 4,669,444 kWh/Yr
Total DHW Load: 3,631,677 kWh/Yr
Total Cooling Load: 4,612,399 kWh/Yr
Total Heating Load Density: 1.26 kWh/Yr/sqft
Total Cooling Load Density: 0.70 kWh/Yr/sqft

View
Delete

Specker Cluster
N/A
Number of Buidlings: 46
Ground Coverage: 2,917,875 sqft
Total Electrical Load: 8,502,343 kWh/Yr
Total Space Heating Load: 5,107,636 kWh/Yr
Total DHW Load: 6,083,471 kWh/Yr
Total Cooling Load: 6,002,746 kWh/Yr
Total Heating Load Density: 3.84 kWh/Yr/sqft

View
Delete

Equipment Selection for Optimization

Equipment Types

Electric Chiller

Photovoltaic
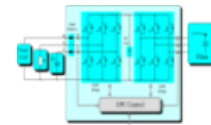
Absorption Chiller

Gas Boiler

Organic Rankine Cycle

Diesel Generator

AC Bus

Fuel Cell

Wind Turbine

Gas Turbine

Electric Heater

Constraints for Optimization

Equipment Selection and Sizing
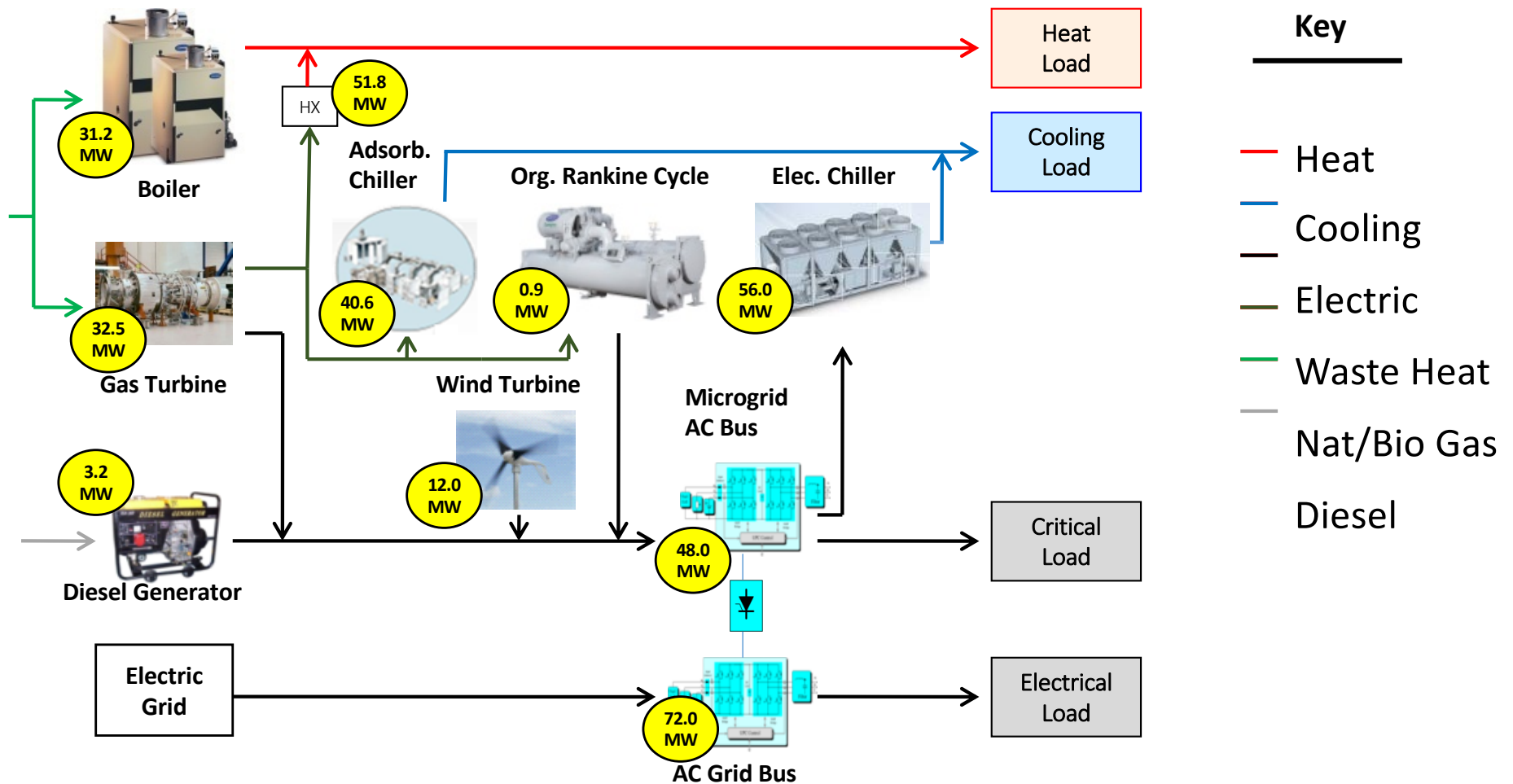
District/Cluster Energy Results

Study List	Study Information	Building Optimization	Installation or Subsection	Decision Analysis	Generate Planning Forms

Details   Cluster   Networks   Equipment & Measure   Constraints   Optimization   **Results**

Installation Results - Energy Comparison

Instructions

Reports

- Annual Energy Comparison
- Energy Overview
- Equipment Overview

Energy: kWh ▾   Power: kW ▾

Study Plan	Natural Gas (kWh)	Peak Natural Gas (kW)	Electricity (kWh)	Pe...
⊞ Base Case	123,771,232	139,420	140,980,944	34
⊞ Baseline	110,828,536	128,586	114,134,760	29
⊞ Building EEMs High	74,824,808	83,670	97,613,848	25
⊞ Building EEMs Realistic	110,502,064	119,182	113,842,288	28
⊞ Building EEMs Realistic with AIT Barracks added	110,455,888	117,735	113,228,744	28
⊞ Building EEMS Realistic with AIT Barracks MTHW	145,015,104	123,478	113,307,272	27

District/Cluster Equipment Results

Multi-Criteria Decision Analysis

Criteria Tree

Demonstration Projects

US Military Academy, West Point (New York)

Portsmouth Naval Shipyard (Maine)

- 60-70% Cost Savings
- 68-75% Time Savings

Table 6-1. Cost summary for analysis using the SME and NZP.

Installation	Number of Buildings	Number of Building Categories	Time Required		Cost of Data Analysis Using, $1000	
			SME	NZP	SME	NZP
USMA, West Point	45	11	5 months	5 wks	167	50
PNSY	127	22	4 months	5 wks	130	50

ERDC/CERL TR-15-28

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
INNOVATIVE SOLUTIONS
for a safer, better world

Environmental Security Technology Certification Program (ESTCP)

Demonstration of the Energy Component of the Installation Master Plan Using the "Net Zero Energy Planner" Tool

Alexander M. Zhivov, Michael P. Case, Richard Liesen, and Matthew Swanson

October 2015

Construction Engineering Research Laboratory

Approved for public release; distribution is unlimited.

Beta Testing

- Master Planning Client

- Marine Corps Installation
  - 100+ Buildings in Study
  - Energy Audit Data
  - GIS Data Import

- Successful Result for Client
  - Learning and Feedback
  - Bumps in the Road

Current Activities

- Complete Redesign + Rewrite of User Interface
  - Environmental Security Technology Certification Program (ESTCP) grant
  - Microsoft Silverlight → Modern JavaScript

- Adding Resiliency Analysis
  - IEA Energy in Buildings and Communities, Annex 73 – Towards Net Zero Energy Public Communities

- More Beta Testing

Conclusion

- Functional, Research-Grade Tool
  - 60+ Installations
  - Demonstrated Cost/Time Savings of 60-70%
- Deficiencies and Gaps
  - Must Be Domain Expert
  - Not User Friendly
  - Missing Features
  - Addressing These in Redesign + Rewrite

Bibliography

- Case, Michael, Richard Liesen, Alexander Zhivov, Matthew Swanson, and James Stinson. 2014. "NY-14-011 – A Computational Framework for Low Energy Community Analysis and Optimization." *ASHRAE Transactions* 120 (1).

- Liesen, R.; Ellis, P.; Zhivov, A.; Herron, D. 2012. "CH-12-008 – Extremely Low Energy Design for Army Buildings: Barracks." *ASHRAE Transactions* 118 (1).

- Swanson, M., Barnes, B.; Liesen, R.; Case, M.; Zhivov, A. 2014. "NY-14-012 – Community-Scale Energy Supply and Distribution Optimization Using Mixed-Integer Linear Programming." *ASHRAE Transactions* 120 (1).

- Zhivov, A.; Case, M.; Liesen, R.; Swanson, M. 2015. *Demonstration of the Energy Component of the Installation Master Plan Using the "Net Zero Planner", ERDC/CERL TR-15-28.* Construction Engineering Research Laboratory: Champaign, IL.

Questions?

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