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AutoBEM for BlocPower

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Electrification and Energy Infrastructure Division

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ABBREVIATIONS

AutoBEM	Automatic Building Energy Modeling
AutoSIM	Automatic building energy model SIMulator
BTO	Building Technologies Office
CRADA	cooperative research and development agreement
DOE	US Department of Energy
EEP	energy efficiency potential
EUI	energy use intensity
GSHP	ground source heat pump
HVAC	heating, ventilation, and air-conditioning
IDF	input data file
MAv2	Model America version 2.0
ORNL	Oak Ridge National Laboratory
TRL	technology readiness level

ABSTRACT

As part of a cooperative research and development agreement (CRADA), the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) and BlocPower partnered to rectify disparities between simulated and actual energy consumption in buildings using various correction methods. This team extended ORNL's building energy modeling capabilities and used bias-correction techniques to reduce the difference between simulated energy consumption estimations and ground-truth consumption data of buildings provided by utilities. ORNL is one of three core DOE laboratories developing the energy modeling tools EnergyPlus and OpenStudio.

ORNL's Automatic Building Energy Modeling (AutoBEM) software can process imagery (satellite, aerial, and street level), lidar, cartographic layers, tax assessors' data, and other data to extract building footprints, height, window-to-wall ratio, building type, vintage, and other properties. AutoBEM (bit.ly/AutoBEM) has created 178,368 building energy models that were empirically validated with 15 min whole-building electrical data from a utility.

This report outlines the ORNL team's use of various techniques—such as the average mean bias error-based correction, quantile mapping correction, and a machine-learning–based approach—and other building-specific information as inputs to mitigate bias in large-scale building energy models for each building type. This data-driven approach enables the assessment of building energy performance through simulations. The discoveries and insights derived from these results hold the potential to enhance our understanding and contribute to the development of a universally applicable bias correction method for evaluating the energy performance of buildings in urban settings.

1. STATEMENT OF OBJECTIVES

This effort will combine BlocPower LLC's (BlocPower) energy services to American cities and extend Oak Ridge National Laboratory's (ORNL's) building energy modeling capabilities to create building models that allow simulation-informed energy efficiency in a way that facilitates smart cities actively being serviced by BlocPower. A Brooklyn-based energy technology startup working to make American cities greener, BlocPower uses proprietary software for urban-scale clean energy projects. BlocPower is a non-federal entity and a venture-backed company seeking to directly fund this project scope of work.

ORNL is one of three core US Department of Energy (DOE) laboratories for building energy modeling. Among the labs' projects are active development for EnergyPlus, DOE's flagship whole-building simulation product, and OpenStudio, a middleware software development kit that creates an energy analysis of a building. Both are open-source and actively supported, with improvements released every 6 months; each new release is downloaded ~40,000 times. ORNL also leads several urban-scale energy modeling efforts to extend building-specific simulations to geographical areas of a city or larger urban area as reported in 10 "Urban-Scale Energy Modeling" seminars presented by ASHRAE. ORNL also has developed several software tools, referred to as Automatic Building Energy Modeling (AutoBEM), for creating, simulating, and analyzing building energy models.

BlocPower is attempting to make buildings more efficient using heat pumps and other technologies. ORNL is the only organization with building data and actionable models of cities at the building level (Model America dataset of 122.9 million buildings; bit.ly/ModelAmerica); required software for generating and simulating models (AutoBEM; bit.ly/AutoBEM); and high-performance computing resources (Theta supercomputer at ALCF using AutoSIM software) required for BlocPower requests for urban-scale building analysis. BlocPower seeks to estimate building energy use and savings to understand which buildings are ideal for technology integration.

2. TECHNOLOGY DESCRIPTION

2.1 BLOCPOWER

Climate technology company BlocPower aims to decarbonize buildings on a large scale by focusing on the following four key areas:

1. Efficiently identifying and engineering retrofits using publicly available, utility, and real-time building performance data.

2. Structuring innovative financing through impact investments and institutional project finance to overcome traditional capital accessibility challenges that often prevent low and moderate-income single-family, multifamily, and small commercial building owners from accessing clean energy retrofits.

3. Working with reliable local contractors and government and utility programs to deliver practical solutions to challenging installation problems faced by building owners.

4. Developing and conducting feasibility analyses for distributed energy resources in utility grid–targeted areas, particularly in low- and moderate-income neighborhoods.

The data and analytics team collects, analyzes, and builds predictive models to understand building owners' energy retrofit needs. BlocPower has developed a flagship software platform, BlocMaps, to provide insights into energy needs across various building characteristics and socioeconomic factors. BlocMaps was designed to inform city governments, utilities, and other stakeholders about decarbonization pathways. The technology uses census information, tax assessments, and real estate data to build machine-learning models that estimate the feasibility of energy retrofits and opportunities to decarbonize heating, ventilation, and air-conditioning (HVAC) systems using heat pumps. BlocPower has partnered with more than 10 cities nationwide to use BlocMaps in running decarbonization programs.

2.2 BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

The building energy modeling team at ORNL's Building Technologies Research and Integration Center has developed capabilities for the detection of building properties, building energy model creation, EnergyPlus simulation engine deployment on high performance computers, scalable simulation, big data analysis with machine learning agents, calibration, and websites and web services for sharing results. These capabilities were developed with investments from the Building Technologies Office (BTO), National Nuclear Security Administration's Defense Nuclear Nonproliferation R&D (NA-22), and the Office of Electricity Delivery and Energy Reliability as part of the Grid Modernization Laboratory Consortium.

AutoBEM was developed to create building-specific energy models for large geographical areas [1–5]. It comprises 17 software packages that can process satellite, aerial, and street-level imagery; lidar; cartographic layers; tax assessor data; and other source data to extract building footprints, heights, window-to-wall ratios, building types, vintages, and other properties. It combines properties into a full OpenStudio or EnergyPlus model. It can also perform quality control and assurance, simulate at scale, store results, analyze buildings use cases, and deploy results in a scalable visual analytics platform. AutoBEM has created 178,368 building energy models, empirically validated with 15 min whole-building electrical use data, from partner utility Electric Power Board of Chattanooga, to inform technology-specific program decisions. The following AutoBEM software packages were used in this project:

- AutoBEM-Gen (technology readiness level [TRL 7]): As the world's fastest building energy model creator, AutoBEM-Gen fuses all data sources listed previously into a model that can be simulated. It generates more than 500 EnergyPlus models in 1 s on a laptop. (The OpenStudio version creates one building energy model every 40 core-seconds.)
- AutoSIM (TRL 7): As the world's fastest building simulator, AutoSIM can simulate 15 min building performance data for 100 metrics over the course of a year for more than 500,000 buildings (45 TB to disk) in 1 hour using the nation's fastest supercomputer—Frontier at ORNL.

3. SUPPORT FOR MISSION OF THE FUNDING DOE OFFICE

DOE's and BTO's respective missions are both central to this work. DOE's mission is to ensure the United States' security and prosperity by addressing energy, environmental, and nuclear challenges through transformative science and technology solutions. BTO's mission is to develop, demonstrate, and accelerate the adoption of cost-effective technologies, techniques, tools, and services that enable high-performing, energy-efficient, and demand-flexible residential and commercial buildings in new and existing buildings markets, in support of an equitable transition to a decarbonized power sector by 2035 and a decarbonized energy system by 2050. Furthermore, BTO aims to reduce energy use intensity of US buildings by 30% by 2030 compared with a 2010 baseline.

This project directly supports the DOE and BTO missions by combining ORNL's scalable analytical capabilities for building energy modeling and heat pump analysis with BlocPower's ability to communicate and implement changes in buildings. Specifically, this project involves building-specific heat pump analysis for every building in 21 US cities. ORNL partnered with BlocPower to develop a comprehensive bias correction approach to reduce the bias from building energy modeling workflows. Informed by simulation and coupled with evaluations of ground source heat pump (GSHP) integration, the analysis directly advances BTO's overarching mission. Correcting biases in a building energy simulation workflow is crucial for integrating a building energy modeling framework to assess the energy performance and efficiency of building stocks. Accurate simulation plays a critical role in understanding nationwide energy patterns and encourages the development and adoption of building technologies. This project delved into the use of various bias-correction techniques to formulate a general approach for mitigating energy simulation biases across different cities spanning various US climate zones.

4. TECHNICAL DISCUSSION OF WORK PERFORMED BY ALL PARTIES

4.1 BLOCPOWER

To support bias assessment and correction tasks, this project requires the collection of ground-truth data for building characteristics and energy consumption. BlocPower has partnered with city governments to collect and aggregate building-level data across various cities, including Chicago, Illinois, and the Georgia cities of Macon, Atlanta, and Augusta. Additionally, publicly available datasets for cities such as Seattle, Washington, and Los Angeles, California, have been included. This information is then fed into the ORNL AutoBEM software to analyze bias and produce input data file (IDF) files.

Once the IDF files are created, BlocPower uses high-performance computing from Amazon Web Services to generate the energy profiles. Within 3 months, the company completed the construction of its entire data pipeline in the cloud, enabling the deployment of BlocMaps, a software-as-a-service solution that provides actionable insights for decarbonizing buildings to various stakeholders. This pipeline led to the generation of more than 30 TB of building energy profiles with speed improvements 16,000 times greater than conventional methods.

4.2 ORNL AUTOBEM SOFTWARE

To refine the evaluation of building energy performance, this project implemented a meticulous preprocessing step to merge raw building energy consumption data (known as ground-truth data) with the Model America v2 (MAv2) dataset from ORNL. As part of preprocessing, city-specific archetypes were generated from MAv2 data, reflecting diverse building stocks. Use of the AutoBEM software for simulations of archetype buildings integrated with both conventional building systems and GSHP-integrated systems enabled the calculation of energy use intensities (EUIs) and estimated energy consumption.

The integration of these archetypes, along with the preprocessed ground-truth data, formed the basis for joined datasets, serving as input for subsequent bias correction. The application of bias correction methods to each city's dataset resulted in the development of a comprehensive bias correction workflow (Figure 1), ultimately yielding refined and accurate building energy consumption profiles. This approach not only enhances the precision of energy performance evaluations but also establishes a robust methodology for handling diverse datasets and simulating building archetypes to improve the reliability of energy consumption assessments.

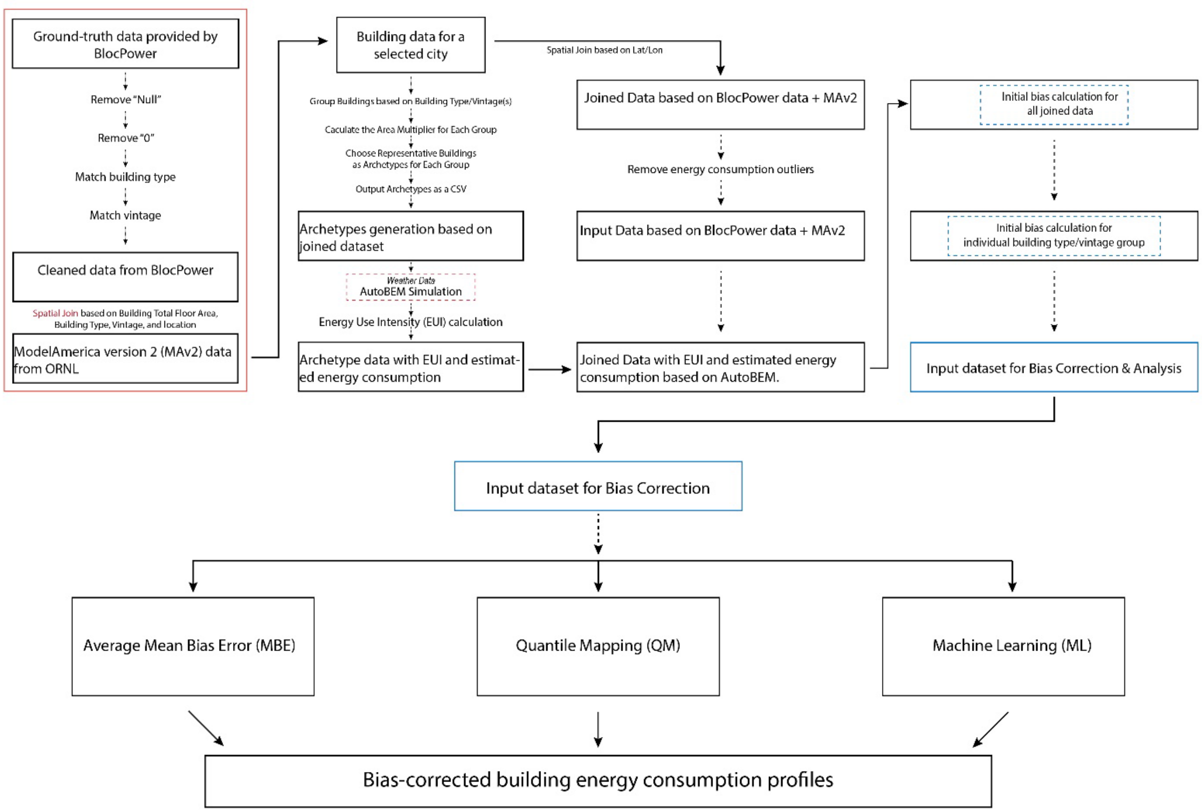

Figure 1. Developed building energy simulation bias correction workflow.

5. PROJECT TASKS COMPLETED BY ALL PARTIES

5.1 TASK 1: IDENTIFY ENERGY EFFICIENCY POTENTIAL (EEP) FOR THE WHOLE OF USA USING EXISTING AUTOBEM MODELS

Task Description: Identify EEP for every US building for which there is an AutoBEM energy model. The intention is not to produce the most accurate estimate of EEP but rather to use currently available data to quickly derive estimates that could help the project team identify priority geographical locations for more detailed analyses.

Task 1.1: Collect data from existing sources, including existing AutoBEM output and open-source building audits, and create a baseline model.

Deliverable: Participant will define EEP calculation. Contractor will apply this calculation to AutoBEM data/models to create a preliminary EEP for sample collection of buildings.

Task 1.2: The baseline model developed in Task 1.1 will be compared to actual audit and energy data to inform potential improvements in the model performance.

Deliverable: Contractor and Participant will collaborate on ways to adjust building parameters and bias correction factors with existing building data. Contractor will provide models and factors that better align with actual energy use data.

Desired Outcome: EEP for every US building from the Model America 1.0 dataset for which we have an AutoBEM energy model.

Quantitative Measure of Success: Availability of EEP score for every building in the US for which we have an AutoBEM energy model. The Contractor will collaborate regarding data access and analysis of EEP.

Deliverable: Contractor provides Participant with updated/improved models. Contractor calculates EEP score for each building using Contractor's Model America v1.0 data.

Estimated Time Required: 1 month

- T1-MAv2_CZ_Archetypes.csv (1.5 MB)—created 2,301 median-area archetypes to represent every building in the United States (141,506,665 buildings) based on climate zone. Fields included in this dataset:

    1. ID—unique building identifier known as "*UBID*"
    2. County—county name
    3. State—state name
    4. CZ—ASHRAE climate zone designation (description, Standard 169-20 Addendum)
    5. Year—estimated year of construction
    6. Centroid—building center location in latitude/longitude (from Footprint2D)

7. Footprint2D—building polygon of 2D footprint (lat1/lon1_lat2/lon2_...)
8. Height_m—building height (meters)
9. Area2D—building footprint area (square feet)
10. Standard—building vintage
11. BuildingType—DOE prototype building designation (IECC = residential) as implemented by OpenStudio standards
12. Mixed—binary indicator of multiple types by floor
13. Mixed_Types—other building types present
14. WWR_surfaces—percent of each facade (pair of points from Footprint2D) covered by fenestration/windows (average 14.5% for residential, 40% for commercial buildings)
15. NumFloors—number of floors (above grade)
16. Area—estimate of total conditioned floor area (square feet)
17. Runtime—estimated time to run the simulation
18. Num_build_per_zone—number of buildings in a climate zone under a specific DOE prototype building and vintage year
19. Total_zone_area—total floor area in a climate zone under a specific DOE prototype building and vintage year
20. Area_multiplier—dividing total floor area by median area value in a climate zone under a specific DOE prototype building and vintage year
21. MedianArea—median value of the floor area in a climate zone under a specific DOE prototype building and vintage year
22. MeanArea—mean value of the floor area in a climate zone under a specific DOE prototype building and vintage year
23. MinArea—minimum value of the floor area in a climate zone under a specific DOE prototype building and vintage year
24. MaxArea—maximum value of the floor area in a climate zone under a specific DOE prototype building and vintage year
25. SDArea—standard deviation value of the floor area in a climate zone under a specific DOE prototype building and vintage year

- Scope for DOE-funded “Reduce Building Electrification Soft Costs & Accelerate Deployment in Priority Geographies” (New, $130K, $91K ORNL)
  - Task 1 (1 month): Contractor (ORNL) provides Participant (BlocPower) with updated/improved models. Contractor calculates EEP score for each building using Contractor’s Model America v1.0 data.
  - Task 2 (1 month): Participant will provide Contractor with prioritized list of regions (e.g., shapefiles) that define the geographical locations for future analysis, along with any building data for those regions.
  - Task 3 (3 months): Contractor will incorporate Participant data for prioritized geographical locations to generate and simulate every building in those regions. Models and simulation output will be provided to Participant.
  - Task 4 (3 months): Participant and Contractor will compare building descriptors for prioritized geographical locations and determine which input sources and adjustment factors will be applied.
  - Task 5 (2 months): Contractor will update building descriptors and models for buildings in prioritized geographical locations.
  - Task 6 (2 months): Contractor will provide models and simulation output. Contractor will apply adjustment factors or calibration techniques for better alignment between models and measured data.
  - Task 7 (2 months): Contractor will generate an estimate of heat pump savings for buildings in prioritized geographical locations.
  - Task 8 (1 month): Publish final CRADA report.

5.2 TASK 2: IDENTIFY PRIORITY GEOGRAPHIES

Task Description: Identify priority geographical locations based on the EEP generated in the previous step and a predetermined value of an overall EEP above 50% of the entire US. The Participant will provide the Contractor with a prioritized list of regions (e.g., shapefiles) that define the geographical locations for future analysis, along with any building data for those regions.

Responsible Party: Participant

Desired Outcome: List of priority geographies

Quantitative Measure of Success: Identified geographies based on the EEP generated in the previous step should have an overall EEP above 50% of the entire US

Deliverable: Participant will provide Contractor with prioritized list of regions (e.g., shapefiles) that define the geographical locations for future analysis, along with any building data for those regions.

Estimated Time Required: 1 month

- Priority cities identified:
    - Melrose, Massachusetts
    - Peterborough, New Hampshire
    - Providence, Rhode Island
    - New Bedford, Massachusetts
    - Worcester, Massachusetts
    - Minneapolis, Minnesota
    - St Paul, Minnesota
    - Cleveland, Ohio
    - Cincinnati, Ohio
    - Richmond, Virginia
    - Kingston, New York
    - New Orleans, Louisiana
    - Martha's Vineyard, Massachusetts
    - Flint, Michigan
    - Muskegon Michigan
    - Kalamazoo, Michigan
    - St. Louis, Missouri
    - Lowell, Massachusetts
    - Reading, Massachusetts
    - San Diego, California
    - Mount Vernon, New York

5.3 TASK 3: PRIORITY GEOGRAPHY MODEL GENERATION

Task Description: Generate and simulate all buildings in the priority geographies with the newest version of AutoBEM (currently version 2.1)

Responsible Party: Contractor

Desired Outcome: Simulated models of all buildings in the priority geographies

Quantitative Measure of Success: The count of produced models based on the newest version of AutoBEM (2.1) in every priority geography should be at least 90% of the total buildings count in that geography

Deliverable: Contractor will incorporate Participant data for prioritized geographical locations to generate and simulate every building in those regions. Models and simulation output will be provided to Participant.

Estimated Time Required: 3 months

- Files were provided via ORNL's electronic file transfer system:
    - AllNew21Cities.zip (130 GB)—OpenStudio and EnergyPlus (*.osm, *.idf) files for all buildings in the 21 cities using MAv2 and BlocPower-injected MAv2 data
    - All21Cities.zip (193 GB)—original OpenStudio and EnergyPlus (*.osm, *.idf) files for all buildings in the 21 cities using MAv2 and BlocPower-injected MAv2 data

5.4 TASK 4: SOURCING BUILDINGS ENERGY AUDIT DATA AND ENERGY BILLS DATA

Task Description: Sourcing building characteristics such as building type, square footage, year built, number and types of thermal zones, room heating and cooling systems, and other energy-related details from available audit data and energy bills data for all buildings in the prioritized geographical locations.

Responsible Party: Contractor and Participant

Desired Outcome: Data to be sourced for every building in prioritized geographical locations on the following:

a) Differences in various buildings' characteristics based on the buildings' audit data and other sources

b) Interval data from utility bills

Quantitative Measure of Success: The number of buildings for which we are able to source this data

Deliverable: Participant and Contractor will compare building descriptors for prioritized geographical locations and determine which input sources and adjustment factors will be applied.

Estimated Time Required: 3 months

- Files were provided via ORNL's electronic file transfer system:
  - 44_Cities_BuildingTypeMapping.zip (708 MB)—building property data (.csv and .parquet) with mapped building types based on MAv2 building type category
- Files were received from BlocPower:
  - BuildingEnergyConsumptionData.zip (19 MB)—building energy consumption open-source data provided by BlocPower based on climate zoning
- Python-based processing scripts sourcing buildings energy audit data and energy bills data from BlocPower

5.5 TASK 5: UPDATING MODELS BASED ON THE AUDIT DATA

Task Description: Use buildings audit data to augment building energy models to be more representative of actual buildings by editing building properties and performance.

Responsible Party: Contractor

Desired Outcome: A more accurate model representative of actual buildings for all the buildings in priority geographies

Quantitative Measure of Success: Statistical accuracy of the updated model should be better than the accuracy of the base model when compared with actual data.

Deliverable: Contractor will update building descriptors and models for buildings in prioritized geographical locations.

Estimated Time Required: 2 months

- Files were provided to BlocPower
  - Spatial joined (BlocPower + MAv2) data files requested by BlocPower for the following eight cities or counties (with file names and file sizes listed):
    - Climate Zone 5A: Evanston, Illinois—Processed_Evanston_Cleaned_v1.csv (91 KB)
    - Climate Zone 4A: Kansas City, Missouri—Processed_Kansas_Cleaned_v1.csv (99 KB)
    - Climate Zone 4A: Montgomery County, Maryland—Processed_Montgomery_Cleaned_v1.csv (254 KB)
    - Climate Zone 4C: Portland, Oregon—Processed_Portland_Cleaned_v1.csv (256 KB)
    - Climate Zone 5B: Reno, Nevada—Processed_Reno_Cleaned_v1.csv (24 KB)
    - Climate Zone 4A: St. Louis, Missouri—Processed_StLouis_Cleaned_v1.csv (100 KB)
    - Climate Zone 5A: Syracuse, New York—Processed_Syracuse _Cleaned_v1.csv (12 KB)
    - Climate Zone 4A: New York City, New York—Processed_NYC_Cleaned_v1.csv (10,476 KB)

5.6 TASK 6: RETUNING MODELS BASED ON ENERGY BILLS

Task Description: To retune simulated models for buildings based on billing data to adjust simulation results and eliminate bias in simulations

Responsible Party: Participant and Contractor

Desired Outcome: Retuned models for buildings in prioritized geographical locations to more accurately estimate actual energy consumption of each building

Quantitative Measure of Success: Statistical accuracy of the retuned model should be better than the accuracy of the base model

Deliverable: Contractor will provide models and simulation output and will apply adjustment factors or calibration techniques for better alignment between models and measured data.

Estimated Time Required: 2 months

- Files were provided:
  - Bias_correction_for_other_cities.xlsx—bias correction results for eight cities requested by BlocPower.
  - Bias_corrected_results.zip—bias-corrected building data files for eight cities requested by BlocPower.
  - Join_Result_withEUI_v1.zip—each individual city's simulation results with EUI and estimated energy consumption columns.

5.7 TASK 7: HEAT PUMP ANALYSIS FOR PRIORITY GEOGRAPHIES

Task Description: To derive heat pump savings estimates by replacing existing HVAC systems with heat pumps and resimulating the energy footprint of buildings.

Responsible Party: Contractor

Desired Outcome: Heat pump savings estimates for every building in prioritized geographical locations

Quantitative Measure of Success: Statistical accuracy of savings estimates

Deliverable: Estimate of heat pump savings for buildings in prioritized geographical locations

Estimated Time Required: 2 months

- Files were provided—the simulated building archetype energy consumption of an HVAC system compared with and without GSHP integration for the cities requested by BlocPower for the 21 cities listed in Task 2.

5.8 TASK 8: FINAL REPORT

Task Description: Publish final CRADA report.

Responsible party: Contractor

Deliverable: Final CRADA report

Estimated Time Required: 1 month

6. SUBJECT INVENTIONS

The primary inventions from this work include extensions for artificial intelligence and big data processing methodologies of transforming imagery (satellite, aerial, street view), lidar, and other buildings databases. These data are then used to generate and simulate building energy models of each of the 141.5 million US buildings at scale on high-performance computing resources. These building energy models were leveraged in this project to predict heat pump savings via urban-scale analyses, including evaluation of other building technologies relevant to electric grid resilience, renewable energy generation and distribution, and climate change impacts. No patents or software copyrights were filed specifically as part of this CRADA, though three previously registered copyrights and two tangentially filed copyrights were extended as part of this work:

1. MAv2—US Copyright awarded (DOE ID#: 90000266)
2. AutoBEM—US Copyright awarded (DOE ID#: 90000265)
    a. AutoBEM:AutoBEMGen (US Copyright TXu 2-141-227) for quickly creating OpenStudio and/or EnergyPlus building energy models from building-specific descriptors (effective May 28, 2019)
    b. AutoBEM:AutoSim (US Copyright TXu 2-141-960) for running EnergyPlus simulations quickly using high-performance computing resources (effective May 29, 2019)
    c. AutoBEM:AutoGen (US Copyright TXu 2-159-000) for quickly editing and creating OpenStudio and/or EnergyPlus building energy models from a list of input parameters and range of input parameter values

7. COMMERCIALIZATION POSSIBILITIES

BlocPower's flagship software product, BlocMaps, is designed to transform the way city planners, utilities, and program managers approach building electrification programs. By leveraging comprehensive data on building characteristics, such as square footage, age, heating system, and fuel types, BlocMaps empowers stakeholders to make informed decisions. BlocPower researchers have advancing BlocMaps in ways that address the inherent biases that often challenge the accuracy of building energy simulations. Such biases can skew the real-world energy performance assessments of specific building stocks, presenting a significant hurdle achieving precise, reliable energy efficiency solutions.

In collaborating with ORNL on this project, BlocPower has developed a comprehensive bias-correction approach to refine the precision of simulating building energy consumption. This methodology will bridge the gap between theoretical models and actual building energy performance, allowing for a more accurate representation of energy consumption patterns. Integrating this bias correction approach into its processes is helping BlocPower to deliver more accurate and reliable estimates of building energy consumption to customers, based on the most precise data available.

8. PLANS FOR FUTURE COLLABORATION

The collaboration between BlocPower and ORNL, particularly in refining the AutoBEM tool through bias correction, opens several promising avenues for future projects. The successful calibration of this tool with real-world data not only enhances its accuracy but also lays the groundwork for more sophisticated, data-driven energy efficiency solutions. Following are two significant opportunities for future collaboration:

- Longitudinal Calibration with Multiyear Meter Data: By integrating multiyear meter data from various cities, the research team can calibrate the bias-corrected AutoBEM output. This process will not only refine the model's accuracy but also allow it to capture complex, behavior-driven, and otherwise elusive aspects of energy consumption. Over time, buildings and their occupants exhibit unique energy usage patterns influenced by myriad factors, including behavioral tendencies, maintenance practices, and operational protocols. Calibrating model output using meter data would greatly improve the ability to generate relatively accurate energy profiles of specific buildings and would allow for more accurate energy savings predictions resulting from implementing energy efficiency upgrade measures.

- Validation of Energy Savings from Upgrade Measures Using Permit Data: Another opportunity involves leveraging permit data to identify buildings that have undergone energy efficiency upgrades. By analyzing the before-and-after meter data of these buildings, the research team can quantify the energy savings resulting from specific upgrade measures. This empirical approach offers a mechanism to validate AutoBEM's capacity to accurately predict the energy saving potential of various retrofitting interventions.

By persistently enhancing the accuracy and applicability of the models, ORNL and BlocPower are enabling people and policy makers to make more informed, data-driven decisions in their pursuit of energy efficiency and sustainability.

9. CONCLUSION

This work presents a comprehensive analysis of accuracy, bias, and limitations in urban building energy modeling, focusing on evaluating the AutoBEM software suite. The study uses several case studies of metered energy consumption data from a large sample of buildings crossing different climates in the United States. The study compares the case study samples to various datasets, including the AutoBEM-generated MAv2 data, tax assessor data, and representative dynamic archetypes. The results indicate that the AutoBEM simulation workflow generates energy consumption estimates that could closely match the aggregated metered energy consumption data at the city scale. Concurrently, the project findings offer valuable insights for reducing bias in building energy simulations across diverse US climate zones.

10. REFERENCES

1. Yuan, J., J. R. New, J. Sanyal, and O. Omitaomu. *Urban Search Data Sources*. ORNL/TM-2015/397. Oak Ridge, Tennessee: Oak Ridge National Laboratory.
2. New, J. R., M. Bhandari, S. Shrestha, and M. Allen. 2018. "Creating a Virtual Utility District: Assessing Quality and Building Energy Impacts of Microclimate Simulations." *Proceedings of the International Conference on Sustainable Energy and Environmental Sensing (SEES)*, Cambridge, UK, June 18–19, 2018.
3. New, J. R., M. Adams, P. Im, H. Yang, J. Hambrick, W. Copeland, L. Bruce, and J. A. Ingraham. 2018. "Automatic Building Energy Model Creation (AutoBEM) for Urban-Scale Energy Modeling and Assessment of Value Propositions for Electric Utilities." *Proceedings of the International Conference on Energy Engineering and Smart Grids (ESG)*, Fitzwilliam College, University of Cambridge, Cambridge, UK, June 25–26, 2018.
4. New, J. R., O. Omitaomu, J. Yuan, H. Yang, T. Carvalhaes, L. Sylvester, and M. Adams. 2017. "AutoBEM: Automatic Detection and Creation of Individual Building Energy Models for Each Building in an Area of Interest." *Proceedings of the 2nd International Energy and Environment Summit*, Dubai, UAE, Nov. 18–20, 2017.
5. New, J. R. New. 2018. "Big Data Mining for Applied Energy Savings in Buildings." *Proceedings of the 5th International Conference on Big Data Analysis and Data Mining*, Rome, Italy, June 20–21, 2018.