Automatic Building Energy Modeling (AutoBEM)

Oak Ridge National Laboratory (ORNL) has developed the Automatic Building Energy Modeling (AutoBEM) software suite to process multiple types of data, extract building-specific descriptors, generate building energy models, and simulate them on High Performance Computing (HPC) resources.

Public data:
ORNL has created a model of every U.S. building! An OpenStudio (v3.1.0) and EnergyPlus (v9.4) of 122,930,327 (97.8%) U.S. buildings was generated using 45 million core-hours of Argonne National Laboratory's Theta supercomputer, shared as State_County.zip, and made free/openly available.

New, Joshua R., Adams, Mark, Bass, Brett, Berres, Anne, and Clinton, Nicholas (2021). "Model America - data and models of every U.S. building. [Data set]." *Constellation*, doi.ccs.ornl.gov/ui/doi/339, April 14, 2021. [DOI]

- Model of every US building – bit.ly/ModelAmerica
- Requires Globus personal endpoint to download
- Before downloading, consider the better-formatted building data and models below.

Sample data:

- New, Joshua R., Bass, Brett, Adams, Mark, Berres, Anne, and Luo, Xuan (2021). "Los Angeles County Archetypes in Weather Research and Forecasting (WRF) Region from ORNL's AutoBEM [Data set]." Zenodo, doi.org/10.5281/zenodo.4726136, Apr. 28, 2021. [Zenodo]
- Data: New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Clark County (Vegas) Archetypes from ORNL's AutoBEM [Data set]." *Zenodo*, doi.org/10.5281/zenodo.4552901, Mar. 21, 2021. [Zenodo]
- Data: New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Model America - Clark County (Vegas) extract from ORNL's AutoBEM (Version 1.1) [Data set]." *Zenodo*, doi.org/10.5281/zenodo.4552901, Feb. 16, 2021. [Zenodo]

Capabilities:

- AutoBEM (peer review) - "Automatic Building detection and Energy Model creation" (AutoBEM) framework has been developed to ingest multiple data sources and create an EnergyPlus (DOE's $95M simulation tool) model of every building in an area of interest. The goal is to create a model of all 124 million U.S. buildings by the end of 2020.
- Digital Twin of all buildings - Once a digital twin of all buildings is created, most what-if questions can be answered in ~6.5 hours. We simulate EE opportunities (technologies or policies) on the world's fastest buildings simulator to quantify the energy, demand, emissions, and $ savings of these opportunities.
- Virtual Utility (poster) - We've used AutoBEM to develop a model of 178,368 buildings for a utility, analyze (building-specific, 15-minute resolution) demand and energy efficiency opportunities, and made some preliminary results available via an interactive web analytics portal at bit.ly/virtual_epb. These results can be aggregated to determine EE opportunities for any geographical area (e.g. critically loaded feeders, substations

Utilities:
AutoBEM has been applied to 178,337 building energy models to create a "digital twin" of all buildings in the service area of the Electric Power Board (EPB) of Chattanooga, TN. Every model has been

compared to EPB's 15-minute electricity use of each building and used to improve the models for many use cases including:

- Demand management – smart thermostats (e.g. pre-conditioning strategies) and water heaters
- Energy efficiency – lighting, infiltration, insulation, HVAC efficiency and types (e.g. dual fuel with dynamic control), water heaters, integrated heat pumps
- Resilience and infrastructure planning – electrification, electric vehicle charging strategies, weather (3-5 days) and climate (10-80 years) impact on building loads on critically-loaded feeders and substations.

Recommended publications:

- Project overview
  - Ingraham, James A. and New, Joshua R. (2018). "Virtual EPB." Presented to Building Technologies Office following the *BTO Peer Review*, 87 slides. Arlington, VA, May 3, 2018. [PPT]
- Savings at utility-scale
  - Bass, Brett, New, Joshua R., and Copeland, William (2020). "Potential Energy, Demand, Emissions, and Cost Savings Distributions for Buildings in a Utility's Service Area." *Energies* journal, Special Issue "Designing, Modeling and Optimizing Energy and Environmental Systems for Buildings," volume 14(1), issue 132, doi.org/10.3390/en14010132, Dec. 29, 2020. [Energies] [PDF] [OSTI]
- Data and algorithms
  - New, Joshua R., Adams, Mark, Garrison, Eric, Bass, Brett and Guo, Tianjing. (2020). "Scaling Beyond Tax Assessor Data." ASHRAE/IBPSA-USA 2020 *Building Performance Analysis Conference & SimBuild* (BPACS), Chicago, IL, Sept. 29 - Oct. 1, 2020. [PDF] [PPT] [MP4]
- Smart-meter quality control
  - Garrison, Eric and New, Joshua R. (2021). "Quality Control Methods for Advanced Metering Infrastructure Data." *Smart Cities* journal, Special Issue "Applied Artificial Intelligence in Energy Systems," volume 4(1), pages 195-203, doi.org/10.3390/smartcities4010012, Jan. 28, 2021. [SmartCities] [PDF]

All Publications:

- Bass, Brett and New, Joshua R. (2022). "How Will United States Commercial Building Energy Use Be Impacted by IPCC Climate Scenarios?" Journal of *Energy*, volume 263(E), doi.org/10.1016/j.energy.2022.125945, Jan. 2023. [Energy] (free til 1/6/23)
- Bass, Brett, New, Joshua R., Clinton, Nicholas, Adams, Mark, Copeland, Bill, and Amoo, Charles (2022). "How close are urban scale building simulations to measured data? Examining bias derived from building metadata in urban building energy modeling." Journal of *Applied Energy*, volume 327(1), doi.org/10.1016/j.apenergy.2022.120049, Dec. 1, 2022. [APEN] (free til 12/3/22)
- Bass, Brett, New, Joshua R., and Wade, Zachary (2022). "Future Typical Meteorological Year (fTMY) Weather Data and Climate Change Impacts to Maricopa County, Arizona." The 2nd ACM International Workshop on Big Data and Machine Learning for Smart Buildings and Cities, Boston, Massachusetts, USA, Nov. 9-10, 2022. [PDF]
- Bass, Brett, New, Joshua R., Berres, Andy, Adams, Mark, Clinton, Nicholas, Leung, Marissa, Tuxen-Bettman, Karin, and Van Groenou, Saleem (2022). "Poster: Environmental Insights Explorer for Buildings." Geo for Good Summit, Mountain View, A, Sept. 19, 2022. [PPT]
- Haowen Xu, Andy Berres, Yunli Shao, Chieh Wang and Joshua New (2022). "Towards a Smart Metaverse City: Immersive Realism and 3D Visualization of Digital Twin." Advances in Scalable and Geospatial Analytics: New Trends, Challenges and Applications, CRC Press, Taylor & Francis Group.
- New, Joshua R., Bass, Brett, Berres, Andy, and Adams, Mark (2022). "Industry partners use ORNL software to trim carbon footprint of buildings" ORNL Science Highlight, Oak Ridge, TN, Sept. 20, 2022. [Article]

- Bass, Brett, New, Joshua, Amoo, Charles, Ezell, Evan, and Copeland, William (2021). "Using Measured Building Energy Data to Infer Building Type for Building Energy Modeling." ASHRAE/IBPSA-USA 2022 Building Performance Analysis Conference and SimBuild (BPACS), Chicago, IL, Sept. 14-16, 2022. [PDF] [PPT]
- Berres, Andy, Bass, Brett, Adams, Mark, New, Joshua R. (2022). "AutoBEM: A Workflow to Automate Building Energy Modeling." Computational and Autonomous Workflows Workshop (CAW 2022) Lightning Talk, Oak Ridge, TN, Sept. 12-13, 2022. [PPT]
- Bass, Brett, New, Joshua R., Rastogi, Deeksha, and Kao, Shih-Chieh (2022). "Future Typical Meteorological Year (fTMY) US Weather Files for Building Simulation (1.0) [Data set]." Zenodo, doi.org/10.5281/zenodo.6939750, Aug. 2022. [Data]
- Mumme, Sven, Brown, Fredericka, Bass, Brett, Shen, Bo, Shrestha, Som, New, Joshua R. and Gluesenkamp (2022). "Implications of Electrifying Residential Space Heating in Cold Climates with Heat Pumps, Envelope Improvements, and Thermal Storage." ACEEE Summer Study Conference, Pacific Grove, CA, August 21-26, 2022. [OSTI] [PDF] [PPT]
- New, Joshua R. and Bass, Brett (2022). "Automatic Building Energy Modeling (AutoBEM) and its Model America dataset: background, capabilities, and discussion with WIP stakeholders." DOE's Weatherization and Intergovernmental Programs (WIP), July 28, 2022. [PPT]
- New, Joshua R. and Bass, Brett (2022). "Automatic Building Energy Modeling (AutoBEM) and the Model America dataset." Digital Twin Demonstrator Forum, June 9, 2022.
- Amoo, Charles (2022). "Urban-Scale Building Energy Modeling: Market Potential, Data Sources, Computational Methods and Visualization." PhD Qualifier Exams Presentation, May 16, 2022.
- Allen-Dumas, Melissa, Berres, Andy, Brelsford, Christa, New, Joshua R., Bass, Brett, Sweet-Breu, Levi, Kurte, Kuldeep, and Sanyal, Jibonananda (2022). "Sustainable Cities: Socioeconomics, Building Types, and Urban Morphology." Smoky Mountain Computational Science Data Challenge (SMCD22), August 23-25, 2022. [Challenge]
- Bass, Brett, New, Joshua R., Curtis, Leland, McNally, Peter, and Sanborn, Stet (2022). "AI-facilitated building design." DOE BTO Brown Bag, March 17, 2022. [PPT]
- Berres, Andy S., Sanyal, Jibonananda, Kurte, Kuldeep R., Dumas, Melissa R., Bass, Brett C., New, Joshua R., Im, Piljae, Urban, Marie L., and Thakur, Gautam (2022). "Traffic-based analyses of buildings advance smart city capabilities." ORNL science article, March 3, 2022. [Article]
- Savage, Neil (2022). "Virtual Duplicates." Communications of the ACM, volume 65(2), pp. 14-16, doi:10.1145/3503798, February 2022. [CACM]
- Webb, Sarah (2022). "Sustainable Cities: Oak Ridge researchers harness Argonne's Theta supercomputer to build energy-efficiency models for all U.S. buildings." ASCR Discovery, January 2022. [Article]
- Xu, Haowen, Berres, Andy, Yoginath, Srikanth, Kurte, Kuldeep, Peleti, Rajesh, New, Joshua R., and Sanyal, Jibonananda (2022). "Towards Adaptive Decision Support: A Perspective from Intelligent and Annotated Visual Analytics for Exploring Big Urban Mobility Data." ASCR Workshop on Visualization for Scientific Discovery, Decision-Making, & Communication, Jan. 2022. [PDF]
- Bass, Brett and New, Joshua R. (2022). "AutoBEM - Dynamic Archetypes." Generates representative models and floor space multipliers for any area of interest, with example data for Las Vegas, doi:10.5281/zenodo.5838465. January 11, 2022. [code]
- Berres, Andy, Bass, Brett, Adams, Mark, Garrison, Eric, and New, Joshua R. (2021). "A Data-Driven Approach to Nation-Scale Building Energy Modeling." 2021 IEEE International Conference on Big Data, Orlando, FL, December 15-18, 2021. [PDF] [PPT]
- Bass, Brett, Curtis, Leland, and New, Joshua R. (2021). "Design Space Data: Informing Common Design Decisions with Pre-Simulated Data." ORNL internal report ORNL/TM-2021/170499, November 19, 2021, 17 pages.
- New, Joshua R. (2021). "Model America - a model of every U.S. building." CalBEM 2021 virtual conference, November 18-19, 2021. [PDF] [MOV]
- Bass, Brett, New, Joshua R., Ezell, Evan, Im, Piljae, Garrison, Eric, and Copeland, William (2021). "Utility-scale Building Type Assignment Using Smart Meter Data." Building Simulation 2021 Conference, Bruges, Belgium, September 1-3, 2021. [PDF] [PPT] [MOV]

- New, Joshua R., Bass, Brett, Berres, Anne S. (2021). "Distribution of potential savings from urban-scale energy modeling of a utility." Building Simulation 2021 Conference, Bruges, Belgium, September 1-3, 2021. [PDF] [PPT] [MOV]
- Berres, Anne S., Bass, Brett, New, Joshua R., Im, Piljae, Urban, Marie, and Sanyal, Jibonananda (2021). "Generating traffic-based building occupancy schedules in Chattanooga, Tennessee from a grid of traffic sensors." Building Simulation 2021 Conference, Bruges, Belgium, September 1-3, 2021. [PDF] [PPT] [MOV]
- Allen-Dumas, Melissa, Brelsford, Christa, New, Joshua R., Berres, Anne, Kurte, Kuldeep, Sanyal, Jibonananda, Sweet, Levi (2021). "Sustainable Cities: Socioeconomics, Building Types, and Urban Morphology." Smoky Mountain Computational Science Data Challenge (SMCD21). Virtual Conference, August 24-August 26, 2021. [Challenge]
- Bass, Brett, New, Joshua R., Adams, Mark, and Berres, Andy (2021). "Model America - WRF Grid Cell Archetype extract from ORNL's AutoBEM (1.0) [Data set]." Zenodo, doi.org/10.5281/zenodo.5154216, August 2, 2021. [DOI]
- New, Joshua R. (2021). "Nation-scale building energy modeling, climate change, and potential grid impacts." IEEE Power & Energy Society General Meeting (PES GM) panel session titled "Emerging applications of data-driven intelligence as an enabler for demand response in wholesale and local markets." Virtual Conference, July 28, 2021. [PPT]
- Data: New, Joshua R., Bass, Brett, Adams, Mark, Berres, Anne, and Luo, Xuan (2021). "Los Angeles County Archetypes in Weather Research and Forecasting (WRF) Region from ORNL's AutoBEM [Data set]." Zenodo, doi.org/10.5281/zenodo.4726136, Apr. 28, 2021. [Zenodo]
- Data: New, Joshua R., Adams, Mark, Bass, Brett, Berres, Anne, and Clinton, Nicholas (2021). "Model America – data and models of every U.S. building." ORNL Constellation, https://doi.ccs.ornl.gov/ui/doi/339, April 14, 2021.
- Data: New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Clark County (Vegas) Archetypes from ORNL's AutoBEM [Data set]." *Zenodo*, doi.org/10.5281/zenodo.4552901, Mar. 21, 2021. [Zenodo]
- Data: New, Joshua R., Bass, Brett, Adams, Mark, and Berres, Anne (2021). "Model America - Clark County (Vegas) extract from ORNL's AutoBEM (Version 1.1) [Data set]." *Zenodo*, doi.org/10.5281/zenodo.4552901, Feb. 16, 2021. [Zenodo]
- Wang, Jing, Ye, Yunyang, Zuo, Wangda, New, Joshua R., and Rose, Amy (2021). "City-scale Building Occupancy Prediction using Geographic Information System Data." *engrXiv* journal, doi.org/10.31224/osf.io/658yb, Feb. 9, 2021. [engrXiv] [PDF]
- Garrison, Eric and New, Joshua R. (2021). "Quality Control Methods for Advanced Metering Infrastructure Data." *Smart Cities* journal, Special Issue "Applied Artificial Intelligence in Energy Systems," volume 4(1), pages 195-203, doi.org/10.3390/smartcities4010012, Jan. 28, 2021. [SmartCities] [PDF]
- Bass, Brett, New, Joshua R., and Copeland, William (2020). "Potential Energy, Demand, Emissions, and Cost Savings Distributions for Buildings in a Utility's Service Area." *Energies* journal, Special Issue "Designing, Modeling and Optimizing Energy and Environmental Systems for Buildings," volume 14(1), issue 132, doi.org/10.3390/en14010132, Dec. 29, 2020. [Energies] [PDF] [OSTI]
- Allen-Dumas, Melissa R., Rose, Amy N., New, Joshua R., Omitaomu, Olufemi A., Yuan, Jiangye, Branstetter, Marcia L., Sylvester, Linda M., Seals, Matthew B., Carvalhaes, Thomaz M., Adams, Mark B., Bhandari, Mahabir S., Shrestha, Som S., Sanyal, Jibonananda, Berres, Anne S., Kolosna, Carl P., Fu, Katherine S., and Kahl, Alexander C. (2020). "Impacts of the Morphology of New Neighborhoods on Microclimate and Building Energy Use." *Renewable & Sustainable Energy Reviews*, volume 133, 110030, ISSN 1364-0321, doi.org/10.1016/j.rser.2020.110030, November 2020. [RSER] [PDF]
- New, Joshua R., Adams, Mark, Garrison, Eric, Bass, Brett and Guo, Tianjing. (2020). "Scaling Beyond Tax Assessor Data." ASHRAE/IBPSA-USA 2020 *Building Performance Analysis Conference & SimBuild* (BPACS), Chicago, IL, Sept. 29 - Oct. 1, 2020. [PDF] [PPT] [MP4]
- Bass, Brett and New, Joshua R. (2020). "Future Meteorological Year weather data from IPCC Scenarios." ASHRAE/IBPSA-USA 2020 *Building Performance Analysis Conference & SimBuild* (BPACS), Chicago, IL, Sept. 29 - Oct. 1, 2020. [PDF] [PPT] [MP4]

- Presentation: New, Joshua R. (2020). "Digital Twin of a Utility: Beyond Urban-Scale Building Energy Modeling." *Invited Speaker* to ORNL's monthly Energy Talks, Oak Ridge, TN, July 11, 2020. [PPT]
- Bass, Brett and New, Joshua R. (2019). "Potential Demand Reduction from Buildings in a Simulated Utility." Invited speaker to the *ACM BuildSys conference UrbSys workshop*, Columbia University New York City, NY, November 10, 2019. [ACM] [PDF] [PPT]
- Presentation: Hong, Tianzhen, Jain, Rishee, New, Joshua R., Reinhart, Christoph, Polly, Ben, Luo, Xuan (2019). "Panel - Urban Information and Energy Modeling." *Proceedings of the IBPSA Building Simulation Conference*, Rome, Italy, Sept. 2-4, 2019. [PPT]
- New, Joshua R., Adams, Mark, Garrison, Eric, Copeland, William, Smith, Brian, and Campbell, Andy (2019). "Nailing the Peak: City-Scale, Building-Specific Load Factor and Contribution to a Utility's Hour of Critical Generation." *Proceedings of the IBPSA Building Simulation Conference*, Rome, Italy, Sept. 2-4, 2019. [PDF] [PPT]
- New, Joshua R. (2019). "Automatic Building detection and Energy Model creation (AutoBEM) technologies for remote audit of individual buildings at urban scales." Invited speaker to the *EnergyExchange*, presented as part of a seminar titled "Energy and Water Assessments: Virtual and Conventional", Denver, CO, August 20-22, 2019. [PDF]
- Hussein, Ahmed, Eicker, Ursula, and New, Joshua R. (2019). "A Comparison Between Two Urban-Scale Methods for The Assessment of Heat Energy Demand and Photovoltaic Potential in New York City, USA." Proceedings of the *European International Conference on Transforming Urban Systems (EICTUS)*, University of Strasbourg, France, June 26-28, 2019. [PPT]
- New, Joshua, Copeland, William, and Ingraham, James (2018). "Poster: Virtual Electric Power Board of Chattanooga, TN (EPB)." ORNL BTO Peer Review, April 15, 2019. [Poster]
- Garrison, Eric, New, Joshua R., and Adams, Mark (2019). "Accuracy of a Crude Approach to Urban Multi-Scale Building Energy Models Compared to 15-min Electricity Use." Best PhD Student Paper award. In *Proceedings of the ASHRAE Winter Conference*, Atlanta, GA, Jan. 12-16, 2019. [PDF] [PPT]
- Luo, Xuan, Macumber, Dan, New, Joshua R., and Judkoff, Ron *(Seminar Chair)* (2018). "Seminar - Multiscale Building Energy Modeling, Part 10." In *Proceedings of the ASHRAE Winter Conference*, Atlanta, GA, Jan. 12-16, 2019. [LBNL] [NREL] [ORNL]
- New, Joshua R. (2018). "TEDergy Talk: Automatic Building Energy Modeling (AutoBEM)." In *Proceedings of the Building Performance Analysis Conference and SimBuild (BPACS)* co-organized by ASHRAE and IBPSA-USA, Chicago, IL, Sept. 26-28, 2018. [PDF] [PPT]
- New, Joshua R., Garrett, Aaron, Sanyal, Jibonananda, Slattery, Bob, Gehl, Anthony, and Miller, William A. (2019) "Big Data Mining for Assessing Calibration of Building Energy Models." In *International Journal of Computer & Software Engineering (IJCSE)*, volume 3, issue 136, Sept. 8, 2018. [PDF]
- New, Joshua R., Adams, Mark, Im, Piljae, Yang, Hsiuhan, Hambrick, Joshua, Copeland, William, Bruce, Lilian, Ingraham, James A. (2018). "Automatic Building Energy Model Creation (AutoBEM) for Urban-Scale Energy Modeling and Assessment of Value Propositions for Electric Utilities." In *Proceedings of the International Conference on Energy Engineering and Smart Grids (ESG)*, Fitzwilliam College, University of Cambridge, Cambridge city, United Kingdom, June 25-26, 2018. [PDF] [PPT]
- Ingraham, James A. and New, Joshua R. (2018). "Virtual EPB." Presented to Building Technologies Office following the *BTO Peer Review*, 87 slides. Arlington, VA, May 3, 2018. [PPT]
- New, Joshua R., Omitaomu, Olufemi, Yuan, Jiangye, Yang, Hsiuhan (Lexie), Carvalhaes, Thomaz, Sylvester, Linda, and Adams, Mark (2017). "AutoBEM: Automatic Detection and Creation of Individual Building Energy Models for Each Building in an Area of Interest." In *Proceedings of the 2nd International Energy and Environment Summit*, Dubai, UAE, November 18-20, 2017. [PDF] [PPT]
- New, Joshua R. (2017). "ORNL projects related to the Urban Dynamics Institute (UDI) and Automatic Building Energy Model creation (AutoBEM)." Presented as part of a multi-lab workshop at the *Smart Cities Week*, Washington, D.C., October 3, 2017. [PPT]
- New, Joshua R., Chen, Yixing, Choi, Joon-Ho, and Bass Abushakra *(Seminar Chair)* (2017). "Seminar 28 - Urban-Scale Energy Modeling, Part 5" presenting "Automatic Building Energy Model Creation (AutoBEM)." In *Proceedings of the ASHRAE Annual Conference*, Long Beach, CA, June 26, 2017. [ORNL] [LBNL] [USC]

- New, Joshua R., Adams, Mark, Bhandari, Mahabir, Shrestha, Som, and Sanyal Jibonananda (2017). "Auto-generated Building Energy Models (AutoBEM) of Urban Morphologies and Analysis of Microclimate Interaction." Presented to the Urban Dynamics Institute Scientific Advisory Board, March 23, 2017. [Poster]