Urban-MET: Modeling Urban Energy Savings Scenarios using Earth System Microclimate and Urban Morphology

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Microclimate Effects on Energy Use

Why build the Urban Microclimate and Energy Tool (Urban-MET)
•Neighborhood morphology can make as much as an 83% difference in energy use in some climate zones

What can this tool do for us?
•Show measured and modeled energy efficiency of various buildings in selected urban areas for different morphologies under different microclimatic conditions

•Project potential energy savings by morphology for climatically distinct US cities

•Give implications for different morphologies of future climate and urban growth scenarios by providing an interactive 3D visualization environment for testing idealized neighborhood additions (residential and commercial)

Integration of several different approaches provides improved analysis and planning in three research areas:
•Earth system modeling
•Climate impacts, adaptation and vulnerability
•Urban planning and development

Climate Modeling: Global to Urban Micro

Where are we now?
•On integrating urban processes into an earth system model, the Community Land Model Urban component within CESM has gone a long way toward bringing together two-way interactive global climate change, regional weather and atmospheric chemistry and urban heat island effects.

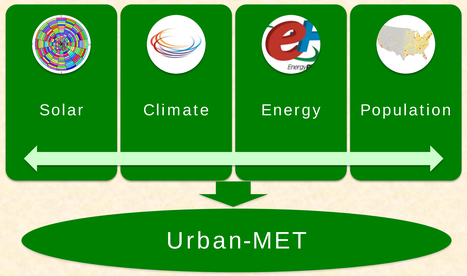
•The system can evaluate changes in local climate and their impacts to the global system by incorporating urban extents, urban canyons, urban parks, and roof and road fractions of grid cells, and identify contributing processes within these components to an urban heat island effect.

Modeling Gaps Addressed with Urban-MET

Once completed, Urban-MET would enhance urban information systems in the following ways:

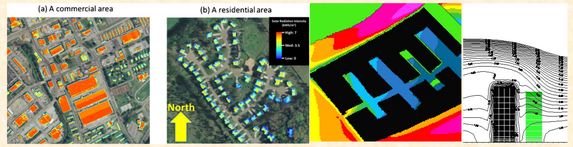
Spatially Explicit	• Population • Urban morphology • Building level thermal and radiative properties
Micro Climate	• Boundary layer heat island, pollution, precipitation • Heat Island circulation (wind vectors) • Rooftop solar fraction input
Energy	• Full building-level energy modeling
Population Projection	• Population projections for 2030 and 2050 • Idealized morphologies for testing new growth • Interactive visualization

Four Modeling Capabilities within a Single Framework



By combining solar, climate, energy and population tools, we can examine more deeply the interaction of urban and environmental systems.

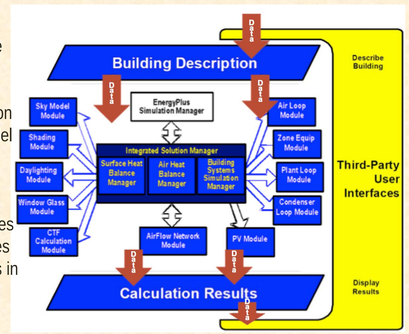
Solar and Microclimate



- LiDAR imagery, including 3D building topography,is used in calculation of variations in long and shortwave radiation due to sun angle variations by latitude, season and time of day. Multispectral imaging techniques are used to calculate neighbouring effects from building shadows, and determine various land cover from their frequency spectra.
- Micro-climate calculation of subgrid variables at high resolution,captures building and neighbourhood-level processes affecting the amount of energy customers use for heating and cooling. Differences in neighbourhood morphologies affect these processes.

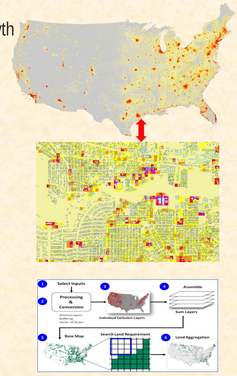
Building Energy Use

The building energy simulation portion of the framework calculates energy use at neighbourhood resolution using microclimate model results and energy consumption trends of various functionally and climatically different types of cities. Initial examples include neighbourhoods in Houston, Knoxville and Chicago.

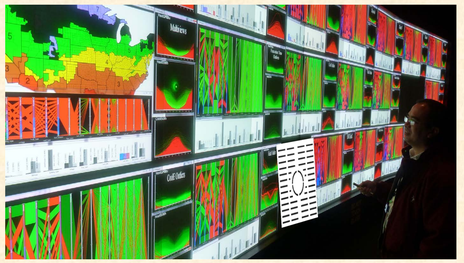


Projecting Urban Morphological Changes for Future Years

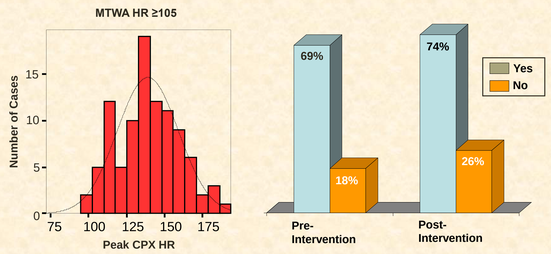
- Site for residential and commercial growth using LandCast methodology
- Determine neighborhood by neighborhood the best morphology to accommodate that new growth
- Evaluate greenspace options using unique ORNL capabilities
- Analysis is high resolution and spatially explicit
- Visualization is interactive with planning and development professionals



Developing Idealized 21st Century Morphologies

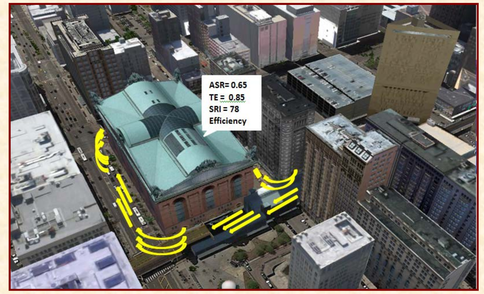


Sensitivity analyses are run that test various components of morphological design to determine the set of parameters contributing to the most efficient geometries. These include performance tests of the various combinatorial permutations involving building use type, building height, density, surface-to-volume geometry and open space ratios for each neighborhood for different combinations for heat-energy and cooling-energy efficiency. Results are used to determine which of these characteristics represents the best morphology in terms of energy use for each neighborhood in each city. From these results we derive idealized morphologies for examination of future development scenarios.



3D Interactive Visualization

Visualization for each city simulation includes:
•3D representation of building configurations of actual cities
•Animation of changes in temperature, precipitation, humidity and airflow within the urban terrain of those cities
•Simultaneous building energy use
•Interactive analysis tools, including a mechanism for users to "try out" different archetypal and actual morphologies for city development and to observe changes to the microclimate and building energy use with each block addition and in each climate scenario.



References

Bhandari, M.S., S.S Shrestha, and J.R. New (2012). Evaluation of Weather Data for Building Energy Simulations, *Journal of Energy and Buildings*, 49(0), 109-118.

Kodysh, J.B., O.A. Omitaomu, B.L. Bhaduri and B.S. Neish (2013). Methodology for estimating solar potential on multiple building rooftops for photovoltaic systems, *Sustainable Cities and Society*, 8, 31-41.

McKee, J.J., A.N. Rose, E. Bright, T. Huynh, and B. Bhaduri (2015). A Locally-Adaptive, Spatially-Explicit Projection of U.S. Population for 2030 and 2050. *Proceedings of the National Academy of Sciences*, 112(5), 1344–1349, doi: 10.1073/pnas.1405713112 .

Omitaomu, O.A, Blevins, B.R., Jochem, W.C., Mays, G.T., Belles, R., Hadley, S.W., Harrison, T.J., Bhaduri, B.L., Neish, B.S., and Rose, A.N. (2012). "A GIS-Based Multi-criteria Decision Analysis Approach for Evaluating New Power Generating Sites." *Journal of Applied Energy*.

Acknowledgements

This manuscript has been authored by employees of UT-Battelle, LLC, under contract DE-AC05-00OR22725 with the U.S. Department of Energy.