NSF Workshop on

Implication of Urban Scale Occupant Behavior for Resilient Building Design, Operation and Policy Making

May 13th, 2024

Syracuse University, Syracuse, USA

Workshop Outcome Report

Dr. Bing Dong

Director, Built Environment Science and Technology (BEST) Lab

Professor, Department of Mechanical and Aerospace Engineering

Syracuse University

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1. Background

Despite occupying only 3% of the Earth's land, cities drive 60% - 80% of energy consumption and contribute to about 75% of carbon emissions [1], of which the building sector accounts for more than 40% [2] A foreseeable trend is that the global urbanization process will continue to advance, which puts excessive pressure on limited energy resources. To solve this problem, researchers and engineers apply urban building energy models (UBEM) as a potential tool to simulate the building energy demand and evaluate the energy efficiency at the urban scale [3]. Though UBEMs are widely used, most of them are based on simplistic or default assumptions, leading to simulation results deviating significantly from realistic data [4]. To achieve high accuracy and practicality of UBEM and provide sufficient reliability to support energy decision-making, the assumptions and uncertainty of sensitive input parameters related to building physics, energy systems, and occupant behavior need to be carefully considered [5].

One of the most important factors and uncertainty sources is occupant-related input parameters with high levels of randomness and diversity [6]. Over the past few decades, researchers have consistently attempted to use more detailed data in various types and more advanced methods to capture the realistic characteristics of occupant behavior (OB) in buildings, improving the precision of OB models. However, the accuracy of the models can not directly equal to the practicality. Especially at the urban scale, highly accurate simulation of OB in the entire region which contains thousands of buildings will be a huge challenge for computing and data collection. It’s widely agreed that OB models should be built based on its application scenarios and scales, selecting the appropriate method, and using the quantity and quality-suitable data at the right level of details [7].

Traditional occupant behavior modeling has been studied at the building level, and it has become an important factor in the investigation of building energy consumption. However, studies modeling occupant behaviors at the urban scale are still limited while such behavior is becoming a key factor in urban building and system energy modeling and energy policy making [8]. Recent work has revealed that urban big data can enable occupant behavior modeling at the urban scale [9]. However, utilizing existing data sources and modeling methods in building science to model urban scale occupant behaviors has challenges. The challenges for studying

occupancy behavior at an urban scale are: (a) urban scale occupant behavior is stochastic and complex in nature [10]; (b) lack of occupant behavior data sets to understand spatial and temporal diversity among all different buildings with different functions and occupant behaviors [11]; and (c) lack of an appropriate modeling approach to integrate social demographical and equity with urban scale occupant movement inside and outside buildings. In addition, climate changes such as more extreme heat or cold events and power outages also affect occupants physiologically and psychologically and thus change their behavior. Modeling human behavior has been studied in other domains such as traffic analysis, epidemiology, communication, disaster management, and marketing [12]. The goal of this workshop is to bridge the data sources and methodology gap between building science and beyond through bringing people from the multiple disciplines of building science, social science, energy policy, communication, civil engineering, transportation, public health, and others. The anticipated impact is significant contribution to foundational knowledge for improving the quality of urban living and reducing energy consumption.

2. Objectives and Topics

The objective of this workshop is to identify the research gaps in existing urban scale occupant behavior research including what the obstacles are and what is needed from NSF, and the identification of future research directions. This workshop aims to: (a) advance general knowledge of building science, engineering, and modeling through round-table discussions; (b) advance knowledge of methodological development in urban scale occupant behavior research for built environment through panel presentations and intensive technical discussions; (c) provide a collaborative platform for engineers, social science, policy and public health faculty and graduate students to exchange ideas; (d) provide future research directions and encourage enhanced involvement of faculty and students to participate in relevant research; (e) provide insights on better community building design and operation under future climates.

Panels topics include:

(1) Modeling occupant behavior at a community level

What are the modeling requirements of occupant behavior at a community level? What are new modeling methods of occupant behavior at a community level?

(2) Data sources and human mobility modeling approaches

What data sources have been used in other domains that could potentially enhance modeling capabilities for current building science applications?

(3) Applications in resilient building design, operation and policy making

What are potential future research directions for building design, operation, and policies at a community level, with enhanced data sources and modeling methods from other domains?

3. Workshop Organization

Organizing Committee

Members of the organizing committee of the workshop were:

- Bing Dong (**Chair**), Associate Professor, Department of Mechanical Engineering, Syracuse University
- Zheng O'Neill (Advisory Committee), Associate Professor, Mechanical Engineering, Texas A&M University
- Da Yan (Advisory Committee), Professor, School of Architecture, Tsinghua University
- Menghao Qin (Advisory Committee), Professor, Department of Environmental and Resource Engineering, Technical University of Denmark
- Jin Wen (Advisory Committee), Professor, Civil, Architectural and Environmental Engineering, Drexel University
- Clinton J. Andrews (Advisory Committee), Professor, School of Planning and Public Policy, Rutgers University
- Yongxin Tao (Advisory Committee), Professor, Department of Mechanical Engineering, Cleveland State University

- **Panelists**

The following are the invited speakers (listed in the presentation order):

Name	Affiliation
Invited Keynote	
Dr. Tianzhen Hong	Lawrence Berkeley National Laboratory
Panel 1 Modeling Occupant Behavior at A Community Level	
Prof. Clinton J Andrews	Rutgers University
Prof. Da Yan	Tsinghua University
Prof. Nan Ma	Worcester Polytechnic Institute
Dr. Jeetika Malik	Lawrence Berkeley National Laboratory
Panel 2 Data Sources and Human Mobility Modeling Approaches	
Prof. Ryan Wang	Northeastern University
Prof. Xinyue Ye	Texas A&M University
Prof. Xinwu Qian	University Of Alabama
Dr. Robert N Stewart	Oak Ridge National Laboratory & University of Tennessee
Panel 3: Applications In Resilient Building Design, Operation and Policy Making	
Prof. Lucy Qiu	University Of Maryland College Park
Prof. Simi Hoque	Drexel University
Dr. Jian Zhang	Pacific Northwest National Laboratory
Prof. Amanda Webb	University Of Cincinnati

4. Workshop Summary

Panel 1 Modeling occupant behavior at a community level

- **Panel presentation summary:**

This panel consists of four presentations:

Dr. Clinton J. Andrews's presentation "Relating Ambient Observations of Environmental Stressors to Personal Exposures" pointed out that personal exposures to environmental stressors including extreme heat and air pollution often correlate poorly with ambient observations at the neighborhood and urban scales. Time spent indoors is part of the explanation, alongside the significant microclimatic variations that exist within a given neighborhood or city. He discussed a current project in Elizabeth, NJ to build fixed indoor and outdoor sensor networks while also deploying mobile sensors. The fixed sensors support predictions of next-hour conditions and the mobile sensors reveal how occupants adapt. The combined network helps occupants, building operators, and public officials to safely manage extreme heat and air pollution.

Dr. Da Yan's "Exploring the Impacts of Heterogeneity and Stochasticity in Occupant Behavior on Urban Building Energy Models" introduced uncertainty in occupant behavior (OB) into the UBEM workflow and assesses the differences in the impacts of heterogeneity and stochasticity on cooling demand. In the case study of residential building stock, it is found that stochasticity in occupancy decreases the peak cooling demand by 54%, whereas the uncertainty in air-conditioning (AC) behavior has less effect. Heterogeneity is the main reason for the diversity in cooling demand, whereas stochasticity better reflects the dynamics. Occupancy and AC behavior models with higher fidelity are required to obtain results with higher spatial or temporal resolution, which could be selected according to the UBEM applications.

In Dr. Nan Ma's presentation "Listening More to Building Occupants on Social Media: Leveraging Natural Language Processing into Indoor Environmental Quality Evaluation", she addressed the challenges of conventional Post Occupancy Evaluation (POE) methods, which struggle to fully capture occupant dissatisfaction with indoor environmental quality (IEQ) due to predefined questionnaire formats and labor-intensive data collection. Given these limitations, this research leverages open-access, open-ended 1.2 million scraped social media reviews using natural language processing (NLP) techniques to determine the prevalence of IEQ complaints, assess the extent of occupant dissatisfaction, and investigate the economic value of IEQ satisfaction.

Dr. Jeetika Malik's presentation "The Human Dimension of Building Decarbonization: A Sufficiency Imperative" focused on a sufficiency approach involving an absolute reduction in

energy consumption while being consistent with equity and environmental limits. She introduced sufficiency-oriented framework that fosters an equitable approach to decarbonizing buildings while considering the planetary boundaries. She also discussed the need for modeling sufficiency-oriented occupant behavior at scale.

- **Panel discussion summary:**

The panel discussion centered around seven topics:

Topic 1: How to choose a focus for community-scale models and avoid overwhelming detail?

- Suggested taking a more bottom-up approach, allowing people to talk organically and collecting data first before deciding on the model.
- Emphasized the importance of clear goals and objectives in data collection and model development, focusing on key variables that drive the desired outcomes.
- Advocated for a balanced approach that combines both top-down and bottom-up perspectives, using social media platforms to engage communities and gather insights.

Topic 2: How to use and translate model results and measurement results to convince stakeholders to make changes?

- Discussed the use of personal air monitors in public housing projects to empower residents to collect data and understand their own exposures, fostering awareness and prompting action.
- Highlighted the importance of public awareness and education, encouraging students to engage with their families and communities to raise awareness about environmental issues.
- Described collaborations with utilities and government agencies to provide technical assistance and recommendations based on research findings, aiming to address specific community needs and challenges.
- Mentioned efforts to compare data with existing standards and update knowledge, accordingly, advocating for evidence-based design and control measures.

Topic 3: How to address biases in data, such as lower-rated hotels being perceived as having lower-quality rooms?

- Shared a methodology for stratifying hotel prices per night and examining satisfaction levels across different economic strata, allowing for a more nuanced understanding of customer satisfaction regardless of price point.
- Mentioned that she does not filter out anything at the beginning of the process and works on filtering later.

Panel 2 Data Sources and Human Mobility Modeling Approaches

- **Panel presentation summary:**

In this panel, 4 presentations are included:

Dr. Ryan Wang's discussed the symbiotic relationship between small, big, and synthetic data in studying urban mobility in his presentation "Urban Mobility: Small Data, Big Data, and Synthetic Data": Small data offers detailed behavioral insights, while big data facilitates predictive analytics through expansive datasets from various sensors and devices. Synthetic data fills gaps where actual data is limited, upholding privacy while ensuring comprehensive analytical models. The presentation also outlined effective strategies for data integration, spotlighting the transformative impact on urban transport systems, and highlighting the balance between data utility and ethical considerations in a concise exploration of city-scale movement dynamics.

In the presentation "Class Distribution, Human Mobility, and Campus Digital Twin" by Dr. Xinyue Ye, he explored the intersection of class distribution, human mobility, and campus digital twin applications, focusing on their role in optimizing space utilization and enhancing campus efficiency. He introduced an interactive visual analytics system that tackles these issues. The findings underscore the importance of integrating human mobility into campus digital twin models to improve decision-making. The system's effectiveness, adaptability, and real-world applicability are demonstrated, highlighting its role in practical DT implementation for built environments.

Dr. Xinwu Qian's presentation "Understanding the Community Impacts of Public Charging Infrastructure Using Human Mobility Data" aimed to offer an in-depth understanding of the influence of public charging infrastructure (PCI) deployment on community dynamics by mining extensive real-world data from vehicle trajectories, residents, visiting patterns, and activity location data. He discussed how users choose PCIs and examine the broader effects of PCIs on community dynamics and revealed important structured crowd behavior in choosing PCIs, the race and class biases in PCI accessibility, the quantification of implicit socioeconomic barriers to PCI access, and the potential effects of PCI development on local businesses.

Dr. Robert N. Stewart talked about the Global Building Intelligence (GBI) project integrating disparate building knowledge within a Bayesian framework in his presentation "Building Level Attribution for Urban-Scale Modeling and Simulation". By situating attribution in a probabilistic space, GBI facilitates data harmonization across scales and modalities, anticipating technological advancements. Furthermore, GBI's flexible framework allows for the incorporation of less structured forms of knowledge, such as experiential or subject matter expertise. This holistic approach not only streamlines data integration but also supports downstream modeling and simulation, particularly with Monte Carlo methods. Ultimately, GBI contributes to a more comprehensive understanding of building dynamics at both local and global levels, laying the foundation for informed urban planning and decision-making.

- **Panel discussion summary:**

<u>Topic 1: What is the biggest challenge for urban-level big data?</u>

- Identified the purpose of buildings poses a major challenge, as it critically informs the building's design and operation, yet it is difficult to ascertain from available data.
- The primary issue is converting vast amounts of urban data into actionable insights. Despite the opportunity for multidisciplinary collaboration, personal interests sometimes hinder data sharing, complicating the utilization of big data.
- The challenge lies in integrating local knowledge, such as familiarity with a physical space, into the data. Understanding and interacting with an environment goes beyond what raw data can provide.

Panel 3 Applications in Resilient Building Design, Operation and Policy Making

- **Panel presentation summary:**

4 presentations are included in this panel:

Dr. Lucy Qiu discussed several recent research papers related to the equity and distributional considerations of energy transitions in her presentation "Equity and Distributional Considerations of Energy Transitions". She highlighted that energy plays a critical role in addressing climate change and satisfying human needs, and changes in energy systems can have unequal and distributional effects on different sectors and consumer groups. Such changes can result from climate change, new energy technologies, and government interventions. She examined the negative impact on housing prices from hydrogen infrastructure facilities and the implications for environmental justice and the unequal impact on the power system resilience due to extreme weather and natural disasters. Finally, she illustrated that how government programs may address both equity challenges and energy transitions.

In Dr. Simi Hoque's presentation "Overheating in Residential Buildings", she described ongoing efforts to model the impacts of extreme heat conditions in residential buildings across climate zones in the United States. The intent is to associate indoor heat exposure with physiological outcomes across different residential building typologies. Using the DOE residential building prototypes as a baseline, they simulated indoor temperature, humidity, and wet bulb temperature due to heat wave conditions in households with and without mechanical air conditioning.

The presentation, by Dr. Jian Zhang, "A New Database of Building-Space-Specific Internal Loads and Load Schedules for Performance-Based Code Compliance Modeling of Commercial Buildings" presented a database of default building-space-specific loads and load schedules for use in energy modeling, and in particular code compliance modeling for commercial buildings. The existing sets of default loads and load schedules are reviewed and the challenges behind using them for specific research topics are discussed. Then, the proposed method to develop the building-space-specific loads and load schedules is introduced. After that, the database for these

building-space-specific loads and load schedules is presented. In addition, one case is studied to demonstrate the applications of these loads and load schedules.

Dr. Amanda Webb explored mechanisms for integrating equity-related data and metrics into BEM in her presentation “Integrating Equity-Related Data and Metrics into Urban Building Energy Modeling”. She indicated that the benefits and burdens of building energy use are unevenly distributed across society, producing underlying patterns of inequity in urban areas. Building energy modeling (BEM)—especially at the urban scale—offers a potential tool for understanding how energy and decarbonization retrofits might help reduce these inequities. However, equity has yet to be operationalized in a BEM context. She helped to establish potential applications for this work, describe current data barriers, and highlight promising methodologies.

- **Panel discussion summary:**

Topic 1: Trade-offs in Building Design and Policymaking

- Ensuring comfort and well-being might require initial higher investments in HVAC systems that are energy-efficient but costly upfront.
- Policy measures must navigate the economic impacts on lower-income populations who might bear the brunt of increased housing costs due to upgraded building standards.
- Consider the impact of construction disruptions on communities and provide measures to mitigate these effects.

Topic 2: Impacts on Disadvantaged Communities During Low-Carbon Transitions

- Increased cost of living due to the premium on 'green' technologies and infrastructures.
- Limited access to the benefits of new technologies due to affordability issues.
- Job losses in traditional industries without adequate retraining for new green jobs.

Student Poster Competition

The workshop also included a student poster competition (with more than 20 students participating) and funded 8 Ph.D. students from different universities in the USA to participate.

Prof. Zheng O'Neill from Texas A&M University, Prof. Menghao Qin from Technical University of Denmark and Dr. Jie Zhao from Delos Lab were invited as judges. Nathaniel Smith from Texas A&M University, Zixin Jiang from Syracuse University and Jesse Piburn from University of Tennessee won the prize.

Also, the workshop was partly open to local participants, including graduate students and researchers from Syracuse University, SUNY College of Environmental Science and Forestry, etc. The students engaged in exchanges and discussions with experts, scholars, and other students from around the world through this workshop.

5. Future Directions

The workshop concluded with the following recommendations for future research:

- **Complexity of Human Behavior**

Accurately modeling the varied and dynamic human behavior across different settings remains a significant challenge.

- **Data Privacy and Ethical Concerns**

Protecting personal data while gathering detailed behavior insights for modeling presents substantial privacy and ethical challenges.

- **Integration with Building Simulation Tools**

Effectively incorporating occupant behavior into building performance simulations is complicated by technical and computational barriers.

- **Cross-Disciplinary Collaboration Difficulties**

Facilitating effective collaboration across disciplines like psychology, sociology, and engineering for behavior modeling poses significant coordination challenges.

- **Advancement in Sensing Technology and Data Analytics**

Enhancements in IoT and sensor technologies, coupled with advanced data analytics, could revolutionize the precision of occupant behavior predictions.

- **Development of Privacy-Respecting Data Protocols**

Establishing data collection protocols that respect privacy while enabling detailed analysis is critical for ethical behavior modeling.

- **Standardization of Urban Occupant Behavior Modeling**

Creating and adopting standardized methods for occupant behavior modeling can improve its applicability and comparability across studies.

- **Focused Interdisciplinary Research Initiatives**

Increasing support for interdisciplinary research can advance the development of comprehensive and accurate behavior modeling methods

Reference

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8. Happle, Gabriel, Jimeno A. Fonseca, and Arno Schlueter. "A review on occupant behavior in urban building energy models." *Energy and Buildings* 174 (2018): 276-292.

9. Ren, Jiawen, et al. "A Systematic Review of Occupancy Pattern in Urban Building Energy Modeling: From Urban to Building scale." *Journal of Building Engineering* (2024): 110307.

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10. Liu, Zhaoru, et al. "Exploring the impacts of heterogeneity and stochasticity in air-conditioning behavior on urban building energy models." *Sustainable Cities and Society* 103 (2024): 105285.

11. Nejadshamsi, Shayan, et al. "Data sources and approaches for building occupancy profiles at the urban scale–A review." *Building and Environment* 238 (2023): 110375.

12. Dong, Bing, et al. "Occupant behavior modeling methods for resilient building design, operation and policy at urban scale: A review." *Applied Energy* 293 (2021): 116856.

Appendix A

NSF Workshop on Implication of Urban Scale Occupant Behavior for Resilient Building Design, Operation and Policy Making

Appendix B: Participant List

ABIGAIL ANDREWS	RUTGERS UNIVERSITY, USA
CLINTON J. ANDREWS	RUTGERS UNIVERSITY, USA
JIANLI CHEN	THE UNIVERSITY OF UTAH, USA
FAN CHENG	SHENZHEN UNIVERSITY, CHINA
YOUNGSIK CHOI	TEXAS A&M UNIVERSITY, USA
SHUANG CUI	THE UNIVERSITY OF TEXAS AT DALLAS, USA
HASHANI DE SILVA	UNIVERSITY OF CINCINNATI, USA
ZHIPENG DENG	SYRACUSE UNIVERSITY/UNIVERSITY OF CENTRAL FLORIDA, USA
BING DONG	SYRACUSE UNIVERSITY, USA
JIANHUA FAN	TECHNICAL UNIVERSITY OF DENMARK, DENMARK
LEI FANG	TECHNICAL UNIVERSITY OF DENMARK, DENMARK
XIN GUO	SYRACUSE UNIVERSITY, USA
ANDREA JEAN HOE	SYRACUSE UNIVERSITY, USA
TIANZHEN HONG	LAWRENCE BERKELEY NATIONAL LABORATORY, USA
SIMI HOQUE	DREXEL UNIVERSITY, USA
WENFENG HUANG	SYRACUSE UNIVERSITY, USA
ZIXIN JIANG	SYRACUSE UNIVERSITY, USA
YONGJUN JIN	SYRACUSE UNIVERSITY, USA
GUOWEN LI	TEXAS A&M UNIVERSITY, USA
LU LI	SYRACUSE UNIVERSITY, USA
SHUNDONG LI	WORCESTER POLYTECHNIC INSTITUTE, USA
YUEWEI LI	SYRACUSE UNIVERSITY, USA
YUGUO LI	UNIVERSITY OF HONG KONG, CHINA (HONG KONG)
HANJIE LIN	SYRACUSE UNIVERSITY, USA
TONG LIN	SYRACUSE UNIVERSITY, USA
YAPAN LIU	SYRACUSE UNIVERSITY, USA
ZHENLEI LIU	OAK RIDGE NATIONAL LABORATORY, USA
NAN MA	WORCESTER POLYTECHNIC INSTITUTE, USA
ZHIHAO MA	THE UNIVERSITY OF UTAH, USA
JEETIKA MALIK	LAWRENCE BERKELEY NATIONAL LABORATORY, USA
JARAD MASON	HARVARD UNIVERSITY, USA
GUILLAUME MAURIN	UNIVERSITY OF MONTPELLIER, FRANCE
SHAYAN MIRZABEIGI	SYRACUSE UNIVERSITY, USA
CECILE MONTEUX	PARIS SCIENCES ET LETTRES UNIVERSITY/ESPCI, FRANCE
KUMAR NADDUNURI	INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR, INDIA
ZHENG O'NEILL	TEXAS A&M UNIVERSITY, USA
ZHIHONG PANG	LOUISIANA STATE UNIVERSITY, USA
	SYRACUSE UNIVERSITY
AMARASINGHAGE T.D. PERERA	PRINCETON UNIVERSITY, USA
JAVIER PEREZ CARVAJAL	MATERIALS SCIENCE INSTITUTE OF MADRID, SPAIN
JESSE PIBURN	OAK RIDGE NATIONAL LABORATORY, USA
XINWU QIAN	THE UNIVERSITY OF ALABAMA, USA
MENGHAO QIN	TECHNICAL UNIVERSITY OF DENMARK, DENMARK
ZHAO QIN	SYRACUSE UNIVERSITY, USA
LUCY QIU	UNIVERSITY OF MARYLAND COLLEGE PARK, USA
CARSTEN RODE	TECHNICAL UNIVERSITY OF DENMARK
IAN M SHAPIRO	SYRACUSE UNIVERSITY
CHRISTIAN SERRE	NATIONAL CENTRE FOR SCIENTIFIC RESEARCH, FRANCE
JIALEI SHEN	NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, USA
ZHENHUA SHI	THE UNIVERSITY OF UTAH, USA
NATHANIEL SMITH	TEXAS A&M UNIVERSITY, USA
SAMEERAA SOLTANIAN-ZADEH	SYRACUSE UNIVERSITY, USA
ROBERT N. STEWART	OAK RIDGE NATIONAL LABORATORY, USA
LIANGZHU WANG	CONCORDIA UNIVERSITY, CANADA
RYAN WANG	NORTHEASTERN UNIVERSITY, USA
XIAO WANG	TSINGHUA UNIVERSITY, CHINA
XUEZHENG WANG	SYRACUSE UNIVERSITY, USA
YEQING WANG	SYRACUSE UNIVERSITY, USA
AMANDA WEBB	UNIVERSITY OF CINCINNATI, USA
REISA WIDJAJA	UNIVERSITY OF TEXAS AT SAN ANTONIO, USA
DOYUN WON	NATIONAL RESEARCH COUNCIL, CANADA
WENBO WU	UNIVERSITY OF TEXAS AT SAN ANTONIO, USA
DA YAN	TSINGHUA UNIVERSITY, CHINA
YITING YANG	SYRACUSE UNIVERSITY, USA
XIAOFENG YE	UNIVERSITY OF MARYLAND COLLEGE PARK, USA
XINYUE YE	TEXAS A&M UNIVERSITY, USA
RUI ZHANG	OAK RIDGE NATIONAL LABORATORY, USA
JENSEN ZHANG	SYRACUSE UNIVERSITY, USA
JIAN ZHANG	PACIFIC NORTHWEST NATIONAL LABORATORY, USA
XINGXING ZHANG	DALARNA UNIVERSITY, SWEDEN
YUHANG ZHANG	TEXAS A&M UNIVERSITY, USA
JIE ZHAO	DELOS LABS, USA
WENBING ZHAO	CLEVELAND STATE UNIVERSITY, USA
WEIWEI ZHENG	SYRACUSE UNIVERSITY, USA
JI ZHOU	SYRACUSE UNIVERSITY, USA

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Appendix C: Workshop Program

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Center of Excellence in
Environmental & Energy Systems

AGENDA OVERVIEW

MAY 13 NSF WORKSHOP

8:30 - 9:00	Breakfast and Registration	
9:00 - 9:05	Welcome & Introductions	Bing Dong (Syracuse University)
9:05 - 9:35	Multi-Scale Modeling of Building Decarbonization and Climate Resilience	Tianzhen Hong (Lawrence Berkeley National Laboratory)

PANEL 1: MODELING OCCUPANT BEHAVIOR AT A COMMUNITY LEVEL (CHAIR:CLINTON J. ANDREWS)

9:35 - 9:50	Relating Ambient Observations of Environmental Stressors to Personal Exposures	Clinton J. Andrews (Rutgers University)
9:50 - 10:05	Exploring the Impacts of Heterogeneity and Stochasticity in Occupant Behavior on Urban Building Energy Models	Da Yan (Tsinghua University)
10:05 - 10:20	Listening More to Building Occupants on Social Media: Leveraging Natural Language Processing into Indoor Environmental Quality Evaluation	Nan Ma (Worcester Polytechnic Institute)
10:20 - 10:35	The Human Dimension of Building Decarbonization: A Sufficiency Imperative	Jeetika Malik (Lawrence Berkeley National Laboratory)
10:35 - 11:15	Discussion	Notetaker: Hashani De Silva (University of Cincinnati)
11:15 - 11:25	Photo Time	
11:25 - 12:25	Student Poster Competition	
12:25 - 13:25	Lunch	

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PANEL 2: DATA SOURCES AND HUMAN MOBILITY MODELING APPROACHES (CHAIR:RYAN WANG)

13:25 - 13:40	Urban Mobility: Small Data, Big Data, and Synthetic Data	Ryan Wang (Northeastern University)
13:40 - 13:55	Class Distribution, Human Mobility, and Campus Digital Twin	Xinyue Ye (Texas A&M University)
13:55 - 14:10	Understanding the Community Impacts of Public Charging Infrastructure Using Human Mobility Data	Xinwu Qian (The University of Alabama)
14:10 - 14:25	Building Level Attribution for Urban-Scale Modeling and Simulation	Robert N. Stewart (Oak Ridge National Laboratory University of Tennessee)
14:25 - 15:05	Discussion	Notetaker:Nathaniel Smith (Texas A&M University)
15:05 - 15:20	Coffee Break	

PANEL 3: APPLICATIONS IN RESILIENT BUILDING DESIGN, OPERATION AND POLICY MAKING (CHAIR: LUCY QIU)

15:20 -15:35	Equity and Distributional Considerations of Energy Transitions	Lucy Qiu (University of Maryland College Park)
15:35 - 15:50	Overheating in Residential Buildings	Simi Hoque (Drexel University)
15:50 - 16:05	A New Database of Building-Space-Specific Internal Loads and Load Schedules for Performance based Code Compliance Modeling of Commercial Buildings	Jian Zhang (Pacific Northwest National Laboratory)
16:05 - 16:20	Integrating Equity-related Data and Metrics into Urban Building Energy Modeling	Amanda Webb (University of Cincinnati)
16:20 - 17:00	Discussion	Notetaker: Xiaofeng Ye (University of Maryland)
17:00 - 17:30	Student poster competition award ceremony & Workshop Summary	
17:30 - 18:30	Lab tour	
18:30 - 20:30	Reception Dinner	

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