

PROMETHEUS

An aerial photograph of a city skyline at sunset. The sky is a mix of orange, yellow, and blue. The city is filled with numerous skyscrapers of varying heights and architectural styles. A wide river flows through the city, with a multi-lane highway bridge crossing it. In the foreground, there is a large green park area with trees and a small boat docked at a pier. The overall scene is a vibrant and detailed urban landscape.

03

BUILDINGS, CITIES, AND PERFORMANCE

Edited by Narjes Abbasabadi

Journal of the PhD Program in Architecture
IIT Architecture Chicago

PROMETHEUS

03

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Narjes Abbasabadi

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Journal of the PhD Program in Architecture

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Buildings, Cities, and Performance

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PROMETHEUS: JOURNAL OF THE PHD PROGRAM IN ARCHITECTURE

Why *Prometheus*?

Prometheus is a peer-reviewed journal that presents research-in-progress developed for the annual student-run symposium organized by the PhD Program of the College of Architecture, Illinois Institute of Technology. Each year, PhD students are selected to serve as editors of the journal. The research featured in each issue is produced primarily by PhD students from IIT and universities all over the world who participated in the annual symposium. It utilizes different methodologies to explore questions related to architecture and engineering, as well as allied disciplines such as design, landscape architecture, and urbanism. Additionally, each issue of *Prometheus* includes an annual overview of the academic accomplishments of our PhD students, plus related activities ranging from our weekly Architecture Research Forum lectures to social events aimed at fostering community.

Authors

Rahman Azari, PhD, Assistant Professor and former Director of the PhD Program
College of Architecture, Illinois Institute of Technology

Michelangelo Sabatino, PhD, Director of the PhD Program, Professor and former Dean
College of Architecture, Illinois Institute of Technology

Why did we select Prometheus as the symbol and masthead of our journal? He was the irreverent Titan who stole fire to pave the way for the advancement of humankind. From our vantage point in Chicago, we understand that fire is both a tool for destruction and creation. The Great Fire of 1871 leveled the city and provided Daniel H. Burnham and Edward H. Bennett with a reason to devise the Plan of Chicago (1909). Without the fire of modern blast furnaces, the steel girders and supporting beams in our Ludwig Mies van der Rohe-designed S. R. Crown Hall would not have been possible.

As a College of Architecture within a science and technology-rich university, our faculty and PhD students are committed to fostering an environment of interdisciplinary inquiry. Since the early 1940s, research with real-world applications has been produced by our Master of Science Program graduates. Our PhD Program in Architecture was established in the late 1990s as a continuation of the research conducted by MS students in collaboration with faculty. In the intervening years, we have trained researchers who have made significant contributions within academia and in practice across the globe.

We hope *Prometheus* will serve as a platform for emerging researchers who, like the symbol and masthead of this journal, take risks that lead to game-changing innovation at the service of humankind.

We wish to thank Narjes Abbasabadi for her efforts as the editor as well as organizing the symposium, Melinda Van Leer for her copyediting oversight, and designers Bud Rodecker and Alyssa Arnesen of Thirst.

Funding for this publication was provided by the John Vinci Distinguished Research Fellowship and the College of Architecture.

EDITOR'S INTRODUCTION

Cities are responsible for significant amounts of energy-related carbon emissions worldwide. With population growth, uneven expansion of urban areas, and climate change, pursuing environmental sustainability through reducing energy consumption and associated emissions in cities is a global priority. Today, cities represent the biggest challenges—and opportunities—to achieve sustainable development. Research on contemporary architecture and urbanism with a focus on sustainability is a critical way to enhance environmental performance and develop low-carbon cities. The articles included in this third issue of *Prometheus* explore the theme of *Buildings, Cities, and Performance*, and focus on a broad range of sustainability-related topics that engage emerging researchers and graduate students in dialogue addressing the gaps and future trends of energy performance research within an urban context. The theme was chosen to interrogate the deployment of architecture and planning with scaling-up environmental awareness and sustainability as a guiding principle which indeed reflects the *Prometheus* name—symbolizing risk, foresight, and savior—through taking steps to advance methods to understand the risks posed by climate change, project energy/environmental performance of cities, and ultimately contribute in promoting global sustainability.

The articles included in this volume were presented at the 3rd International Graduate Student Symposium of the PhD Program in Architecture at the Illinois Institute of Technology (IIT), in November 2018, which brought together researchers and graduate students to contribute, discuss, and collaborate on how to transition to more sustainable cities, and how to explore ways to reduce energy consumption and associated emissions. This volume contains novel research contributions in the academic field of sustainable architecture and technologies of the built environment, particularly projecting energy performance of buildings as the largest contributors to urban energy use and emissions. Over 60 researchers with different disciplinary backgrounds, including architecture, engineering, urban design, and planning, contributed to this publication. The volume is structured in four parts based on thematically grouped articles: 1) Urban Environmental Performance; 2) Urban and Building Performance: Comfort, Environmental Indoor Quality, and Energy; 3) Materials, Systems, and Building Performance; and 4) Climate, Design, and Performance. The articles highlight theoretical, methodological, modeling, and empirical studies on building and urban environmental quality, energy, air pollution, and life cycle assessment.

The dominant themes that united the papers focus on developing data-driven and simulation-based frameworks, and methodologies for measuring and understanding the performance of buildings and cities. My paper proposes an integrated data-driven framework for urban energy use modeling that aims to provide a holistic image of urban energy use at multiple scales and aggregate across end-uses. With considering urban socio-spatial context, it gives insight on the multifaceted and intricate relationships between urban attributes, and building and transport energy performance. In another article, Surekha Tetali and Nina Baird present a method for projecting urban heat island conditions in several densely populated Indian cities using remote sensing data and discuss how to mitigate heat island effects through effective built environment design principles. Sokratis Papadopoulos and Constantine Kontokosta open up the issue of building energy benchmarking as a significant approach for understanding and improving the energy performance of existing buildings across the city and showing how ENERGY STAR® models trained on nationwide samples can be flawed and are not generalizable to city-specific cases. They propose a conceptual model for future building energy benchmarking by contextualizing statistical analysis and using local data sources. In another study, Mehdi Ashayeri proposes a framework for

Author

Narjes Abbasabadi
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predicting indoor air quality and energy consumption of naturally ventilated urban buildings through applying a hybrid data-driven and simulation-based approach. Another study by Irmak Turan and Christoph Reinhart present a simulation-based framework for assessing visual connectivity within an open plan office to better understand the occupant's visual experience through quantitative means.

To sum up, the articles included in this volume demonstrate the need for developing methods and tools for quantifying performance from a multi-dimensional perspective and analyze the sustainability of the built environment by exploring the different design and planning approaches using various case studies. Most of the articles highlight the importance of contextualized methodologies corresponding to local characteristics and shed light on responsive strategies to increase the performance of cities compatible with nature and human health.

Acknowledgments

The symposium featured presenters from Carnegie Mellon, CEPT University, Chongqing University, Drexel University, GRIHA Council, IIT, Iowa State University, MIT, New York University, Penn State, University of Massachusetts Amherst, University of Biskra, University of Catania, University of Illinois at Urbana-Champaign, University of Florida, University of Pittsburgh, University of Washington, and the U.S. National Institute of Standards and Technology (NIST). In addition to paper presentations, this symposium included four keynote speeches: *Cities for the Millennials—Design Tools in Support of Sustainable Urban Architecture* by Dr. Christoph Reinhart, Professor and Director of Building Technology Program at MIT; *Architecture in a Warming World* by Norbert Lechner, Professor Emeritus at Auburn University; *Low Entropy, Smart, and Healthy Cities* by Dr. Stephen Ray, Assistant Professor and Director of Sustainability at North Park University; and *Shaping Future Cities to be Smart, Sustainable, and Resilient* by Dr. Sybil Derrible, Director of Complex and Sustainable Urban Networks Lab at the University of Illinois at Chicago. We concluded the symposium's presentations, critical review, debate, and networking with an exciting dinner at the Tadao Ando-designed exhibition space at Wrightwood 659 in Chicago.

I would like to thank all who made this symposium and publication possible. First, I would like to thank Dean Michelangelo Sabatino for initiating and supporting the annual IIT PhD students symposium and establishing the *Prometheus* journal. I would also like to thank him for supporting the symposium and the journal financially with the John Vinci Distinguished Research Fellowship. I am also grateful for the support of our sponsors in organizing the symposium: Wanger Institute for Sustainable Energy Research (WISER) and Skidmore, Owings & Merrill (SOM). I would like to thank Dr. Rahman Azari for helping in organizing the symposium. I want to particularly thank the scientific committee, as well as Kevin Harrington (IIT) for guiding the tour and giving the introduction about the IIT campus. Finally, I would like to express appreciation to all the researchers and PhD students who submitted papers and attended the symposium, as well as my fellow PhD students at IIT for their efforts and their support, especially: PhD Candidates Marcos Petroli, Mehdi Ashayeri, and Zahida Khan. I would like to thank Dr. Dan Whittaker, PhD alumnus, for organizing and supporting the evening dinner. Because it is a very important future research need, the topic of the 2019–20 symposium will remain as the dominant theme—*Buildings, Cities, and Performance*—with a focus on simulation-based and data-driven approaches as identified in the previous year's symposium. I'm looking forward to receiving your contributions.

SYMPOSIUM OVERVIEW

Buildings, Cities, and Performance: November 16–17, 2018

Cities account for a significant portion of global anthropogenic greenhouse gas emissions, due to population growth and urbanization. With major contributions to energy demand and carbon emissions in cities, building-related urban energy use should be the foundation of local and global agendas to meet carbon reduction targets. The 3rd International Graduate Student Symposium that is hosted by the PhD Program at IIT Architecture will explore the theme of “Buildings, Cities, and Performance.” The symposium provides a platform to engage in and enhance the dialogue around future trends of energy performance research in the building sector within an urban context. The symposium highlights graduate student contributions in architecture, engineering, urban design and planning, landscape architecture, and other related disciplines.

Nota bene: Presentation information, titles and affiliations are reproduced as they appeared in the symposium program in 2018.

NOVEMBER 16: OPENING, LOWER CORE, S.R. CROWN HALL

Introduction and Welcome: Rahman Azari, PhD; Peter Kilpatrick, PhD, Provost; Michelangelo Sabatino, PhD, Dean of the College of Architecture *Illinois Institute of Technology*

Keynote: MIT Cities for the Millennials—Design Tools in Support of Sustainable Urban Architecture

Christoph Reinhart, PhD, Professor and Director of Building Technology Program *Massachusetts Institute of Technology*

Reception and Holiday Gospel Concert

Upper Center Core

NOVEMBER 17: PAPER SESSIONS, S.R. CROWN HALL

Campus Tour: Kevin Harrington

Illinois Institute of Technology

Introduction: Narjes Abbasabadi, PhD

Illinois Institute of Technology

Keynote 1: Architecture in a Warming World

Norbert Lechner, Professor Emeritus *Auburn University*

PAPER SESSION A-1

Urban Environmental Performance

A New Look into District Energy Systems for Energy Efficient Neighborhoods

Alpha Jacob Arsano, Shreshth Nagpal, and Christoph Reinhart *Massachusetts Institute of Technology*

Mapping and Quantifying Urban Heat Islands in India's Most Dense Cities

Surekha Tetali and Nina Baird *Carnegie Mellon*

Evaluating Urban Ventilation in the Urban Grid of Barcelona and Berlin: A Comparative Study on the Relationship Between Wind Direction and Urban Morphology

Homeira Mirhosseini *Penn State University*

An Integrated Data-Driven Framework for Urban Energy Use Modeling

Narjes Abbasabadi *Illinois Institute of Technology*

Revisiting City Energy Performance Grading: The Inadequacy of Current Standards and The Promise of Big Data

Sokratis Papadopoulos and Constantine Kontokosta
New York University

PAPER SESSION A-2

Urban and Building Performance: Comfort, Environmental Indoor Quality, and Energy

A New Framework for Evaluating Indoor Views and Internal Visual Connectivity in Open Plan Workspaces

Irmak Turan and Christoph Reinhart *Massachusetts Institute of Technology*

A Framework for Performance-Based Facade Design for Optimizing Energy, Comfort, and Cost

Mahsa Minaei and Ajla Aksamija
University of Massachusetts Amherst

An Integrated Machine Learning and Simulation Framework for Indoor Air Quality and Energy Use (IAQ-EU)

Mehdi Ashayeri *Illinois Institute of Technology*

Investigating the Spatial Variation and Relationship Between Building and Transportation Energy Use for Residents of Philadelphia Metropolitan Region

Shideh Shams Amiri, Simi Hoque, Earl Lee, and Nariman Mostafavi *Drexel University*

Climate Change Impacts on Office Buildings Performance: A Case Study of Philadelphia, USA

Hamed Yassaghi and Simi Hoque *Drexel University*

Network Simulation and Scale-Model Experimental Study of Natural Ventilation in Subway Stations

Yanan Liu, Zhen Zeng Yujie Zhang, and Yimin Xiao
Chongqing University

Human Behavior In Outdoor Public Spaces of Tall Urban Morphology: A Microclimatic Study of Inter-Relationships Between Outdoor Thermal Comfort, User's Attendance, and Physical Urban Forms

Zahida Khan *Illinois Institute of Technology*

Keynote 2: Low Entropy, Smart, and Healthy Cities

Stephen Ray, PhD, Assistant Professor and Director of Sustainability *North Park University*
Technical Advisor *Skidmore, Owings and Merrill*

PAPER SESSION B-1

Materials, Systems, and Building Performance

Interaction of Chilled Beam Flows and its Impact on Air Circulation and Thermal Comfort in Buildings

Nikhilesh Ghanta, Barry Coflan, and Leon Glicksman
Massachusetts Institute of Technology

Lessons from the Creation of a Thermally Isolated Structural Steel and Reinforced Concrete Museum Building

Daniel Whittaker *Illinois Institute of Technology*

On the Impact of Height Limitation Ordinances of Ultra-Tall Buildings; Chicago and Dubai

Amjad Alkoud *Illinois Institute of Technology*

Fast Estimation of Buildings' Embodied Energy Using Economic Input-Output Method for an Urban Model

Rezvan Mohammadziazzi and Melissa M. Bilec
University of Pittsburgh

Embodied Carbon in MEP Systems: A Simplified Life Cycle Assessment (LCA) Method for MEP Systems in Commercial Office Buildings of the Pacific Northwest

Barbara Rodriguez, Kathrina Simonen, Hyun Woo Lee, and Monica Huang *University of Washington*

A Novel Statistical Model for Monitoring and Predicting Energy Behavior in an Office Building

Thulasi Ram Khamma, Yuming Zhang, Stéphane Guerrier, and Mohamed Boubekri *University of Illinois at Urbana-Champaign and Penn State University*

Knowledge Representation and Reasoning Framework for Building Energy Monitoring

Parastoo Delgoshaei, Mohammad Heidarinejad, and Amanda J. Pertzborn *National Institute of Standards and Technology (NIST) and Illinois Institute of Technology*

PAPER SESSION B-2

Climate, Design, and Building Performance

Designing an Energy-Efficient Residential Building in Hot and Arid Region of Iran, City of Yazd

Farzad Hashemi *Iowa State University*

Enhancing Natural Ventilation Through Massing: New Possibilities for Turkish Mass Housing

Ezgi Bay *Illinois Institute of Technology*

Net-Zero Energy School Buildings in Cold Climate: Design Strategies and Techniques

Hamed Hakim, Andriel Fenner, Mohamad Ahmadzadeh Razkenari, and Charles Kibert *University of Florida*

Development of Energy Performance Index Benchmark for Cold Climatic Regions of India

Giriraj Srivastava and Ankit Bhalla
Illinois Institute of Technology and GRIHA Council, New Delhi, India

The 'Particlizing' of the Matter

Grazia Maria Nicolosi *University of Catania*

Parametric Optimization of Courtyard's Configuration in Typical Saharan Houses

Benharra Houda and Mahaya Chafik *University of Biskra*

The Impacts of Naturally Ventilated Double-Skin Facade Configurations on Energy Performance for Super-Tall Office Buildings

Yohan Kim *Illinois Institute of Technology*

Prototype of Net-Zero Energy School for Hot and Dry Climate in Indian Context

Amanda Thounaojam, Shoumik Desai, Yashima Jain, Dharini Sridharan, and Ankit Debnath *CEPT University*

Keynote 3: Shaping Future Cities to be Smart, Sustainable, and Resilient

Sybil Derrible, PhD, Director of Complex and Sustainable Urban Networks Lab *University of Illinois at Chicago*

Reception

Tadao Ando Gallery, Wrightwood 659