

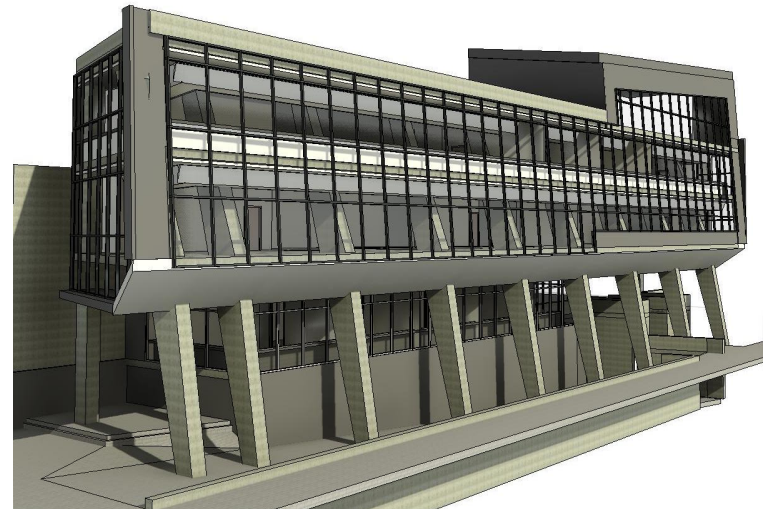
Sensing, Digital Twins, and the Built Environment: Integrated Infrastructure Sensing

Melissa M. Bilec, PhD

Co-Director, Mascaro Center for Sustainable
Innovation

George M. and Eva M. Bevier Endowed Chair
Department of Civil & Environmental
Engineering

Special Assistant to the Provost for
Sustainability
University of Pittsburgh



May 29, 2026



University of
Pittsburgh

Mascaro Center for Sustainable Innovation



Photo Credit: inhabitat

Energy and water are deeply
coupled but managed in
silos

Center for Sustainable Landscapes

One of the Greenest Buildings in the World

The Center for Sustainable Landscapes (CSL) at Phipps Conservatory and Botanical Gardens generates all of its own energy and treats all storm and sanitary water captured on-site. It is the first and only building to meet seven of the highest green certifications:



LIVING
BUILDING
CHALLENGE™

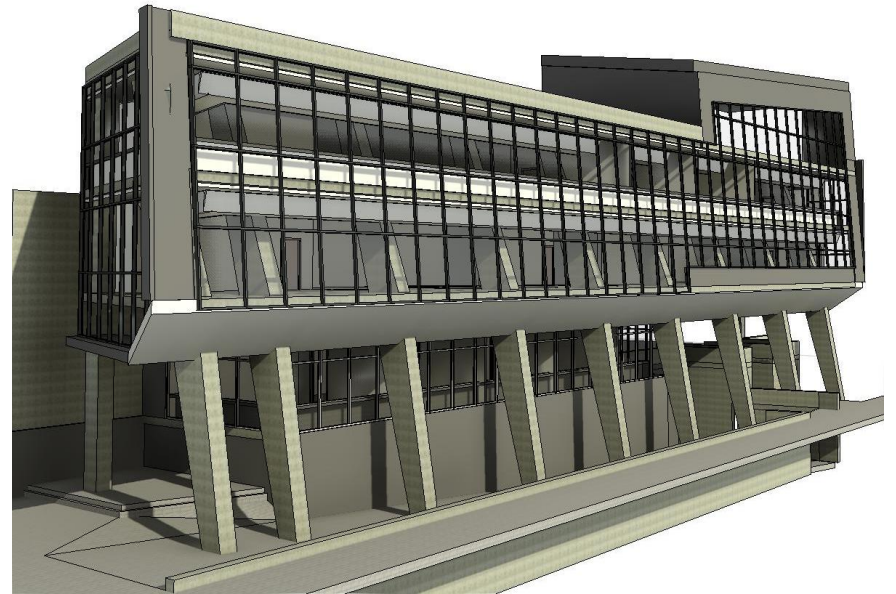


fitwel®

2019
SITES PLATINUM

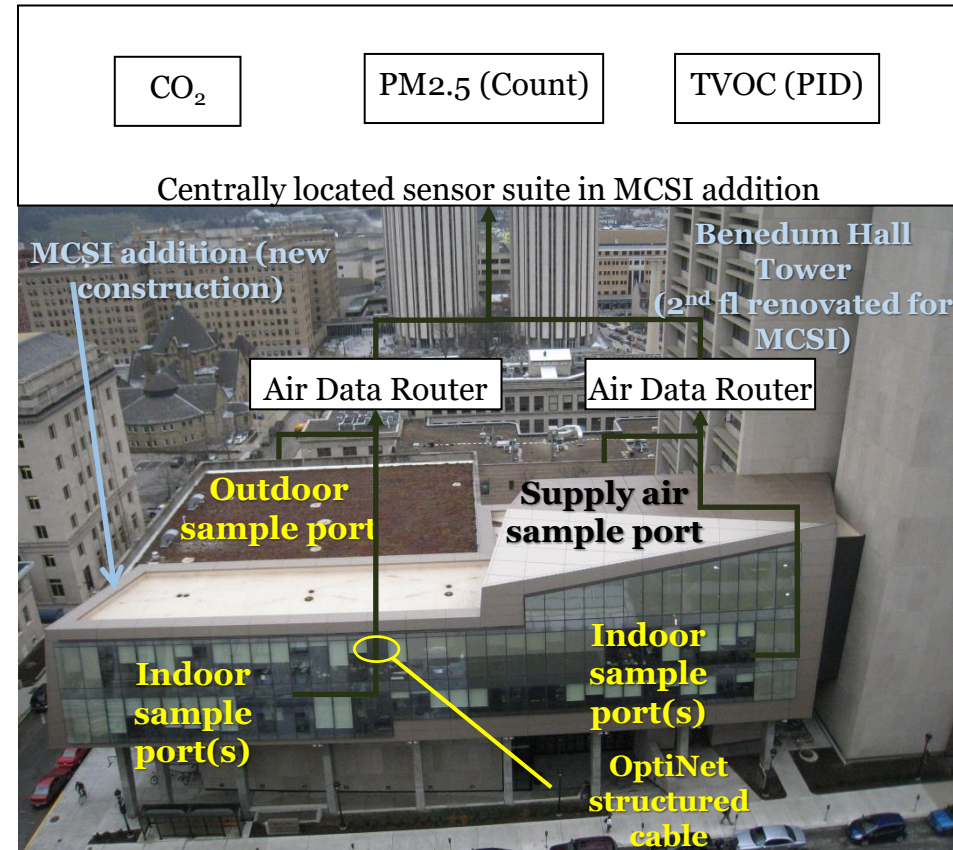
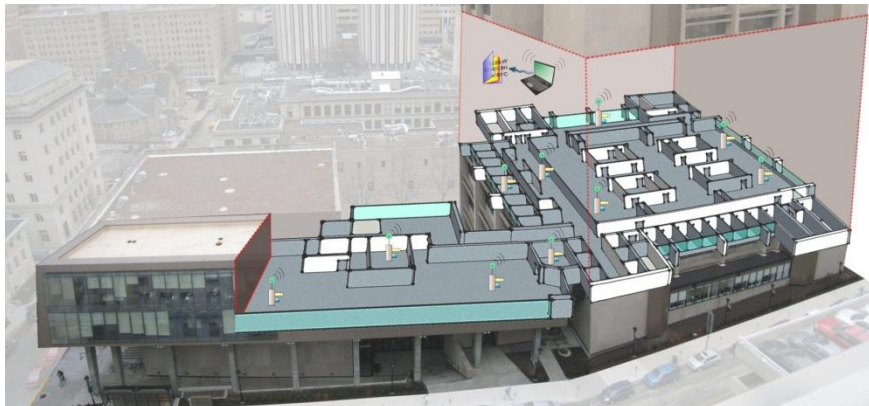
BREEAM® USA
delivered by bre

Buildings: The Intervention Point





- Existing building automation system supplemented by AirCuity OptiNet™ system
- Senses HVAC variables + indoor/outdoor CO₂, PM_{2.5} and TVOCs



From Sensing to Digital Twins

Sensing Layer

Meters, IoT sensors, BAS data streams across energy and water systems

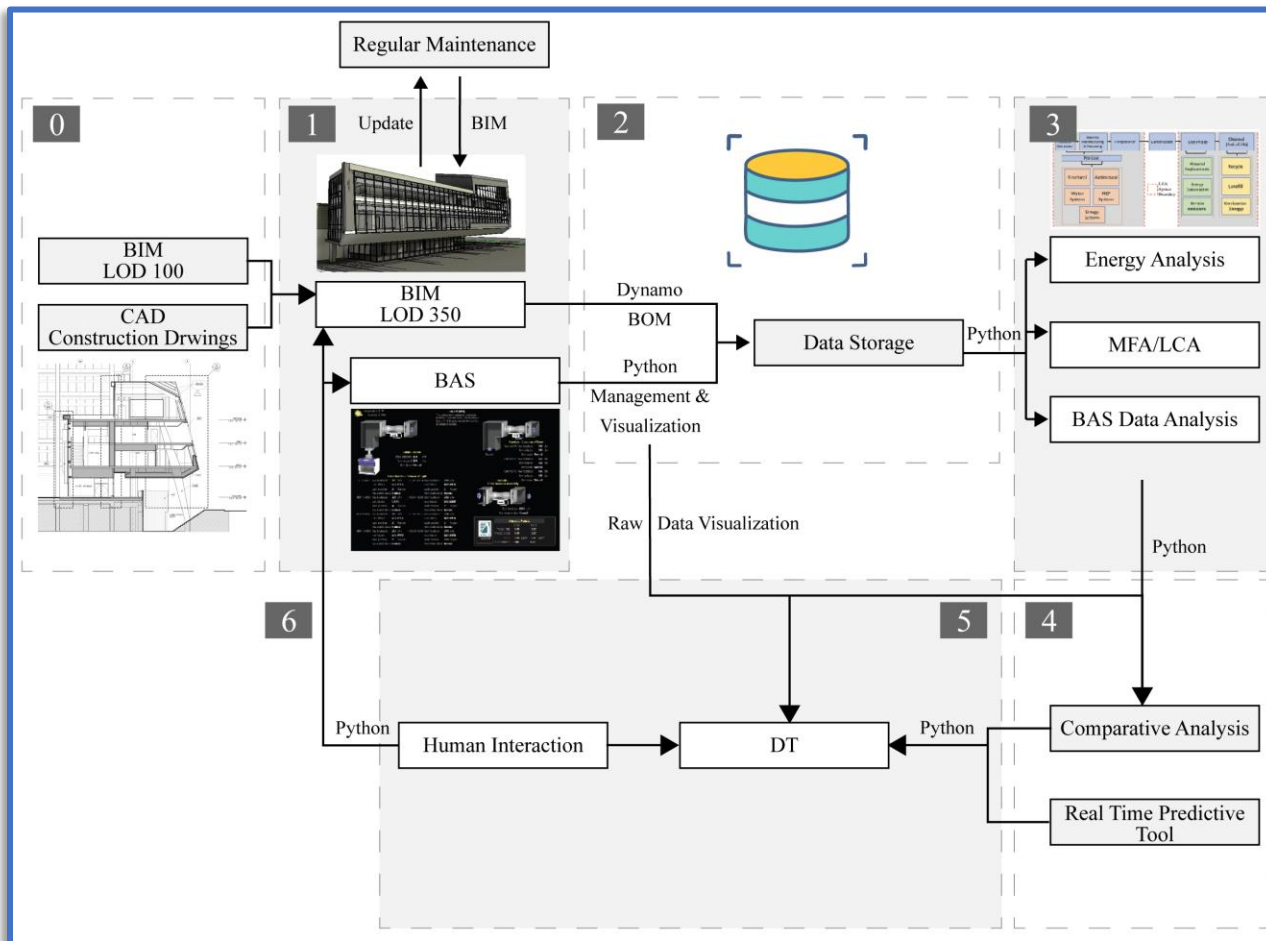
Digital Twin

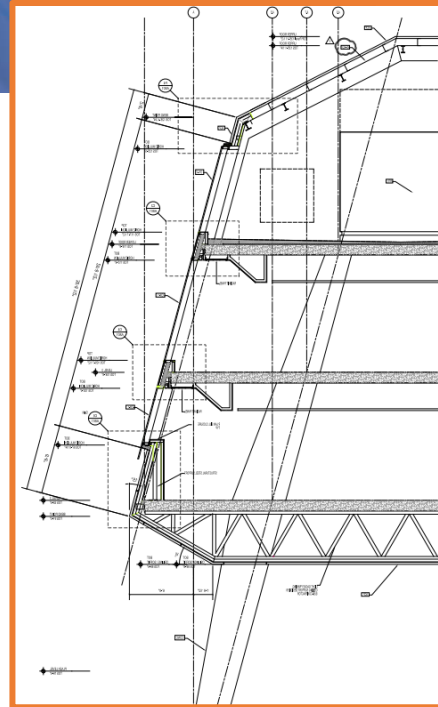
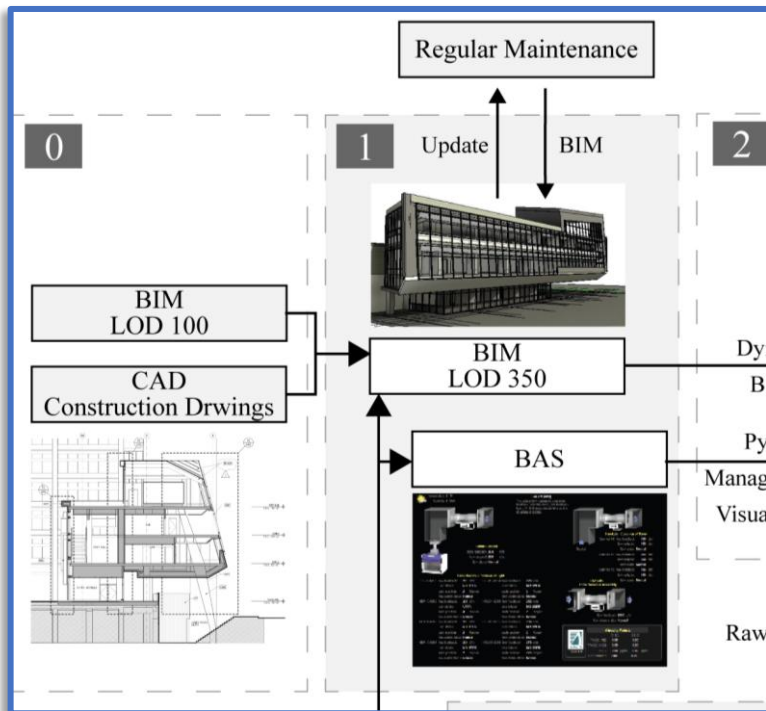
Integrated dynamic model of building/district performance —

LCA + Circular Economy

Long-term material, energy, and water analysis.

How?



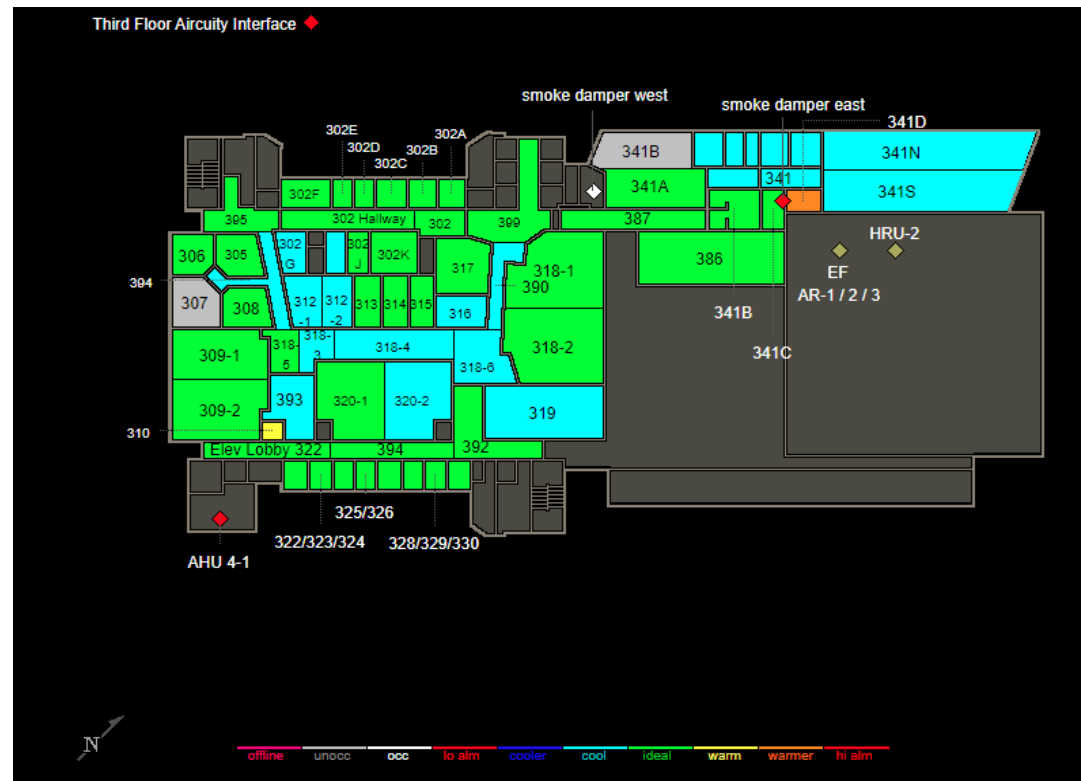
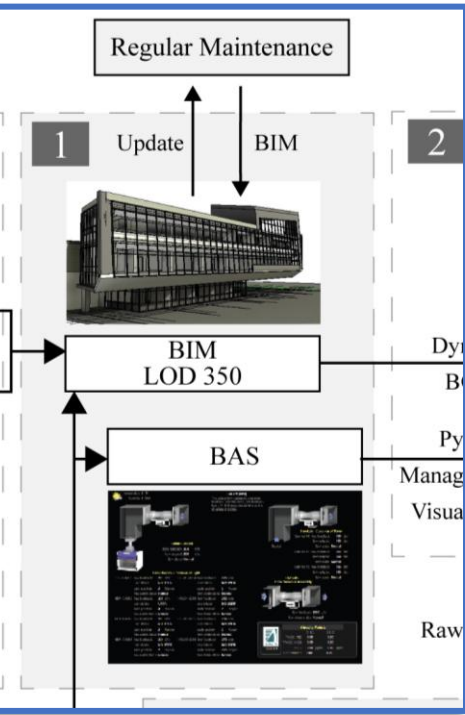


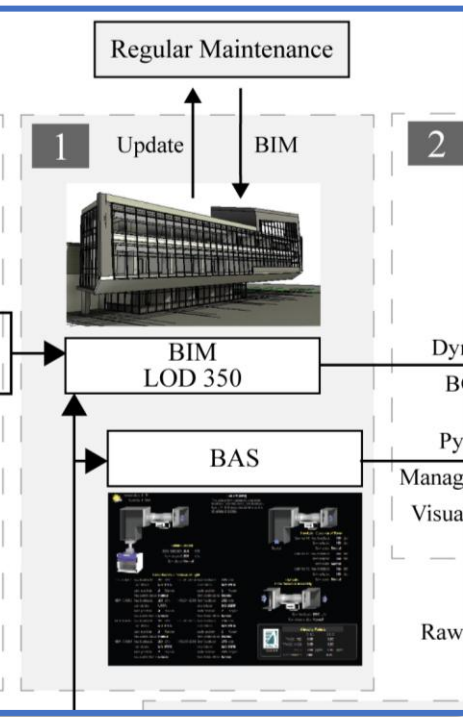
- LOD 100 BIM
- Architectural drawings
- Two-fold use
 - 3D replica of the physical asset
 - Data storage

UPIISC

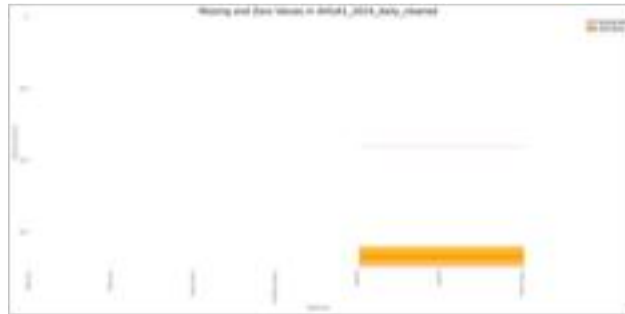
UNIVERSITY OF
PITTSBURGH
INFRASTRUCTURE
SENSING

COLLABORATION WORKSHOP

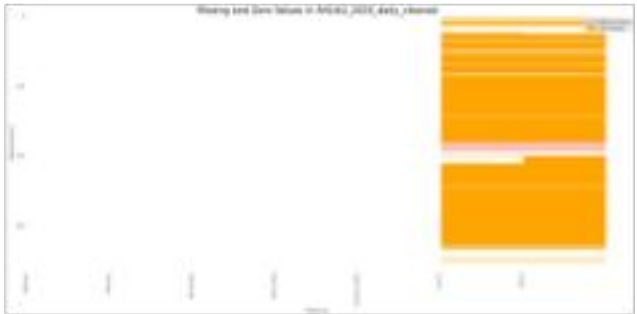




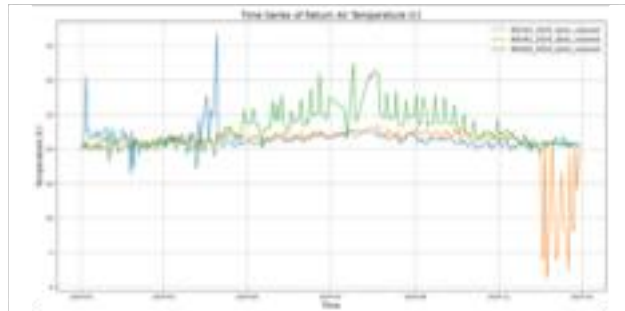
A - Null and Zeroes Value Floor 1



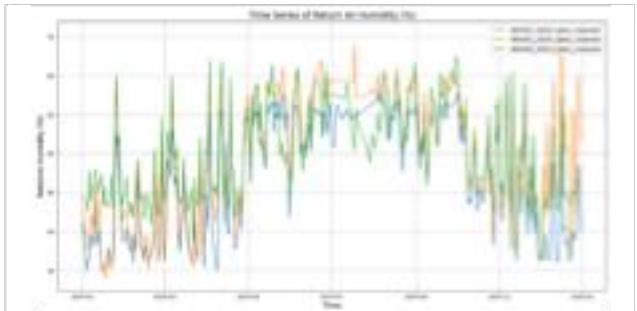
B - Null and Zeroes Value Floor 2



C - Time Series Temperature Values All Floors



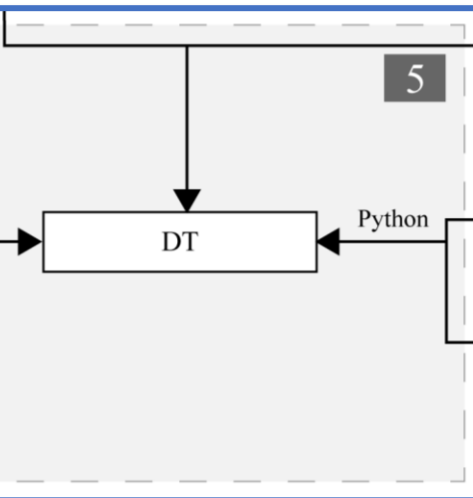
D - Time Series Humidity Values All Floors



BAS full mapping executed

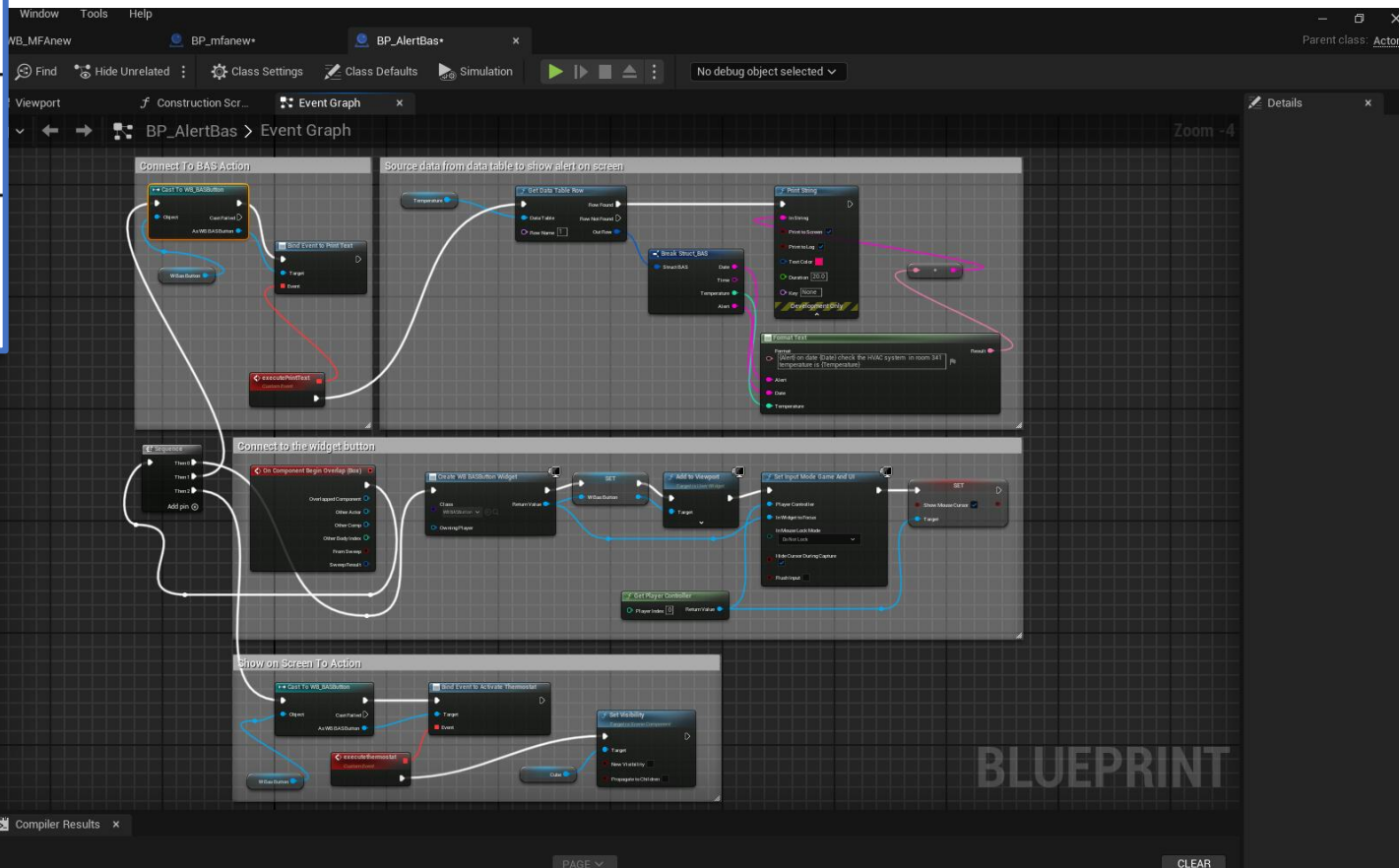
- Semantic inconsistencies and missing data
- Interoperability

DT blueprints environment is used to assign actions or create user interfaces to explore data in an immersive context



Unreal Engine interface showing a search bar and a list of components and variables.

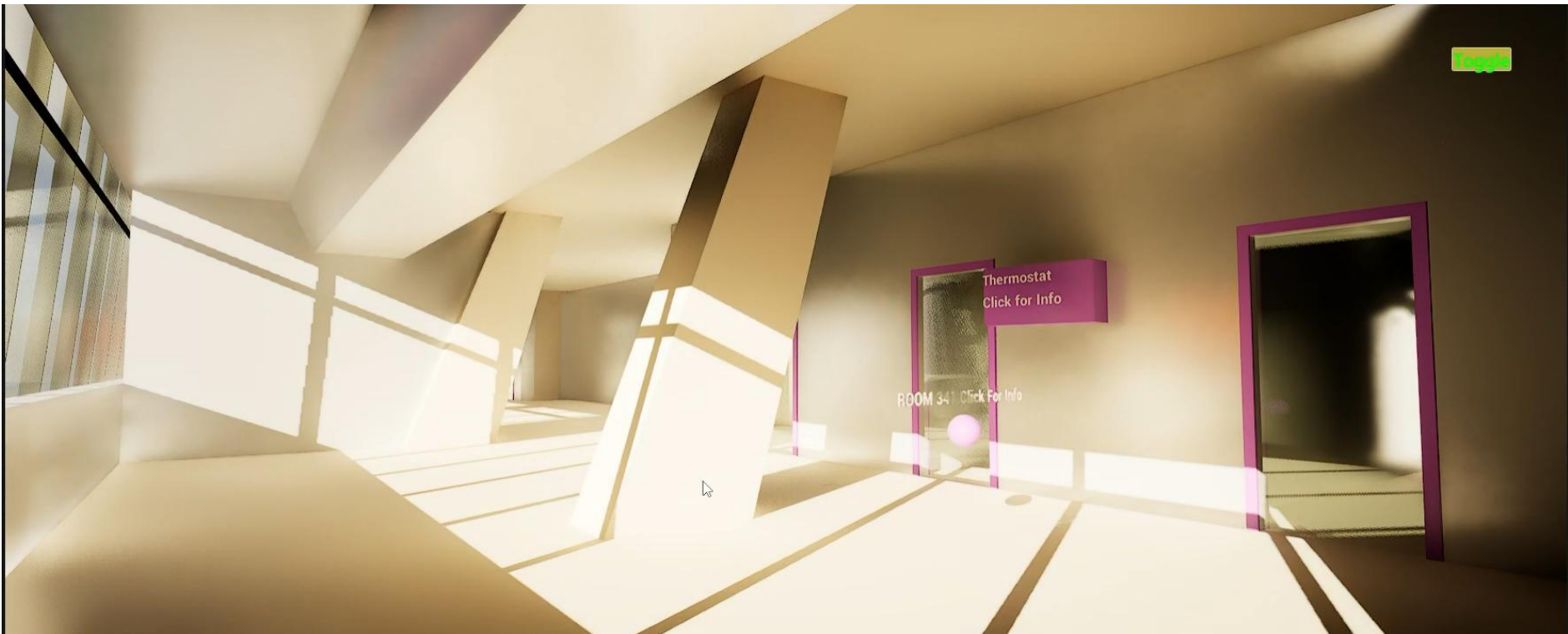
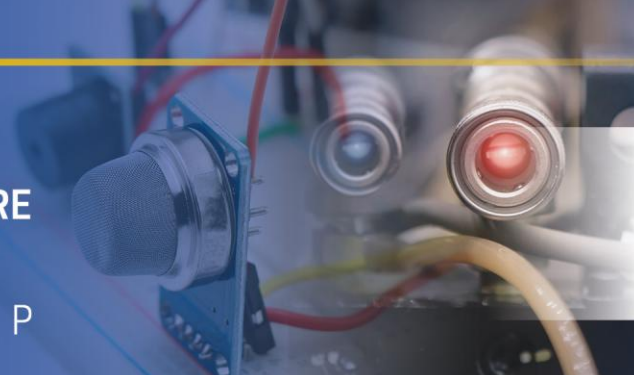
- GRAPHS**
 - EventGraph
- FUNCTIONS** (22 OVERRIDABLE)
 - ConstructionScript
- MACROS**
- VARIABLES**
 - Alert
 - Date
 - Temperature
 - W_BasButton
- COMPONENTS**
 - Name
 - String
 - Data Table
 - User Widget
- EVENT DISPATCHERS**



UPIISC

UNIVERSITY OF
PITTSBURGH
INFRASTRUCTURE
SENSING

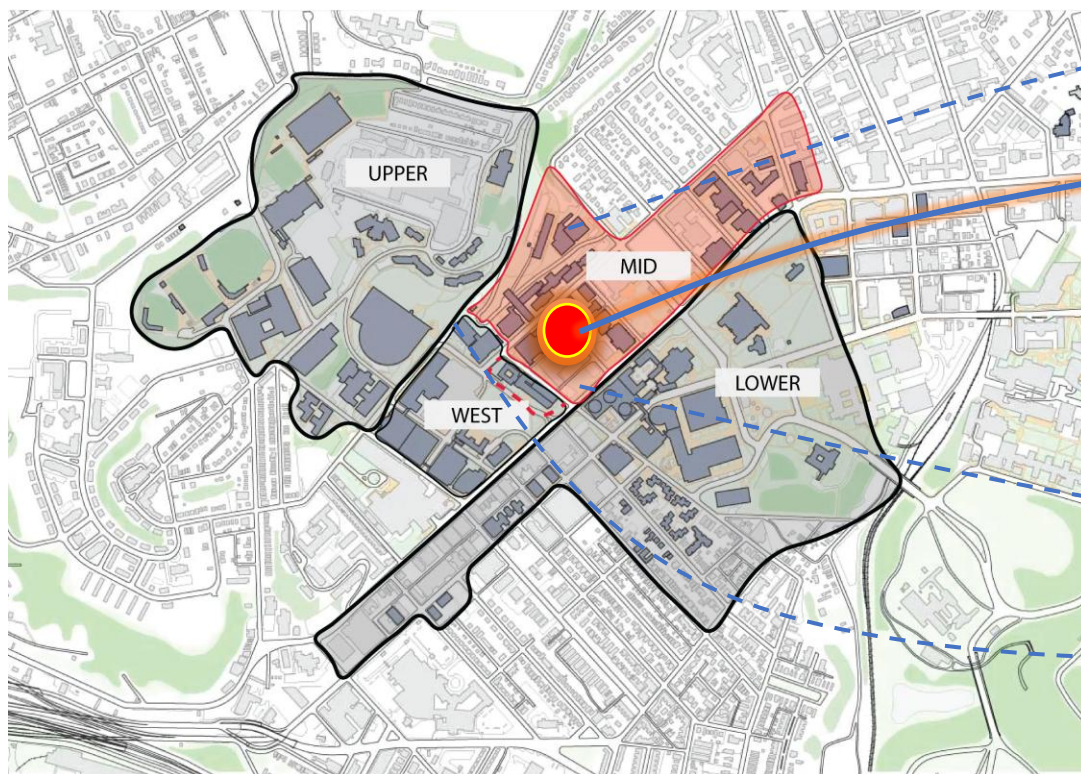
COLLABORATION WORKSHOP



University of
Pittsburgh

Mascaro Center for Sustainable Innovation

University of Pittsburgh Oakland Campus



Single-Building
DT

Additional DT

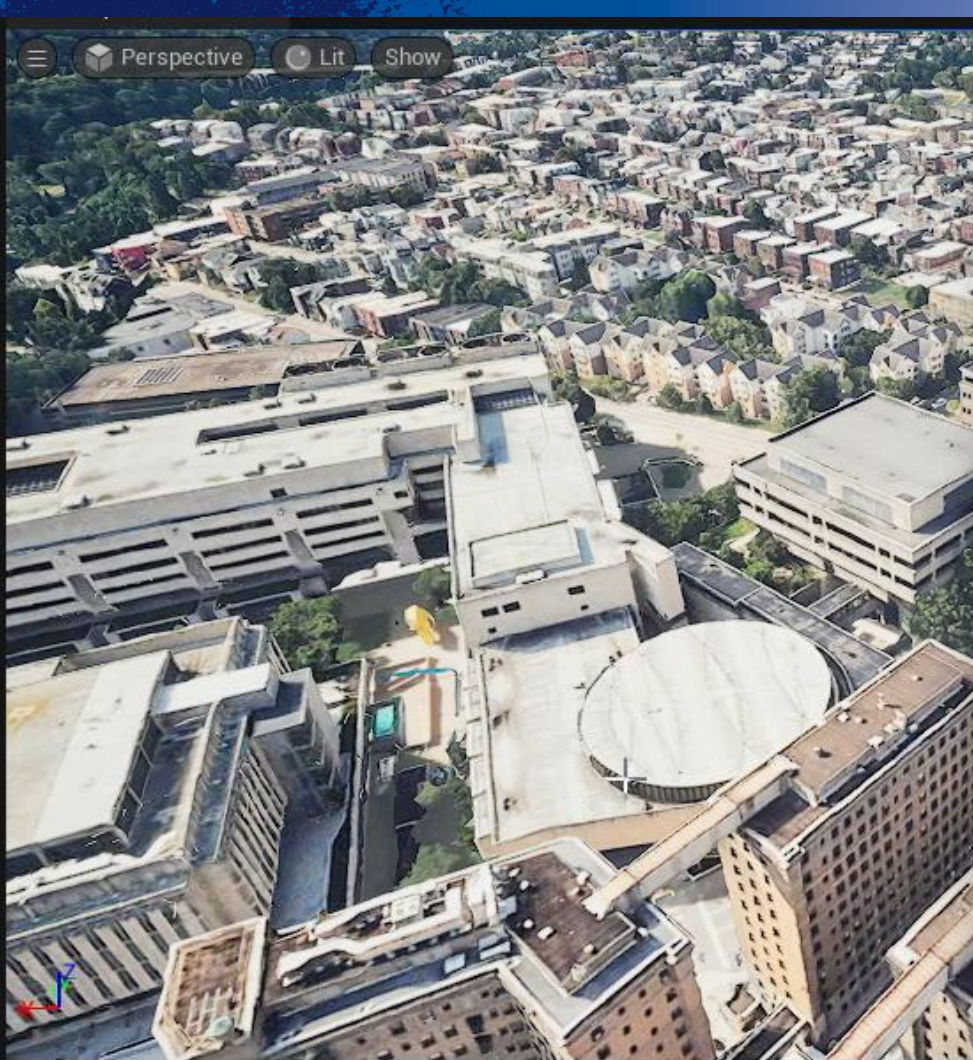
Additional DT

Additional DT



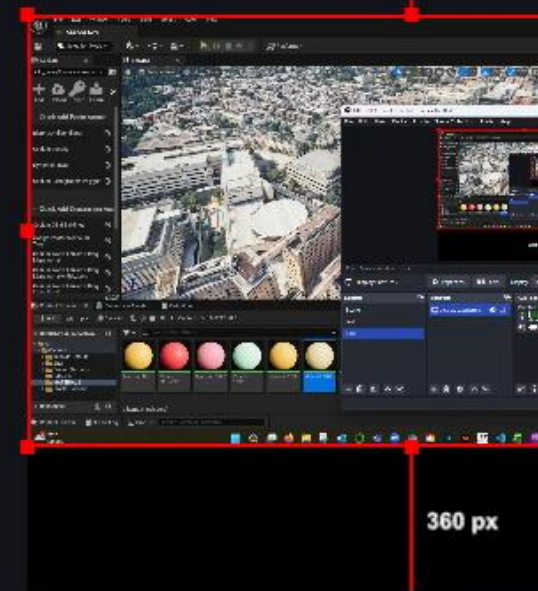
University of
Pittsburgh

Mascaro Center for Sustainable Innovation

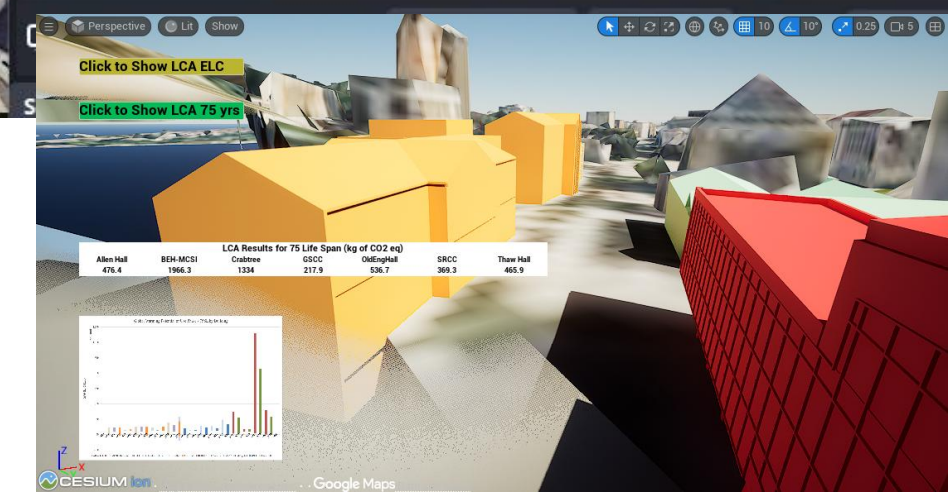


OBS 31.0.3 - Profile: Untitled - Scenes: Untitled

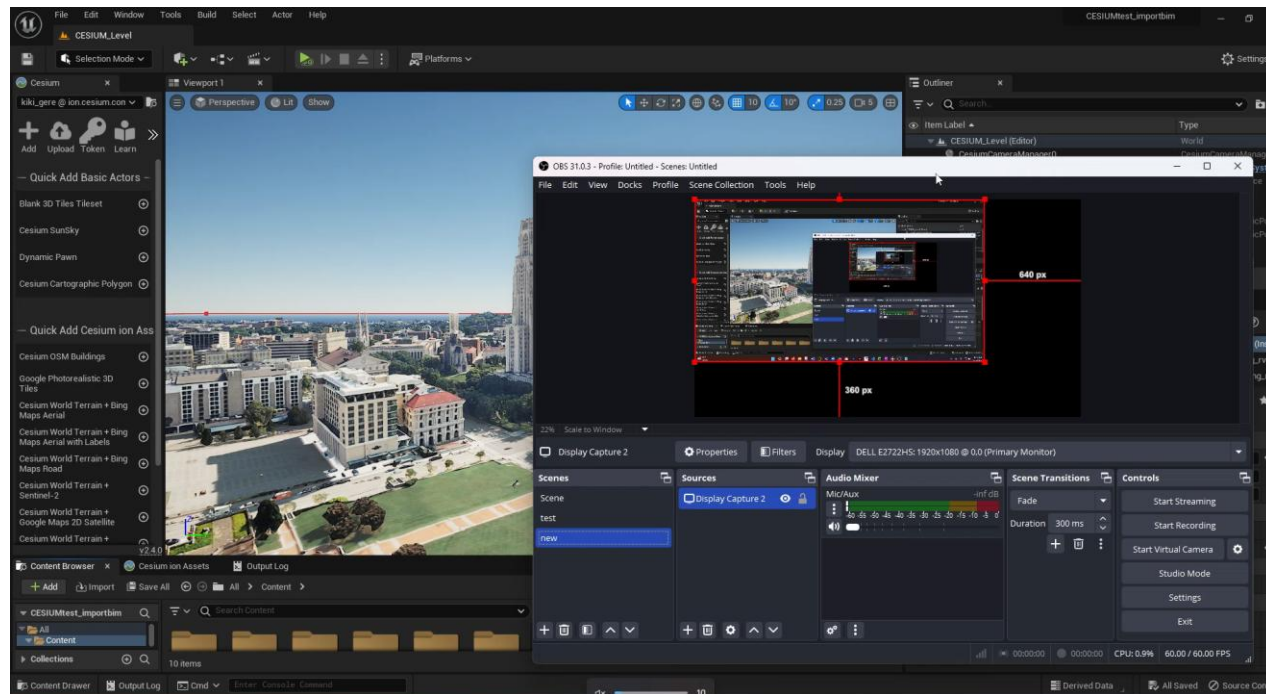
File Edit View Docks Profile Scene Collection Tools Help



22% Scale to Window



- We can adapt the single DT for a multi-resolution data environment
- We are operationalizing water and energy concepts in DT development
- We are working to enable the visualization of aggregated information at the system scale
- Temporal data resolution on some assets is limiting real-time capabilities, despite demonstrated usefulness also with less data-rich environments



Open Questions

Governance

1

Who owns the twin? Water and energy utilities operate under separate regulatory regimes. What institutional structures enable shared sensing infrastructure?

Data Access

2

Sensing generates value, but for whom? How do we design infrastructure data systems that are open enough to enable research and closed enough to protect operators?

Scaling

3

What does a district-scale or city-scale digital twin require that a building-scale twin does not? Where are the technical and social bottlenecks?



University of
Pittsburgh

Mascaro Center for Sustainable Innovation

Acknowledgements

Funding

National Science Foundation: NSF 2035150 (Hoque & Bilec) | NSF 2332246, CLIMA (Fascetti, Bilec, Brigham)

Research Team

Federica Geremicca, Uzzal Hossain, Isabella Cicco, Sam Copeland, Rezvan Ziazi
All collaborators at the Mascaro Center for Sustainable Innovation

Selected Publications

Geremicca, F., Fascetti, A., Brigham, J., Bilec, M.M. (2026). "Digital Twins for Sustainable Buildings: From Framework to Strategy Guidelines and Application." *Energy & Buildings*. Volume 359, 2026,117332, ISSN 0378-7788, <https://doi.org/10.1016/j.enbuild.2026.117332>

- Geremicca & Bilec (2024). Searching for new Urban Metabolism techniques. *Sustainable Cities and Society*.
- Mohammadizazi & Bilec (2023). Quantifying and Spatializing Building Material Stock. *Journal of Cleaner Production*.
- Hasik et al. (2017). Evaluating life cycle environmental benefits of water reuse systems. *Environmental Science & Technology*.

