

Sustainable Urban Infrastructure

Report of a Workshop Sponsored by the U.S. National Science Foundation

August 15-16, 2019

Georgia Institute of Technology
Atlanta, Georgia



Residents Playing in Perkerson Park Splash Pad, Atlanta Georgia

A workshop on Sustainable Urban Infrastructure, funded by the National Science Foundation, was held at the Georgia Institute of Technology on August 15 and 16, 2019. This report is a synopsis and synthesis of this workshop. Approximately 50 researchers, practitioners and students convened to engage on the challenges of sustainable urban infrastructure. This material is based upon work supported by the National Science Foundation under Grant No. 1929920.

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NSF Call for the Next Generation of Sustainable Urban Systems Science

Near the beginning of the workshop, Anil Pahwa of the National Science Foundation described the origins of NSF's December 2018 call for proposals for workshops on sustainable urban systems (NSF 2018). In his remarks, Dr. Pahwa noted that ~80% of the US population lives on ~3% of the land area in the form of urban systems that consist of cities surrounded by rural areas. He closed by describing a host of scientific challenges such as framing and modeling urban socioeconomic futures, understanding how actors can effectively coordinate to build and maintain sustainable urban systems, and developing workforce capability to address this multi-scale complexity. It is in this context that this workshop was convened on the campus of the Georgia Institute of Technology in Atlanta on August 15-16, 2019 with funding provided by the National Science Foundation (Award #1929920).

Workshop Goals

Urban infrastructure – electricity, natural gas, water, wastewater, transportation, and buildings – can last for centuries. It strongly influences the people, environment, and communities in which they are embedded. This workshop brought together diverse experts and practitioners to identify new approaches to urban sustainability. Research disciplines included engineering, infrastructure ecology, biologically inspired design, complex systems, and mega-scale computation. Practitioner approaches included corporate sustainability, community-based equity and justice, and technology platforms for economic transformation.

Organizers and Attendees

Workshop Chair and Co-Chairs

- Chair: **Dr. Valerie Thomas**, Anderson-Interface Professor of Natural Systems in the H. Milton Stewart School of Industrial and Systems Engineering (with a joint appointment in the School of Public Policy), Georgia Institute of Technology
- Co-Chair: **Dr. Kim Kurtis**, College of Engineering Associate Dean for Faculty Development and Scholarship, and Professor School of Civil and Environmental Engineering, Georgia Institute of Technology
- Co-Chair: **Dr. Ivonne Santiago**, Clinical Professor Department of Civil Engineering, University of Texas at El Paso. As Clinical Professor, Dr. Santiago's main responsibility at UTEP is to foster projects that connect education and research to engineering practice and real-world applications.

Additional Workshop Organizing Committee Members

- **Dr. Michael Chang**, Deputy Director, Brook Byers Institute for Sustainable Systems, Georgia Institute of Technology
- **Dr. John Crittenden**, Director, Brook Byers Institute for Sustainable Systems, Hightower Chair and Georgia Research Alliance Eminent Scholar in Environmental Technologies, Professor School of Civil and Environmental Engineering, Georgia Institute of Technology
- **Dr. Cliff Davidson**, Thomas C. and Colleen L. Wilmot Professor of Engineering, Environmental Engineering Program Director, Civil & Environmental Engineering, Syracuse University
- **Dr. Michael Lepech**, Associate Professor of Civil and Environmental Engineering and Senior Fellow at the Woods Institute for the Environment, Stanford University
- **Dr. Miguel Velez-Reyes**, George W. Edwards, Jr./El Paso Electric Distinguished Professor and Department Chair in Electrical and Computer Engineering Professor, University of Texas at El Paso

Note Takers

- **Mr. Osvaldo Broesicke** – Ph.D. Candidate, Civil and Environmental Engineering, Georgia Tech
- **Dr. Francesca Lolli** – Postdoctoral Researcher, Civil and Environmental Engineering, Georgia Tech
- **Mr. Jaden Johnston** – Ph.D. Candidate, Industrial and Systems Engineering, Georgia Tech

Attendees

- **Omar Asensio**; Public Policy Georgia Tech
- **Baabak Ashuri**; Building Construction Georgia Tech
- **Michael Balchanos**; Aerospace Systems Design Lab Georgia Tech
- **Lauren Baldwin**; Creosote Collaborative
- **Cyrus Bhedwar**; Southeast Energy Efficiency Alliance
- **Osvaldo Broesicke**; Civil & Environmental Engineering Georgia Tech
- **Marilyn Brown**; Public Policy Georgia Tech

- **Michael Chang**; Sustainable Systems Georgia Tech
- **Matt Cox**; Greenlink Group
- **John Crittenden**; Civil & Environmental Engineering Georgia Tech
- **Cliff Davidson**; Civil & Environmental Engineering Syracuse
- **Yi Deng**; Earth & Atmospheric Sciences Georgia Tech
- **Scott Duncan**; Aerospace Systems Design Lab Georgia Tech
- **Ellen Dunham-Jones**; Architecture Georgia Tech
- **Steve Foran**; Advanced Planning Group Jacobs
- **Jairo Garcia**; City & Regional Planning Georgia Tech
- **Melissa Gilbert**; Environmental Studies Temple University
- **Caroline Golin**; Google
- **Veronica Gonzalez**; City of Juarez
- **Santiago Grijalva**; Electrical & Computer Engineering Georgia Tech
- **Ed Groark**; Worldwatch Institute
- **Emily Grubert**; Civil & Environmental Engineering Georgia Tech
- **Subhro Guhathakurta**; City & Regional Planning Georgia Tech
- **Joy Hicks**; Home Depot
- **Jennifer Hirsch**; Serve-Learn-Sustain Georgia Tech
- **Michael Hunter**; Civil & Environmental Engineering Georgia Tech
- **Kaye Husbands Fealing**; Public Policy Georgia Tech
- **Thomas Igou**; Civil and Environmental Engineering Georgia Tech
- **Jaden Johnston**; Industrial & Systems Engineering Georgia Tech
- **Maggie Kelley**; Southeast Energy Efficiency Alliance
- **Courtney Kimmel**; Captain Planet
- **Kimberly Kurtis**; Civil & Environmental Engineering Georgia Tech
- **Debra Lam**; Smart Cities Initiative Georgia Tech
- **David Large**; Management University of Ottawa
- **Kincho Law**; Civil & Environmental Engineering Stanford
- **Michael Lepech**; Civil & Environmental Engineering Stanford
- **Audrey Leous**; Central Atlanta Progress
- **Francesca Lolli**; Civil & Environmental Engineering Georgia Tech
- **Mandy Mahoney**; Southeast Energy Efficiency Alliance
- **Dimitri Mavris**; Aerospace Engineering Georgia Tech
- **Samantha McDonald**; Greenlink Group
- **Christopher Novack**; Georgia Ports Authority
- **Na'taki Osborne-Jelks**; Environmental & Health Sciences Spelman College
- **Anurag Pande**; Civil & Environmental Engineering Cal Poly - SLO
- **David Pedrick**; Southface Institute
- **Srinivas Peeta**; Civil & Environmental Engineering Georgia Tech
- **Paulette Richards**; Ayamedia
- **Catherine Ross**; City & Regional Planning Georgia Tech
- **Baris Salman**; Civil & Environmental Engineering Syracuse
- **Ivonne Santiago**; Civil Engineering UTEP
- **Rich Simmons**; Strategic Energy Georgia Tech

- **Frank Southworth**; Civil & Environmental Engineering Georgia Tech
- **Daniel Studdard**; Atlanta Regional Commission
- **Valerie Thomas**; Industrial & Systems Engineering Georgia Tech
- **Iris Tien**; Civil & Environmental Engineering Georgia Tech
- **James Tsai**; Civil & Environmental Engineering Georgia Tech
- **Pascal Van Hentenryck**; Industrial & Systems Engineering Georgia Tech
- **Miguel Velez-Reyes**; Electrical & Computer Engineering UTEP
- **Brent Verrill**; Brook Byers Institute for Sustainable Systems Georgia Tech
- **Kari Watkins**; Civil & Environmental Engineering Georgia Tech
- **Marc Weissburg**; Biological Sciences Georgia Tech

Organizations Represented

- Georgia Tech; Research University
- Stanford University; Research University
- University of Texas at El Paso; Research University, Hispanic Serving Institution
- Syracuse University; Research University
- Jacobs; Architecture-Engineering-Construction Firm
- Ayamedia; Art and Storytelling
- Southeast Energy Efficiency Alliance; Non-profit Energy Efficiency Advocate
- Greenlink Group; Clean Energy Technology and Consulting
- Google; Multi-national Technology Company
- Southface – Non-profit Energy Efficiency Advocate
- Central Atlanta Progress – Business funded civic development advocate
- Cal Poly - San Luis Obispo; Research University
- City of Juarez, Mexico
- Spelman College; Historically Black College for Women
- Atlanta Regional Commission; Municipal Planning Organization
- Georgia Ports Authority; State Agency
- Temple University; Research University
- Captain Planet; Non-profit Environmental Advocate
- University of Ottawa; Research University (Canada)
- Home Depot; Home Improvement and Construction Retailer
- Creosote Collaborative; Urban planning, design, and sustainability consulting firm based in El Paso, Texas
- World Watch Institute; Globally focused independent environmental research organization

5 Key Takeaways of the Workshop

In addition to academicians, members of community organizations, representatives of state, regional and municipal agencies, neighborhood groups, and industry stakeholders all participated in the workshop. Relationships were formed and strengthened; people got to know each other. The workshop served as a vehicle for exploring research project ideas and formed bonds that will support future collaborations. Several broad and related themes emerged, regarding how to work with stakeholders and communities, the questions and problems that are of interest to stakeholders and people in communities, how to develop relationships in order to get the data and access needed to do the research, and how to affect decisions. The following points summarize the key points raised through the workshop.

#1. Researchers need to listen, and not talk so much. Researchers need to ask people what they need, and to look for people and organizations that would like to collaborate. Early community building is essential, before collaboration can start. Engaging in small, pre-research projects can form relationships and provide a basis for future collaboration.

#2. The pain points for people in communities are not infrastructure per se; they are health, jobs, food and other immediate requirements. Sustainable infrastructures may provide solutions, or part of the solutions. But the issues need to be framed in terms of what matters directly to people. The issues that matter directly to people need to be the metrics and performance indicators.

#3. In addition to building relationships, successful collaborative projects require clarity and simplicity of presentation. Even in organizations that are interested in improving the operation of their infrastructure, data are closely held. Understanding the relationships and the decision-making process, and being involved in the existing frameworks is essential to building and maintaining collaborations and programs.

#4. Sustainable urban infrastructures involve decisions by the private sector as well as governments at a range of levels. Some infrastructure decisions, such as the building of renewable electricity, are to an increasing extent, decisions made by the private sector rather than by government. Corporate procurement is outpacing utilities for solar and wind, for example.

#5. Being present is key to ensuring that research findings can be incorporated in decision-making. A major topic of discussion was how to affect decisions and how decisions are made. Often it is not really a technology decision and it is not really an economic decision; it is a decision based on vested interests and who is in the room when the decisions are made. Being present is key to ensuring that research findings can be incorporated into decision-making.

Creating sustainable urban infrastructures requires development of relationships across academia, the private sector, government, and in communities. It will require reframing of issues through conversations with all these stakeholders. Research projects must provide timely direct benefit, over extended periods of time, as much to build trust and understanding as to support long term futures. Even small projects, meaningfully involving a range of stakeholders, can be key to building the urban sustainable systems of the future.

Summary of Workshop Transactions

The remainder of this report summarizes the schedule, presentations, discussions, and queries of the two-day workshop. Designed as a series of questions, conversations and challenges, the meeting focused on how to build effective collaboration with stakeholders and communities.

Agenda

Day 1 – Thursday August 15, 2019

8:30AM – Breakfast and Registration

9:00 – Welcome, introduction, and overview – Valerie Thomas, Georgia Tech

9:15 – Knowledge co-production for sustainable urban infrastructure – Session Chair: Professor Emily Grubert, Georgia Tech; Panelists: Matt Cox (Greenlink Group); David Pedrick (Southface Institute); Jairo Garcia (Urban Climate Nexus)

10:15 – Break

10:45 – Describe the future of sustainable urban infrastructure (Part 1) – Session Chair: Professor Michael Lepech, Stanford; Panelists: Pascal Van Hentenryck (Georgia Tech), Daniel Studdard (Atlanta Regional Commission); Audrey Leous (Central Atlanta Progress)

12:00 – Lunch

12:30 – Urban Sustainability Research in Oakland, El Paso, and Syracuse – Panelists: Michael Lepech (Stanford), Cliff Davidson (Syracuse), Ivonne Santiago (UTEP), Miguel Velez Reyes (UTEP)

1:30 – Making Connections, Providing Value for sustainable urban systems – Session Chair: Professor Ivonne Santiago, University of Texas at El Paso; Panelists: Na'taki Osborne-Jelks (Spelman College), Omar Asensio (Georgia Tech), Paulette Richards (artist); Marc Weissburg (Georgia Tech)

2:45 – Break

3:15 – Afternoon Breakout Groups – If a larger collaborative project were funded, what could you do? Sketch projects and ideas involving researchers, business, and policy makers at the urban scale. What future do we want to explore? 200-300 words.

4:15 Report back from breakout groups – Session Chair: John Crittenden, Georgia Tech

5:00 Adjourn

6:00 Dinner in groups

Day 2 – Friday August 16

8:30AM – Breakfast and Registration

9:00 – **Keynote: Sustainable and Connected Infrastructure** – Steve Foran, Senior Consultant, Jacobs Engineering with introduction by Michael Chang, Georgia Tech

9:45 – **Where can we have the most impact in urban infrastructure systems?** – Session Chair: Professor Cliff Davidson, Syracuse University; Panelists: Maggie Kelley (Southeast Energy Efficiency Alliance), Lauren Baldwin (Creosote Collaborative), and Ed Groark (Worldwatch Institute)

10:30 – **Break**

11:00 – **Describe the Future of sustainable urban infrastructure (Part 2)** – Session chair: Professor Miguel Velez Reyes, University of Texas El Paso; Panelists: Caroline Golin (Google); Rich Simmons (Georgia Tech); Kincho Law (Stanford University)

12:00 – **Lunch**

12:30 – **Vision for Smart Cities: Campus as Experimental Apparatus** – Dimitri Mavris, Michael Balchanos and Scott Duncan, Aerospace Systems Design Laboratory, Georgia Tech with introduction by John Crittenden, Georgia Tech

1:30 – **Afternoon Breakout Groups** – Select favorite project ideas from day 1 and further develop them

2:30 **Report back from breakout groups favorite project ideas** – a Session Chair: Michael Chang, Georgia Tech

4:00 **Adjourn**

On Knowledge Co-Production

One theme of the workshop was to better understand knowledge co-production. How can researchers, practitioners, stakeholders and citizens work together to learn how urban infrastructures are working and how urban systems can be more sustainable? The workshop opened with a panel discussion, led by Georgia Tech professor Emily Grubert, with Matt Cox of the Greenlink Group, David Pedrick of Southface Institute and Jairo Garcia of Urban Climate Nexus. All three of these non-governmental organizations (NGOs) are practitioner organizations, working with stakeholders, citizens, and policy makers in support of urban sustainability goals.

How do you see collaboration with others?

- Matt Cox identified keys to success: delineate clear tasks and goals; do not overstretch people or resources; clarify expectations.

- Jairo Garcia pointed out that, in working with cities: cities have problems and they have data. Universities have the capacity to process the data, to provide information and to create solutions. However, getting the data from cities can be difficult and requires a lot of relationship building. The time scales of cities and academic can differ. Academics often may not provide a long enough time scale to build relationships, and also that can take too long to execute projects.
- David Pedrick said there is a lot of work to be done before collaborations can start. It is important to build with the community and create places to share data and expertise. Early community building is fundamental.

How we can keep continuity in relationships and projects given that people transition to other jobs?

- Jairo Garcia said that stakeholders can put pressure on government to continue relationships as administrations change. For example, the Bloomberg Climate Challenge, which included Atlanta in the American Cities Climate Challenge, encouraged the city to continue the collaboration over time. Collaborators can ensure that conversations, cooperation, and collaborations continue over time.
- Matt Cox emphasized the need for strategy in maintaining connections and programs. It is important to be aware of which are the important relationships and to continue talking with these people during their campaigns, to link the projects with the campaign commitments. Relationships with “street level bureaucrats” are important and there is less turn over than with higher level officials.
- David Pedrick stressed that knowledge of how to run a project needs to be maintained over time, even as personnel change.

What kinds of projects and proposals from academia would your organizations like to participate in?

- Matt Cox said that there is already an excellent example: the Georgia Drawdown project, which is identifying the 100 most impactful actions for Georgia to address climate change. Matt Cox’s organization, Greenlink, has been asked to help in this project, drawing on its applied modeling and multi-criteria decision analysis work.
- Jairo Garcia said that academics love heavy language; this must be avoided when presenting to the City. People working in the City government have 20 meetings a day and have 20 minutes to read a proposal. Academics should prepare a one-page memo; it must be easy to read and right to the point, pointing out short term benefits balanced with long term goals. Governments are short sighted; they need something that is achievable NOW.
- David Pedrick emphasized the need to be very clear up front on what data is needed and what it will take to get that data. There needs to be a very clear conversation on methodology.
- Jairo Garcia emphasized the need to understand what the politicians want. What are their priorities? To work with politicians, you need to be a politician and, perhaps analyzing social media can help understand stakeholder desires and develop credible, salient and legitimate approaches (policies) to create more sustainable urban infrastructure.

Are academics missing something by working with NGOs rather than directly with the community?

- Catherine Ross (Professor, Georgia Tech) said it is important to have a practical orientation. We need to learn a second language because we have to speak the same language as the people we want to communicate with. We need to learn to listen. People don't like it that we talk a lot; we need to listen.
- Matt Cox said it is important to remember who your client is. Speed is essential. Give precise deliverables and deadlines; because, governmental workers are more strict in providing deliverables and meeting deadlines as compared to academia.
- Jairo Garcia said that if you have a translator who can go back and forth between the community or government and academic, you can be more effective. It is important to create relationships in the community and that community will pass the on the message. It is a back and forth relationship.
- Marilyn Brown (Professor, Georgia Tech) said that some reports are not incorporated into policy recommendations because they are not peer-reviewed.

How can we encourage your NGOs to publish?

- Jairo Garcia said: Yes, this would be great! The problem is, there isn't a lot of time to publish when you work in city government. We need more interactions with students who have the time to publish. There are successful examples: the Atlanta Regional Commission has connected interns with governments.
- Matt Cox said: The largest limitation to publishing is Bandwidth. It is hard to put time in to publishing because it won't pay the bills.

Can the academic community be mediators?

- Matt Cox said we need to do more mediating between the community and the government. We can bring the community or city officials to town halls. We are working on issues that are not solved; they are momentarily resolved.
- Jairo Garcia said we need help from social scientists to better engage with the community.

On the future of Sustainable Urban Infrastructure (Part 1)

Another theme of the workshop is to describe the future. A panel featuring practitioners creating new infrastructure and researchers modeling future systems was chaired by Professor Michael Lepech of Stanford University (workshop organizing committee member). The panel included Professor Pascal Van Hentenryck of Georgia Tech, who is modeling socially aware transit systems; Daniel Studdard of the Atlanta Regional Commission, which has projects on resiliency scenarios, climate impacts, and sustainability in freight transportation, and Audrey Leous of Central Atlanta Progress, which is developing a comprehensive plan for downtown Atlanta including urban heat island effects and water and energy use in buildings.

How do we forecast the future impacts of today's policies?

- Audrey Leous said that they have climate projects from Georgia Tech, and urban heat island projects for downtown Atlanta. What they need is research on smaller districts: not at the full city scale, and not at the building scale, but at the scale of a city block or city district.
- Pascal Van Hentenryck said: Data, data, data. We can do detailed simulation and visualization; we can do before and after projections. We can support pilot projects. The issue: it is a time-consuming process.
- Daniel Studdard said that, for example, they have extensive air quality modeling capabilities. But there are strains in developing new solutions. UPS, for example, as they increase their deliveries, it would be cost effective for them to switch to electric vehicles, but the charging infrastructure is not yet available. We need to better understand how available funding can be used effectively in our region. There are many programs available that could support car pooling and bus systems.
- Michael Lepech said that we have stochastic information, but how do we share this? We can share it in Excel to make it more accessible. How can we make uncertainty auditable?

How do we deal with uncertainty?

- Pascal van Hentenryck said they do a lot of stochastic optimization modeling. They can extract simple policy rules. But there is uncertainty in policy decisions.
- Audrey Leous said they need to hire people to make assessments, but they need them to do it on time and on a budget. They do recognize that many of these models are uncertain. BUT, they need to make decisions NOW.
- Daniel Studdard said that new behavior can follow four scenarios: as is, new tech, environmentally friendly, and against technology.

What would you do if you had \$100 million?

- Is it useful to talk about the future of sustainable urban areas as akin to an Apollo or Manhattan project? Does the messiness of cities and the process to change them preclude bold goal setting?
- Audrey Leous: Implementation of Downtown Atlanta Master Plan.
- Pascal van Hentenryck: Next generation of mobility systems
- Daniel Studdard: Transit investments inside Atlanta. (But, regional behavior is hard to change.)
- Audrey Leous said she needs to identify economic assessments to convince stakeholders at different scales.

What are the low hanging fruit?

- Audrey Leous: Energy and water systems.

- Pascal van Hentenryck: Africa has the ability to develop micro-grids without the issues of the US. They will be able to develop decentralized systems. In the US, we can incentivize people to think differently about their behavior; we can learn from past systems and pivot. If you want to reduced greenhouse gas emissions, transportation is 30%. You can make big changes by electrifying car systems. However, we also need to increase resilience.
- Daniel Studdard: It was much less expensive to develop trains when cities were young. It is extremely expensive now. Financing these systems may also be a challenge, especially when the people with voting power want it while people without voting power do.
- Ed Groark (Worldwatch Institute): You will not have sustainable cities until you address the land use component. Distributed energy, water and manufacturing are all land use issues.
- Pascal van Hentenryck: Removing parking may address some of these land use issue. It is a multi-objective optimization; you need to plan for all desires of living; not everyone wants to live in high density cities.

What have we learned? What are we trying?

A third theme of the workshop was to learn from the participating city groups: Atlanta, El Paso, Syracuse and Oakland.

El Paso Texas

- Ivonne Santiago (Clinical Professor, University of Texas at El Paso) said: It's important to listen. And it's important to be a crusader.
- El Paso used to one of the top ten safest cities. But with the recent mass shooting that has changed. Every time the border shuts down, it's chaos at the university. In the Rio Grande basin, it is impossible to distinguish El Pas from Juarez; it is a single huge urban area. It is desert, with flash floods, growth promoted by commerce, and air pollution problems.
- The El Paso waster service board has been mitigating drought by wastewater reclamation and conservation policies. Outside of the irrigation system there is no water in the river. When there is water in the river it is used instead of groundwater. A conservation issue is that the 120 gallon per person per day cap incentivizes irrigation for landscaping. The desalination plant is the largest in the world. A key issue is access to water in the colonias. People living in the Jaurez colonia are 190 times more likely to get sick from drinking water compared to those in the colonias in El Paso.
- Lauren Baldwin of the Creosote Collaborative discussed their focus on creating passive green infrastructures. The Paso del Norte is a 90 mile shared use trail. They have workshops for education and implementation of the ideas; working with the city they have created a smart cities team.



El Paso Green Infrastructure Workshop. Courtesy of Lauren Baldwin and Ivonne Santiago.

Syracuse New York

- Cliff Davidson and Baris Salman discussed several projects underway in Syracuse related to the urban sustainability theme. One involves ongoing experiments at the Onondaga County Convention Center green roof (0.56 hectares). They are monitoring precipitation, runoff down the roof drains, and soil moisture to determine the water balance on the roof as a function of time. A related project on the green roof is an energy balance obtained by tracking the heat flow downward through the roof in the summer, and upward from interior space in the winter. They are also modeling both the heat flow through the roof and the evaporation/transpiration of water from the soil and plants.

Another project involves computer-based surveys and in-person workshops with leaders of government, business, NGOs, and research institutions in Syracuse and Onondaga County on urban resilience to climate change. They ask questions such as what types of events are of most concern (Heat waves, Severe cold, Floods, Droughts, Blizzards, etc.), what can be done to build resilience against these events, and what are the obstacles to building resilience. This work is part of the Sustainable Research Network funded by NSF, where Syracuse is one of several partner institutions, led by Arizona State.

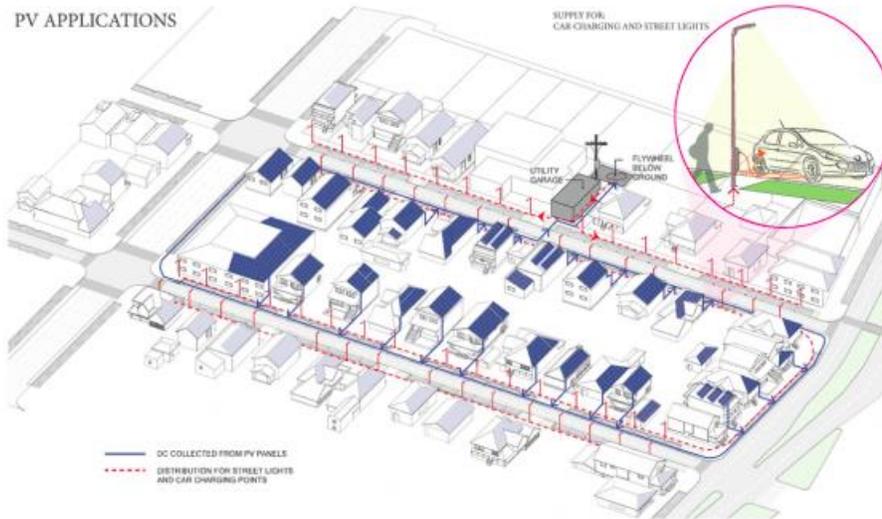
- They are developing course components to enhance students' exposure to real-time infrastructure management. Students work collaboratively in instrumenting components of the south campus drainage network.



Syracuse Convention Center Green Roof.

Oakland California

- Professor Michael Lepech, working in the San Francisco Bay Area, identified challenges in water, energy, and social resilience. There is pressure between urban growth and agriculture, along with seismic risks and fire. Gentrification and socio-economic challenges are pushing people farther away from city centers.
- As a smaller example, Stanford University has a new energy system for cooling and heating water, reducing greenhouse gas emissions by 68%.
- At the city scale, San Francisco has a smart city challenge, focused on mobility. Oakland also has a smart city program including an Ecoblock project, testing the idea that blocks can be more effective than individual buildings in achieving resource efficiencies. Working at the block scale might be more efficiency for sharing resources and infrastructures.
- More broadly, San Francisco, Berkeley and Oakland form a resilience triangle, with respective challenges of earthquakes, sea-level rise, and socio-economic disparities.



Oakland Ecoblock Project. Courtesy of Michael Lepech, Stanford University.

Making connections and providing value

This session addressed how effective researchers and practitioners are in teaching and learning, led by Ivonne Santiago (University of Texas at El Paso). The panelists were Na'taki Osborne Jelks (Spelman College), Omar Asensio (Georgia Tech), Paulette Richards (artist), and Marc Weissburg (Georgia Tech). Before and during this session, Michael Lepech used “Poll Everywhere” to receive questions from the audience to be asked of the panel.

- Na'taki Osborne Jelks has been working with the Watershed Alliance in Atlanta, focusing on discriminatory treatment of communities in west and southwest Atlanta. There was combined sewage overflow in to a park; the community pushed to have the sewer separated in that part of town, and the City of Atlanta is now investing in green infrastructure.
- Paulette Richards is an artist who focuses on translating scientific language into terms that the community can access. She uses puppetry in STEAM education, to introduce students to robotic concepts, and uses upcycled and recycled materials.
- Marc Weissburg, a professor at Georgia Tech, said that we need to approach teaching as we approach research: step back and reassess things; decide first what the problem is, then develop an approach together. We need to listen to community needs; we also need to be able to tell a story from the community. Unless we are able to educate people into these roles, we will not have as much impact as we would like. However, this kind of education is very difficult. What are the barriers in the corporate environment, in the educational programs that are available?

What are the Incentives for an Artist to be involved in this work? What is the role of art?

- Paulette Richards: For me, it combines values and creativity. You need to be able to relate to your community. There are articles at C4 Atlanta, and at local Makerspaces. Also, we need to consider land use and also the legacy of land use. Geography has been defined by race; changing the landscape also changes race relations. Sustainable infrastructure planning has to consider that too.
- Valerie Thomas: Working with artist Paulette Richards was a collaboration, the art discussions improved the science.
- Marc Weissburg: Everyone has an inherent understanding of art.
- Ivonne Santiago: I dance in class to illustrate what I am explaining.
- Na'taki Osborne Jelks: I try to make things fun and interactive.

How can researchers engage with communities?

- Na'taki Osborne Jelks: Consider the audience knowledge. Have fun and engage with food, childcare, things for kids. Engage the community on things that interest the community. Listen! It is not a transaction, it is a collaboration. Again: listen to what is the specific community problem.
- Marc Weissburg: Put some attention to how you start the conversation. Do not say “you should do this or that.” It is not a question of being a scientist, but how do you approach the conversation. Be prepared to tell a story that is different from what they have heard before. It is better to ask: “What are the changes in your community that you have observed and how can we explore them?” How you frame the problem is important. You must continue to frame this multiple times to gain their trust. Considering ourselves as the authority is not a good model for teaching. We teach how to solve problems. The process is as important as the results.

If a large collaborative project were funded, what would you do?

Participants were divided into groups and went to different rooms for discussion. Here are some of their proposed projects.

Urban Infrastructure in an Era of Free Energy

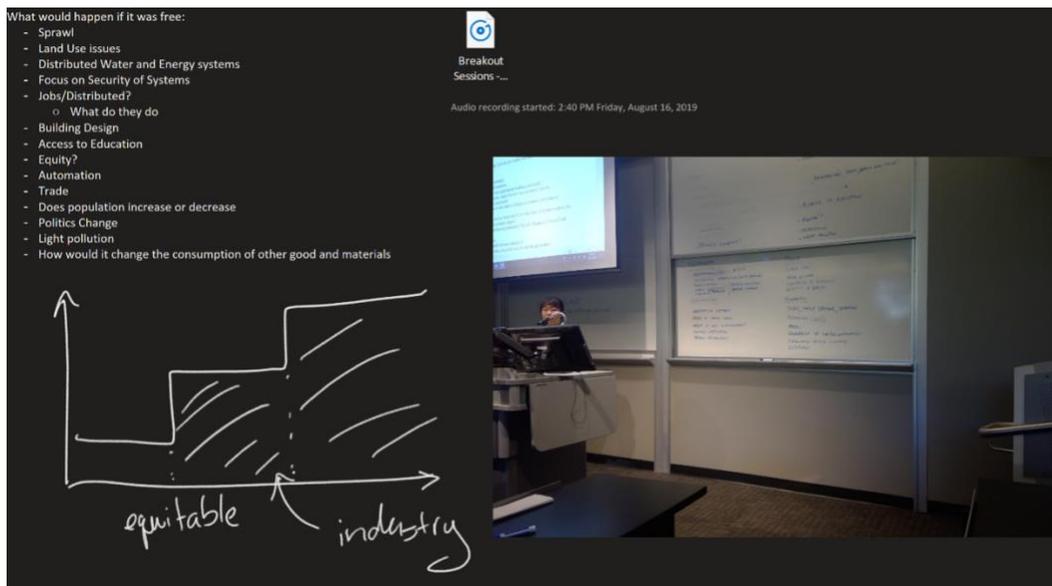
Interesting inquiries often arise when we ask the question, “What happens when the most important input to a process or system is free?” This SRN asks the question, “What would our urban areas look like, what infrastructure would we build, and what would our communities look like if energy were completely free?” The question implies that energy is free in the direct sense (i.e., free to the user), and free of all externalities (i.e., energy use does not cause pollution). Stemming from this question, a number of potential research questions arose;

- (1) How would potable water consumption change if desalination, pumping, and treatment are all “free”? How might this affect other consumption of water (i.e., agriculture, municipal, industrial water)?

- (2) How would materials consumption, recycling, and use change if energy, the primary cost driver of raw material extraction, material processing, and supply chain costs, is free? Would we develop different materials that would use energy in very different ways?
- (3) How would we structure our urban communities if transportation, which is heavily influenced by the cost of energy, is free?
- (4) How would food systems change if the energy that is needed to harvest, process, and deliver nutrition is free?
- (5) What kinds of buildings would we live, work, learn, and spend time in if energy were free? Would they have bigger windows? More open spaces? Different designs?
- (6) From a societal viewpoint, what is the effect on poverty if the cost of energy (and therefore all consumables that require energy for production) is driven to zero?
- (7) How would free energy affect developed countries differently than developing countries?
- (8) Does this result in a more sustainable outcome? Does this create a less sustainable outcome? Should energy be cheap or free? Should it be infinitely expensive?

While this hypothesis may seem far fetched, the exponentially decreasing cost of solar power and wind power is driving the world toward this reality. The questions posed above are only a subset of interesting lines of thought that might stem from the exercise of asking, “What if energy were free?” What research could we plan and perform at this time to prepare, or drive towards, such a future reality?

This research would require the collaboration of material scientists, physical scientists, engineers, economists, sociologists, business community, government, and NGOs.



Report out from the free energy group

Designing a City from Scratch

If we had the opportunity to design a city from scratch, without any of the legacy systems, and existing structures or barriers, what would that “ideal” city look like? How would we design our city? What would we want our housing to look like, e.g., density, style? How would we design our infrastructure systems? What would be the balance between static elements of the city and movable dynamic elements? We would want to design to meet technological and societal needs, meeting population energy, water, and mobility needs, as well as promoting societal cohesion and decreasing loneliness. We would want a

balance between development and nature, meeting at the threshold between the two. We would also want to make sure to keep what makes cities unique.

The Nineveh Urban Agriculture Project

This project explores the potential of urban agriculture to reduce the environmental impact of urban food systems by lowering greenhouse gas emissions, minimizing water and energy use, and reducing urban carbon footprints (NRC 2015). By focusing specifically on neighborhood blocks, one outcome of this project may be improved urban food access.

While social science researchers have been examining food security and urban agriculture issues for some time, this project would engage stakeholders in defining KPIs (key performance indicators) for quantitatively assessing the role urban agriculture could play in sustainable urban infrastructure.

Project Development Project

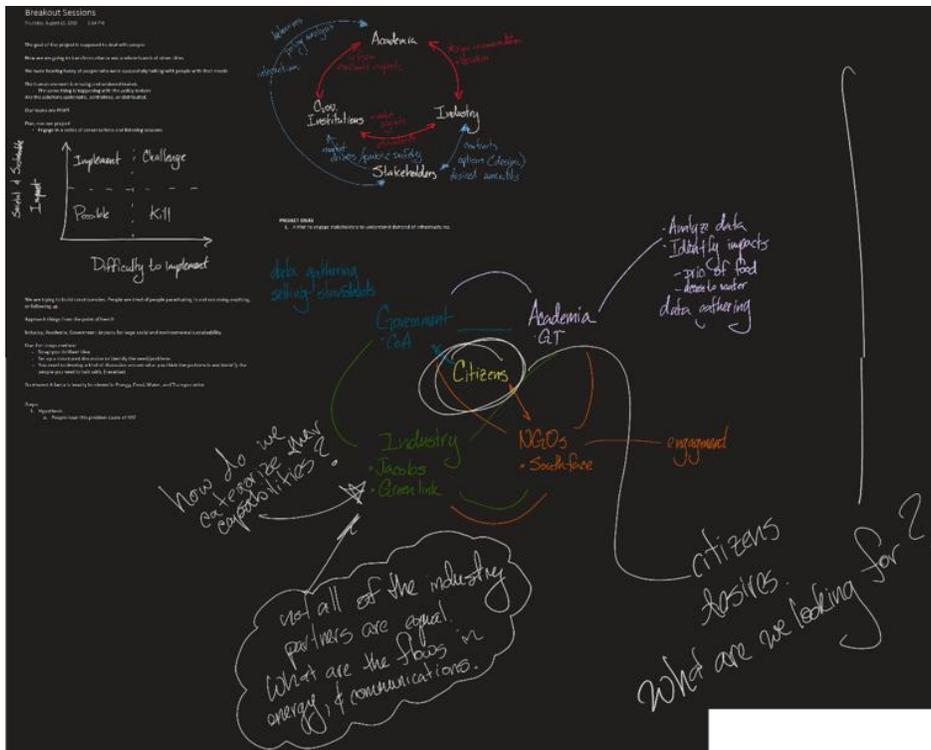
We can develop a strong industry-municipality-academia-community collaboration that has high potential for significant societal and sustainability impacts.

We heard that we need to listen. We have work to do before we are ready to develop a large project. This meeting is part of that but we can and need to do more. We will talk with non-academics about what they are interested in, what their issues are. This will include conversation with stakeholders in industry, municipalities and other governments, and community stakeholders.

We can use an iCorps-type process to develop our program. This will provide greater specificity regarding our “customers” and our product. Then we will act on some of the ideas to develop small projects or activities based on the meetings.

In academia, at Georgia Tech for example, we do have platforms such as CEISMC and Serve-Learn-Sustain; these are structures we can use to forge community links. Instead of sustainability, what if we change the metrics to health, human rights, jobs, economic disparities. Consider what will have impact in Southwest Atlanta. With health as a framing, this can include health of the individual, and health of the community, through food, jobs, and other pathways.

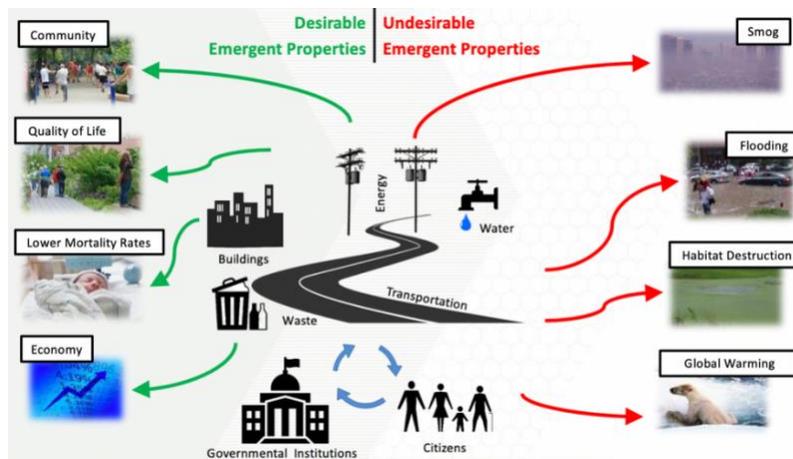
We can develop a diagram to discuss and identify projects that can have high potential. Use four quadrant diagram to categorize projects – significant enough, doable enough, meets our capabilities, etc.



Figures from a breakout group.

The Challenge of GigaTechnology

John Crittenden, Georgia Tech, presented a concept for an integrated research program on sustainable urban infrastructure (Pandit et al. 2017; James et al. 2016). He characterized the challenge of GigaTechnology, the largest systems in which humans manipulate mass and energy. Research topics in the stakeholder engagement area include citizen capacity building, data analytics, policies and market drivers for adoption, preferences for key performance indicators, and equity. Focusing on the platform concept of Manufacturing 4.0, there is a sustainable development opportunity in conceiving and establishing a sustainable engineering toolbox that can blueprint sustainable urban infrastructures and contract out the construction and implementation.



Emergent Properties from Interacting Infrastructures. Courtesy of John Crittenden

How do we create a common vocabulary and language? What is it going to cost?

In his keynote presentation, Steve Foran, Jacobs Engineering, asked: What does it truly mean to be interdisciplinary? How do we know we are answering the right problem? Foran discussed how Jacobs is using models of ecosystems for urban systems, and how companies like Jacobs can work with researchers to explore new approaches, such as ecological network analysis, transforming an ecological network analysis to an urban planning model or a campus or regional plan.



Figure courtesy of Jacobs Engineering.

Foran said, “The power of this approach is in the integration of the work and research being done around the globe. Our team looks across the sectors and finds the connections and relationships and leverages their collective knowledge. It is a different kind of thinking a different kind of collaboration and a different kind of organization.”

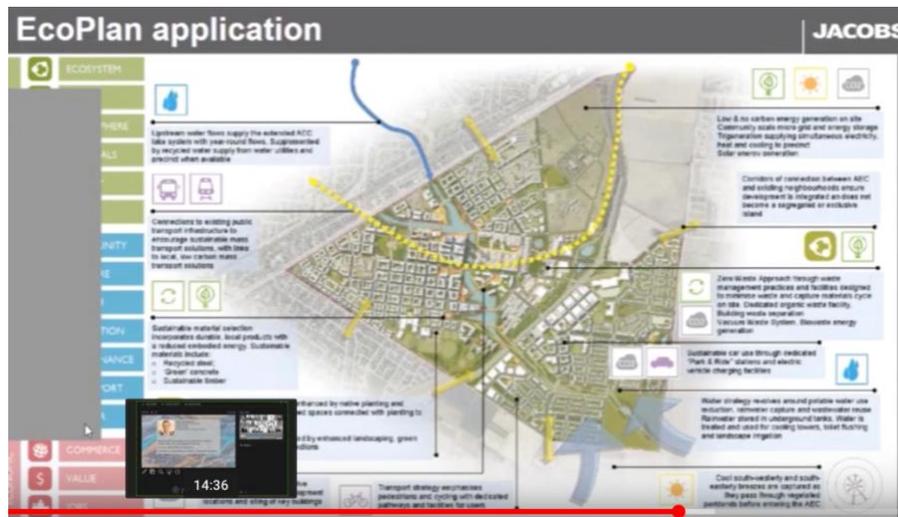


Figure courtesy of Jacobs Engineering.

Where can we have the most impact in urban infrastructure systems? How has research led to change? What can collaboration bring that we cannot do alone?

Chaired by Cliff Davidson (Syracuse University) the panel included Maggie Kelley from the Southeast Energy Efficiency Alliance, Ed Groark from Worldwatch Institute, and Lauren Baldwin from the Creosote Collaborative.

What are the challenges to making the city sustainable? Where can research play a role?

- Maggie Kelley said that research can shorten the gap between the actual situation and future improvement, and explain the big picture.
- Lauren Baldwin gave an example of the project on composting. By understanding what the everyday issues are for the city management people, and by solving them, you can move forward and talk about the big picture. In the area of green infrastructure, we had to have specific data on specific areas of the city to convince them that green infrastructures can help. It can be really frustrating.
- Cliff Davidson said that poverty is a big issue. There will be no sustainability if we have this income inequality. Equity is a huge problem. The issue of equity has to be addressed when we discuss sustainability.

What is the optimum strategy to move forward in dealing with today's issues and also long term projects?

- Lauren Baldwin: Solve some of the issues with collaboration, then maybe ask for money.
- Maggie Kelley: You come with the resources, not asking for help. Cities hate being asked for money.
- Jairo Garcia: Approach the city with partners that are already working with the city, and "be introduced" by working with the partner first. Find the good partner, then leverage the project.

What is the relationship of publications to action?

- Ed Groark said: Publications are read by those already interested in sustainability. Moving to an academic audience can inspire young people for their future profession, and can develop curriculum to introduce sustainability into academic programs.

What is your theory of change?

- Maggie Kelley: We look to the pain points. We seek co-production. In low income areas we either have renters or low income legacy owners subject to gentrification. There has been little discussion of renters. The real problem that families are facing is "why are all these kids going to the emergency room for asthma?" We need to realize where the research meets the people. We can work with Medicare on pediatric asthma. The strategy for improvement may be the infrastructure, but it is not the pain point.

- Ed Groark: What is our theory of change? At Worldwatch, most of our books were being read by people who already knew about the topic. We are moving to an academic audience to encourage students to choose careers in sustainability.

Describe the future of Sustainable Urban Infrastructures (Part 2)

Drawing on the previous panels, this session was designed to bring forward new and additional approaches. The session featured practitioners managing change and researchers modeling change, and was chaired by Professor Miguel Velez-Reyes of the University of Texas El Paso. Panelists included Dr. Caroline Golin from Google, Rich Simmons from Georgia Tech, and Kincho Law from Stanford University.

- Caroline Golin described Google's process for procuring renewable energy for their data centers. Costs for renewables are now low, and through contracts they can mitigate risks.
- Kincho Law of Stanford University said that Smart Cities aren't smart unless the people are smart too. Advocates for low income areas are needed. There are four things that smart and sustainable systems need to address: cybersecurity and privacy, managing the costs of cyberinfrastructure development, and equity and inclusion, to ensure that the economic growth provided by new technologies is equitably distributed. He noted the example of interstate highways: the development of the interstate highway system in the United States brought economic benefits, but also created poverty in areas that were left behind (Law and Lynch 2019).
- Rich Simmons of Georgia Tech said it is important to think about how we relate to the world. Our challenge in research is how we move our ideas in to the low risk domain for our energy systems so they can be tested and integrated. People will invest in renewable energy regardless of our plans. We have to inform our community, introducing metrics such as energy return on investment (EROI) and energy stored on investment (ESOI). The goal of this group can be to introduce these additional metrics. Georgia Tech is about to have the first microgrid in the state, with 200 kW of natural gas, 200-300 W of batteries, and 200 kW of diesel.
- The panelists discussed that the grid has been designed over 80 years for unidirectional transmission. There is now a massive amount of infrastructure that is not designed for distributed electricity or multiple types of electricity sources. The challenge is to create a new grid for the future. Technologies are changing so rapidly that many of the technologies that we invest in today may become stranded assets, still being paid for although no longer used.
- Nick Cooper of the Georgia Public Service Commission encouraged participants to get involved in the planning process. Although vertical integration has its critics, we argue that there are benefits to the vertical integration of the electricity system in Georgia. The market will not regulate itself, as highlighted by the situation in the west. It is up to the public to decide what kinds of transitions we want. If you want to affect what the plans are, then get in contact with the Integrated Resources Plan (IRP). This is the state's three-year energy plan.
- Dimitri Mavris, Georgia Tech, said that you have to work with the people who have the authority. He said they have done a lot of small tasks to be helpful, and that has provided a basis for ongoing larger projects. There are examples of places with centralized administration where decision makers have direct authority to make changes: city states such as Hong Kong and Singapore.

Vision for Smart Cities: Campus as Experimental Apparatus

Dimitry Mavris, with assistance from Scott Duncan and Michael Balchanos, Georgia Tech, presented their work on energy analysis at the building level across Georgia Tech.

- When everyone is optimizing their part, you end up with a sub-optimal solution. To create the urban system of systems, enables are artificial intelligence, machine learning, big data, and edge computing. Stressors are rising energy costs, weather threats, emergency threats, and cyber threats. In their work on the GT campus they initially focused on energy and water, and progressed to safety and mobility; in future years moving will be moving to information technology, supply chain, and ecological services.

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Appendix A: Responses to Pre-meeting Survey

Prior to the workshop, all participants were asked to answer a set of five open-ended questions. All responses were then aggregated and analyzed for keywords. Results below show the frequency of keywords appearing among all responses and a brief statement summarizing the general nature of the responses.

Q#1: How best can researchers, practitioners, and community groups work together on the topic of sustainable urban infrastructure? Especially if you have worked in such a collaboration, please describe what you thought worked well.

<i>Word</i>	<i>Occurrences</i>	<i>Rank</i>
<i>community</i>	30	1
<i>infrastructure</i>	16	2
<i>researchers</i>	14	3
<i>groups</i>	13	4
<i>research</i>	13	4
<i>work</i>	13	4
<i>practitioners</i>	12	5
<i>needs</i>	10	6
<i>these</i>	9	7
<i>problems</i>	9	7
<i>how</i>	8	7
<i>communities</i>	8	7
<i>best</i>	8	7
<i>projects</i>	8	7
<i>time</i>	8	7
<i>what</i>	8	7
<i>urban</i>	8	7
<i>real</i>	7	8
<i>important</i>	7	8
<i>students</i>	7	8
<i>often</i>	7	8
<i>atlanta</i>	7	8
<i>worked</i>	7	8
<i>city</i>	7	8
<i>different</i>	7	8
<i>very</i>	7	8
<i>design</i>	6	9
<i>project</i>	6	9
<i>get</i>	6	9
<i>then</i>	6	9

General observation:

- It may be helpful to focus on “needs” or “problems” within the “communities” (e.g., allow community groups to define research problems?)

Q#2: What future would you like to explore? Specific technologies? Social or economic outcomes? What leads from here to there?

<i>Word</i>	<i>Occurrences</i>	<i>Rank</i>
<i>energy</i>	27	1
<i>systems</i>	22	2
<i>infrastructure</i>	19	3
<i>how</i>	18	4
<i>urban</i>	17	5
<i>future</i>	13	6
<i>interested</i>	13	6
<i>these</i>	12	7
<i>grid</i>	10	8
<i>social</i>	10	8
<i>technology</i>	9	9
<i>data</i>	8	10
<i>carbon</i>	8	10
<i>sustainable</i>	8	10
<i>people</i>	8	10
<i>what</i>	7	10
<i>low</i>	7	10
<i>transportation</i>	7	10
<i>economic</i>	7	10
<i>centralized</i>	7	10
<i>like</i>	7	10
<i>communities</i>	7	10
<i>our</i>	7	10
<i>system</i>	7	10
<i>change</i>	6	11
<i>management</i>	6	11
<i>issues</i>	6	11
<i>should</i>	6	11
<i>new</i>	5	12
<i>green</i>	5	12

General observation:

- Energy is the keystone topic

Q#3: What training could support employment and workforce development in sustainable urban infrastructures?

<i>Word</i>	<i>Occurrences</i>	<i>Rank</i>
<i>training</i>	18	1
<i>sustainable</i>	16	2
<i>data</i>	15	3
<i>urban</i>	14	4
<i>infrastructure</i>	13	5
<i>sustainability</i>	9	6
<i>energy</i>	8	7
<i>people</i>	7	8
<i>needs</i>	7	8
<i>systems</i>	6	9
<i>analytics</i>	6	9
<i>need</i>	6	9
<i>technologies</i>	5	10
<i>engineering</i>	5	10
<i>development</i>	5	10
<i>future</i>	5	10
<i>workforce</i>	5	10
<i>assessment</i>	5	10
<i>how</i>	5	10
<i>new</i>	5	10
<i>digital</i>	5	10
<i>time</i>	5	10
<i>think</i>	5	10
<i>what</i>	4	11
<i>community</i>	4	11
<i>problems</i>	4	11
<i>system</i>	4	11
<i>infrastructures</i>	4	11
<i>complexity</i>	4	11
<i>these</i>	4	11

General observation:

- Data, data, data – how to get it; how to analyze it

Q#4: What kinds of RESEARCH projects have the most impact? What are levers of change for sustainable urban infrastructure? What are some past projects that have had impact?

<i>Word</i>	<i>Occurrences</i>	<i>Rank</i>
<i>research</i>	30	1
<i>projects</i>	22	2
<i>sui</i>	17	3
<i>impact</i>	15	4
<i>change</i>	11	5
<i>what</i>	11	5
<i>data</i>	10	6
<i>important</i>	9	7
<i>energy</i>	9	7
<i>project</i>	8	8
<i>use</i>	8	8
<i>how</i>	7	9
<i>performance</i>	7	9
<i>urban</i>	7	9
<i>these</i>	7	9
<i>policy</i>	7	9
<i>infrastructure</i>	7	9
<i>benefits</i>	6	10
<i>adoption</i>	5	11
<i>real</i>	5	11
<i>sustainable</i>	5	11
<i>involved</i>	5	11
<i>public</i>	5	11
<i>problem</i>	5	11
<i>systems</i>	5	11
<i>engagement</i>	4	11
<i>changes</i>	4	11
<i>transportation</i>	4	11
<i>georgia</i>	4	11
<i>buildings</i>	4	11

General observation:

- Use data to demonstrate performance / benefits
- Can ideas from projects be adopted? Made real?
- Involve / engage the public

Q#5: Describe a collaborative project on sustainable urban infrastructure that you would like to participate in, and describe what your role or activity would be.

<i>Word</i>	<i>Occurrences</i>	<i>Rank</i>
<i>infrastructure</i>	17	1
<i>urban</i>	17	1
<i>like</i>	17	1
<i>energy</i>	11	2
<i>building</i>	10	3
<i>project</i>	10	3
<i>research</i>	9	4
<i>systems</i>	9	4
<i>how</i>	8	5
<i>new</i>	8	5
<i>system</i>	8	5
<i>sustainable</i>	8	5
<i>transportation</i>	7	6
<i>data</i>	7	6
<i>interested</i>	6	7
<i>projects</i>	6	7
<i>help</i>	6	7
<i>performance</i>	6	7
<i>use</i>	6	7
<i>model</i>	6	7
<i>impacts</i>	6	7
<i>social</i>	5	8
<i>water</i>	5	8
<i>technologies</i>	5	8
<i>health</i>	5	8
<i>integrated</i>	5	8
<i>management</i>	5	8
<i>along</i>	5	8
<i>based</i>	5	8
<i>design</i>	5	8

General observation:

- Building Energy Systems?
- Sustainable Transportation?
- Social Impacts?
- Modeling

Appendix B: Conference Code of Conduct

The following code of conduct was provided to all participants before and upon arrival at the workshop.

Conference Code of Conduct

Advancing a Research Network for Sustainable Urban Infrastructure

Georgia Institute of Technology

August 15-16, 2019

The following code-of-conduct addresses sexual harassment, other forms of harassment, and sexual assault, and includes clear and accessible means of reporting violations of the policy or code-of-conduct.¹

Conference Organizers Commitment

The organizers of this conference are committed to providing a safe and productive meeting environment that fosters open dialogue and the exchange of scientific ideas, promotes equal opportunities and treatment for all participants, and is free of harassment and discrimination. All participants are expected to treat others with respect and consideration, follow venue rules, and alert staff or security of any dangerous situations or anyone in distress. Speakers are expected to uphold standards of scientific integrity and professional ethics. This includes notifying organizers in advance of the meeting about any possible conflicts of interest. The organizers recognize that there are areas of science that are controversial. This conference can serve as an effective forum to consider and debate science-relevant viewpoints in an orderly, respectful, and fair manner. The policies herein apply to all attendees, speakers, exhibitors, staff, contractors, volunteers, and guests at the conference and related events.

The organizers of this conference prohibit any form of harassment, sexual or otherwise. Harassment should be reported immediately to any of the Conference Chairs:

Chair, Dr. Valerie Thomas; valerie.thomas@isye.gatech.edu; (404) 385-7254

Co-Chair, Dr. Kim Kurtis; kkurtis@gatech.edu; (404) 385-0825

Co-Chair, Dr. Ivonne Santiago; isantiago@utep.edu; (915) 747-8478

As an NSF funded conference, harassment can also be reported directly to NSF at programcomplaints@nsf.gov.

What is Harassment?

Harassment includes speech or behavior that is not welcome or is personally offensive, whether it is based on ethnicity, gender, religion, age, body size, disability, veteran status, marital status, sexual orientation, gender identity, or any other reason not related to scientific merit. It includes stalking, unnecessary touching, and unwelcome attention.

¹ This Conference Code of Conduct was adapted from the *AAAS Annual Meeting Code of Conduct*; adopted by the AAAS Board of Directors October 2016; <https://meetings.aaas.org/policies/>; accessed March 19, 2019.

Behavior that is acceptable to one person may not be acceptable to another, so use discretion to be sure that respect is communicated. Harassment intended in a joking manner still constitutes unacceptable behavior. Retaliation for reporting harassment is also a violation of this policy, as is reporting an incident in bad faith.

Reporting Harassment

The organizers of this conference are committed to supporting a productive and safe working environment for everyone at the meeting. If an individual experiences or witnesses harassment, they should contact the conference Chairs as noted above, or use a venue phone and ask for security if they feel unsafe.

While on Georgia Tech's campus, Georgia Tech Police are available by dialing 911 or while on or off campus at **(404) 894-2500**. All complaints will be treated seriously and responded to promptly.

If an individual experiences harassment, it is recommended that, in addition to notifying conference Chairs, they write down the details, as they may be asked to fill out a report. They are not expected to discuss the incident with the offending party. Their confidentiality will be maintained to the extent that it does not compromise the rights of others.

If an individual wishes to file a formal complaint of harassment:

- Notify Conference Chairs (Thomas, Kurtis, or Santiago).
- The Chair(s) will discuss the details with the individual filing the complaint, then with the alleged offender; seek counsel if the appropriate course of action is unclear; and report findings to the Georgia Tech Office of Human Resources or the Georgia Tech Police Department as appropriate, AND to the conference funding sponsor (National Science Foundation).
- The Chair(s) will consult with the individual filing the complaint prior to taking any action.

Conference organizers reserve the right to remove an individual from the conference without warning or refund, prohibit attendance at future conferences, and notify the individual's employer.

For any questions about this policy, please contact Dr. Valerie Thomas, Conference Organizing Chair, at valerie.thomas@isye.gatech.edu; (404) 385-7254.