# Connecting the Smart-City Paradigm with a *Sustainable Urban Infrastructure Systems Framework* to Advance Equity in Communities

**NSF Award #1737633**
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**S&CC-IRG Track 1, 2017**

| Principal Research Investigators (Name, Institution) | Community Partners (Name, Institution) |
|---|---|
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**Website:** http://www.spatial.cs.umn.edu/Project/smart-city/index.html

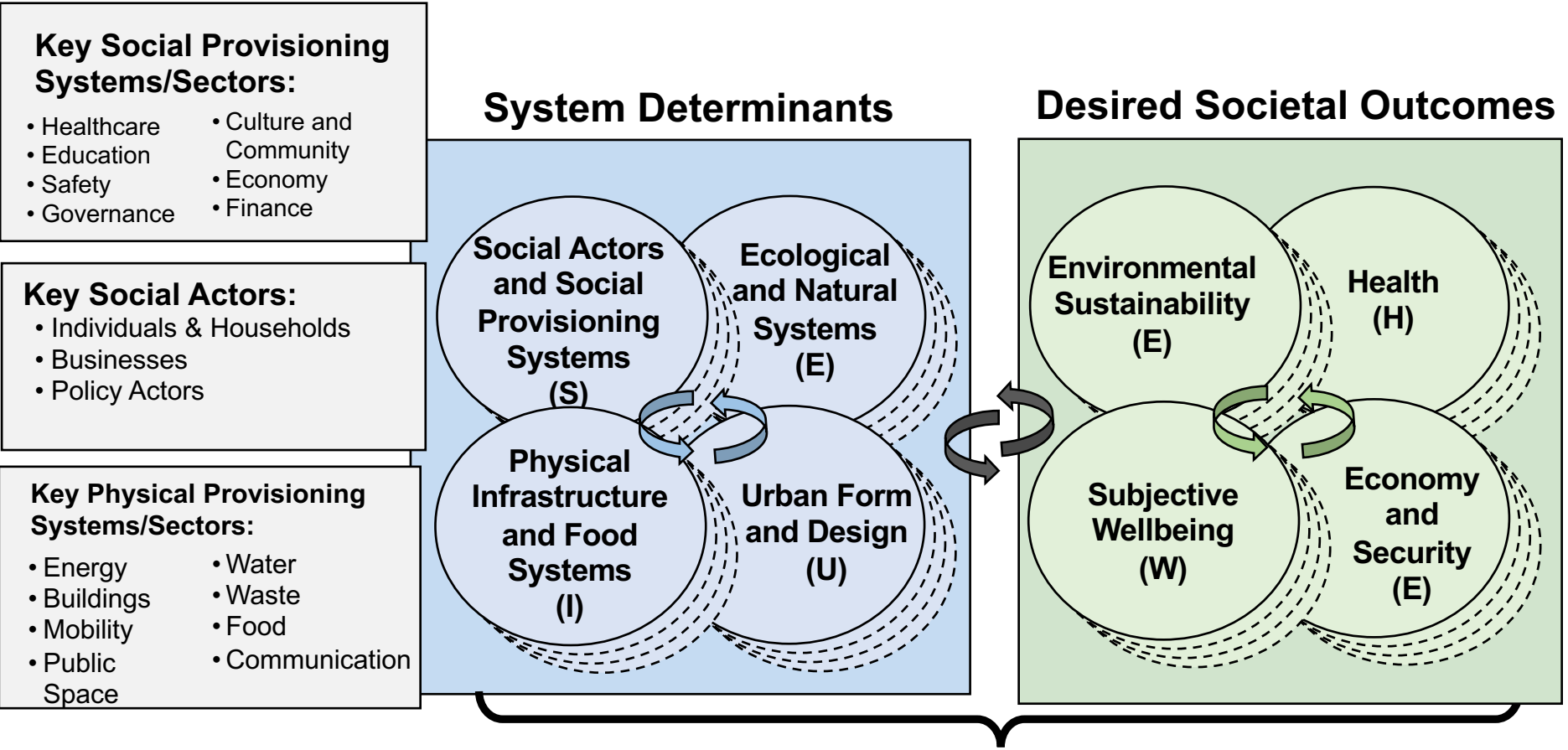# Overarching Project Vision and Goals

- Overarching vision: Link the smart city paradigm on sensor technologies and data sciences with an interdisciplinary integrated Social-Ecological-Infrastructural & Urban Systems (SEIUS) framework to advance desired social outcomes.

- Overarching goal: Develop science and models for **equity-first spatial planning** with emerging physical infrastructure transitions in cities, such as distributed energy, electricity mobility, green infrastructure, and their interactions, as they impact well-being (W), health (H), environment (E), and social equity (E).

- We conduct interdisciplinary community-engaged research with:

| | |
|---|---|
| 4 Local governments | Minneapolis, St Paul, Tallahassee, Hennepin County. |
| K-12, teachers & students | Minneapolis Public Schools, St. Louis Park High School, MN |
| Multi-community Organizations | ICLEI-USA, National League of Cities, Metro-Lab, City/County Management Association, Hennepin University Partnership, and Metropolitan council of the twin cities. |

# Theme 1: Fine Scale Database to assess Inequality and Equity in Urban Systems addressing Multiple Determinants & Outcomes

# Foundational Advances: Articulates Social Equity in Multi-Sector Sustainable Urban Systems & Develops a Fine Scale Database

**Key Social Provisioning Systems/Sectors:**

- Healthcare
- Education
- Safety
- Governance
- Culture and Community
- Economy
- Finance

**Key Social Actors:**

- Individuals & Households
- Businesses
- Policy Actors

**Key Physical Provisioning Systems/Sectors:**

- Energy
- Buildings
- Mobility
- Public Space
- Water
- Waste
- Food
- Communication

## System Determinants

- Social Actors and Social Provisioning Systems (S)
- Ecological and Natural Systems (E)
- Physical Infrastructure and Food Systems (I)
- Urban Form and Design (U)

## Desired Societal Outcomes

- Environmental Sustainability (E)
- Health (H)
- Subjective Wellbeing (W)
- Economy and Security (E)

**Equity (E):**
Addresses fairness in the societal distribution of burdens and benefits, across determinants and outcomes, with the goal of reducing disparities for the most disadvantaged

# Sensors and Models Developed

- **Fine-grain Urban Data Set Synthesis (Lead PI: Ramaswami)**
  - Illustrative synthesis of available spatial data for the City of Saint Paul, MN.
  - Co-developed by researchers across four universities: UMN, FSU, PU, UW

- **Low-cost Air pollution sensors (Lead PI: Marshall)**
  - Refined low-cost ($10) passive sensor and imaging approach.
  - Tested precision and detection limit in 20 indoor locations for 8 months.

- **Hyper-resolution physically-based distributed flood modeling (Minneapolis) (Lead PI: Merwade)**

- **Citizen Science for near real-time urban flood simulations (Lead PI: Ramaswami)**
  - Survey at Minnesota 2019 State Fair ~350 responses collected in a week
  - Simplified Fine-Scale Flood Models to Understand Social Equity in Urban Street Flooding
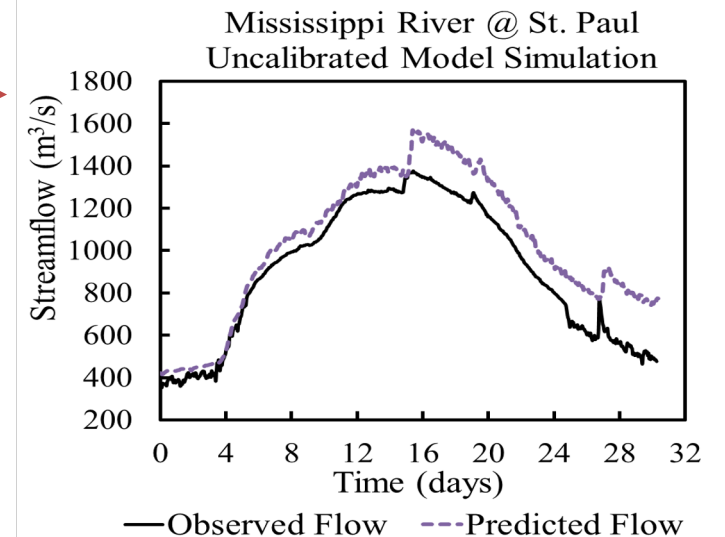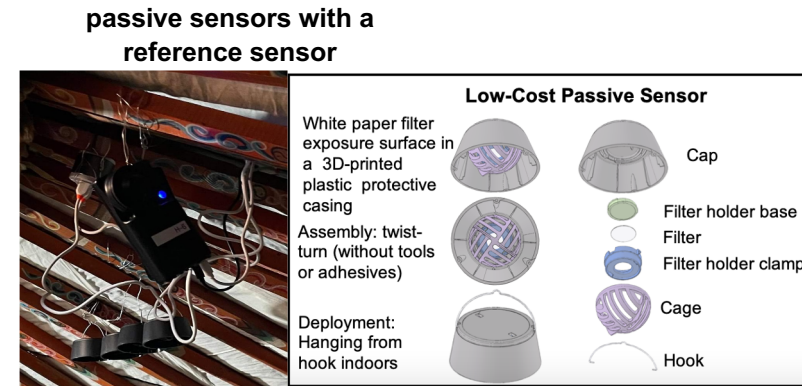
passive sensors with a reference sensor



**Low-Cost Passive Sensor**

White paper filter exposure surface in a 3D-printed plastic protective casing

Cap

Filter holder base
Filter
Filter holder clamp

Assembly: twist-turn (without tools or adhesives)

Cage

Deployment: Hanging from hook indoors

Hook

LOCAL

**Researchers survey fairgoers about street flooding**

The researchers behind the project say while there's plenty of data on flooding from rivers, that's not the case for street flooding.

Author: Jennifer Austin
Published: 6:09 PM CDT August 27, 2019
Updated: 8:54 PM CDT August 27, 2019

KARE 11



Mississippi River @ St. Paul
Uncalibrated Model Simulation

— Observed Flow    - - - Predicted Flow

# Theme 2: Advance spatial data analysis (theory and methods) to understand SEIU-WHEe relationships

# Foundational Research: Methods to Unpack Race and Income Effects on Inequality in Energy Use
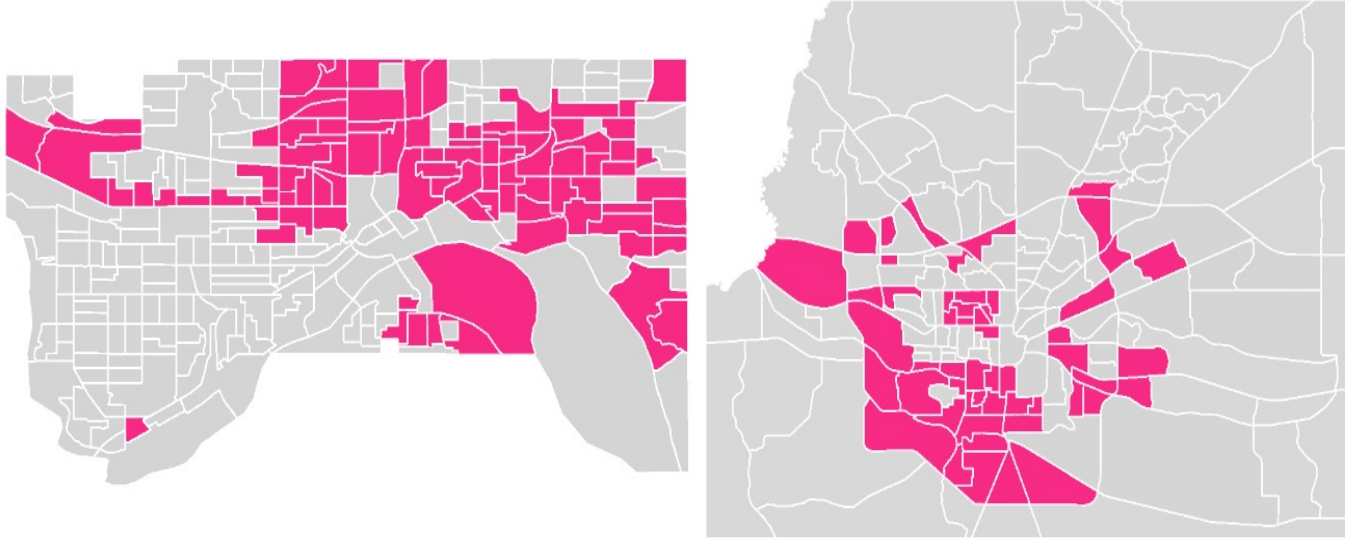


Measuring social equity in urban energy use and interventions using fine-scale data

Kangkang Tong[1,2], Anu Ramaswami[1,2][*], Corey (Kewei) Xu[3], Richard Feiock[3,†], Patrick Schmitz[4,†], Michael Ohlsen[3,5]

PNAS (Forthcoming)

New Fine-Scale Data and Methods to unpack race and income reveal five times greater social disparity in energy use intensity during cooling/heating season that previously known in the US.
Tong, Ramaswami et al, PNAS (forthcoming)

Collaboration across universities and electric utilities in Minnesota and Florida.

Transform our understanding of social inequalities in cities.

# Foundational Advances

- **Methods to measure social equity in urban energy use and interventions**

- **New Deep-learning Algorithms to Map Trees and Gardens from Aerial Imagery**
  - Fulton county (GA), Hennepin, Ramsey counties (MN)

- **Theory and empirical data to address modifiable areal unit problem**
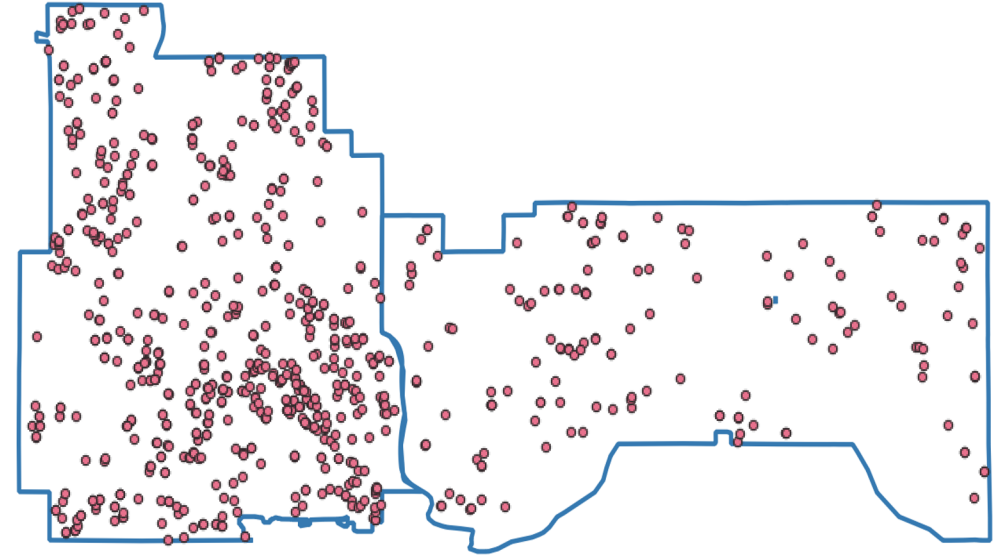
# Theme 3: Community Engaged Research With Cities

*Model and visualize spatial smart-city futures for Equity-First planning using a multi-infrastructure approach*

# Low-carbon Scenario Planning with Twin Cities Met-Council Project

**Co-develop multi-sector transitions scenario planning tool for Equity-First planning in the Twin Cities**

- Autonomous Vehicles
- Green Infrastructure
- Energy Transitions

**In Partnership With….**

**Anu Ramaswami**

**Kara Kockelman**

**Alireza Khani**

**Frank Douma**

PRINCETON UNIVERSITY

TEXAS
The University of Texas at Austin

UNIVERSITY OF MINNESOTA

Sustainable Healthy Cities
A National Science Foundation-supported
Sustainability Research Network (SRN)

I·C·L·E·I
Local Governments for Sustainability

LEIF
Lifecycle Environmental
Impact Footprinting

METROPOLITAN COUNCIL

# Food action planning in Minneapolis



**Launch of food action planning April, 2019**

# Work with the City of Tallahassee

**Impact of E-governance technology on equity in public service delivery**

- **Equity of E-Governance Tools (311 systems)**
  - How Technology-Enabled citizen participation (311) help address service delivery equity during disaster recovery.
  - Technology-enabled citizen participation can potentially narrow or even close the equity gap as people in need actively communicate with government.

- **Estimating Individual Needs for Public Service**
  - The level of needs for the same type of service may vary for people with different socio-economic status
  - Depending on service request data, we use machine learning algorithms to estimate to estimate a score of service needs for all residents in the city.
  - The goal is to compensate low usage of the citizen participation platform and create a more representative and more responsive service delivery mechanism.
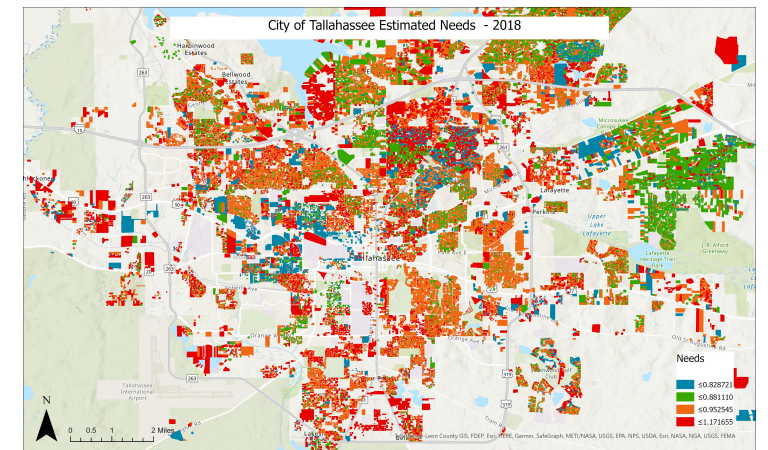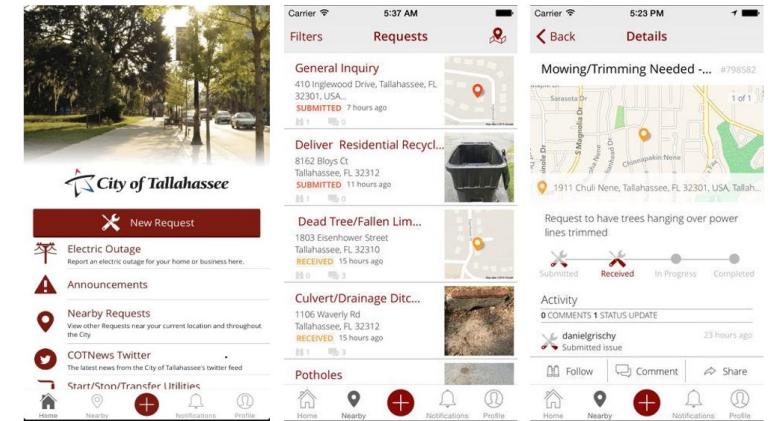
# Theme 4: Education and Research capacity building
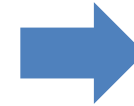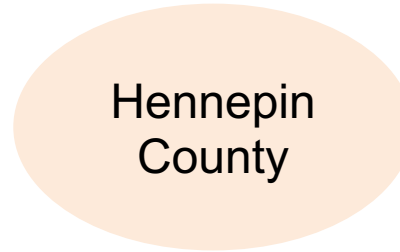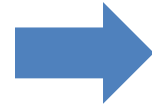
# THEME-4: Education & Workforce Development

- Continue develop & disseminate culturally relevant urban sustainability curriculum.

- Recruit more teachers to implement curriculum and develop new CS activities.

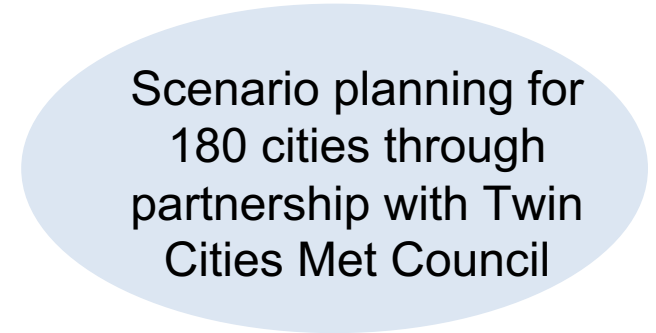- Designed and modified curriculum based on ongoing teacher feedback.



**Collage showing various teacher training activities**

# Project Evolution

At the beginning
of project: 2017

Today: 2021

Three cities:
St. Paul
Minneapolis
Tallahassee

→

Hennepin
County

→

Scenario planning for
180 cities through
partnership with Twin
Cities Met Council

Initial focus on seven
provisioning sectors in the SEIU
framework

→

Expanded to focus on to include
information-communication
infrastructure (ICT) and social
provisioning systems

# Project Impact on Communities

- Exploring Equity First Transitions via Multi-Sector Models: 3 Co-Produced Projects with Cities
  - Twin Cities Met Council, MN: Deep Decarbonization Technologies and Equity Planning
    - Link autonomous and shared vehicles with intervention (e.g., land use, green infrastructure).
    - Scenario planning tool for all 182 cities/communities covering about 3 million people: Integrate models of autonomous vehicle, land use and green infrastructure
  - Minneapolis Food Action Plan
    - Goal: A 2030 roadmap for food systems action; build on previous efforts and plans; align with Milan Urban Food Policy Pact; with data and community input for a more equitable, climate resilient, just and sustainable local food system and local food economy.
    - Covering ~350,000 people
  - Tallahassee, FL: Smart Technologies for Disaster recovery: Equity implications
    - Covering ~190,000 people
- Narrative evaluation through interview of stakeholders at the close project in 2021/2022; measures of social learning

# Conclusions

Our project has made four major contributions:

- Articulating an interdisciplinary actionable data framework for social equity in sustainable urban systems

- Advances in measuring social equity through fine scale data across multiple sectors

- Advances in measuring social equity through new methods unpacking race and income effects

- Real-world impact on communities through scenario planning that will become part of long-term "smart city" plans for sustainability and equity

# Anticipated outcomes & success measures for next year

- **Theme-1:** Improving fine-grain dataset collection

- **Theme-2:**
    - Social science theory for unequal access to infrastructure
    - Generalize spatial variability aware neural networks for variability in neural network architectures.
    - Investigate spatial dimension of algorithmic transparency.

- **Theme-3 :** Complete equity-first future planning with communities
    - With Met-Council project, Prof. Ramaswami and Prof. Douma will co-develop multi-sector transitions scenario planning tool for Equity-First planning in the Twin Cities.
    - Equity in Greenhouse Gas Emissions exploratory scenario planning at the regional scale. 2021 Consortium of scenario planning.
    - Complete evaluation of community impact

- **Theme-4:**
    - Refine the curriculum and educational material.