The Georgia Tech Tianjin University Shenzhen Institute

The Research Center for Green Buildings and Sponge Cities

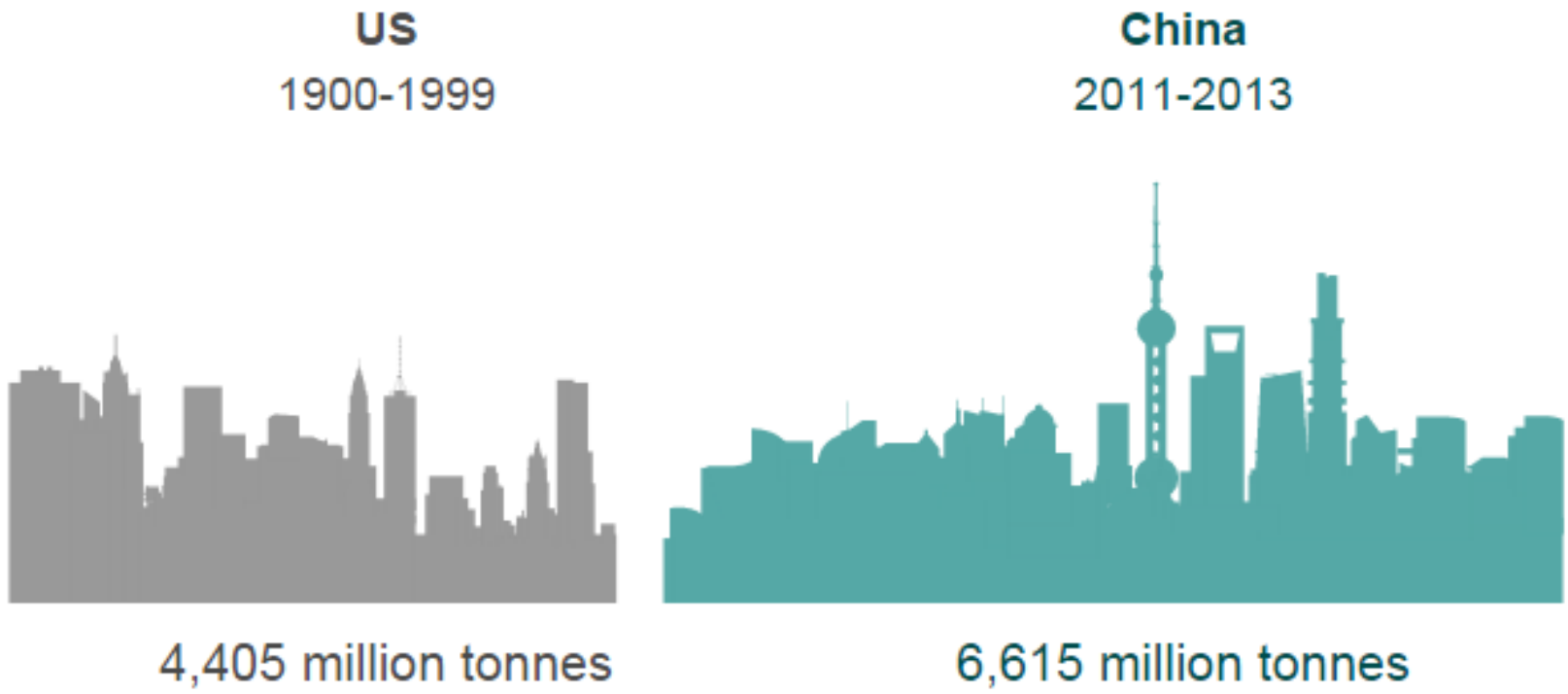
Gigatech: The largest infrastructures in which humans manipulate matter and energy.

Tianjin University

Georgia Tech

Georgia Tech Brook Byers Institute for Sustainable Systems

China Used More Cement in Three Years than the US did in a Century



Both are Gigatech: ~10^{14} moles of Calcium

China’s Infrastructure Challenge

By 2025:

- 5 billion square meters of road will be paved.
- 170 mass-transit systems could be built
- 40 billion square meters of floor space will be built in five million buildings
- Build between 700 and 900 Gigawatts of new power capacity

Systems Engineering: Gigatech

Cities: Transport, Building, Water, Energy, and ICT	• 75% global greenhouse gas emissions • Consume 75% of natural resource • 54% global population; 82% US Population • 78% global energy use • 80% global GDP • Worldwide, Surface transport is worth $10 trillion per year
Infrastructure	• Infrastructure requires $90 trillion investment by 2030 (UNEP) • Infrastructure lasts more than 50 years and 80-90% of its impact occurs in use phase • Global infrastructure needs to double in the next 35 years and it took 5500 years to get to this point • US infrastructure will increase 40% by 2030 • US housing market is valued at approximately 27 trillion dollars
Adaptation to Climate Change	In 2014, Farmers paid insurance claims resulting from strong storms a year earlier that had overwhelmed sewer systems around Chicago and flooded homes and businesses. Farmers claimed that the municipalities knew about climate change and its increased potential to cause flooding and yet failed to take reasonable preventative actions.

ICT: Information and Communication Technology

天津大学 Tianjin University

The Research Center for Green Buildings and Sponge Cities

- Strong research and educational team
- Strong financial and industrial support
- Sustainable Infrastructure

Georgia Tech

Tianjin University

- The first modern higher education institution in China
- One of the first batch of universities under“985”Project

Georgia Tech

- Ranked 2rd in civil engineering in the US
- Top institute with emphasis on science and technology

Shenzhen

- First Special Economic Zone
- One of five largest and wealthiest cities of China:
- GDP = 3 Trillion RMB

Core Strengths in Sustainable, Resilient and Integrated Infrastructure

- Urban Water Systems (e.g., low impact development, water reclamation, rainwater harvesting, sponge city)
- Green buildings and infrastructure
- Urban Performance Simulation (High Performance Computation, Model Federation, Multiple Design Optimization)
- Urban Big Data Analytics for Urban Monitoring and Control
- Urban Big Data Analytics: Determination Citizen Preferences and Improving the Adoption Rate of Sustainable Infrastructure

Core Strengths in Sustainable, Resilient and Integrate Infrastructure

- Sensors and Sensor Networks
- Urban Ecological System Services and Structure
- Urban Sea and Resource Development
- Urban Air Quality Control and Health Impacts
- Sustainable Energy Production (including Decentralized Energy Production, Grid Design and Control, Combined Cooling Heat and Power)
- Urban Farming, Hydroponics: Food Energy Water Reduction

Sustainable Engineering

John Crittenden
Sustainable Infrastructure

Valerie Thomas
Sustainable Materials & Energy

Chris Paredis
Systems Engineering

Bert Bras
Sustainable Design & Manufacturing

Ted Russell
Air Quality & Health

Yongshen Chen
Algal Biofuels

Yang Wang
Smart Infrastructure

Santiago Grijalva
Power Systems & Controls

Iris Tien
Resilient Infrastructure

Urban Planning and Design

Steven French
Sustainable Urban Development

Ellen Dunham-Jones
Suburban Redevelopment

Subhro Guhathakurta
Urban Sustainability

Perry Yang
Urban Design

Fried Augenbroe
Intelligent Building Systems

Baabak Ashuri
Sustainable Infrastructure

GIGA TECH TEAM

GIGA TECHNOLOGY

Sustainability Science, Policy, Education, and Commercialization

Marilyn Brown
Energy & Climate Policy

Carl Rust
Innovation & Commercialization

Marc Weissburg
Bio Inspired Design

Tom McDermott
Socio-technical Systems

Jamila Cola
Science Education

Margie Brown
Diversity and Security

Nathan Moon
Accessibility

Michael Chang
Air Quality

Robert Todd
Universal Design

High Performance Computing and Big Data

Richard Fujimoto
High Performance Computing

Haesun Park
Large Scale Data Analytics

Ashok Goel
Artificial Intelligence

Bistra Dilkina
Computational Sustainability

天津大学
Tianjin University

Urban water system and sponge city.

Prof. JI Min

Assoc. Prof. LIU Hongbo

Assoc. Prof. LI Ruying

Assoc. Prof. Zhao Peng

Dr. Zhao Yingxin

Green building and environment

Assoc. Prof. ZHOU Zhihua

Prof. Tian Zhe

Assoc. Prof. Ma Degang

Assoc. Prof. WANG Yuan

Urban energy

Prof. CHEN Guanyi

Assoc. Prof. JI Na

Assoc. Prof. YAN Beibei

Assoc. Prof. DENG Na

Assoc. Prof. LV Xuebin

Urban ecological infrastructure

Prof. ZHAO Lin

Prof. CAO Lei

Dr. MA Wenchao

Urban big data and MIS

Assoc. Prof. MAO Guozhu

Dr. QIAO Zhi

Dr. TONG Yindong

Assoc. Prof. DING Hui

Assoc. Prof. LIU Hong

Urban sea environment and resource use

Prof. WANG Guangyi

Assoc. Prof. LIU Xianhua

Dr. YANG Yongkui

Urban air pollution control

Prof. LIU Qingling

Assoc. Prof. SONG Chunfeng

Dr. SHENG Ying

Engineered System of Systems Vision:

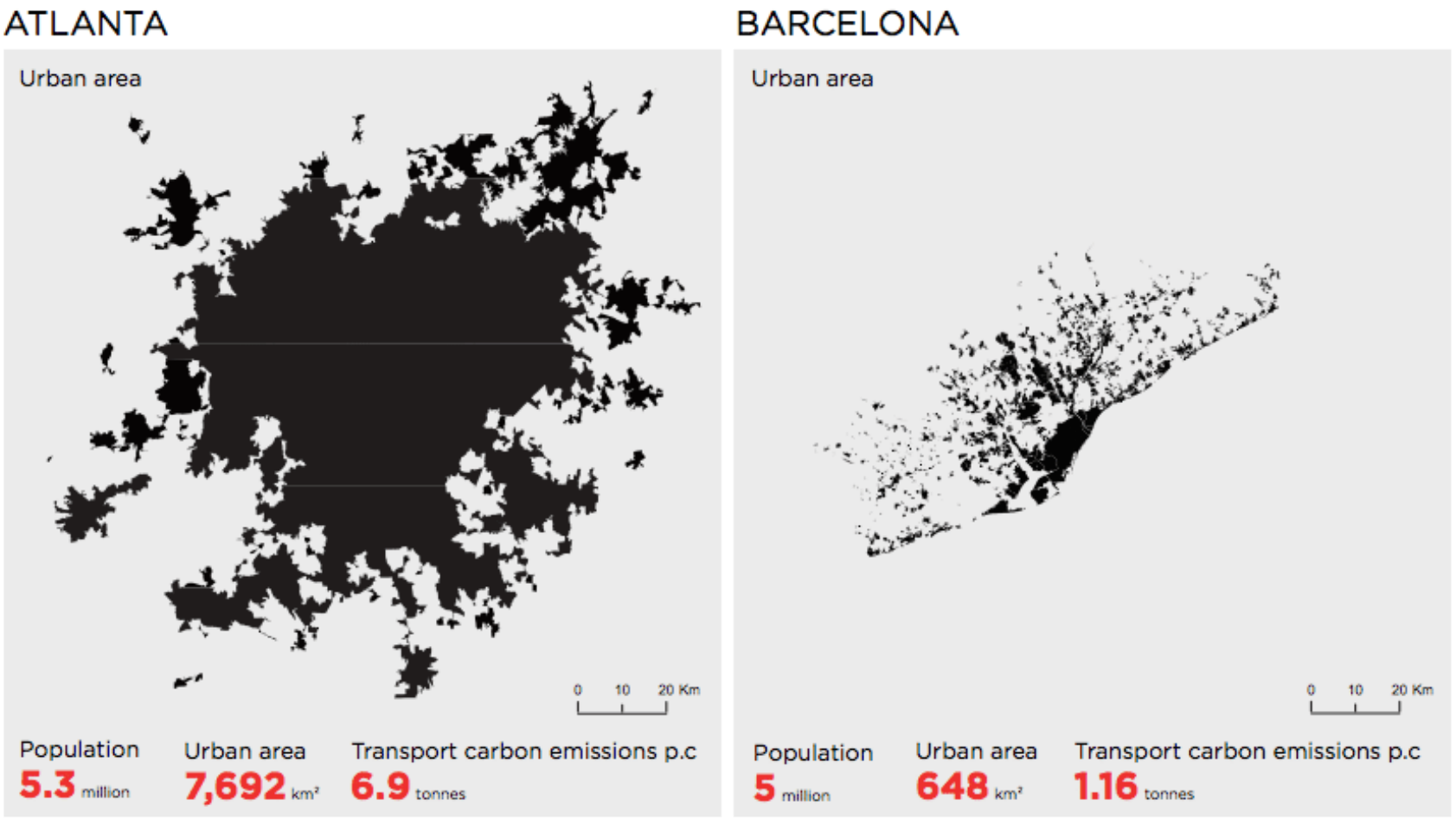
Improve the quality of life, human welfare, and the environment by providing design guidance for integrated sustainable, and resilient infrastructure.

Credit: http://www.terreform.org/

Why We See This?

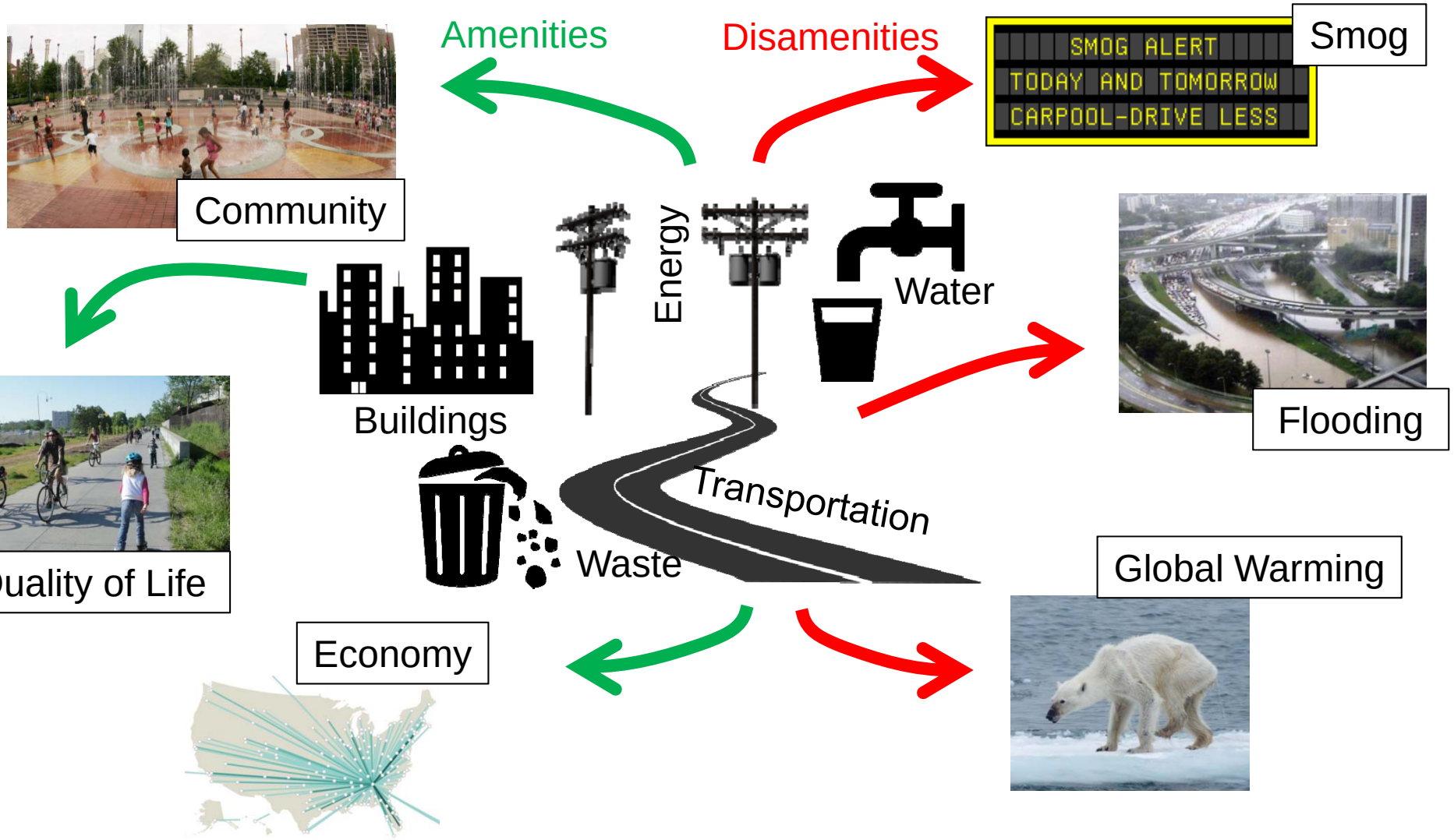
Traffic maps of Atlanta on January 28, 2014.

Why We See This?



Source: LSE Cities 2014

Engineered Urban Infrastructures



Manage Infrastructures as a Whole for Better Future

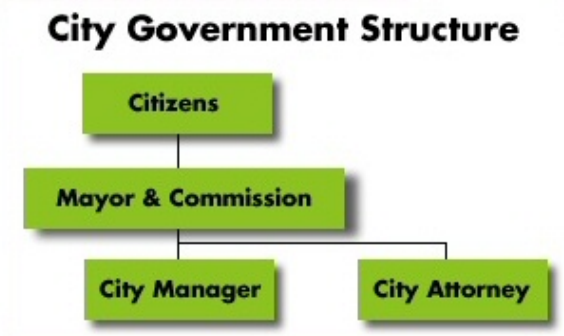
Cities as Complex Adaptive System

- Multi-agent systems: diverse, interdependent, connected, adapting entities

Business &Firms

People

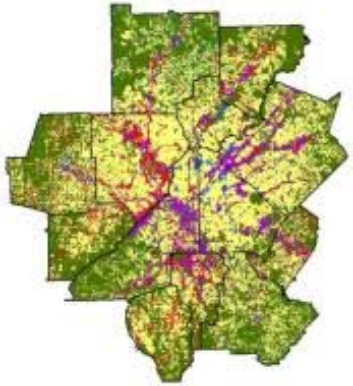
Governments



Urban Systems Complexity

Emergence of desirable amenities (high Tax Revenue and Quality of Life) & undesirable amenities (e.g., poor air quality, low tax revenue, traffic congestion, flooding, etc.)

Macro



Infrastructure Systems

Socio-Economic Environment

Micro

We Can Build Infrastructures that:
(1) Are More Sustainable and Resilient
(2) Create More Wealth and Comfort
But How?

State of the Art: Integration has not yet come to infrastructure

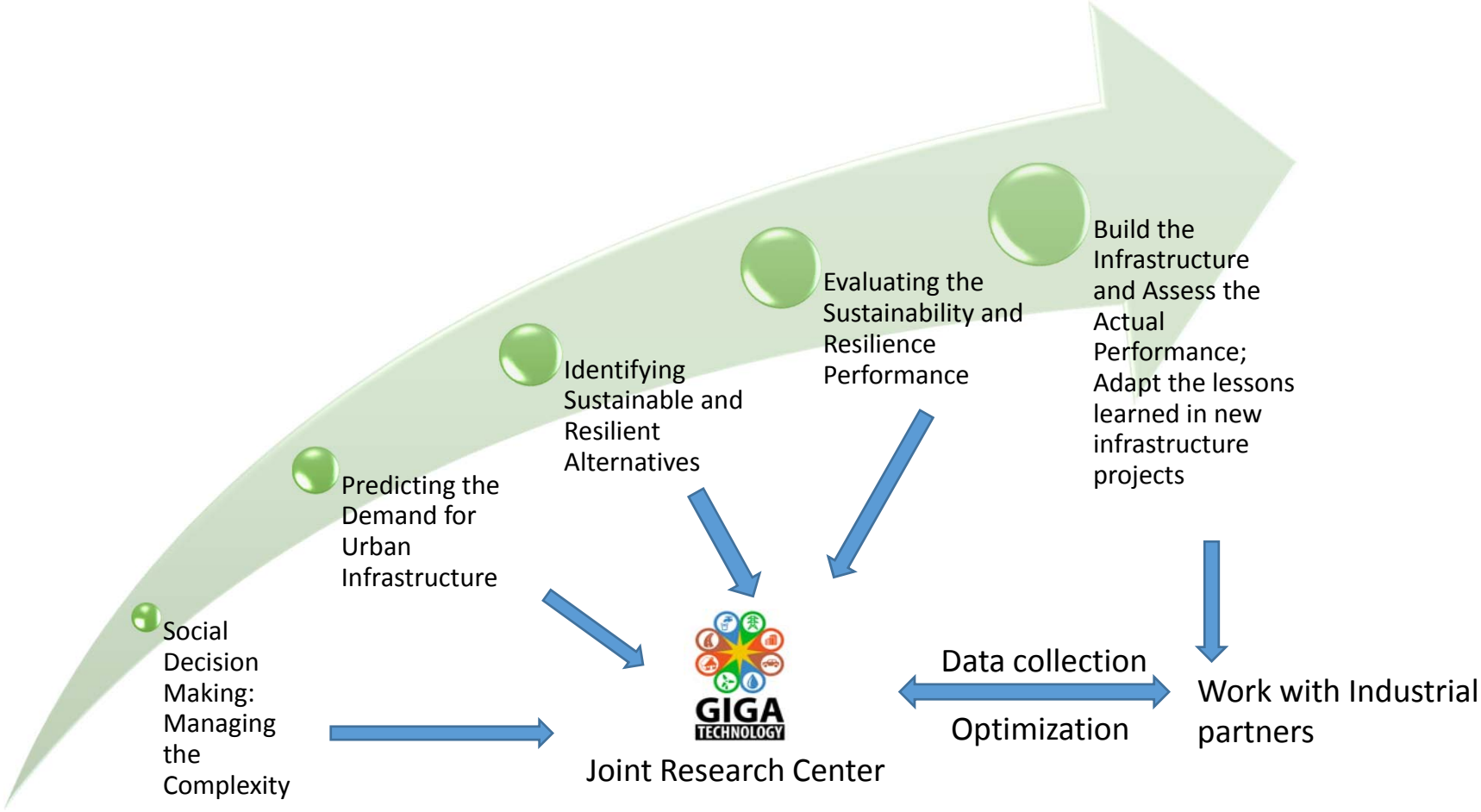
Solution: System of Systems Engineering Approach

Communications are information and communications technology (ICT).

New Transdiscipline: Infrastructure Ecology

- **Infrastructure Ecology** views the *city as a complex adaptive ecosystem* composed of physical, material, and human infrastructures. The Gigatech ERC will reorder this 'system of systems' to reduce energy and resource flows, and drive the creation of infrastructure to increase wealth and comfort, while fostering sustainable, equitable, and resilient cities.
  - ✓ Improve diversity of infrastructure, and improve energy and material flow to mimic natural ecosystems.
  - ✓ Integrate socio-economic dynamics, stakeholders and governance networks to enable livability, equity, and welfare.

Infrastructure Ecology Roadmap to Develop Sustainable and Resilient Urban Infrastructure



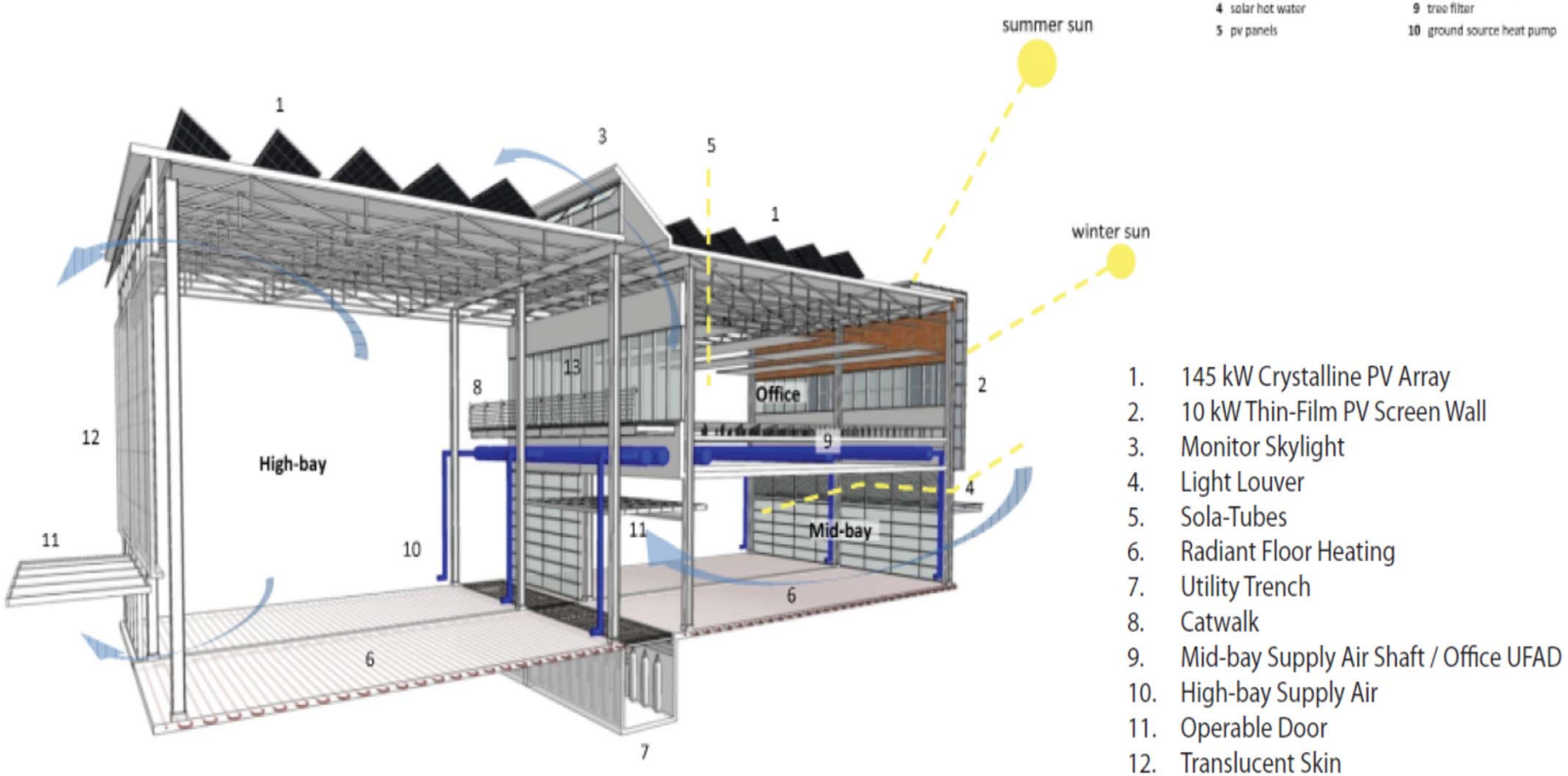
Small Scale Projects

Carbon Neutral Energy Solutions Research Laboratory (CNES)

First LEED Platinum certified building on campus

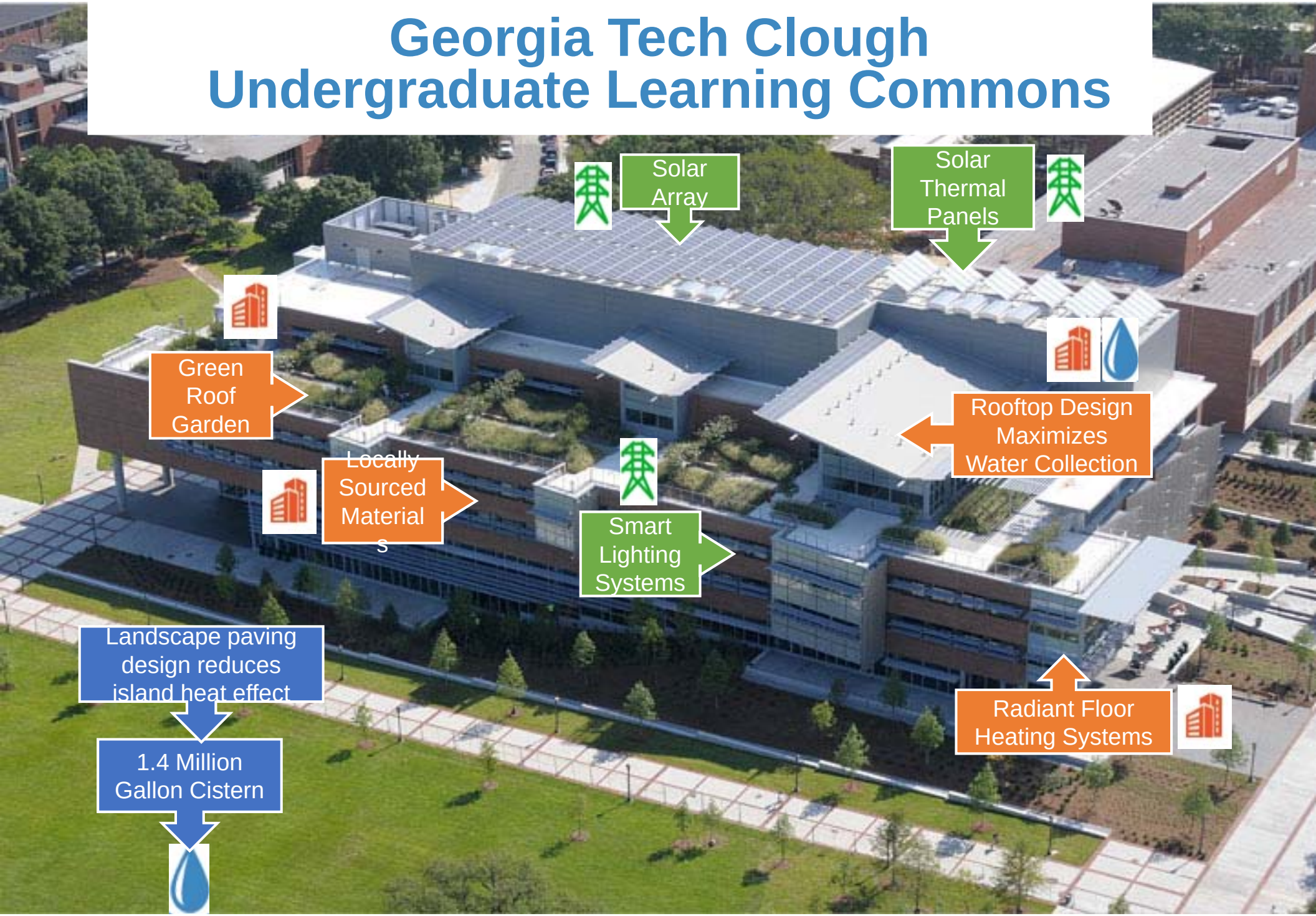
Carbon Neutral Energy Solutions Research Laboratory (CNES)

Building Section



1. 145 kW Crystalline PV Array
2. 10 kW Thin-Film PV Screen Wall
3. Monitor Skylight
4. Light Louver
5. Sola-Tubes
6. Radiant Floor Heating
7. Utility Trench
8. Catwalk
9. Mid-bay Supply Air Shaft / Office UFAD
10. High-bay Supply Air
11. Operable Door
12. Translucent Skin
13. Office Glass Wall

Georgia Tech Clough Undergraduate Learning Commons



Sustainability at Clough Commons

Water Efficiency

Water harvested from a 1.4 million gallon cistern, one of the largest in the U.S., is reused for toilet flushing and water efficient landscaping.

Innovation in Design

An interactive sustainability dashboard displays water and energy usage in real time.

Materials and Resources

Construction materials were transported from a 500-mile radius to minimize fossil fuel consumption. Additionally materials were managed sustainably through on-site recycling, which diverted 75% of construction by-products from a landfill.

Sustainable Sites

The building is oriented to maximize the control of daylight. Open green space is maximized with Tech Green. The green roof minimizes and filters stormwater runoff, as well as reduces the “heat island effect.” A changing room and bike storage are available to staff to reduce automobile usage.

Energy and Atmosphere

Rooftop solar panels provide on-site renewable energy. The mechanical system uses refrigerants with low ozone depleting potential and low global warming potential. A combination of smart lighting techniques is used, including daylight harvesting and motion sensors.

Indoor Environmental Quality

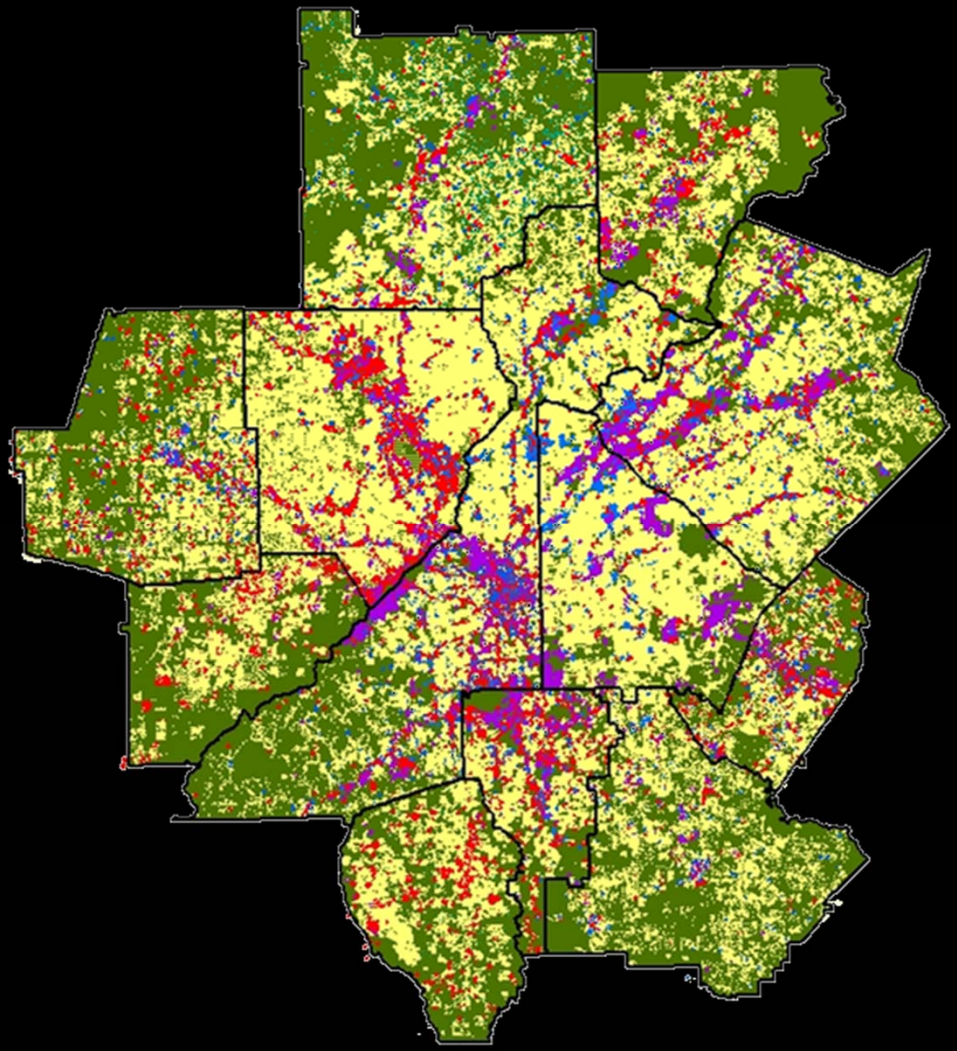
A healthy indoor environment is created through dynamic Carbon Dioxide monitoring and the delivery of outdoor air. Low-emitting materials minimize harmful volatile organic compound exposure from adhesives, sealants, carpets, paints and coatings.

- Green roof garden
- Landscape paving design reduces island heat effect
- Smart lighting systems
- 1.4 million gallon cistern
- 89% projected water reuse
- Interactive sustainability dashboard
- Solar array
- Radiant floor heating systems
- Fully enhanced measurement and verification program
- Locally sourced materials
- Day-lit spaces
- 39 species of native plants used for landscaping
- Rooftop design maximizes water collection
- 360 photovoltaic panels produced by Suniva
- 30 solar thermal panels

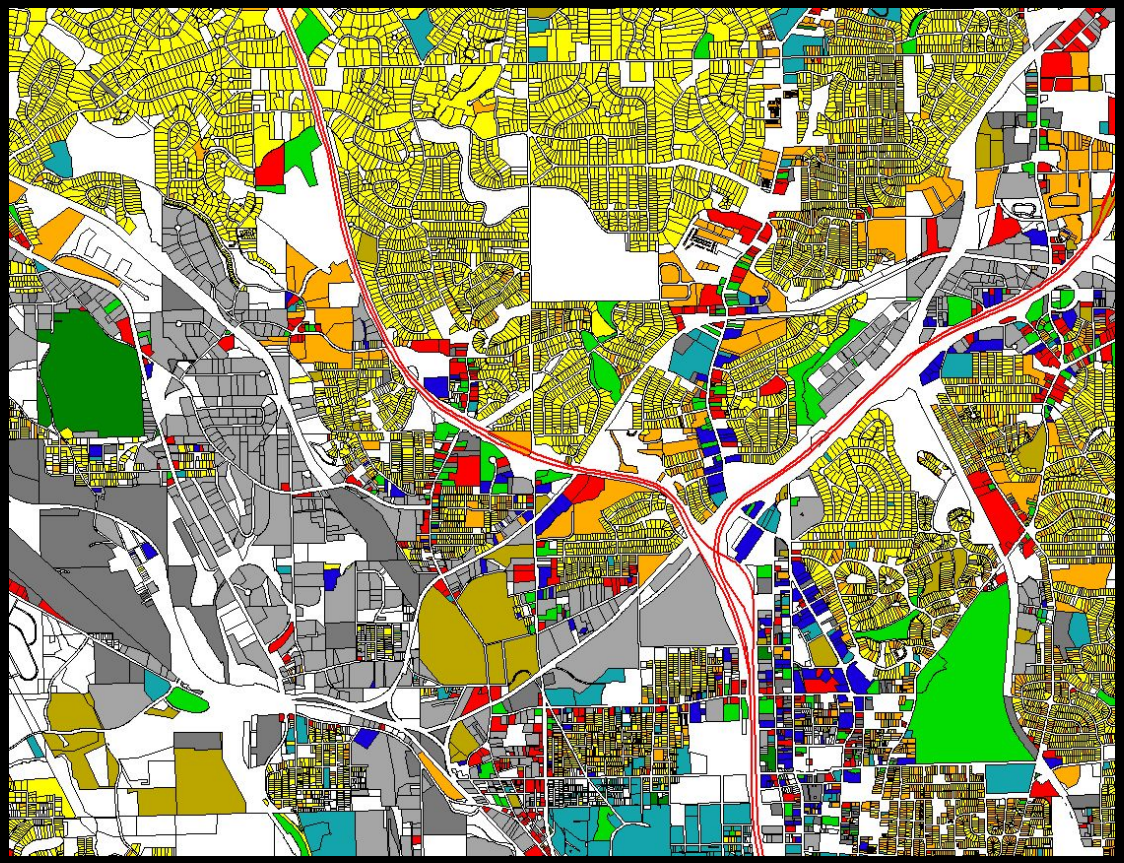
Large Scale Projects

Spatial Databases for Urban Modeling - 1

- The SMARTRAQ project
  - Supports research on land use impact on transportation and air quality
  - 1.3 million parcels in the 13 metropolitan Atlanta non-attainment counties



SMARTRAQ DATA AND ATTRIBUTES

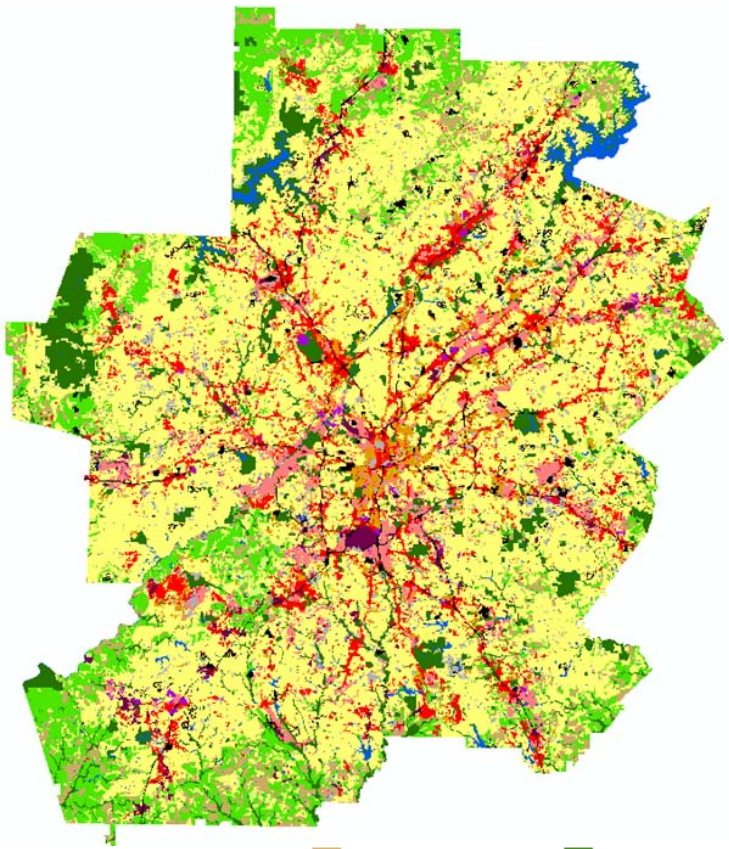


- Land Use Type
- Number of Units
- X,Y Coordinate
- Estimated Sq Feet
- Total Sq Feet

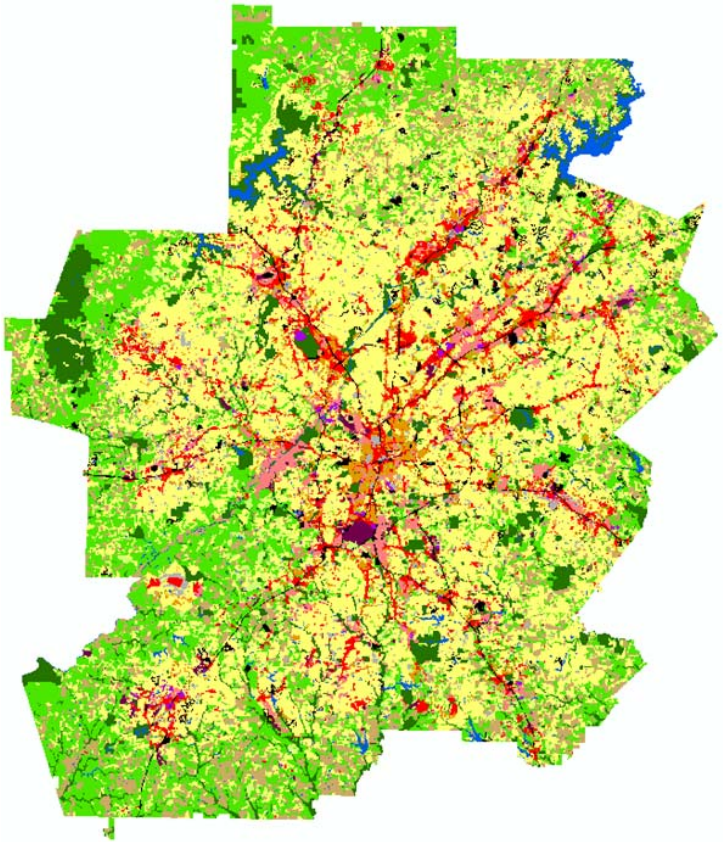
- Address
- Road Type
- City
- Zip Code
- Owner Occupied
- Commercial/Residential
- Zoning
- Sale Price
- Sale Date
- Tax Value
- Assessed Value
- Improvement Value
- Land Value
- Year Built
- No. of Stories
- Bedrooms
- Parking
- Acreage

Projected Growth Scenarios for Atlanta

Business As Usual Year 2030

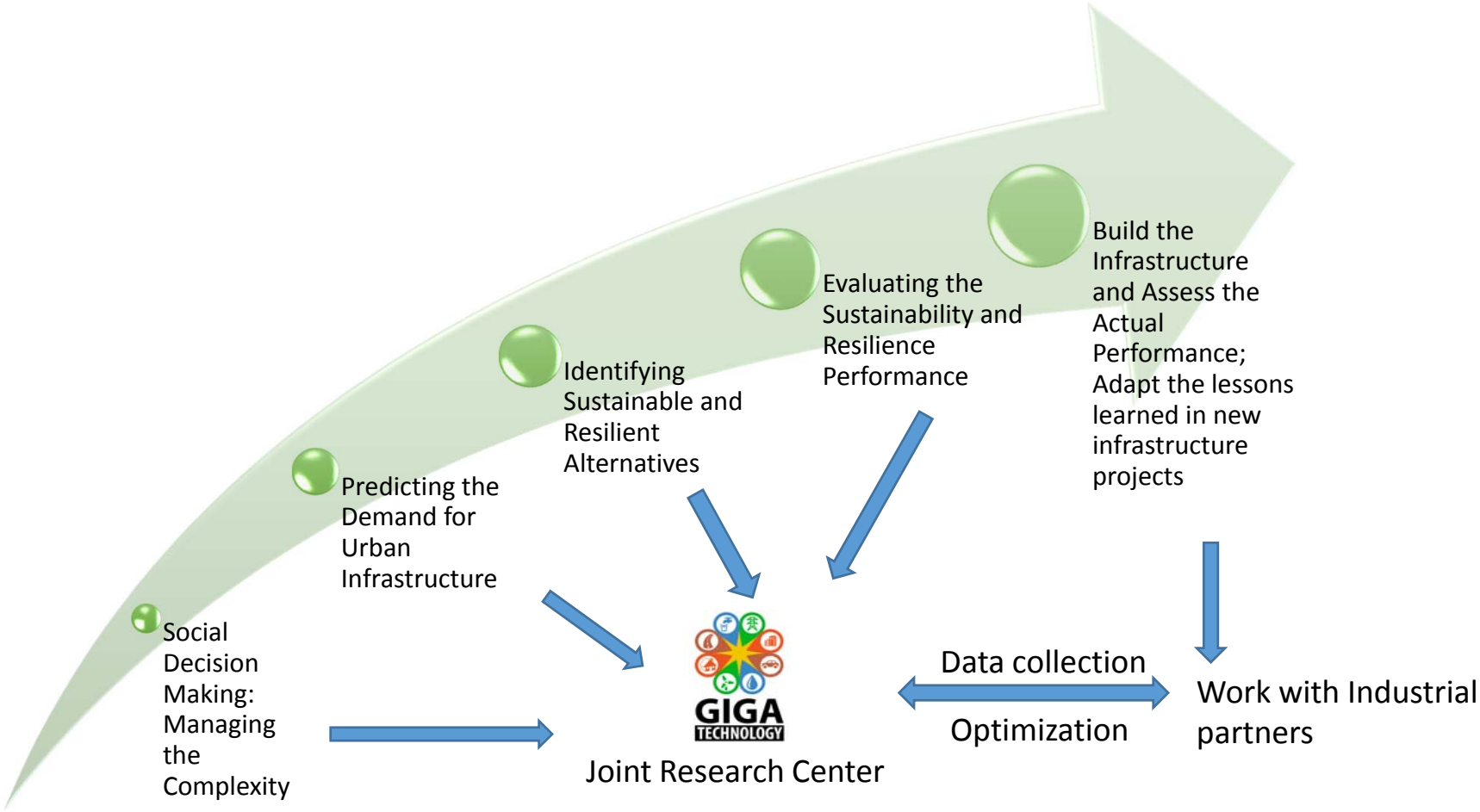


More Compact Development Year 2030

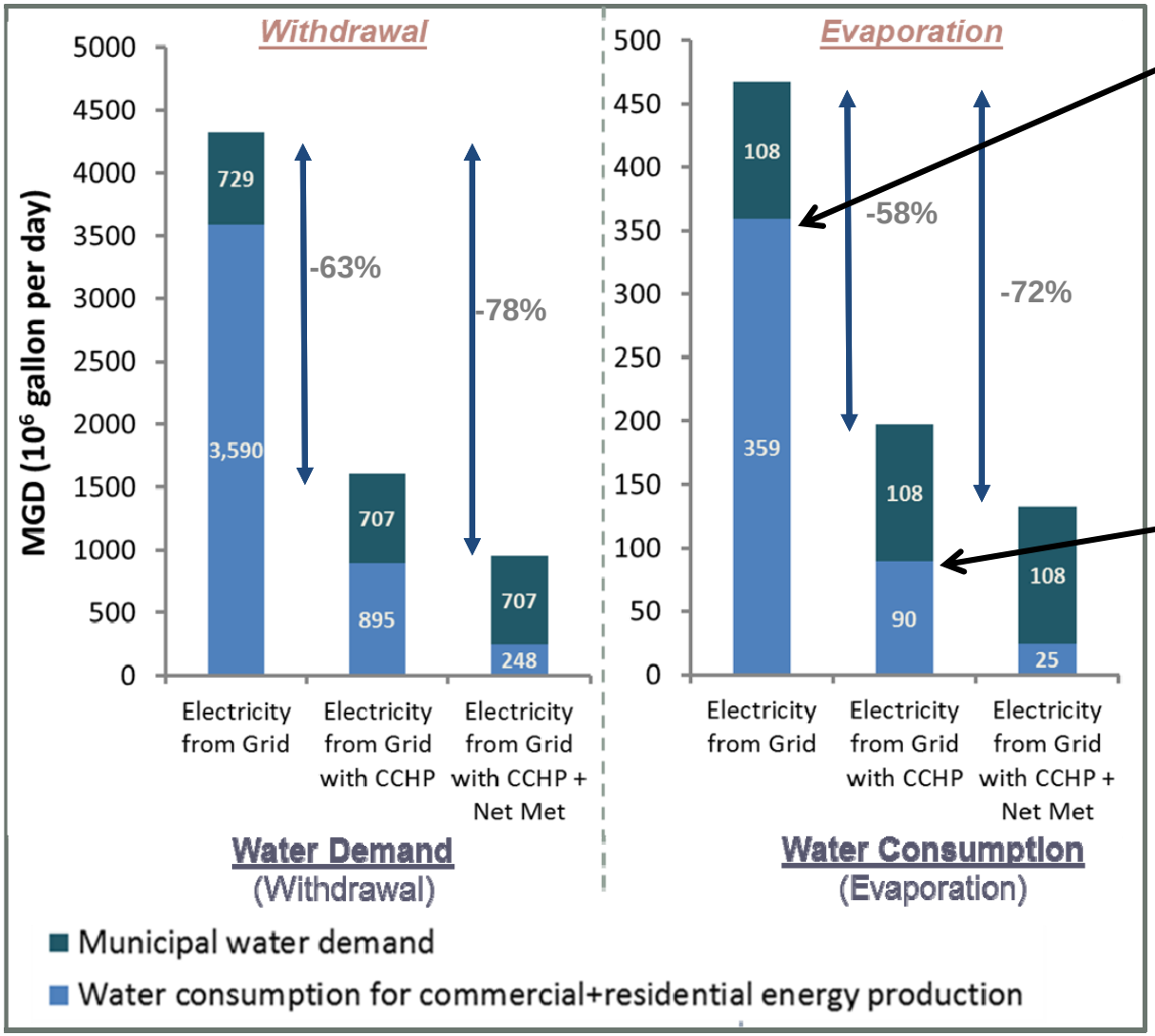


Agriculture
Com_Office
Com_WholeS_Const
Conservation
Forest
HighMulti Res
Industrial
LowMed Res
Open Water
Other Developable
Parks
Pub. Institutional
TCU
Undevelopable

Example for Decentralized Energy:
Infrastructure Ecology Roadmap to Develop Sustainable and Resilient Urban Infrastructure



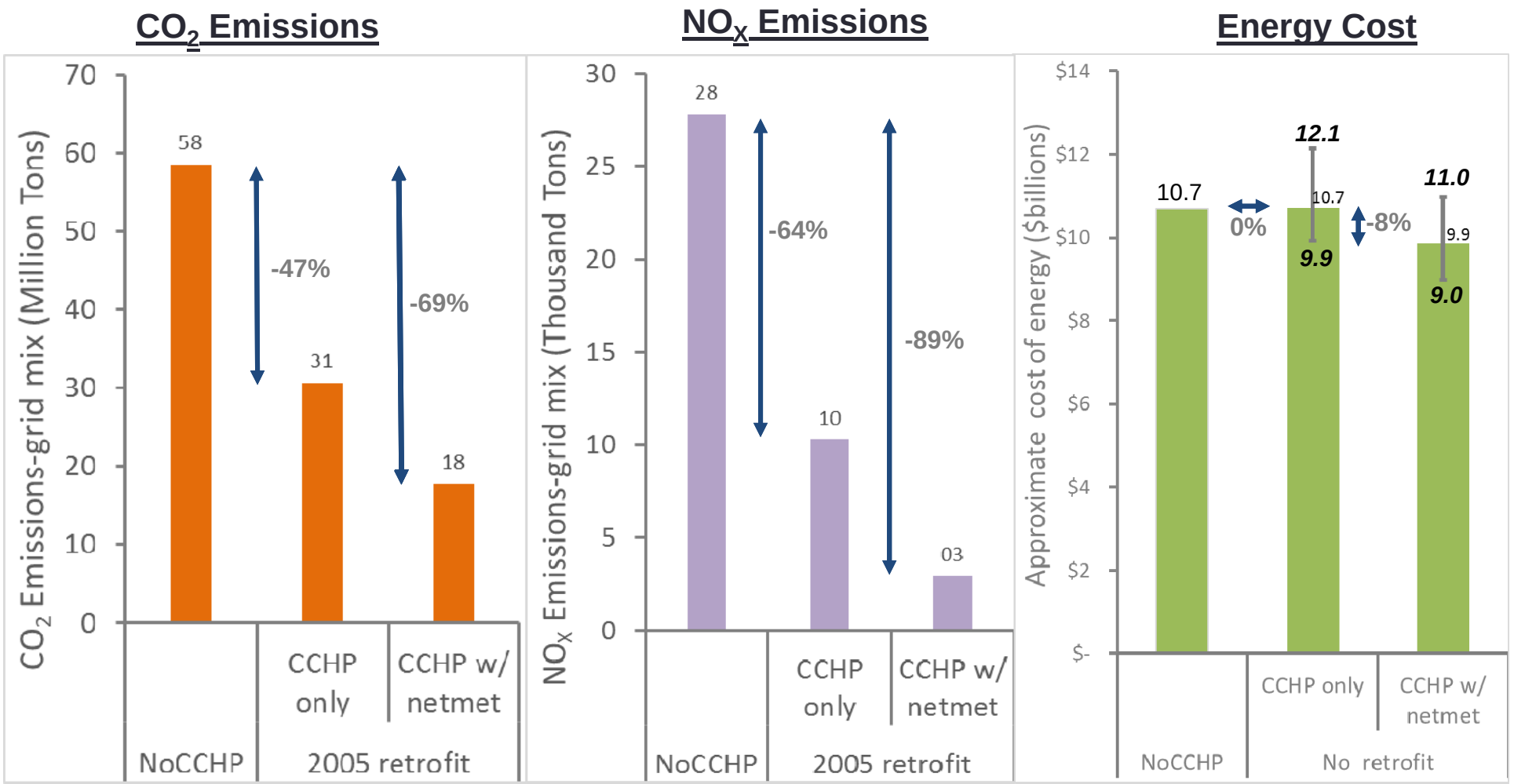
Atlanta Water Demand for New Residential and Commercial Buildings in More Compact Growth Scenario (with low flow fixtures + decentralized CCHP system)



Installation of Air Cooled Microturbines save 2.8 times the amount of water used for domestic consumption

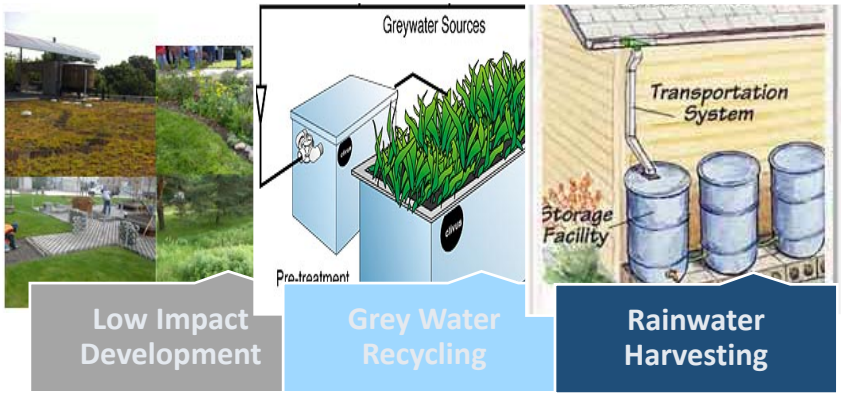
Potential GHG and Cost Reductions in 2030

By 2030, implementation of CCHP in all new and existing residential and commercial buildings could reduce CO_2 emissions by~ 0.04Gt CO_2, NOx emissions by ~ 25000 Tons ,and decrease energy costs by $600 million per year for the Metro Atlanta region.

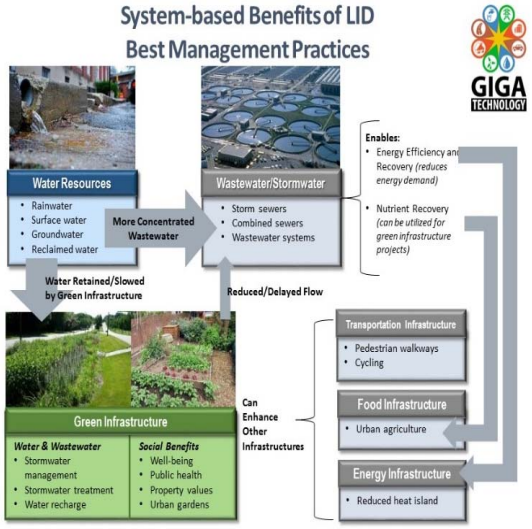


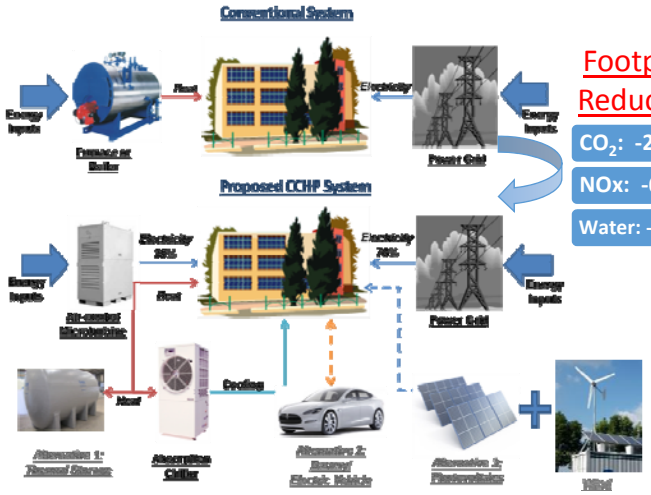
Synergistic Effects of "Infrastructure Ecology"

More than 50 Technologies



Gigatech Platform Enabled Multiple Design Optimization (MDO)





Footprint Reduction

CO_2:	-23%
NOx:	-65%
Water:	-52%

Desirable Amenities for a Given Climate, Topology and Location

The Potential Synergistic Effects

- Improve air quality and health
- Livable environment
- Reduced water and energy consumption
- Lower dependence on centralized systems
- Larger share of renewables in the electricity mix
- Reduced vehicle-miles travelled
- An increase in tax revenue
- Enhanced system resilience

Global Urban Planning| Georgia Institute of Technology

May 2017

Advance Planning Group

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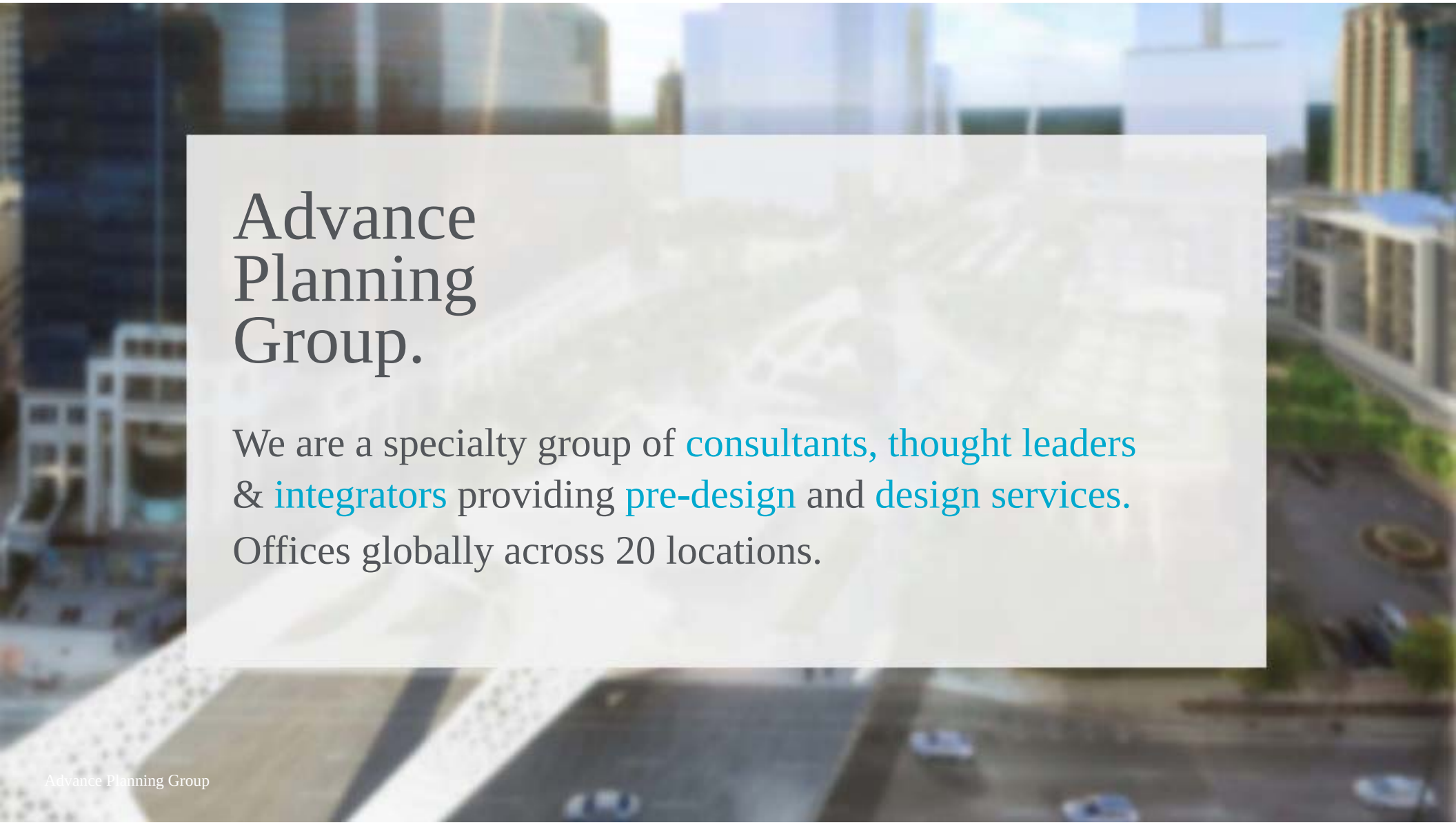

Advance Planning Group.

We are a specialty group of consultants, thought leaders & integrators providing pre-design and design services. Offices globally across 20 locations.

100+

Planners + Designers
Real Estate Strategists

Planning – Urban Design – Green Infrastructure

Advance Planning Group

JACOBS

What We Do.

Develop solutions through proven processes, integrated teams and a relationship-based approach

- Help Clients Define and Resolve Complex Problems
- Top Talent + Best Tools = Real Value
- Innovation + Teamwork + Research

JACOBS

AUSTRALIAN EDUCATION CITY

Confidential Location

Client
Confidential Client

Completion
2015 (Design)

Size
+/- 500 Hectares

Services
Master Planning
3D Visualization
Conceptual Landscape Design
Conceptual Architectural Vision

Australian Education City | Melbourne, Australia

This 500-hectare project will be home to a new university with over 30,000 international students and a vibrant walkable central business district with commercial, residential, and community support facilities. The city is envisioned to be a world-class example of sustainability. It will have a direct connection to Melbourne's extensive transit system; a network of trails, parks, and accessible open space; and aggressive targets for energy use, water recycling, and building performance.

Pole Urbain de Mazagan | El Jadida, Morocco

This new city will incorporate a population of 60,000 residents along with a corporate headquarters, a convention and exposition park, and company clubs/resorts for OCP. Additionally, the new city will become a center for innovation, business incubators and research and development, an expanded university, and new tourism-focused retail and cultural facilities. With a vision of economically and environmentally sustainable development, this new city will incorporate a mix of uses targeted to a range of incomes and a diverse population.

Andres Duany Planning Group

Pole Urbain de Mazagan | El Jadida, Morocco

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TSINGHUA FINANCE & SCI-TECH PARK

MASTER PLAN

Changchun, China

Client
Partnership between Jilin People's Government and Tsinghua University

Completion
2014 (design)

Size
53.1 hectares

Services
Conceptual Master Planning

Tsinghua Finance + Sci-Tech Park Master Plans | Changchun, China

This new innovation district will be a financial ecosystem creating a diverse, resilient cycle of environment and enterprise, culture and commerce. The Tsinghua Financial District will become one of the first cutting-edge Innovation Districts in China. Surrounding the confluence of activity will be innovative businesses and institutions transitioning to hospitality and mixed-use development. The proposed walkable urbanism intends to mitigate the project's impact on the local environment and the Yitong River watershed.

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Tsinghua Finance + Sci-Tech Park Master Plans | Changchun, China

Advance Planning Group

JACOBS

Tsinghua Finance + Sci-Tech Park Master Plans | Changchun, China

Advance Planning Group

JACOBS

JACOBS

XIAMEN SUBWAY LINE 1 TRANSIT ORIENTED DEVELOPMENT

MASTER PLANS

XIamen, China

Client
Confiden al

Comple on
Ongoing

Size
4 Sta ons, 100 Hectares Total

Services
Master Planning
Urban Design
Architecture
Landscape Architecture

Jacobs developed four Transit Sta on Designs and Urban Master Plans for the city of Xiamen in Southeast China. Created as part of a design compe on for select firms, the four sta on areas are situated in urban areas of the city as well as along exis ng waterfronts. The combined land area for all four sta on areas is 100 hectares.

Land use strategies include both mixed densi es and mixed types, while invi ng diversity in future residents in terms of age and financial capabili es. Service retail, specialty retail, and a variety of des na on restaurants not only serve

Xiamen Transit-Oriented Development| Xiamen, China

Jacobs developed four Transit Station Designs and Urban Master Plans for the city of Xiamen in Southeast China. Land use strategies include both mixed densities and mixed types, while inviting diversity in future residents in terms of age and financial capabilities. Service retail, specialty retail, and a variety of designation restaurants not only serve community needs but also support arriving tourists throughout each district.

Advance Planning Group

Xiamen Transit-Oriented Development| Xiamen, China

Advance Planning Group

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Xiamen Transit-Oriented Development| Xiamen, China

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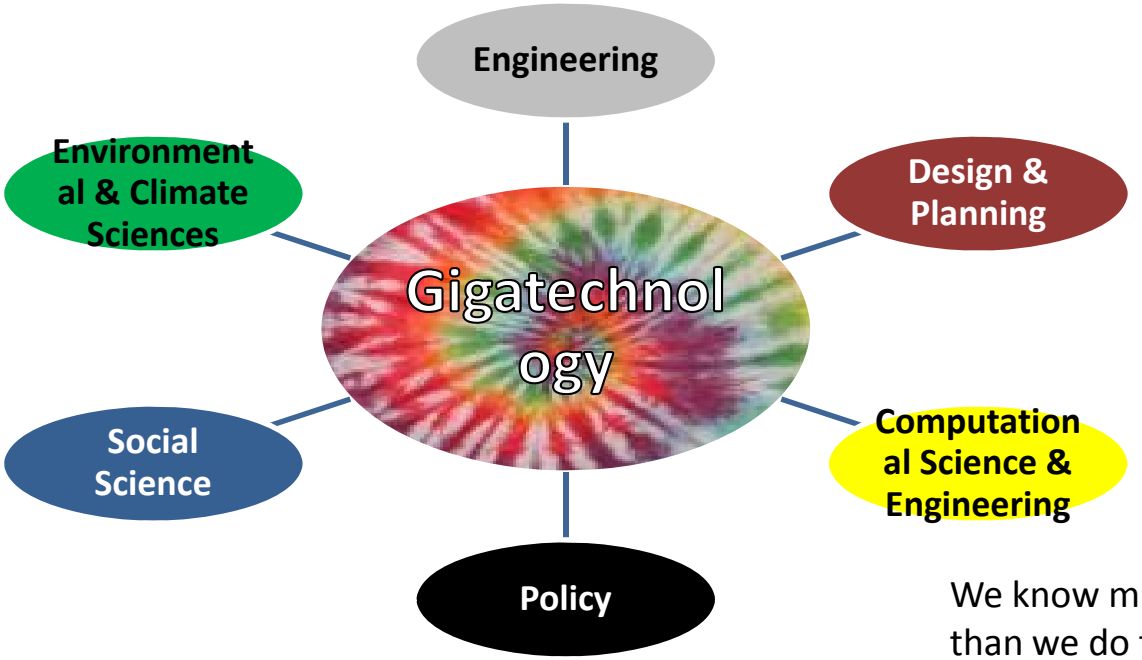
Gigatechnology

Massively Integrated Urban Infrastructure Engineering and Socioeconomic Systems

BIG SCIENCE: Gigatechnology is a newly integrative and use-inspired science committed to the study of the interconnections and interdependencies among very large systems, and the properties that emerge from these interactions.



- How can the **ecology paradigm** be used to understand urban infrastructure systems?
- What new **technologies** are needed to measure, model, and manage infrastructure systems-of-systems?
- What and how do **properties emerge** from infrastructure systems interactions with other systems?
- How can the infrastructure ecosystem be made **more sustainable, resilient, and productive**?

applications

We know much more about the very small (Nanotechnology) than we do the very large (Gigatechnology).

Research Goals

Small Scale:

- The Sustainable Campus Initiative: To treat the new Shenzhen campus master planning as the first research and practical project on sustainability.
- To give a comprehensive and innovative systems-based approach to creating technological, management solutions for net zero carbon, water and waste campus.

Community Scale

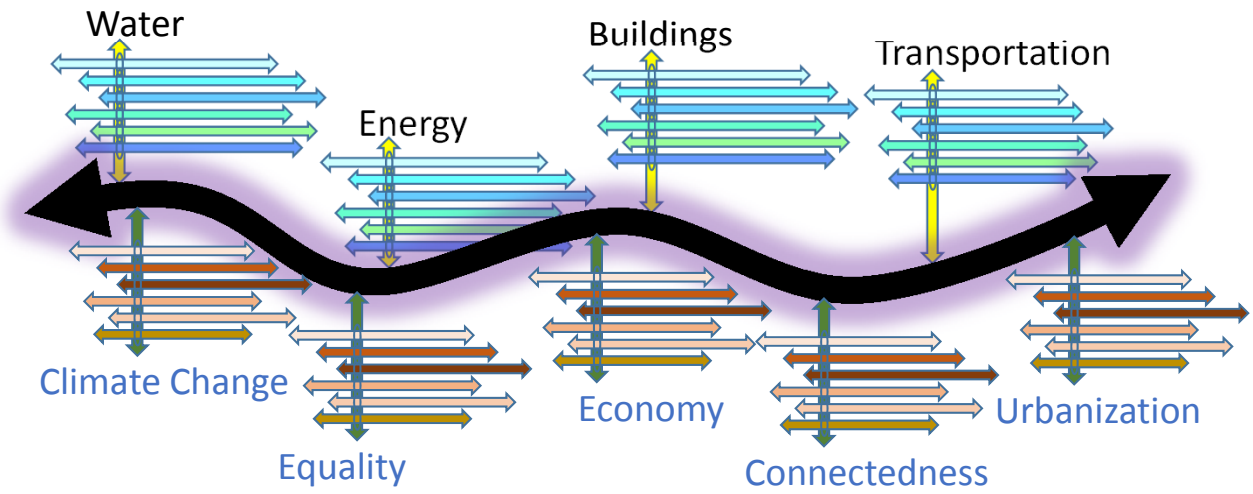
- To uncover the interconnections and interdependencies among civil infrastructure systems and their interactions with social, financial, and natural systems
- To work with industry and government to create the cyber-infrastructure necessary to design, simulate, test, monitor, control, and protect massive, open, and complex infrastructure systems
- To develop and test the laws, rules, standards, and best practices for designing, building, operating, and decommissioning sustainable and resilient infrastructure across its total life cycle
- To develop the pedagogy of engineering massive, open, and complex infrastructure systems
- To recruit and train the first generation of gigatechnologists that is as diverse as the communities in which they reside.

By 2025

1) **Develop a Platform that Can Calculate the Sustainability Performance of Integrated Infrastructure**
2) **Work with Our Strategic Partners to Verify the Approach**

BEST

But there are also other infrastructure value chains to consider too, each with horizontal and vertical integrating opportunities,…

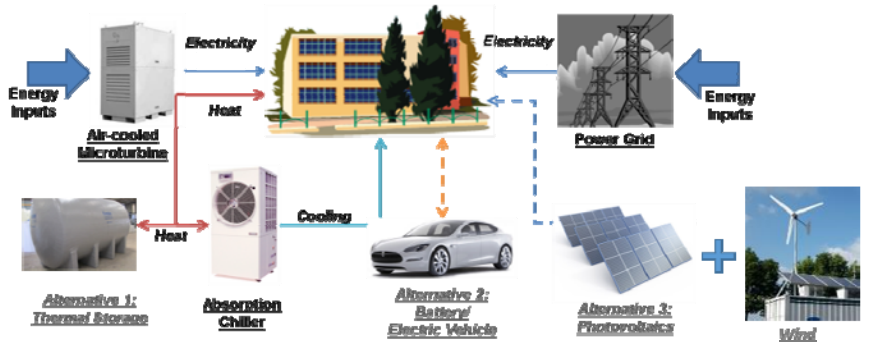
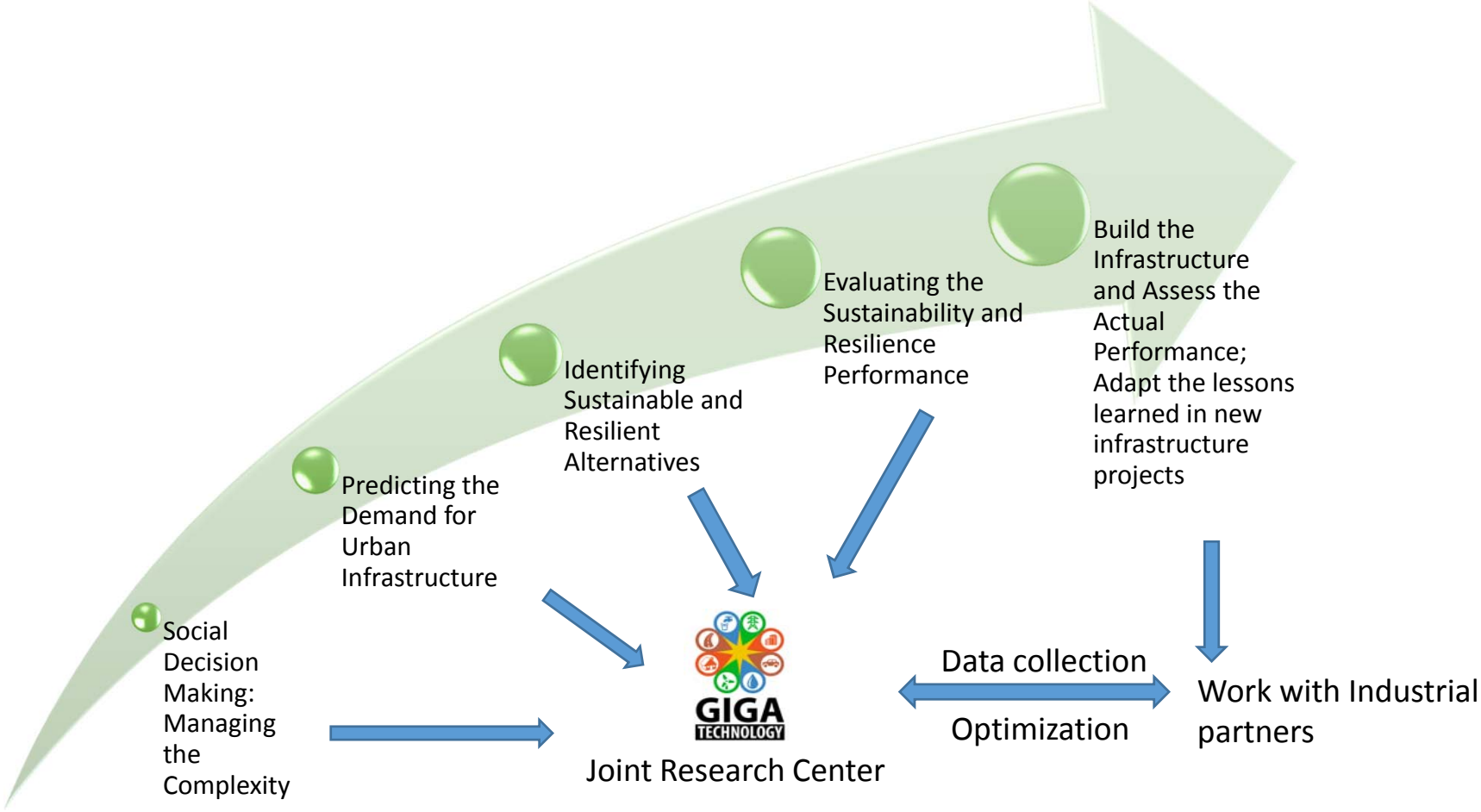


…and all are buffeted by and contributing to internal and external forces acting at micro, macro, and global scales.

Rather than trying to reduce complexity and isolate these systems, massive integration values the connections that do (or could) exist and leverages them for substantial benefit.

Example of Massive Integration

Decentralized microturbines producing heat for district heating & cooling, distributed through a thermal grid and stored in various thermal storage technologies, and electricity, connected to the grid and to batteries (both stationary and in vehicles), the total system of which is managed to improve the system's ability to meet variable heat & power demands and to manage intermittent solar and wind generation.



Infrastructure Ecology Roadmap to Develop Sustainable and Resilient Urban Infrastructure