The Research Center for Green Buildings and Sponge Cities

Gigatech: The largest infrastructures in which humans manipulate matter and energy.
China Used More Cement in Three Years than the US did in a Century

Both are Gigatech: $\sim 10^{14}$ 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.
<table>
<thead>
<tr>
<th>Cities: Transport, Building, Water, Energy, and ICT</th>
<th>Infrastructure</th>
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<tbody>
<tr>
<td>• 75% global greenhouse gas emissions</td>
<td>• Infrastructure requires $90 trillion investment by 2030 (UNEP)</td>
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<td>• Consume 75% of natural resource</td>
<td>• Infrastructure lasts more than 50 years and 80-90% of its impact occurs in use phase</td>
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<td>• 54% global population; 82% US Population</td>
<td>• Global infrastructure needs to double in the next 35 years and it took 5500 years to get to this point</td>
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<td>• 78% global energy use</td>
<td>• US infrastructure will increase 40% by 2030</td>
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<td>• 80% global GDP</td>
<td>• US housing market is valued at approximately 27 trillion dollars</td>
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<tr>
<td>• Worldwide, Surface transport is worth $10 trillion per year</td>
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**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.
Tianjin University
- The first modern higher education institution in China
- One of the first batch of universities under “985” Project

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

The Research Center for Green Buildings and Sponge Cities
- Strong research and educational team
- Strong financial and industrial support
- Sustainable Infrastructure

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

Santiago Grijalva
Power Systems & Controls

Iris Tien
Resilient Infrastructure

Urban Planning and Design

Steve 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

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

Richard Fujimoto
High Performance Computing

Haesun Park
Large Scale Data Analytics

Ashok Goel
Artificial Intelligence

Bistra Dilkina
Computational Sustainability
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. 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 air pollution control

Prof. Liu Qingling
Assoc. Prof. Song Chunfeng
Dr. Sheng Ying
Assoc. Prof. DING Hui
Assoc. Prof. LIU Hong

Urban big data and MIS

Assoc. Prof. Ma Guozhu
Dr. Qiao Zhi
Dr. Tong Yindong

Urban sea environment and resource use

Prof. Wang Guangyi
Assoc. Prof. Liu Xianhui
Dr. Yang Yongkui
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?

Why We See This?

**ATLANTA**

- Urban area: 7,692 km²
- Population: 5.3 million
- Transport carbon emissions p.c: 6.9 tonnes

**BARCELONA**

- Urban area: 648 km²
- Population: 5 million
- Transport carbon emissions p.c: 1.16 tonnes

*Source: LSE Cities 2014*
Engineered Urban Infrastructures

Amenities

Disamenities

Community

Buildings

Energy

Water

Transportation

Waste

Quality of Life

Economy

Smog

Flooding

Global Warming

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

City Government Structure:
- Citizens
- Mayor & Commission
- City Manager
- City Attorney
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.)
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

1. Social Decision Making: Managing the Complexity
2. Predicting the Demand for Urban Infrastructure
3. Identifying Sustainable and Resilient Alternatives
4. Evaluating the Sustainability and Resilience Performance
5. Build the Infrastructure and Assess the Actual Performance; Adapt the lessons learned in new infrastructure projects

Joint Research Center

Data collection

Optimization

Work with Industrial partners
Small Scale Projects
Carbon Neutral Energy Solutions Research Laboratory (CNES)

First LEED Platinum certified building on campus
Georgia Tech Clough Undergraduate Learning Commons

- 1.4 Million Gallon Cistern
- Solar Array
- Solar Thermal Panels
- Rooftop Design Maximizes Water Collection
- Locally Sourced Materials
- Smart Lighting Systems
- Radiant Floor Heating Systems
- Green Roof Garden
- Landscape paving design reduces island heat effect
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.
Large Scale Projects
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

- 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

- Land Use Type
- Number of Units
- X,Y Coordinate
- Estimated Sq Feet
- Total Sq Feet
Projected Growth Scenarios for Atlanta

Business As Usual
Year 2030

More Compact Development
Year 2030
Example for Decentralized Energy: Infrastructure Ecology Roadmap to Develop Sustainable and Resilient Urban Infrastructure

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- Evaluating the Sustainability and Resilience Performance
- Data collection Optimization
- Work with Industrial partners

Joint Research Center
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.
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

Grey Water Recycling

Rainwater Harvesting

Gigatech Platform Enabled Multiple Design Optimization (MDO)

System-based Benefits of LID Best Management Practices

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

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 on-street 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.
Xiamen Transit-Oriented Development | Xiamen, China

Advance Planning Group
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?

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

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

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.

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.

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