Carnegie Mellon University

A Smart Cities Partnership: Pittsburgh & CMU

ACEEE Intelligent Efficiency Conference

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Wilton E. Scott Institute for Energy Innovation

December 6, 2016

Carnegie Mellon University

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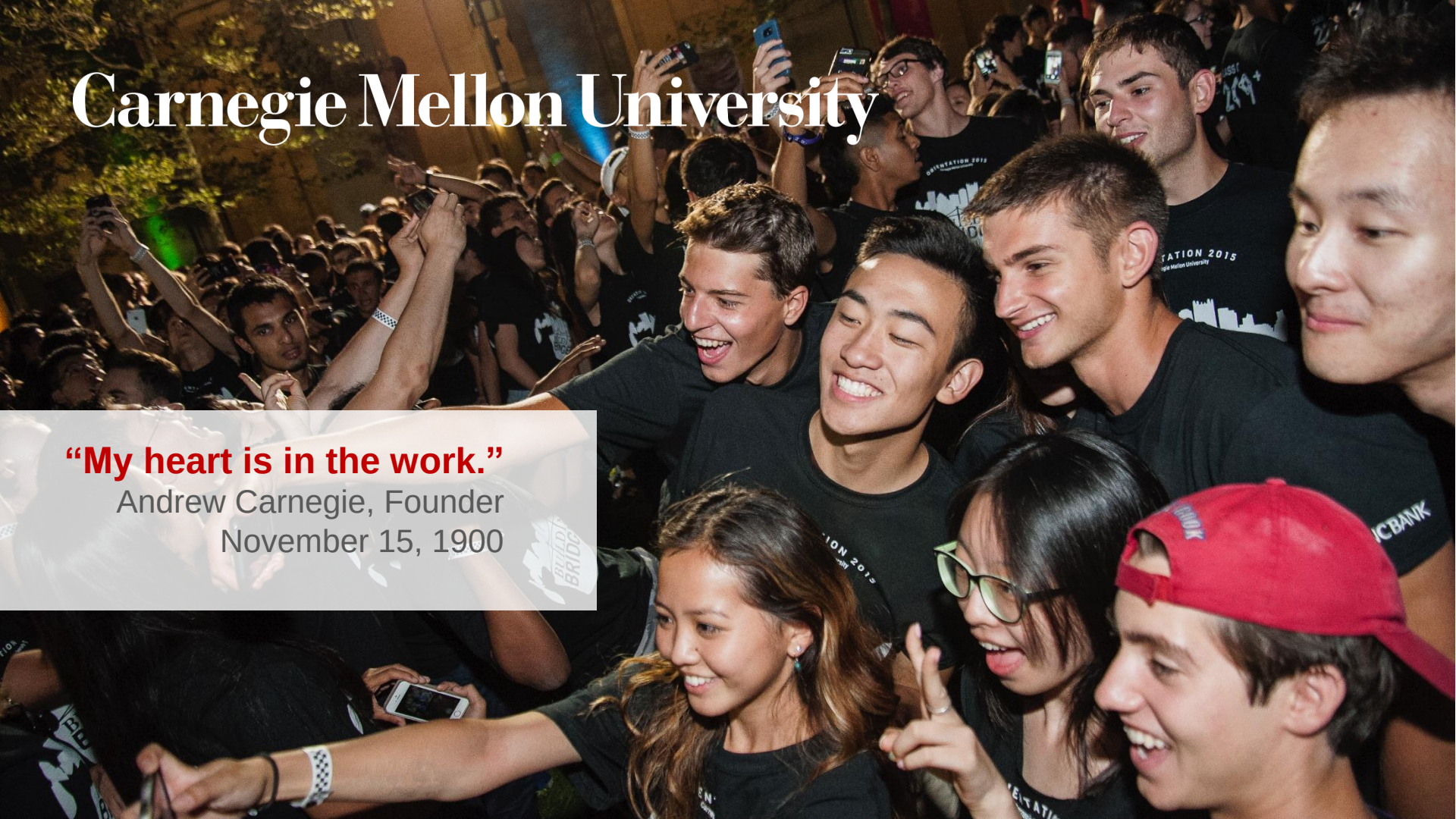
Carnegie Mellon University



“My heart is in the work.”

Andrew Carnegie, Founder

November 15, 1900

Carnegie Mellon University

The Wilton E. Scott Institute for Energy Innovation works across the academic units and colleges of Carnegie Mellon University to uncover solutions for the world's energy challenges through collaborative research, strategic partnerships, public policy, outreach, and education.

Carnegie Mellon University

Sherman & Joyce Bowie Scott Hall

- 107,000 sq ft building, opened on April 30, 2016
- Pursuing LEED Gold certification with one of the largest green roofs in Pittsburgh (19,500 sq ft)
- 14,000 sq ft world class micro/nano fabrication facility
- 8,500 sq ft Eden Hall Foundation Cleanroom is 30-40% more energy efficient than similar size Class 10/100 facilities
- EMI-shielded rooms allow the new Elionix electron beam lithography system to push the fundamental limits of nanoscale lithography
- 19 state-of-the-art wet chemistry decks with vastly improved Nanofab processing capability
- Only university lab worldwide with both iLab and oLab GVD Corporation chemical vapor deposition systems for polymers

Strategic Priorities for the Institute

- New Materials
- Smart Grid
- Building Efficiency
- Pathways to a Low-Carbon Future
  - Benefit and cost analysis of southwestern Pennsylvania region
  - Carbon Intensity Index
- Commercialization and start ups

CMU's core strengths

- Optimization as a core strength
- Systems approach to problem solving and design
- Interdisciplinary collaboration
- Innovative and entrepreneurial faculty, staff and community
- Proximity to start-up epicenter

Convergence of energy across the campus

Carnegie Mellon University

Remaking Cities Institute

Metro21
Carnegie Mellon University

Carnegie Mellon University
STEINBRENNER INSTITUTE
for Environmental Education & Research

Carnegie Mellon University
Heinz College

CAPD Center for Advanced Process Decision-making

Carnegie Mellon University
College of Fine Arts

traffic21
a transportation research institute of Carnegie Mellon University

THE ROBOTICS INSTITUTE

Software Engineering Institute
Carnegie Mellon

Carnegie Mellon University
School of Computer Science

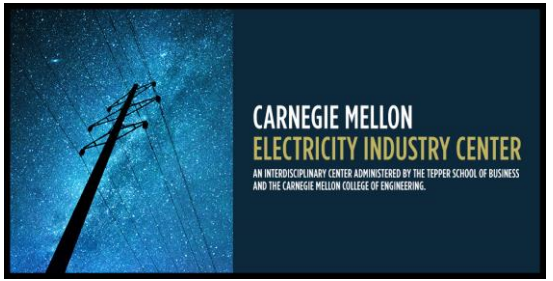
SII Smart Infrastructure Institute

CERCA
Center for Engineering and Resilience for Climate Adaptation

Carnegie Mellon University
Dietrich College of Humanities and Social Sciences

Carnegie Mellon University
Institute for Complex Engineered Systems

NREC
National Robotics Engineering Center



Electrical & Computer ENGINEERING

Technologies for Safe and Efficient Transportation
A U.S. DOT UNIVERSITY TRANSPORTATION CENTER
Carnegie Mellon University
University of Pennsylvania

Carnegie Mellon University
College of Engineering

Pittsburgh has become **a hub for innovation** with intelligent planning, strong partnerships, and innovative thought leaders.

Universities play a growing and central role in the **smart cities innovation ecosystem**, driving regional and national economic growth.

University profile

Students	13,285
Faculty	1,391
Research Centers	126
Schools & Colleges	7

Campuses:
Pittsburgh
Silicon Valley
Qatar

Degree-granting programs:
Africa, Asia, Australia, and Europe

Alumni:
100,000+ in nearly 130 countries

University Profile

SCHOOLS AND COLLEGES

College of Engineering

College of Fine Arts

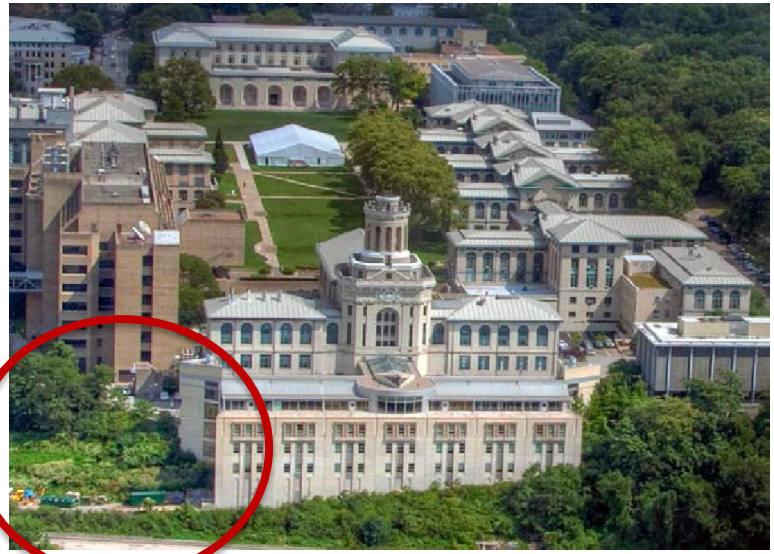
Dietrich College of Humanities and Social Sciences

H. John Heinz III College: Information Systems, Public Policy and Management

Mellon College of Science

School of Computer Science

Tepper School of Business



#1 SCHOOL OF COMPUTER SCIENCE

U.S. News & World Report, 2014

#1 VISUAL COMMUNICATION & MULTIMEDIA

U.S. News & World Report, 2012

#1 INFORMATION & TECHNOLOGY MANAGEMENT

U.S. News & World Report, 2012

#1 STARTUPS PER RESEARCH DOLLAR[1]

Association of University Technology Managers, 2008-12

#2 SCHOOL OF DRAMA

The Hollywood Reporter, 2015

#4 COLLEGE OF ENGINEERING

U.S. News & World Report, 2016

#10 BEST FOR NEW HIRES[2]

Wall Street Journal, 2010

#17 AMONG U.S. UNIVERSITIES

Times Higher Education of London, 2014-15

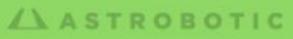
#10 FULL-TIME MBA PROGRAM

Bloomberg Businessweek, 2014

1 CMU ranked first among the Association of American Universities schools.

2 The Wall Street Journal's poll asked recruiters what schools are tops when looking for new hires. CMU ranked in the following categories: Computer Science #1, Finance #4, Business #7 and #10 overall.

Innovation Ecosystem



38 STARTUPS
FROM CMU
LAST YEAR

>$500M
IN FOLLOW-UP
FUNDING

LAST FIVE YEARS

Areas of focus

Brain and Neuroscience

Cybersecurity and Privacy

Advanced Manufacturing

Autonomous Vehicles & Robotics

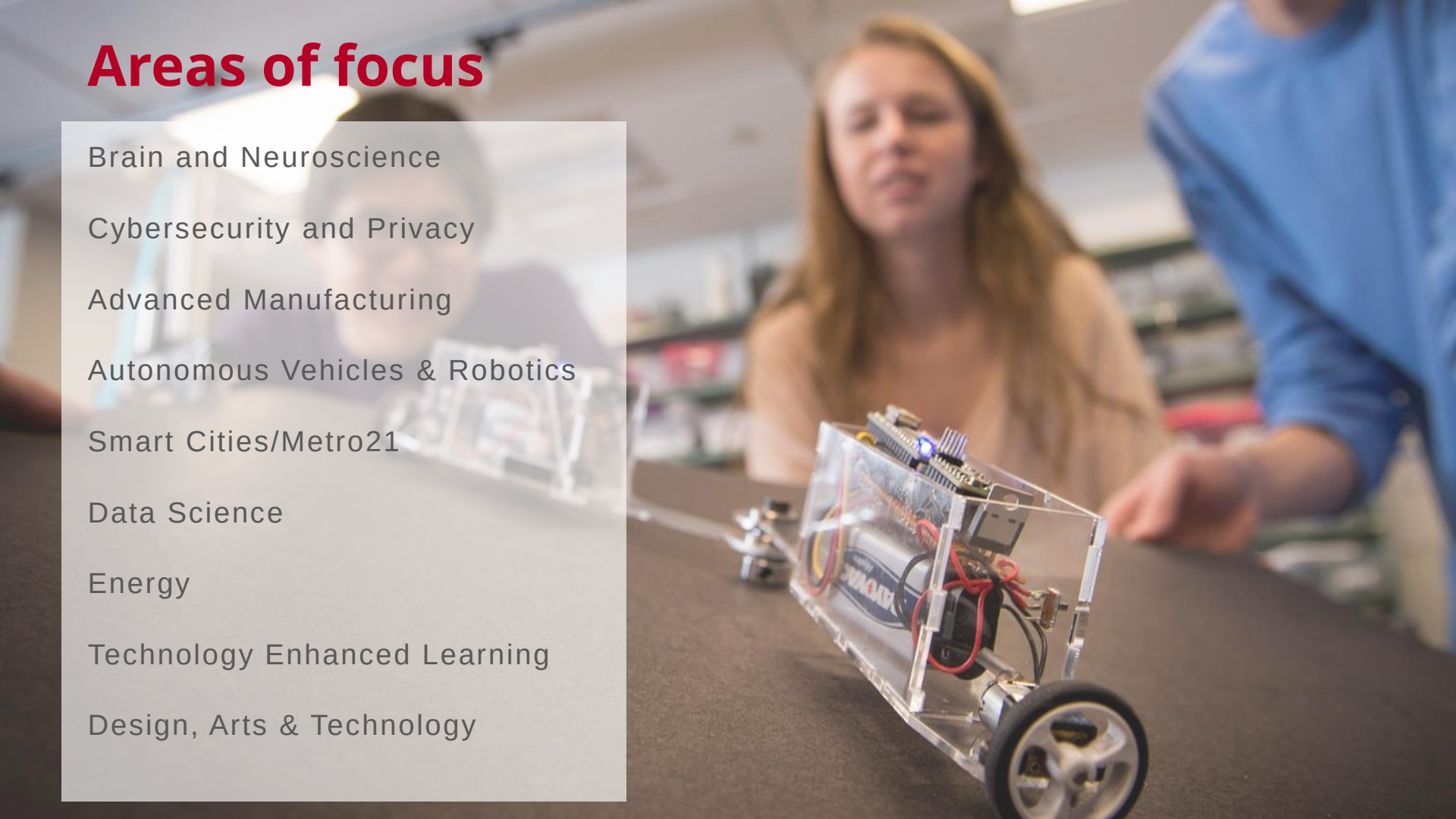
Smart Cities/Metro21

Data Science

Energy

Technology Enhanced Learning

Design, Arts & Technology



Industry Partnerships

More than 350 of the world's most innovative companies have partnered with CMU.

The Age of Urbanization

- In 2008, for the first time in history, more human beings lived in cities than in rural areas. By 2050, nearly 2/3 of the world's projected 9.7B population will live in urban areas.
- Over the last decade, the global urban population has been rising by an average of 65M per year, equivalent to adding seven Chicago every year.
- In China alone, 300M people are expected to move to urban areas over the next 15 years.
- Half of global GDP growth between 2010 and 2025 will come from 440 cities in emerging market; 50% of urbanization involves cities with less than 500K population.
- Cities tend to display greater network effects: with every doubling of a city's population, each inhabitant becomes 15% wealthier, more productive and more innovative.
- Growth of innovation districts, mixed-use spaces, and urban talent pool

In this century, cities will account for

90% of population growth

80% of global CO2

75% of energy use

Environmental impact

Rising levels of pollution

Increased congestion

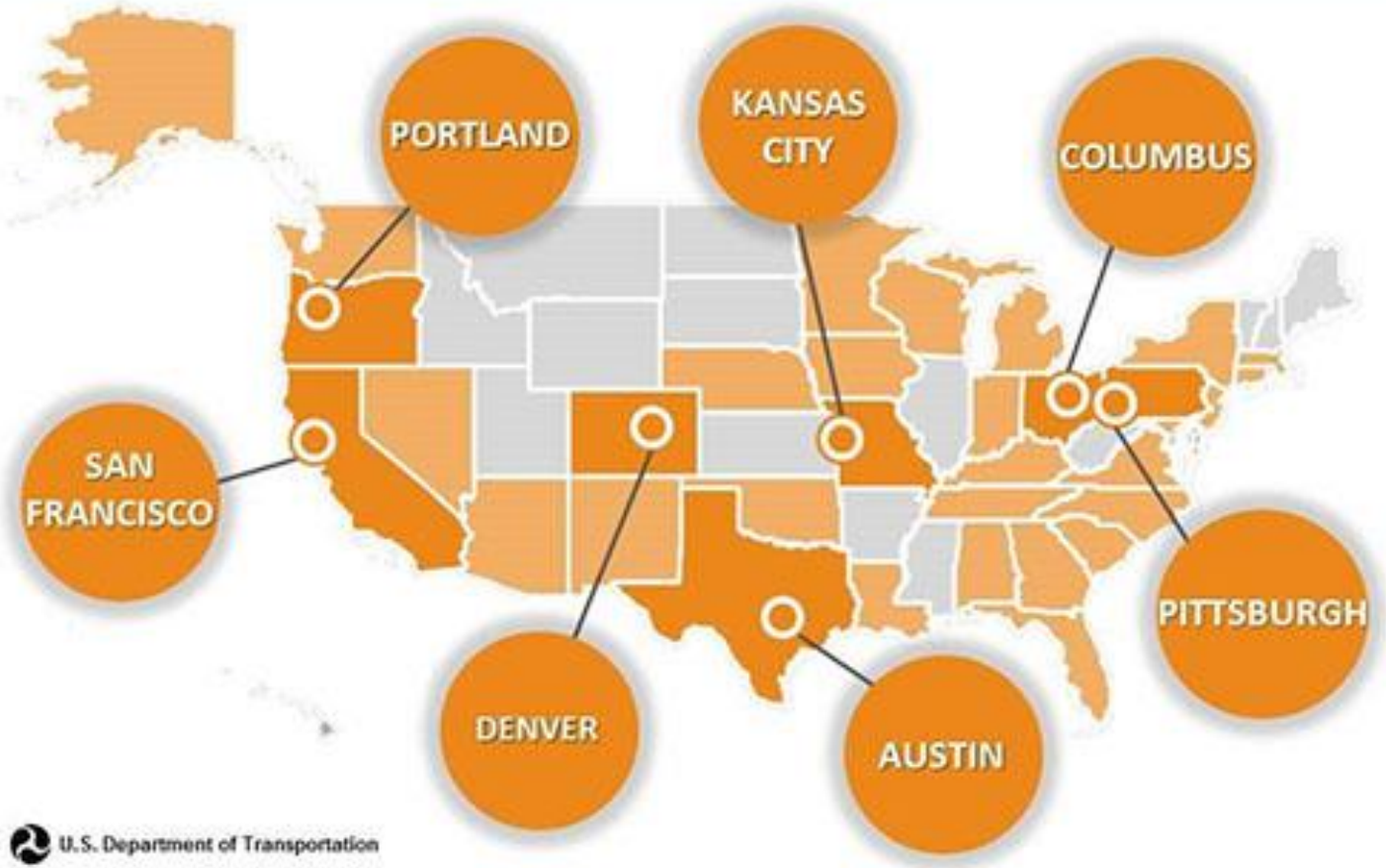
Sustainability of natural resources

Increased crime rates

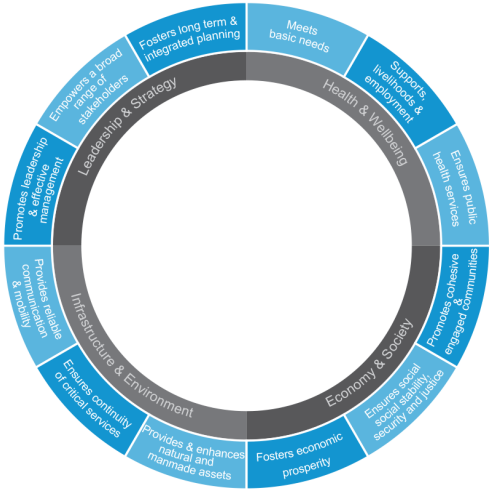
Efficient delivery of city services

Massive infrastructure investment requirements ($10Trillion by 2025)

Smart City Challenge Finalists

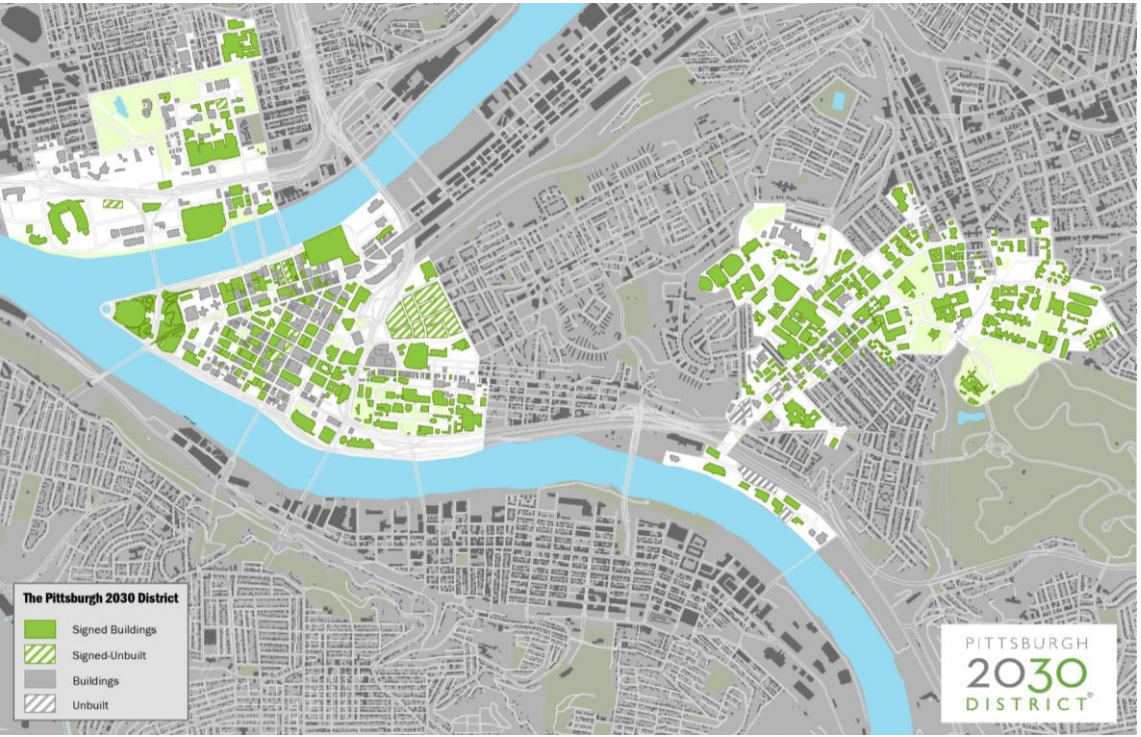


Rockefeller Foundation – 100 Resilient Cities



- AGING INFRASTRUCTURE
- FLOODING
- INFRASTRUCTURE
- POLLUTION

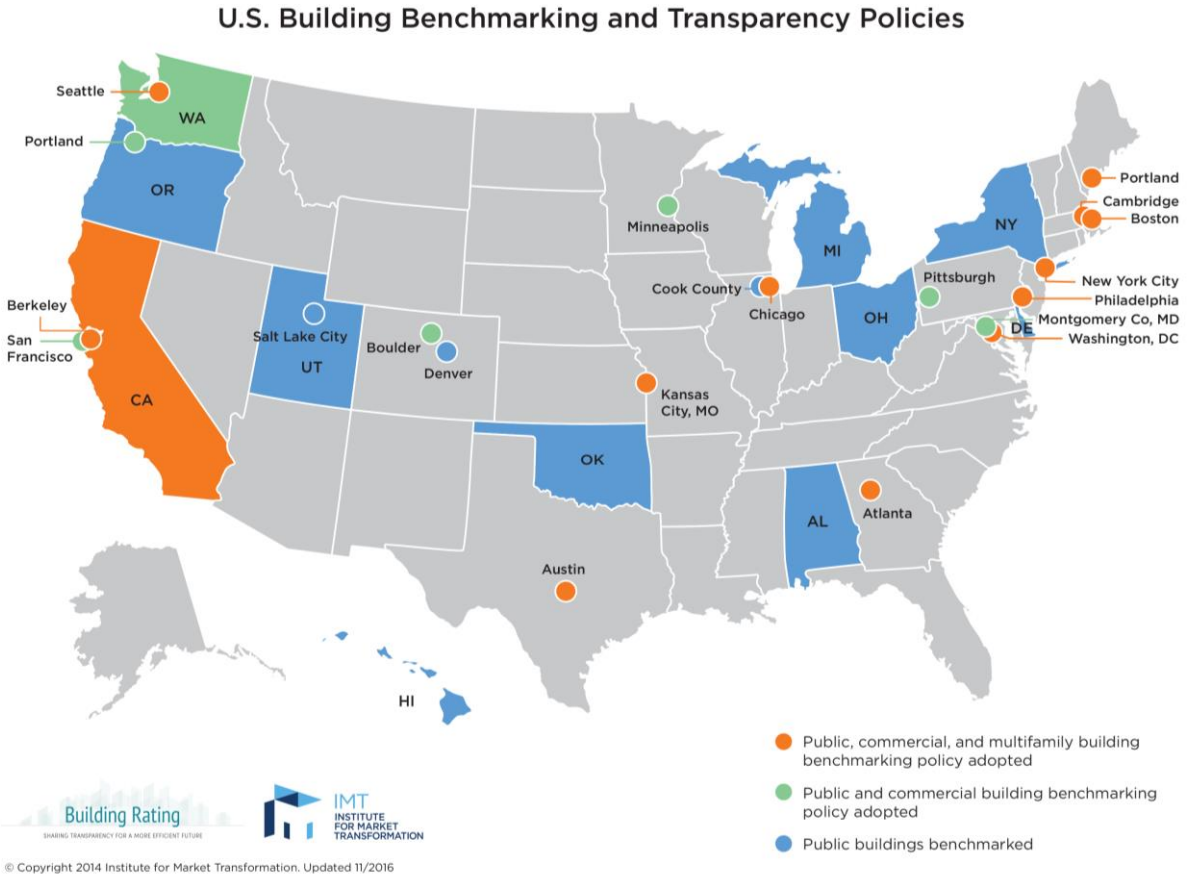
Pittsburgh 2030 District – 482 bldgs, 76.4m sq ft



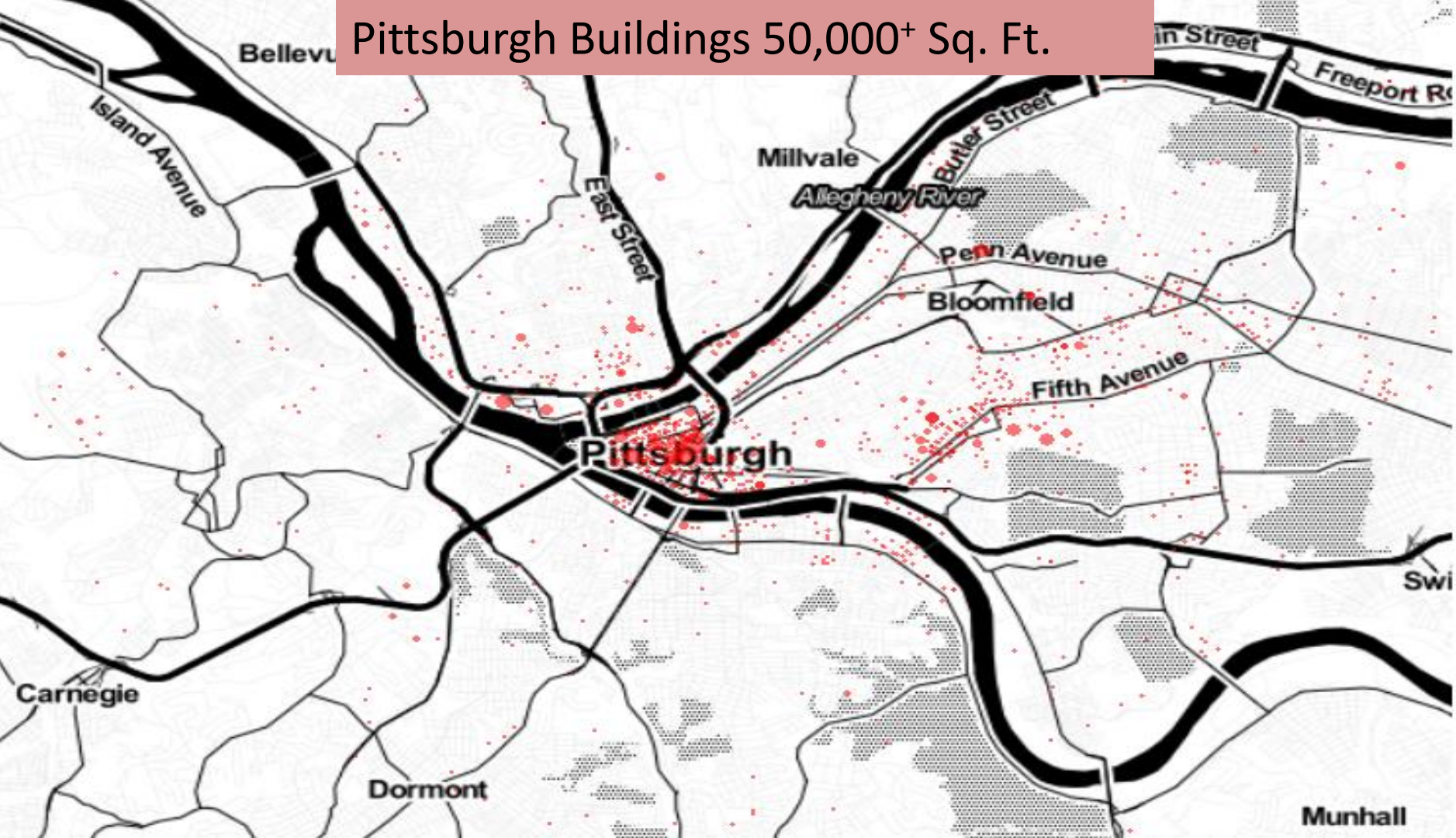
Building Benchmarking Legislation

17 cities and **1** county
have passed benchmarking
and transparency laws

7 cities
have passed
audit laws

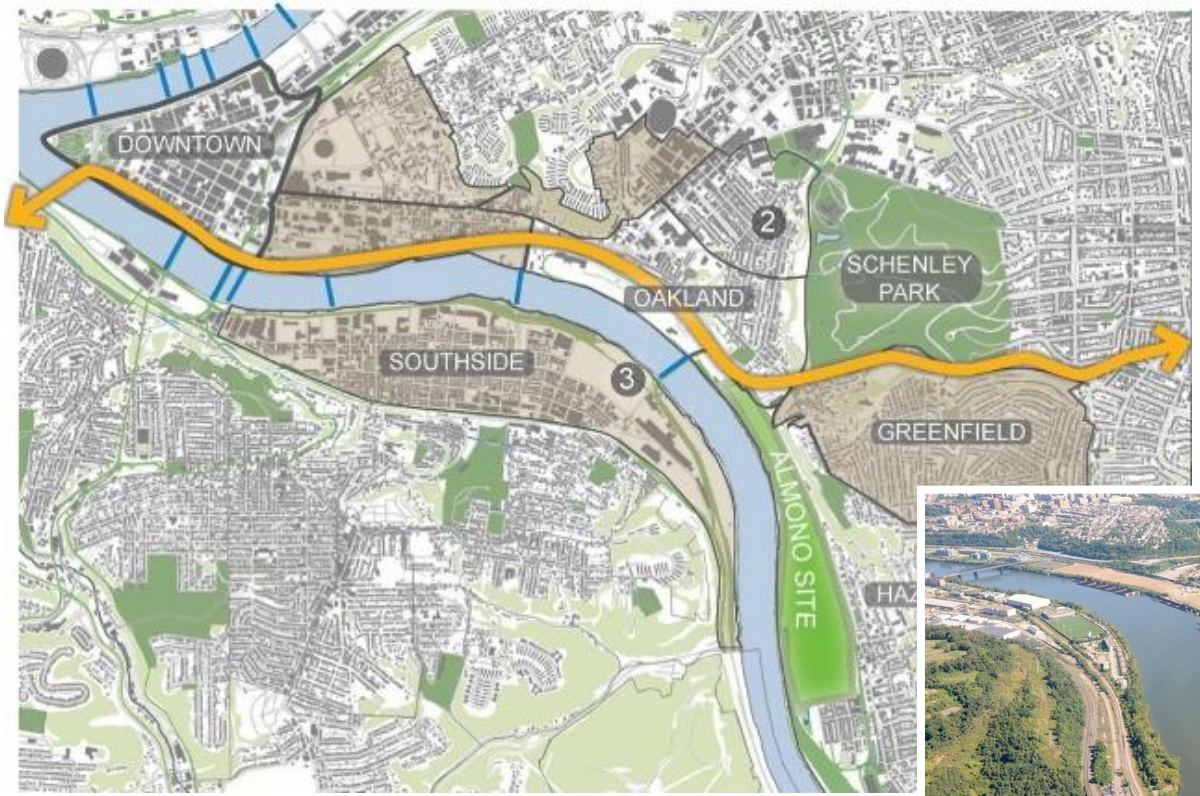


Pittsburgh Buildings 50,000+ Sq. Ft.



CITY
ENERGY
A JOINT PROJECT of NRDC + IMT

ALMONO


DOWNTOWN
2
SCHENLEY PARK
OAKLAND
SOUTHSIDE
3
GREENFIELD
ALMONO SITE

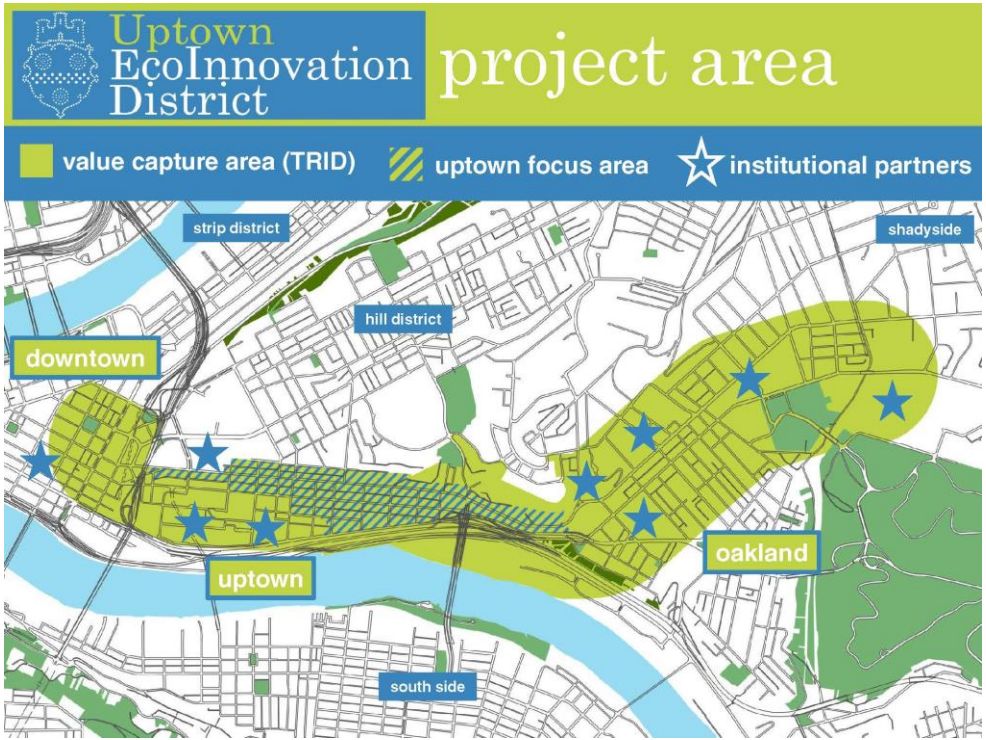
2014

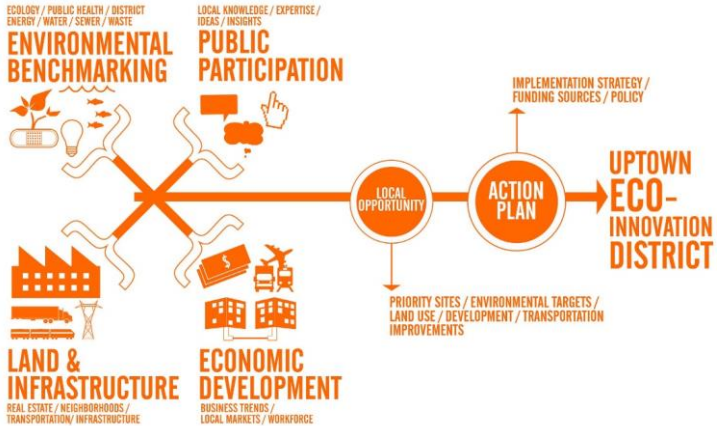
PITTSBURGH

Pittsburgh p4

Performance Measures

Pittsburgh's EcoInnovation District





Mayor's Goal: 2nd Ave = Electric Avenue

Maximize parking facilities potential for energy efficiency, generation, storage and charging

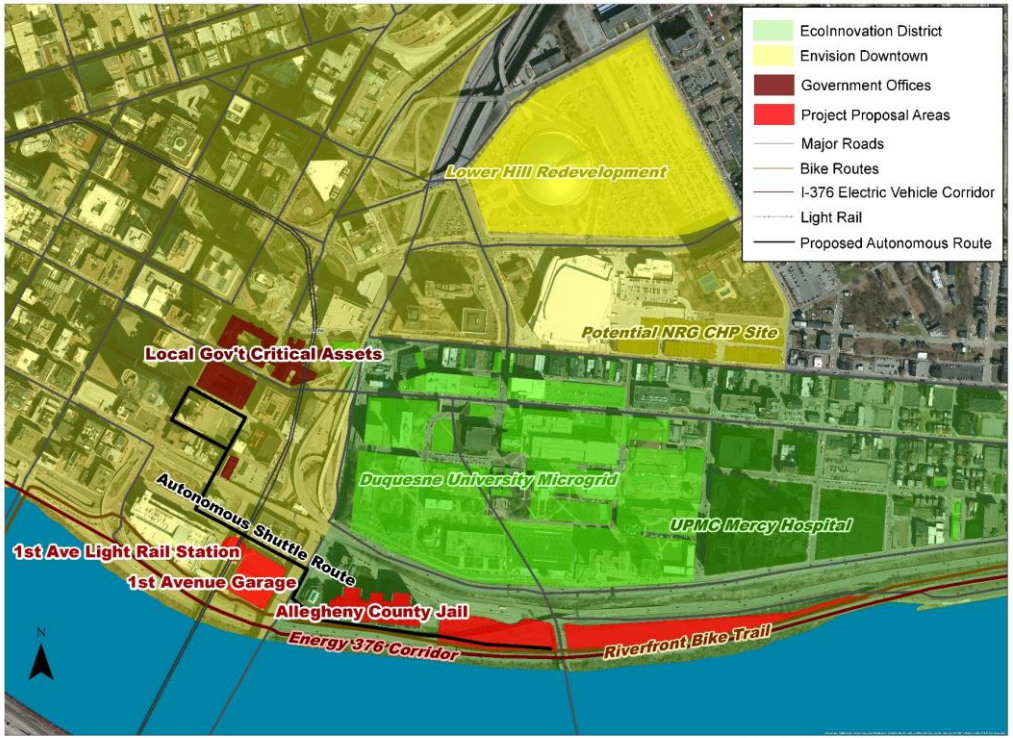
- LED Lighting retrofit with controls demonstrating 64% savings
- Revolving Funding

100% Fossil Free Fleet by 2030

- Permits, Licensing and Inspections fleet
- Fleet of 50 vehicles, currently Ford Foci
- Used for short trips
- Non-emergency vehicles
- Leverage assets with Pittsburgh Parking Authority

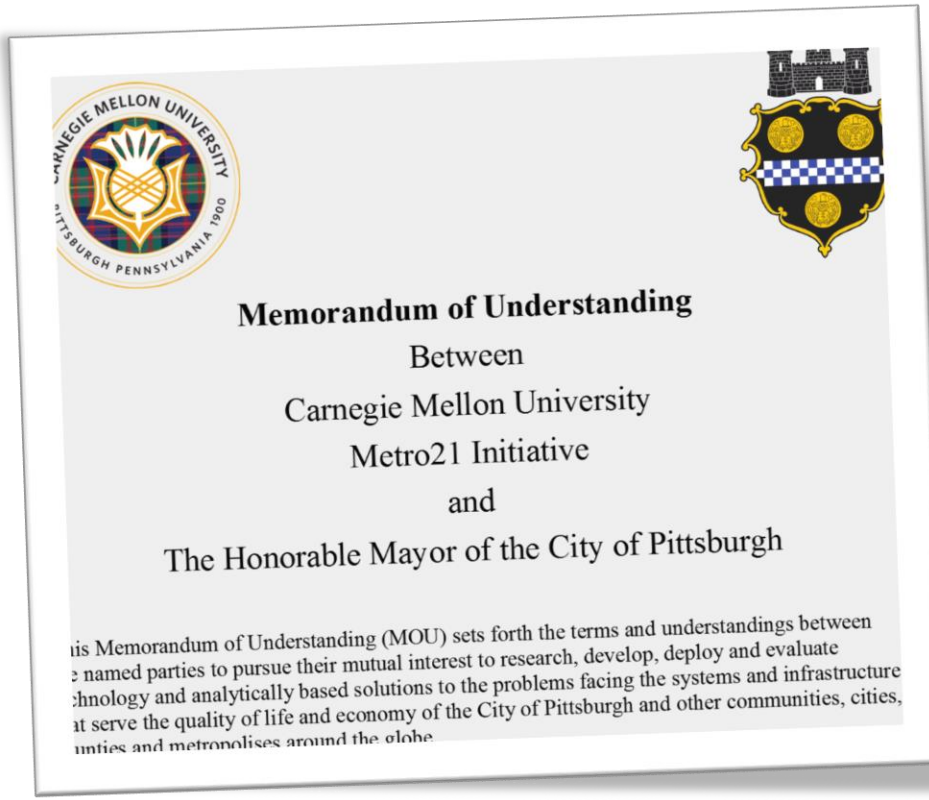
100% Renewable Energy Purchase or Production by 2030

- 50 electric vehicles (Nissan Leaves)
- 25 Level 2 chargers
- Requires a 100kW system- solar, wind
- Backup battery storage and grid connection for redundancy
- Public access to chargers - Energy 376 Corridor with PRCC



Smart Cities Application: City of Pittsburgh, 2016

Local gov supports innovation & partnership



Memorandum of Understanding

Between

Carnegie Mellon University

Metro21 Initiative

and

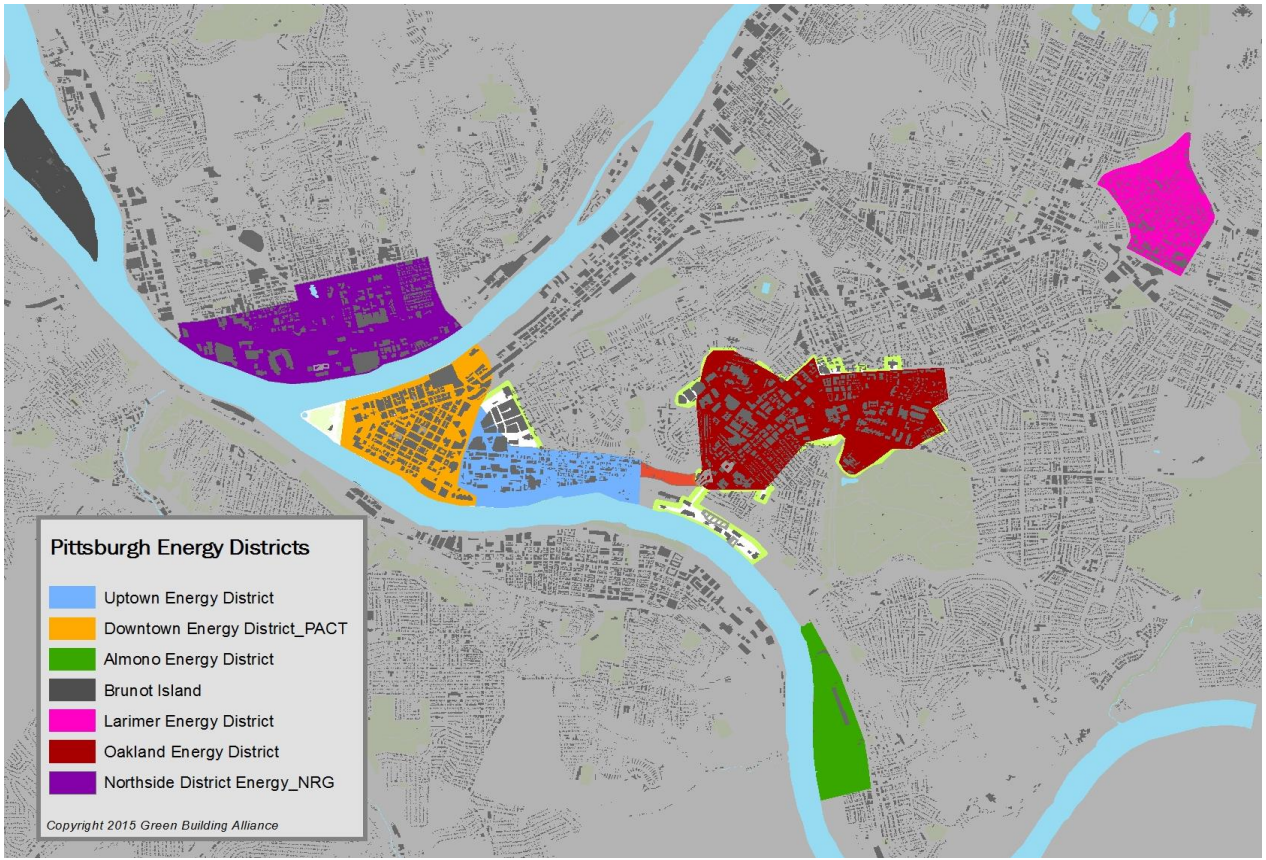
The Honorable Mayor of the City of Pittsburgh

is Memorandum of Understanding (MOU) sets forth the terms and understandings between
e named parties to pursue their mutual interest to research, develop, deploy and evaluate
chnology and analytically based solutions to the problems facing the systems and infrastructure
t serve the quality of life and economy of the City of Pittsburgh and other communities, cities,
unties and metropolises around the globe

Pittsburgh Climate Action Plan 3.0

- Buildings
- Utilities & Systems
- Transportation & Mobile Sources
- Consumption & Resource Recovery
- Food & Agriculture
- Urban Forest, Natural Systems and Carbon Sequestration
- Local Government Operations
- Adaptation
- Community Outreach & Education

District Energy Infrastructure & Capacity



District Energy Planning

Pittsburgh North Shore (NRG Energy)

- 50 year CW/steam/hot water system
- Regulated utility
- 35 customer buildings

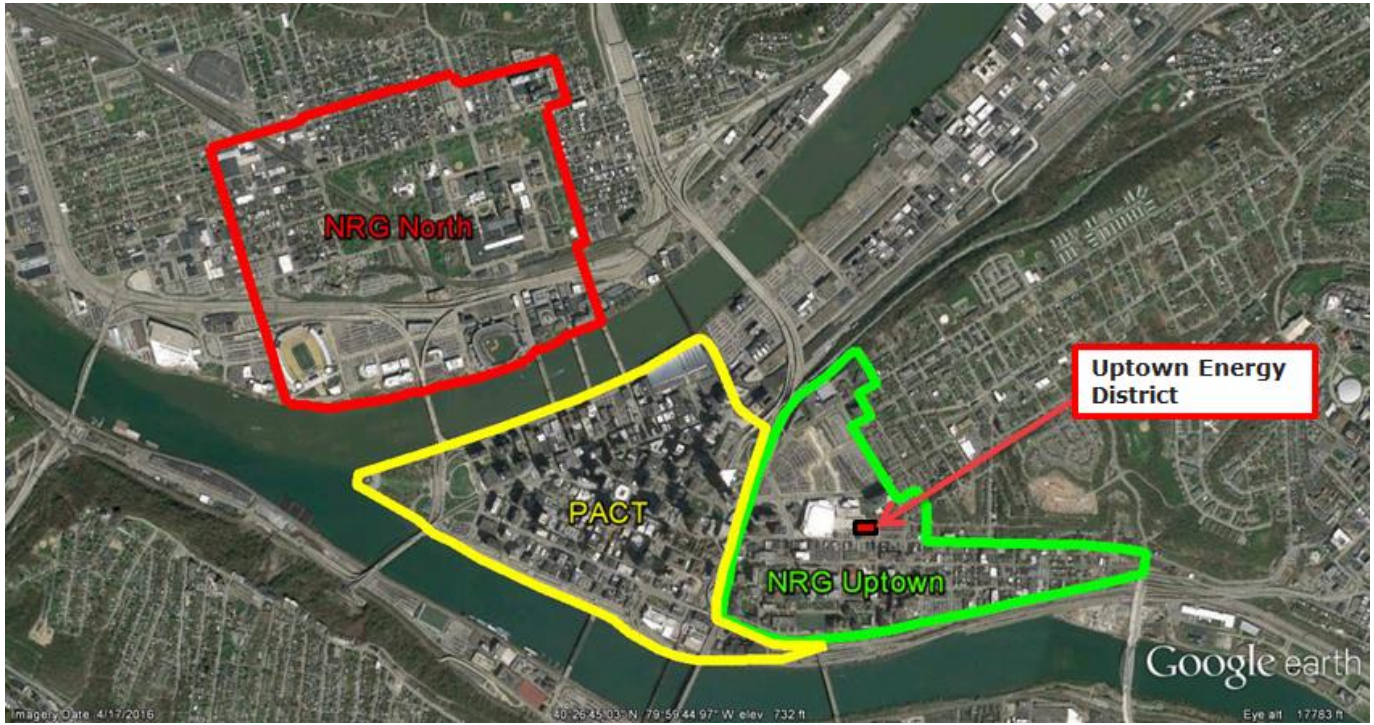
Golden Triangle (PACT)

- 100 year steam system
- City/County Co-op
- NRG Advisory Services is assisting owner on modernizing system
- 55 customer buildings

Uptown (NRG Energy)

- In service early 2018 (planned)
- CW/steam/hot water system
- SEA Lower Hill development site
- UPMC Mercy is anchor customer

North Shore, Golden Triangle & Uptown



Uptown District Energy Center

North Shore – Clear Day
7/4/2014; 11:29AM
Air Quality Index : Good
PM2.5 Level : 4 µg/m3
Relative Humidity : Approx. 40%

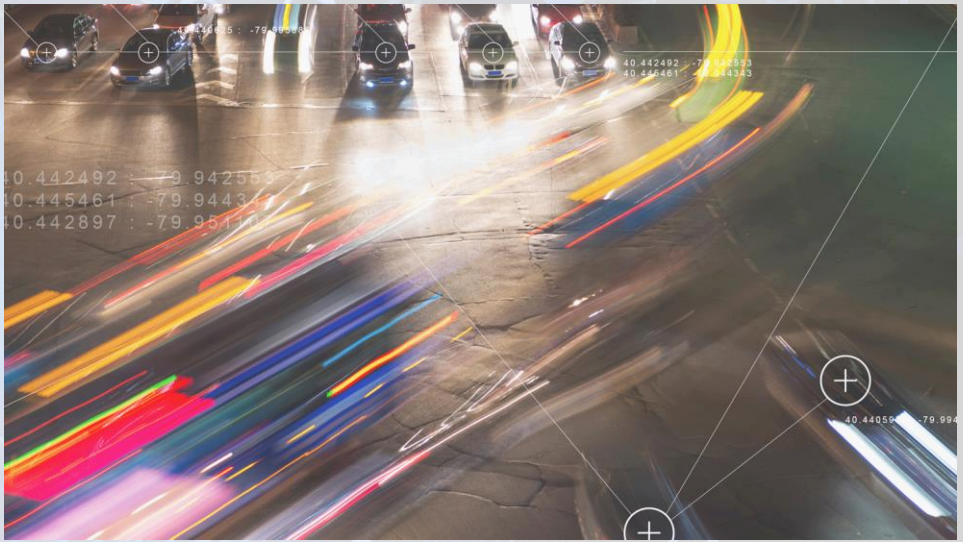
North Shore – "Brown Cloud" Day
4/6/2014; 9:11AM
Air Quality Index : Moderate
$PM_{2.5}$ Level : 24 μg/m^3
Relative Humidity : Approx. 47%

Confluence of 3 Trends + Emergence of Cities as Living Laboratories

1. The age of urbanization and emergence of cities as living laboratories

2. Changing demographics – graying human population and shrinking labor force

3. The acceleration in the scope, scale, ubiquity, and economic impact of technology

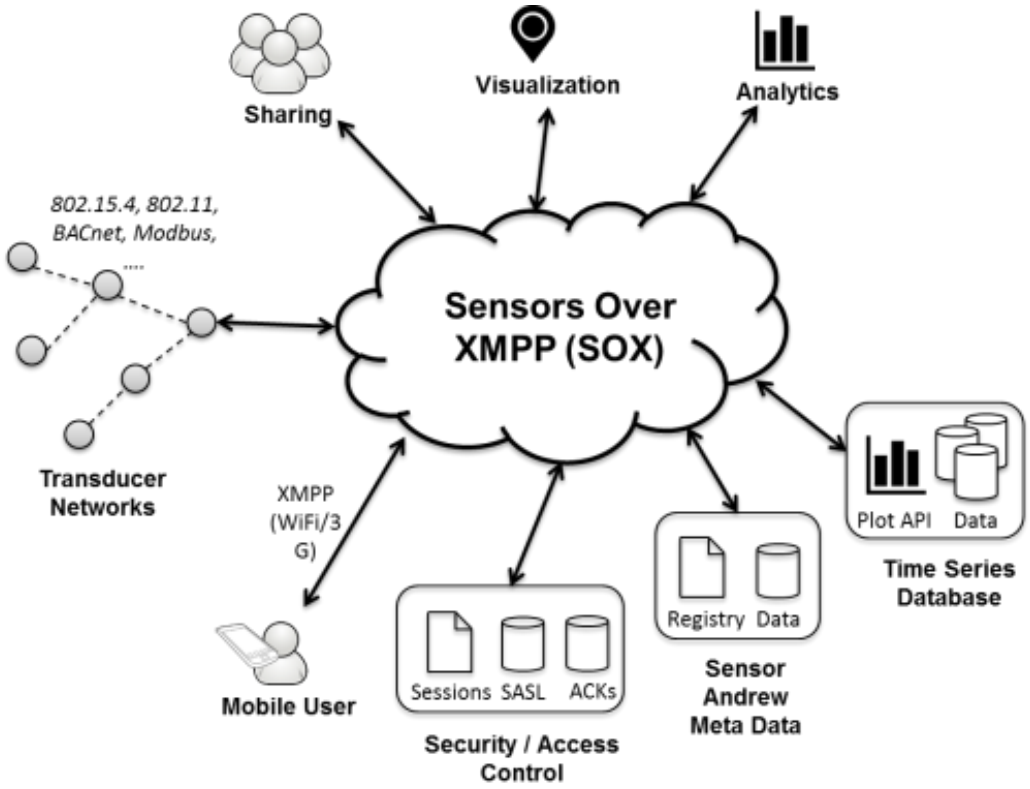


Campus as a living laboratory

Smart Infrastructure Institute

Campus as a living laboratory

Sensor Andrew
A Living Laboratory for Infrastructure Sensing Technologies



Building Data Analytics

Campus/Urban Scale Integration

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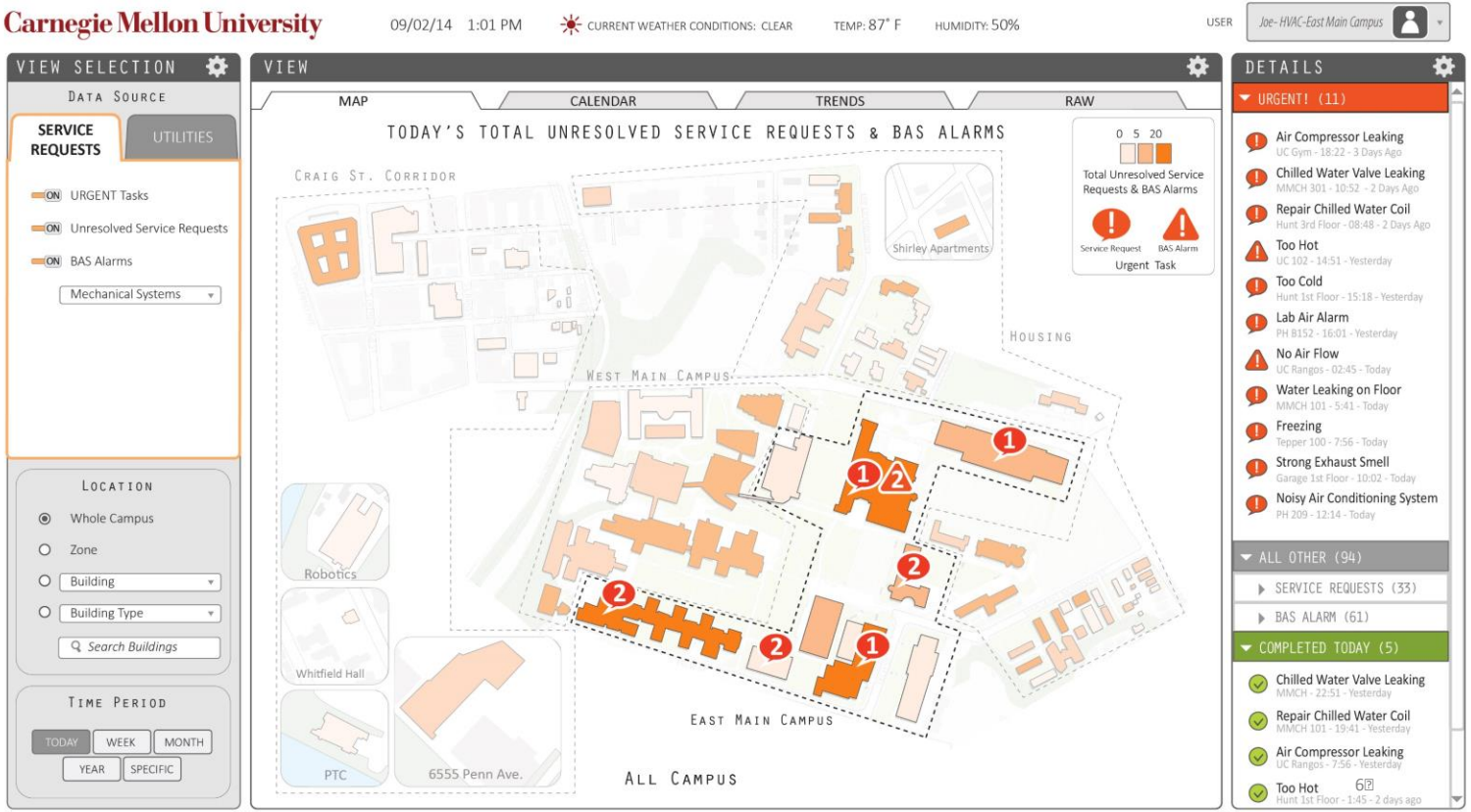
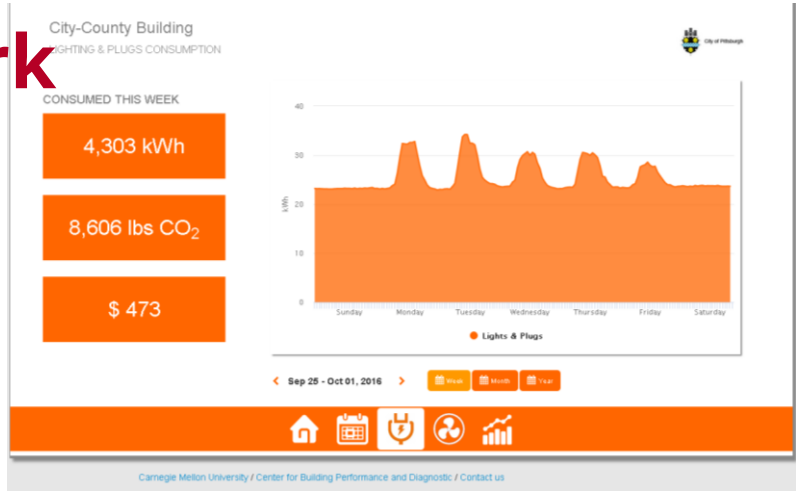
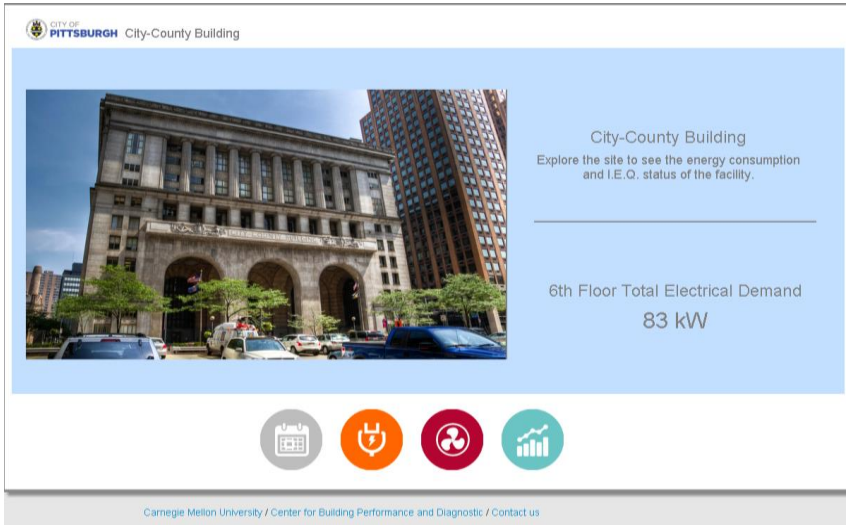


Energy Intelligence Network

- CMU and Metro21 Partnership
- Energy dashboard displays real time energy use for the City County Building
- Additional Pilot Projects
  - BOSS Controls deployment
  - Hite Electric lighting retrofit
  - Smart street lighting





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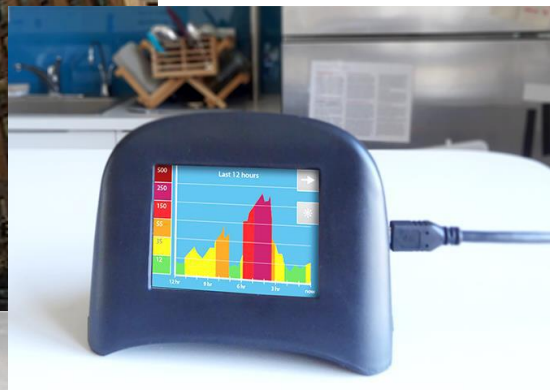
Energy Use & Air Quality in City Buildings

Metro21
Carnegie Mellon University



City-County Building

I.E.Q

PARTLY CLOUDY

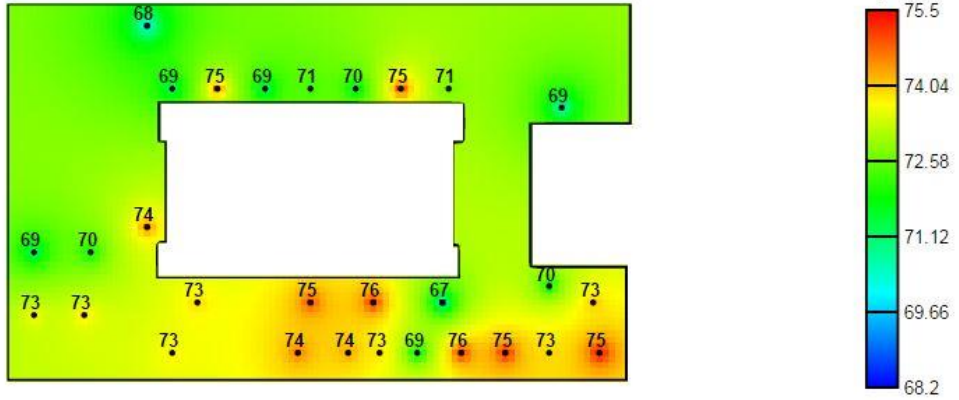
39.15°F
TEMPERATURE

44%
HUMIDITY

440PPM
CO_2

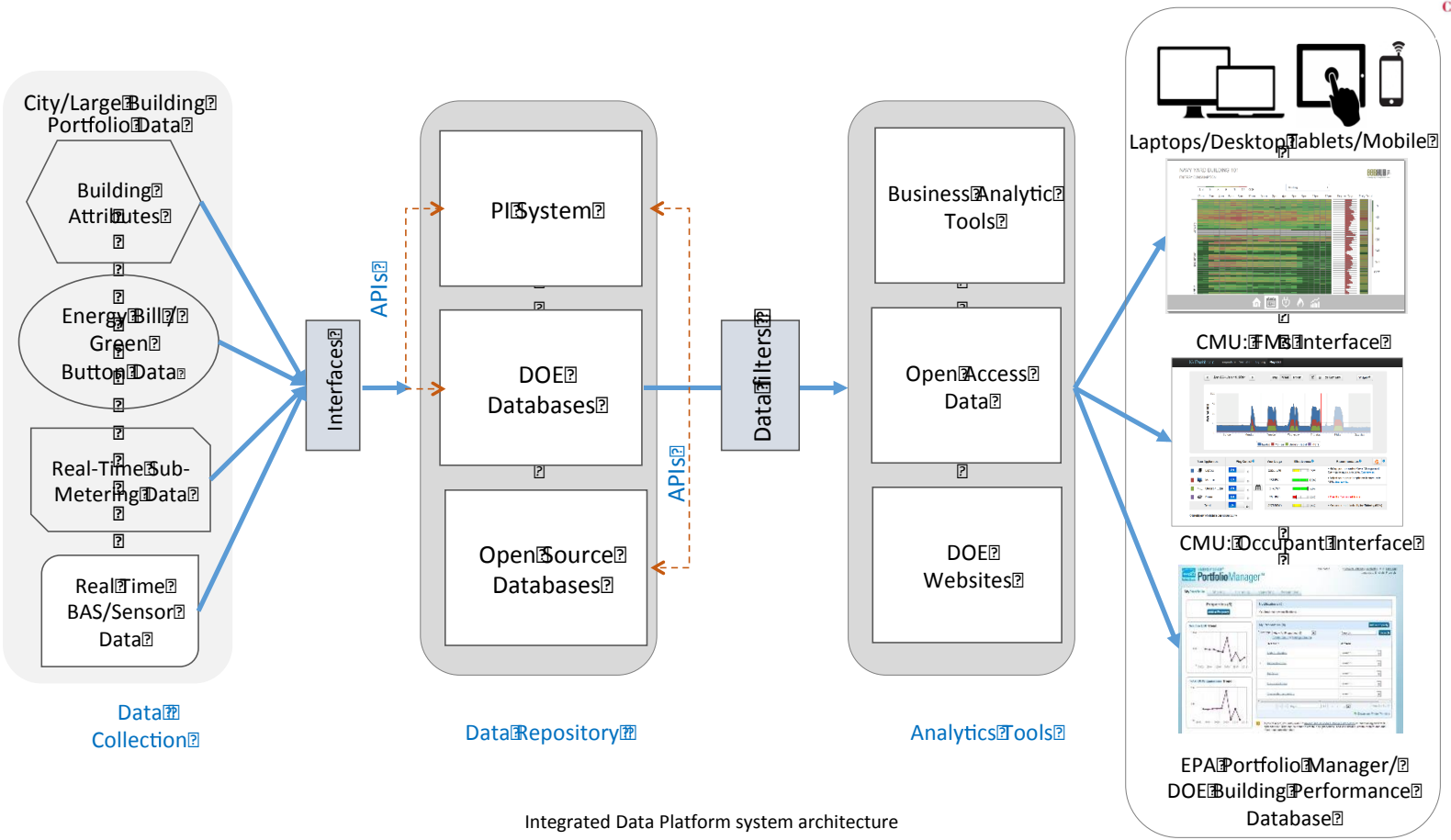
Metro21
Carnegie Mellon University

L6



Temperature

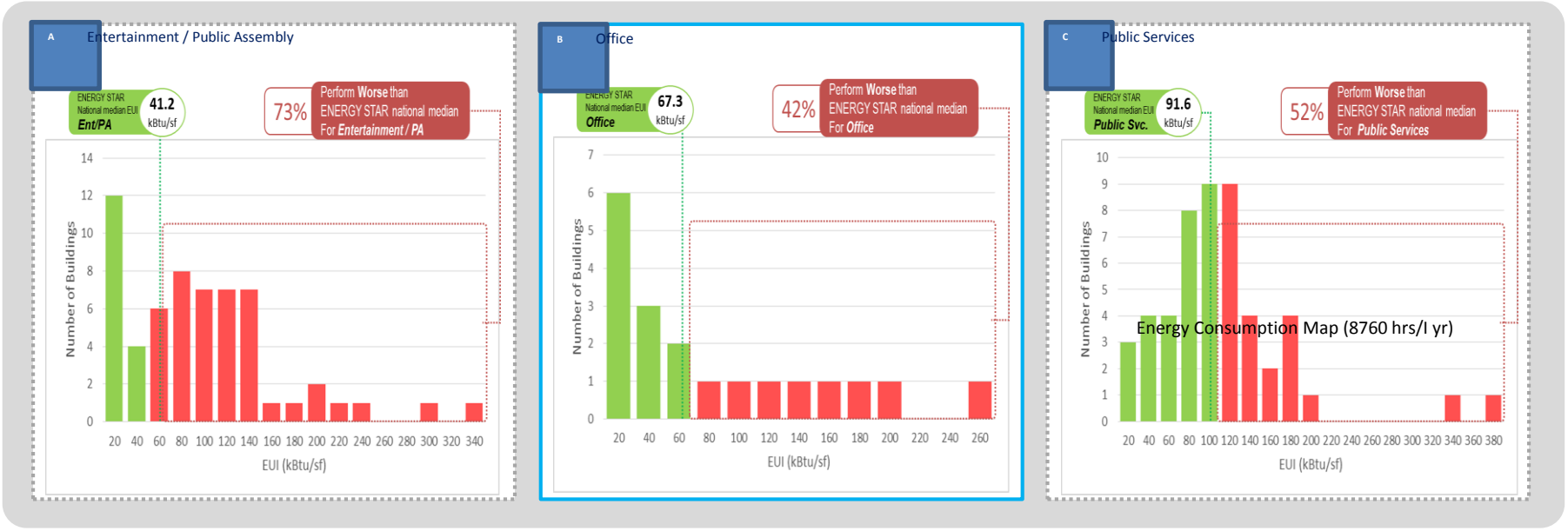
Building Data Analytics – City Portfolio



Integrated Data Platform system architecture

Building Data Analytics

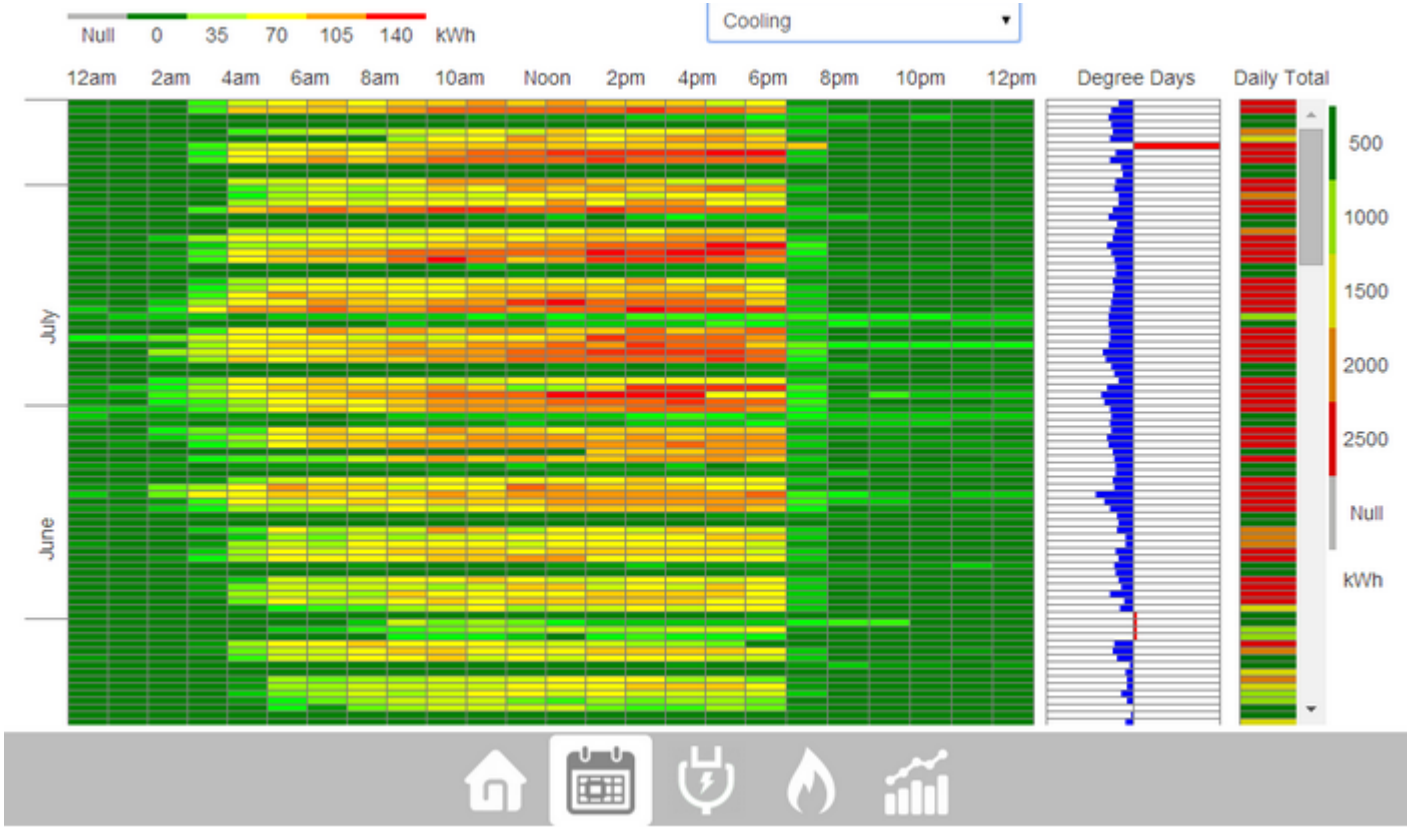
Carnegie Mellon University



Histogram of energy use intensity (EUI) for various building typologies

Building Data Analytics

Carnegie Mellon University

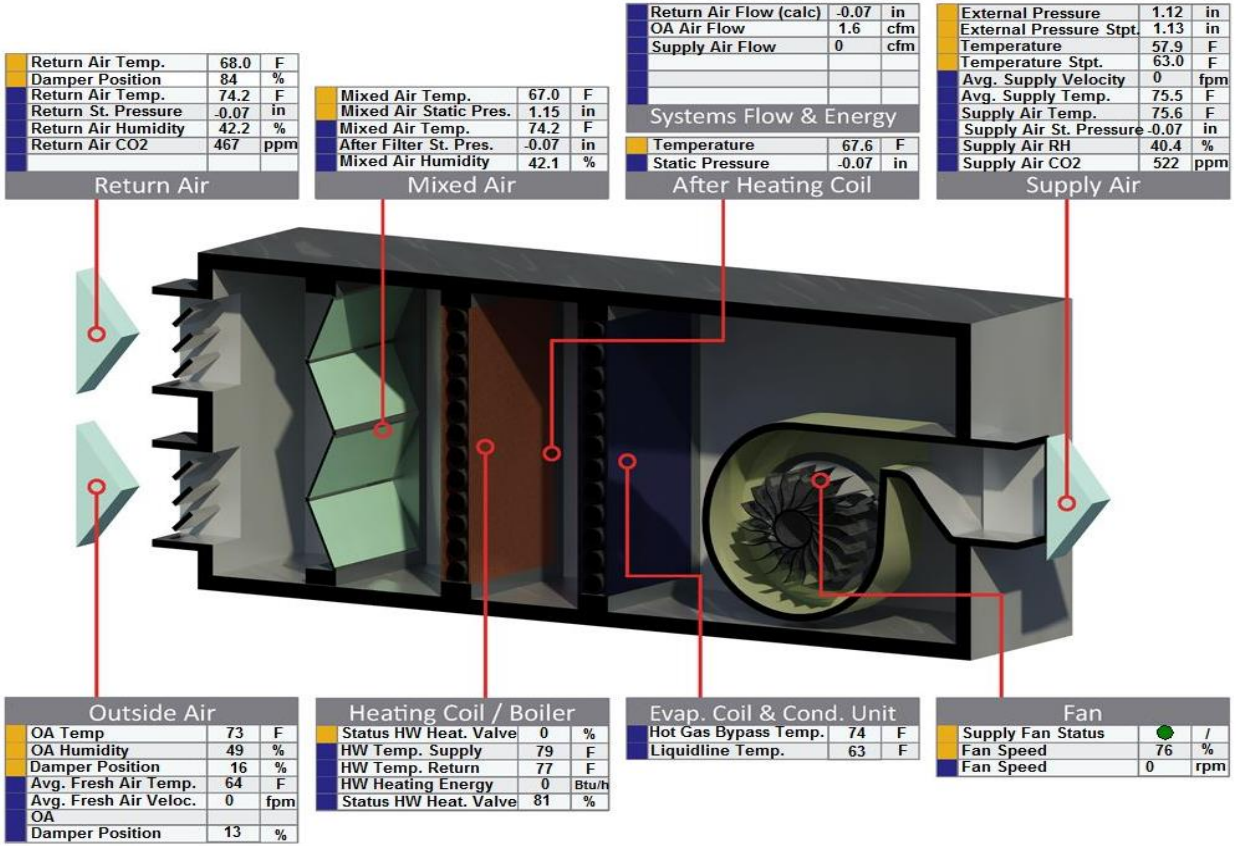


Energy Consumption Map (8760 hrs/l yr)

System Level Sensors, Monitoring

Carnegie Mellon University

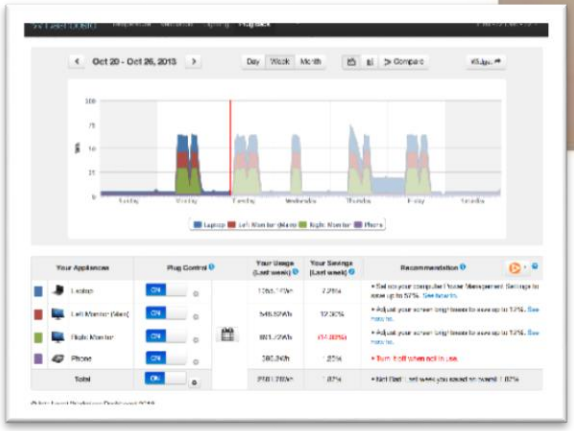
Building Equipment Interface with real-time and trended data for Facility Managers (per system)

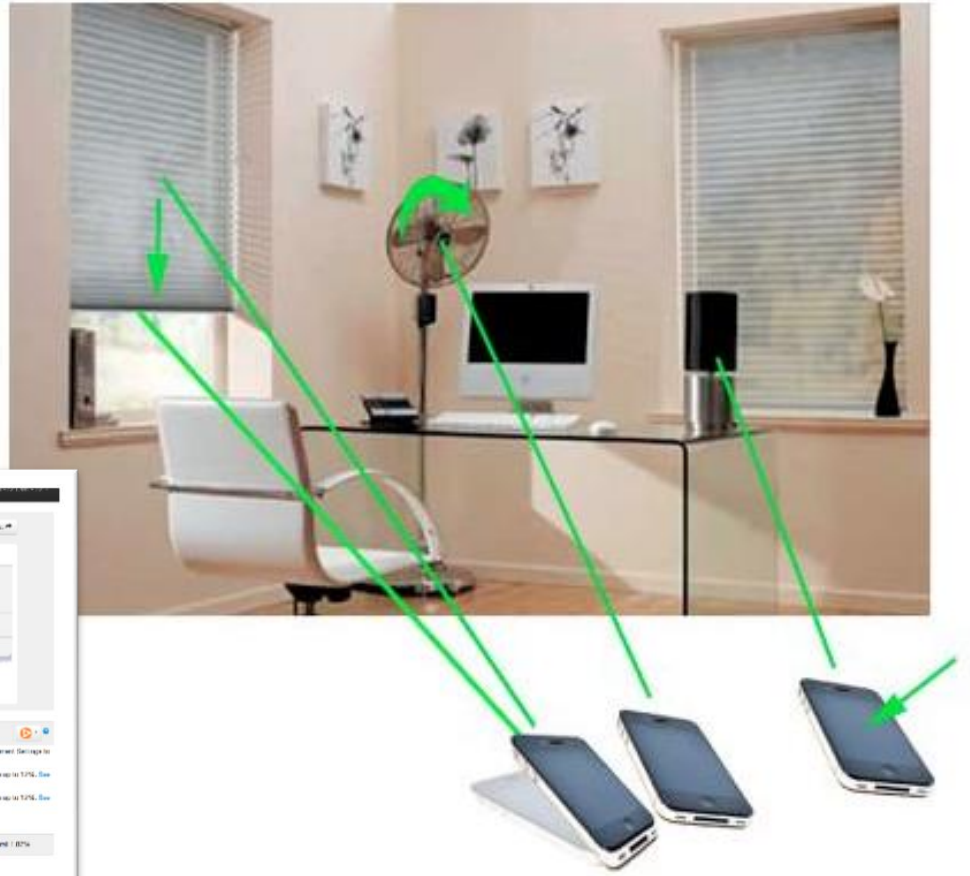


Asset Monitoring

Carnegie Mellon University

Building controls for heating, cooling, lighting and plug load management via mobile devices

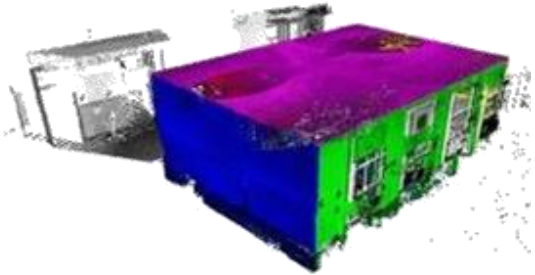




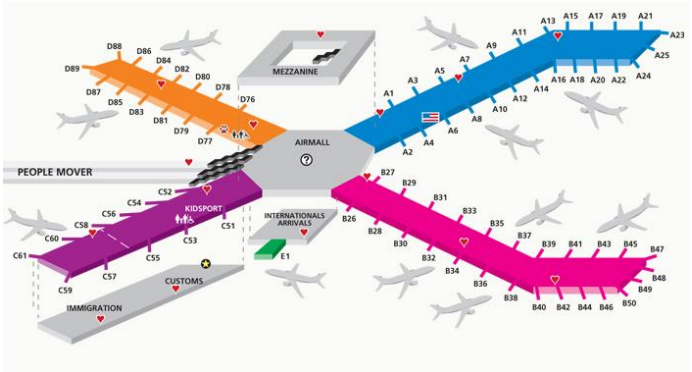
Energy Decision Support

Smart Infrastructure Institute

As-is modeling



Energy management



Direct & Indirect Sensing

Smart Infrastructure Institute

Pipeline Sensing

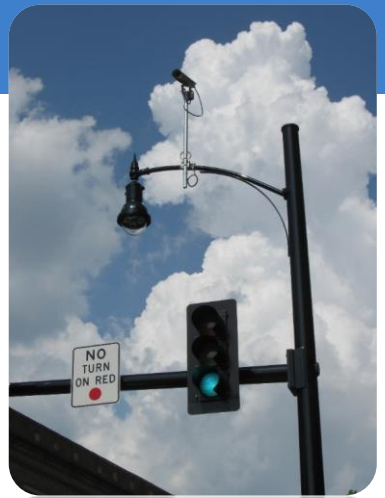
Vehicles as sensors for infrastructure assessment

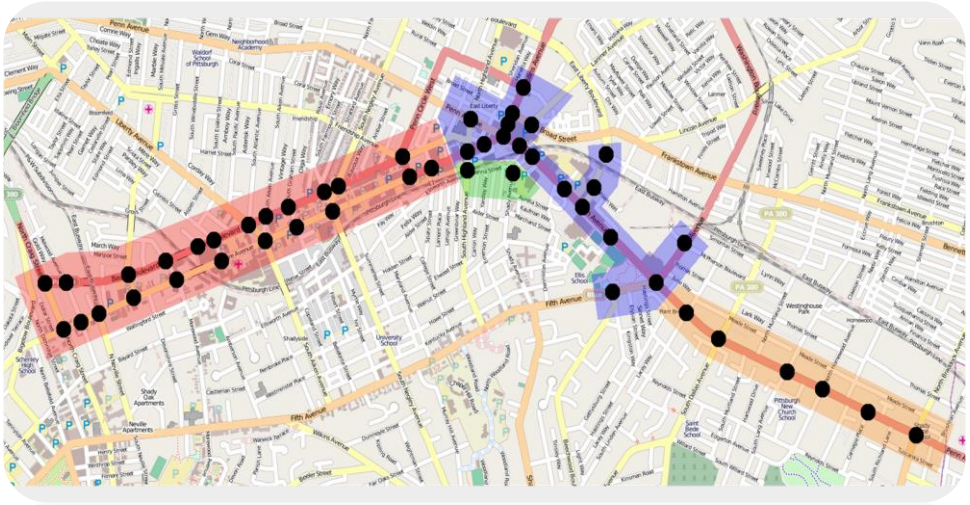
Drone and vision based bridge inspection

Speakers as sensors for indoor localization

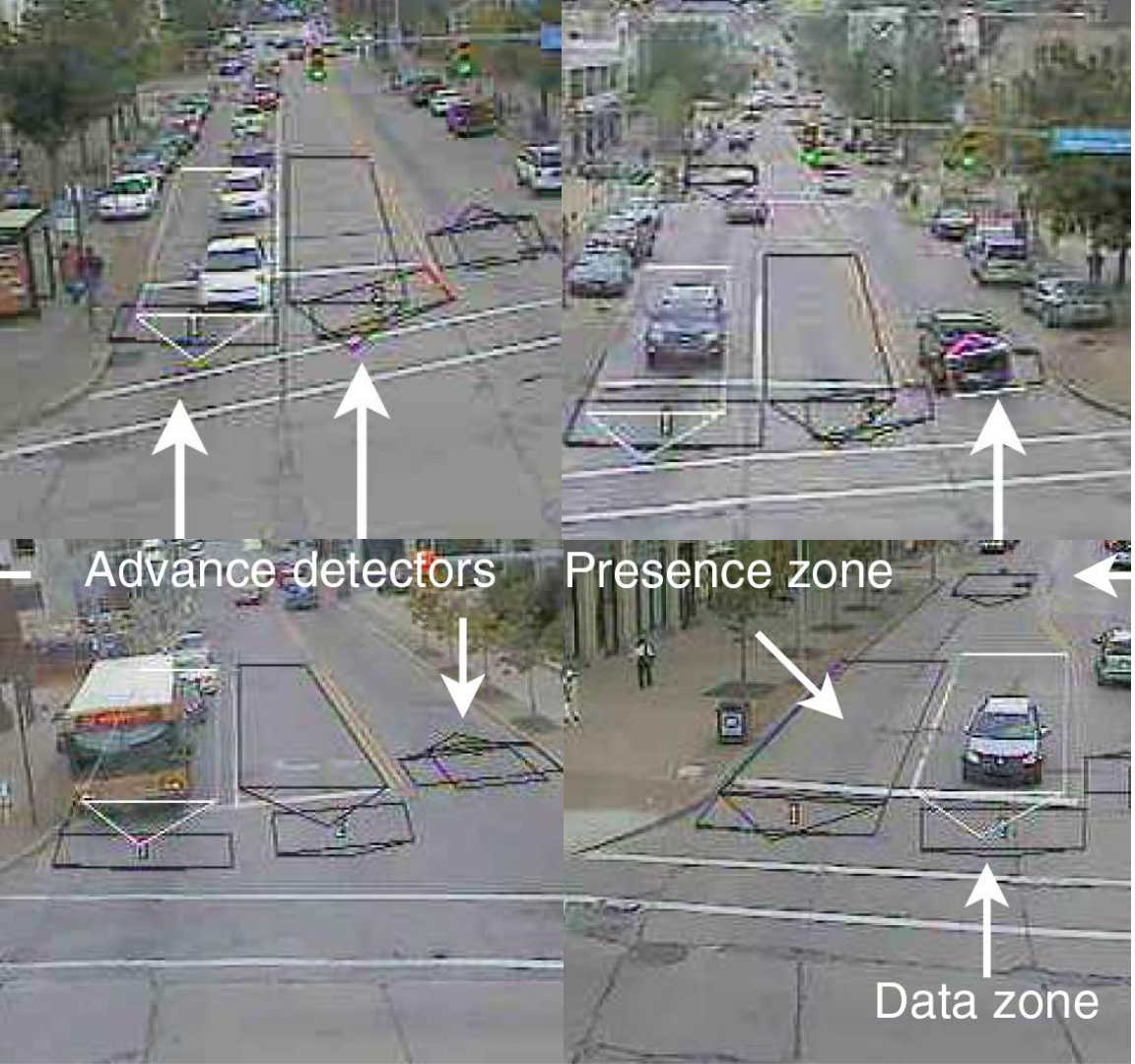
surtrac

Scalable Urban Traffic Control:





Metro21
Carnegie Mellon University



Metro21
Carnegie Mellon University

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A Metro21 Project

% Improvement

	Travel Time	# of Stops	Wait Time	Emissions
Phase 1	26%	31%	41%	21%
Phase 2	24%	40%	42%	21%

Integration with Connected Vehicle Technology

- Greater Safety
- Enhanced Mobility

surtrac

Pittsburgh Deployment

Baum Boulevard

Centre Avenue

UPMC

Highland Ave

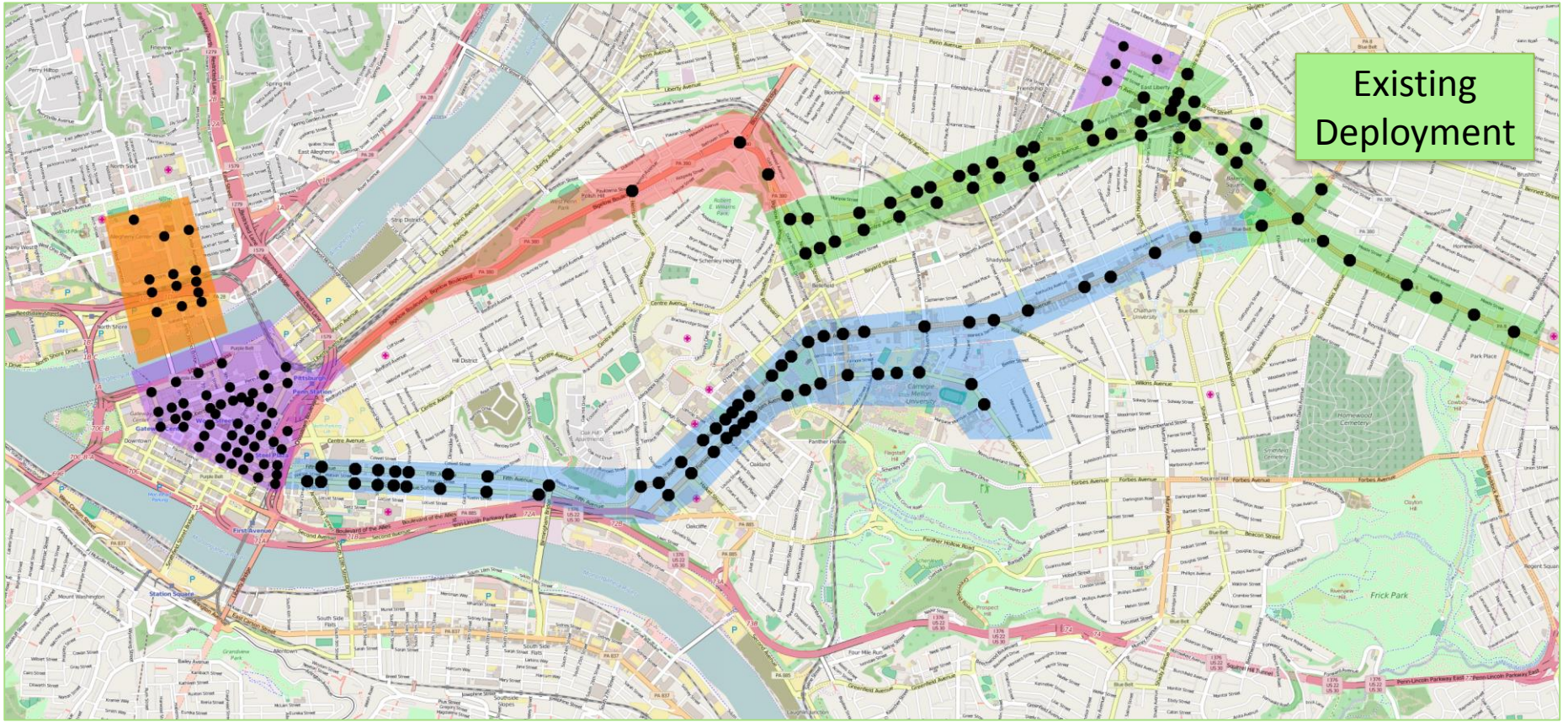
Fifth Avenue

Penn Ave

24 intersections are equipped with DSRC Radio Communications

Pittsburgh Smart City Vision

Metro21
Carnegie Mellon University

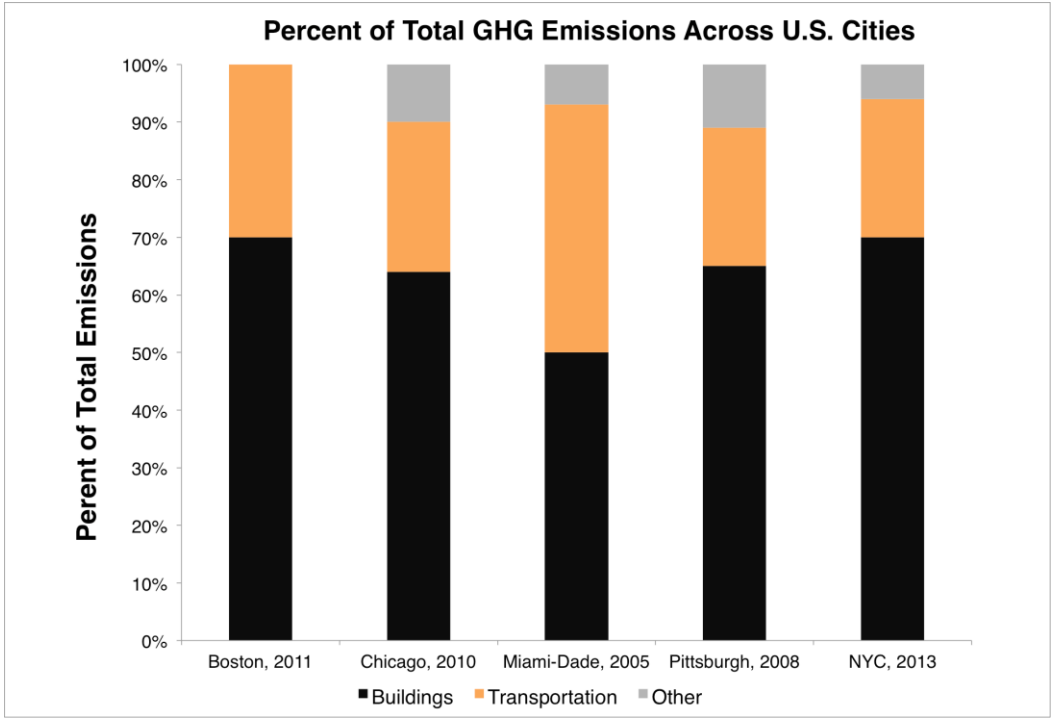


Mobility & Sensing - Automation

CERCA
Center for Engineering and Resilience for Climate Adaptation

Addressing GHG Emissions from Cities Requires Addressing Transportation

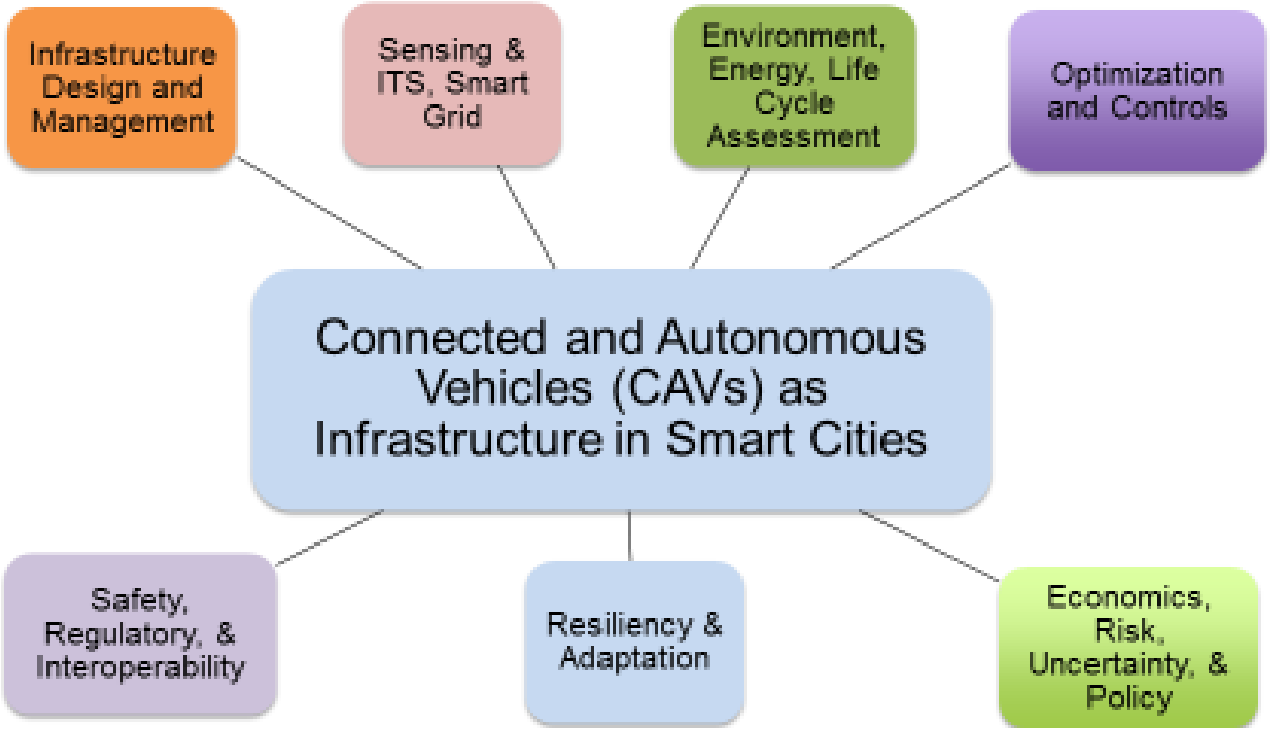
CERCA
Center for Engineering and Resilience for Climate Adaptation



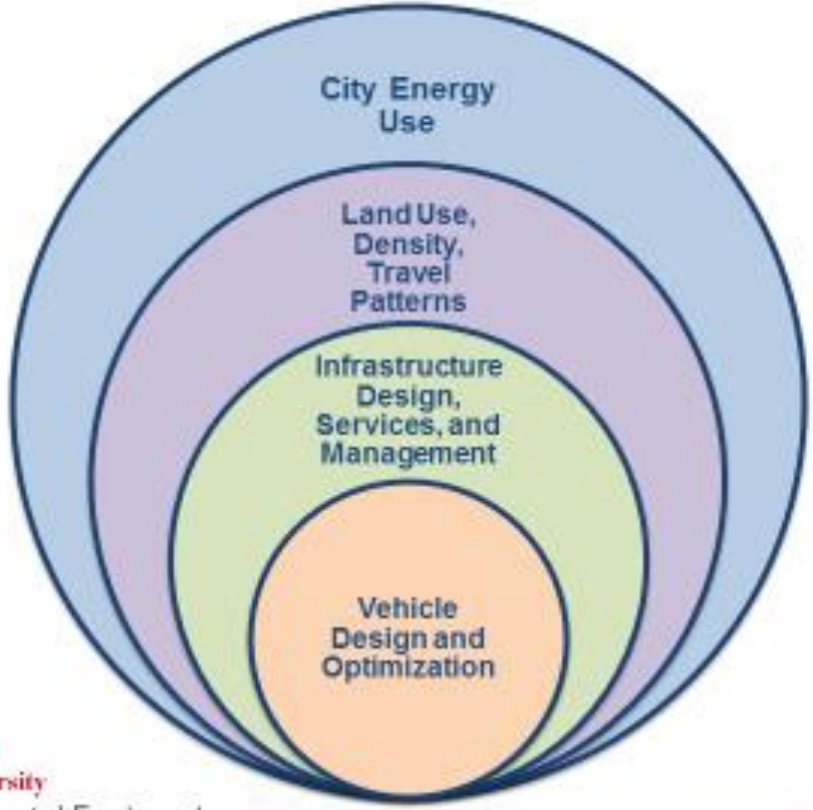
Source: Markolf, 2015

Maximizing Benefits from the Automation-Smart Cities Nexus Requires Transdisciplinary Research

CERCA
Center for Engineering and Resilience for Climate Adaptation



Automation Has Interdependent Effects on Energy



Automation is Coming, How Do We Build Long-Lived Infrastructure?

CERCA
Center for Engineering and Resilience for Climate Adaptation

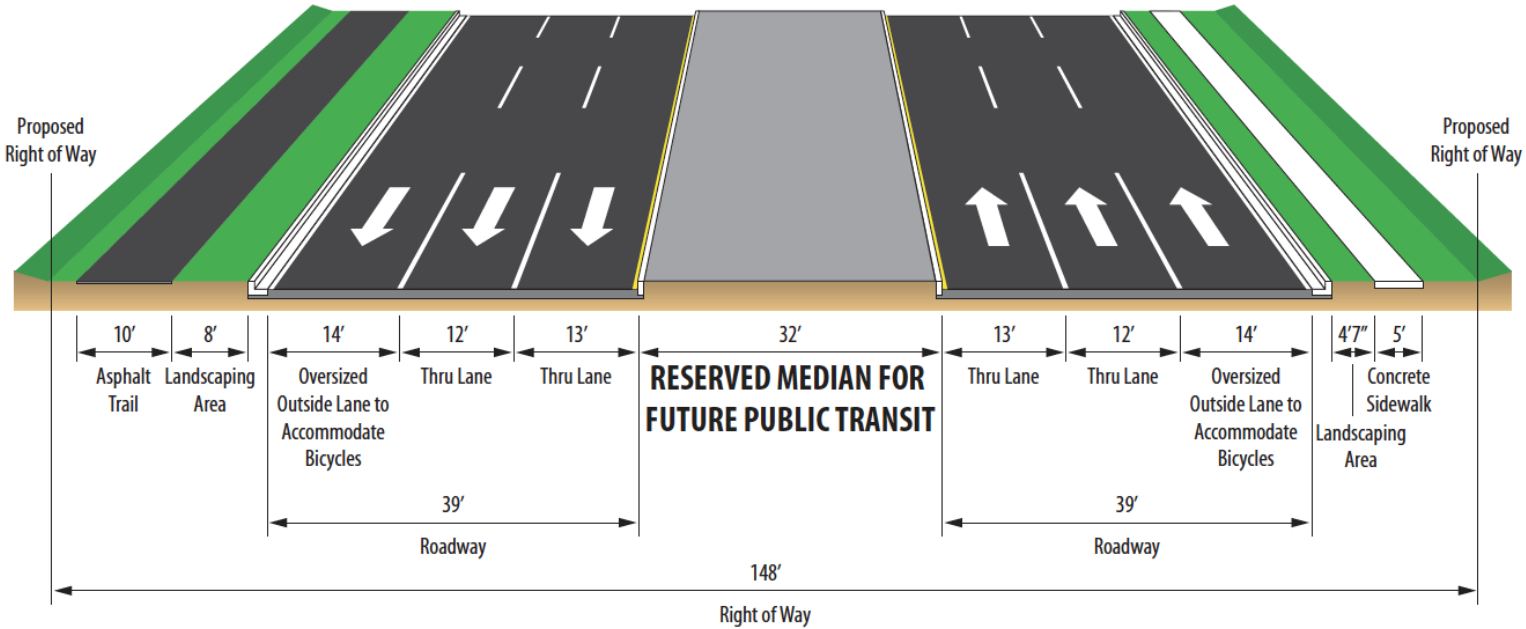
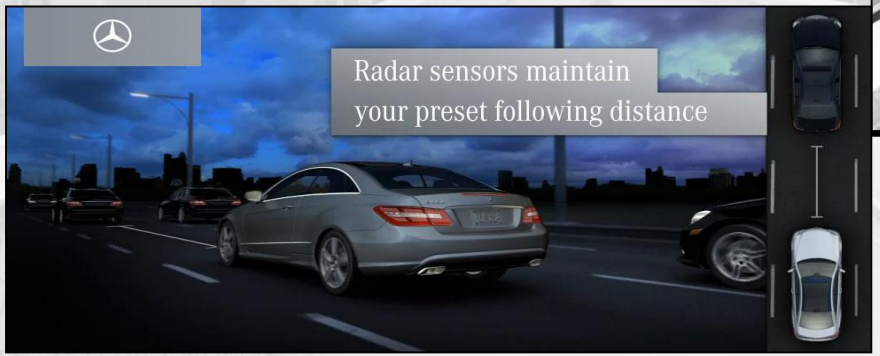


Image: FHWA

The Future is Here

Lane departure warning

Self-parking



Adaptive cruise control

Enabler of New Applications, Products and Markets

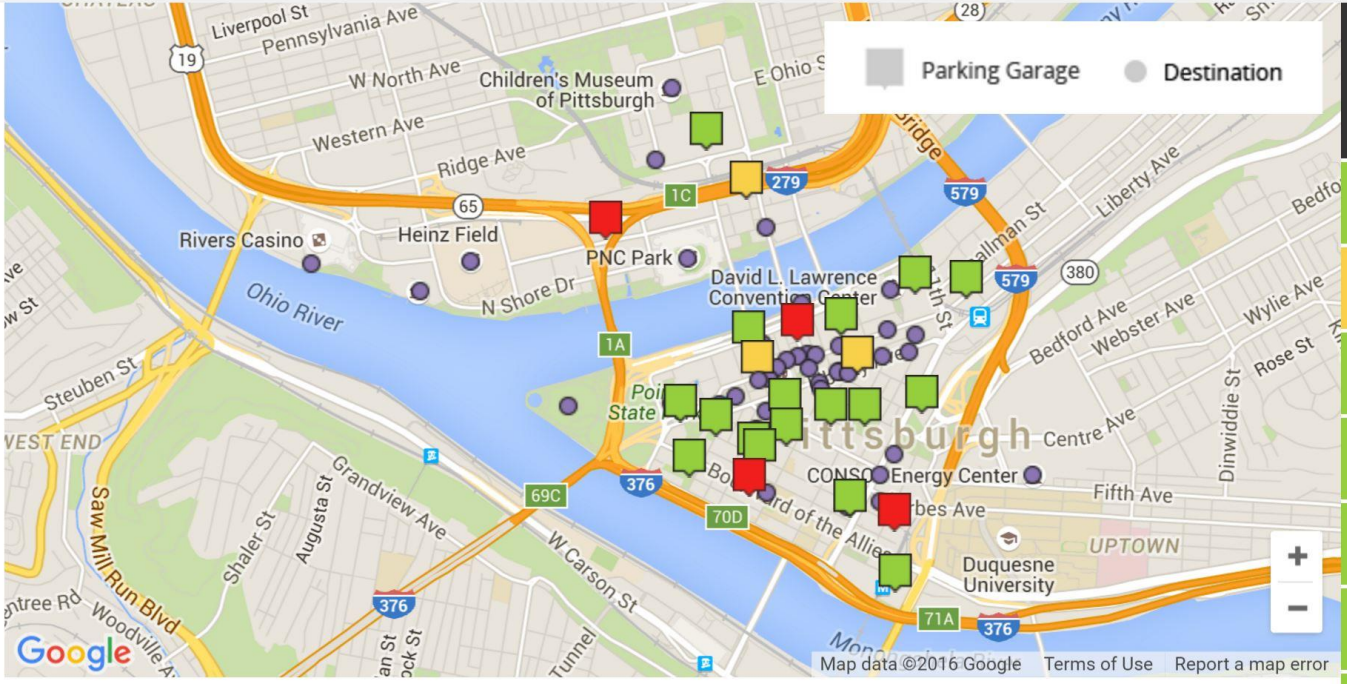
ParkPGH

Real-time parking for Pittsburgh garages.

PITTSBURGH CULTURAL TRUST

Report Inaccuracy

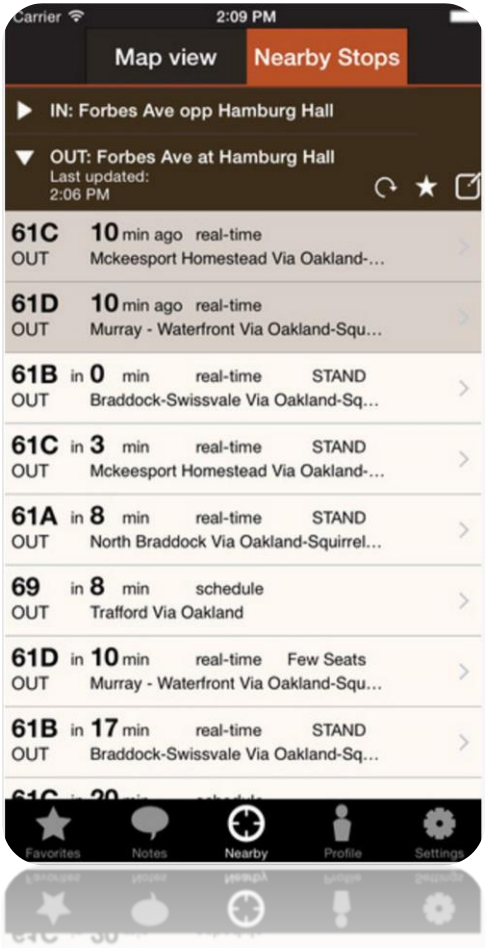
All

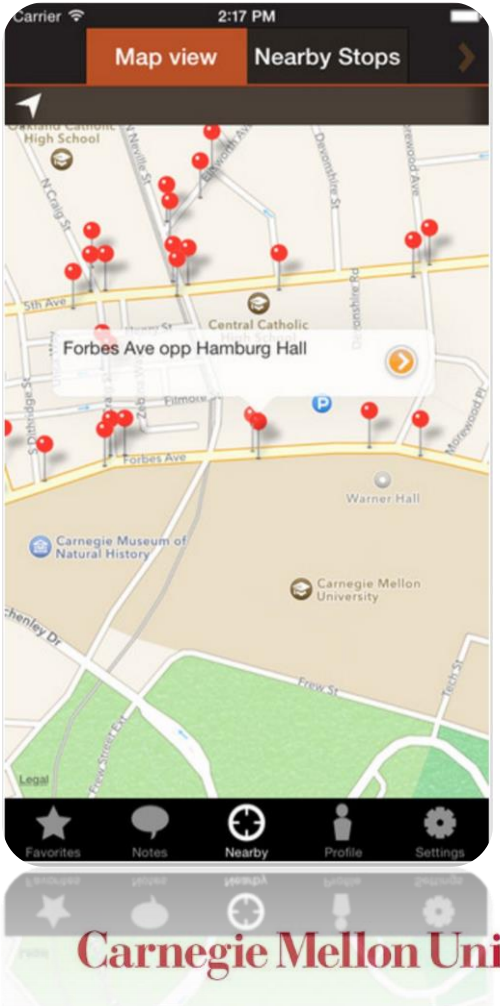


Garages | Destinations

344	11 Stanwix
43	6th & Penn
164	9th & Penn
352	Convention Center
792	First Avenue
322	Ft Duquesne & Sixth

Tiramisu





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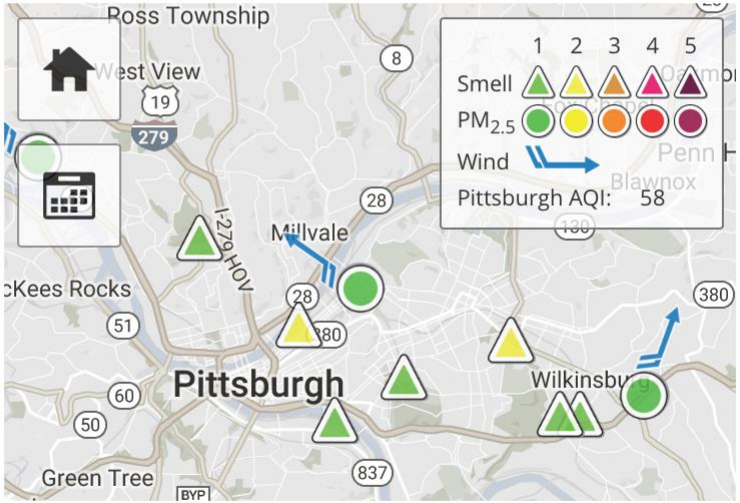
If You Smell Something, Say Something: CMU Launches Mobile App Smell PGH

September 29, 2016
By Adam Shuck



Pittsburgh ranks high on lifestyle and food magazine lists, but a recent report from the American Lung Association found the region is in an unenviable 8th place for annual particle pollution, the worst of any metropolitan area outside of California. Pittsburgh's air quality is not great. And, like residents reporting noxious, throat-burning fumes from neighborhood industrial sites, you might even say it stinks.

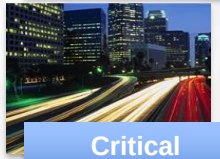
METROLAB NETWORK

Carnegie Mellon University

Emerging Frontiers

Smart Systems: Sensing, Reasoning and Data-driven Decision Making

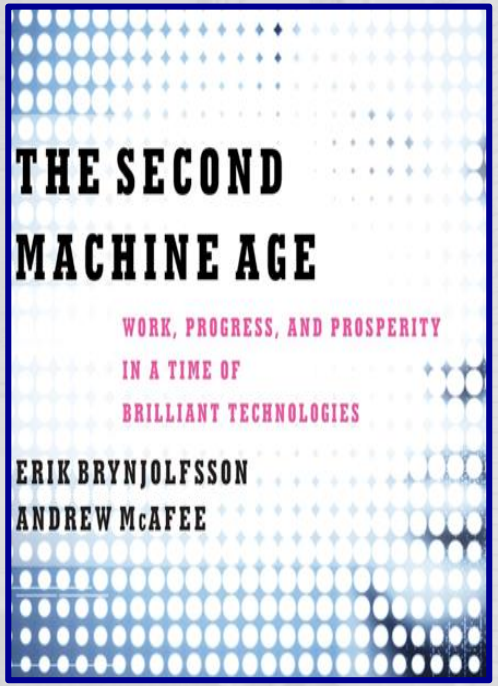
- **Cyber-Physical Systems** aim to deeply integrate computation, communication and control into physical systems
- **Smart everything**… buildings, infrastructure, transportation, cities, health care delivery, energy, environment
- Systems that **adapt, learn and respond**
- **Dependable operation** with high assurance of reliability, safety, security and usability



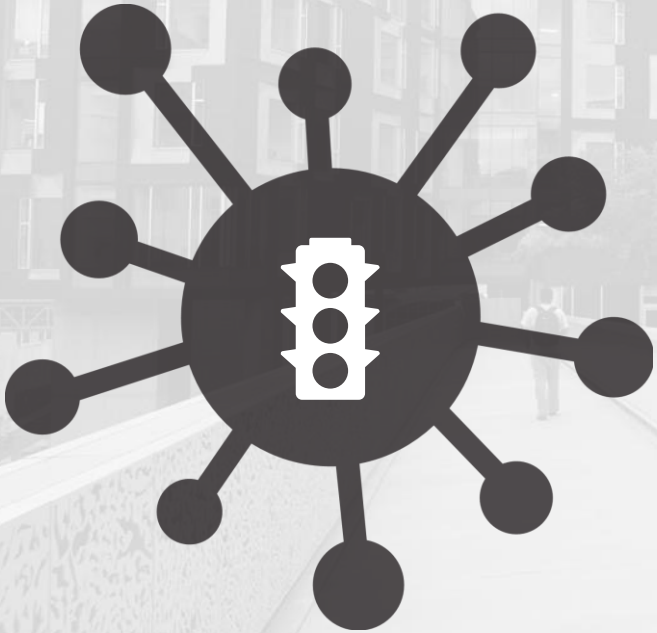
Are We at an Inflection Point?

In the last 10 years alone, we have seen extraordinary advances …

- Self-serving cars
- Complex communication
- Natural language understanding
- Face recognition
- Language translation
- Watson and Jeopardy
- 3D printing and additive manufacturing
- Advanced robotics
- …



Imagine a Day…



By coupling roadway sensors, traffic cameras and individuals' GPS devices, we can **reduce traffic congestion** and generate significant **savings in time and fuel costs**.

Imagine a Day…

By accurately predicting natural disasters such as hurricanes and tornadoes, we can **employ life-saving and preventative measures** that mitigate their potential impact.

Imagine a Day…

By correlating disparate data streams through text mining, image analysis and face recognition, we can **enhance public safety**.

Imagine a Day…

Static infrastructures, such as buildings and bridges, are transformed into **smart, safe and sustainable spaces** that adapt to consumption, growth and changing environmental needs.

·INTRODUCING·
SMART
·PGH·

Carnegie Mellon University

energyweek

March 27-31, 2017

Carnegie Mellon University
Scott Institute
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CMUenergyweek.org

Carnegie Mellon University

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