Building Resilience in Cities & Infrastructure
Increasing resilience reduces risk

Hazard
Probability & Magnitude

Exposure
People and assets in hazard-prone locations

Resilience
Robustness of infrastructure, institutions etc.

Risk (Impact)
Damage, loss of GDP, fatalities, etc.

Influence of cities
Low direct influence
Some influence
Direct control and influence
Key Criteria
To make cities more resilient

Prepare
Endure
Recover

Disaster Impact

Time

Cooperation &
communication
Diversity &
flexibility
Robust design
Redundant
capacity
System control &
adjustment

Prepare
Endure
Recover
Why Resilience?
Cities are often under-prepared for major shocks

Aging infrastructure × High density ÷ Lack of preparedness

It is not simply a case of asking “do we live in hazard zones”? But, “how well prepared are we for the potential hazards?”

waiting for fuel at a garage in Brooklyn, following Superstorm Sandy
Case Study: NYC Electrical Grid
## Changing Hazards
For the New York Metropolitan area

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Flooding Events</td>
<td>• 1 in 100 years</td>
<td>• 1 in 15 years</td>
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<tr>
<td>Drought</td>
<td>• 1 in 100 years</td>
<td>• Unclear</td>
</tr>
<tr>
<td>Heat Wave</td>
<td>• 2 per year</td>
<td>• 8 per year</td>
</tr>
<tr>
<td>Wind events</td>
<td>• 1 storm per 3 years</td>
<td>• More frequent</td>
</tr>
</tbody>
</table>

### Source:
NYC Panel on Climate Change, 2009; ClimAID, NYSERDA, 2012.
Hazards and Risk Review
NYC Metro Grid

Hazards
- Tidal surges
- Flash flood
- High winds (tornado / hurricane)
- Blizzards
- Heat waves
- Droughts

Cost/Damage

Event

2010
- Tornados in 2010 (125 mph winds)
- Blizzard of 2010 – 60 mph gusts / 20” snow

2011
- 2011 Heat Wave – 104°F temperatures
- Outages, loss of subway lines
- Over $400M damage to grid

2012
- Superstorm Sandy – 14 foot surges / 80 mph gusts
- Outages - 139,000 customers affected
- Damage & power loss – 45,000 customers affected
Understanding the Grid

Customers
• 3.3 Million

Substations
• 61, including 18 in flood zones

Lines (T&D)
• 2,200 primary feeders
• 34,000 miles overhead lines (~200 miles critical)
• 94,000 miles underground lines
Exposure & Vulnerabilities
Revealed by Hurricane Sandy

13th Street Substation, Manhattan

- Located in flood zone, designed for 12.5 foot surge
- 14 foot surge during Sandy
- Sea water inundated equipment
- Power lost to 250,000 customers
- Back-up generators failed at NYU-Langone Medical Center
## Protection and Resilience
### Actions & Investments

<table>
<thead>
<tr>
<th>Technology &amp; Investment</th>
<th>Short-term</th>
<th>Medium-term</th>
<th>Longer-term</th>
</tr>
</thead>
</table>
| Enabling actions        | • Flood defences  
• Gas-insulated switchgear  
• Undergrounding  
• Manual demand management  
• Assessment of critical systems  
• Building codes  
• Integrated control centers  
• Reg. reform  | • Decentralized generation  
• Smart grid ready appliances  
• Smart meters & IT infrastructure  
• GIS asset monitoring  
• Communication with customers  | • Relocating installations  
• Automated demand management  
• EV to grid  
• Real-time pricing  
• Integrated development & energy planning |
Action Plan
With cost-benefit

“Do Nothing”
• Anticipated damage to the power grid over 20 years: USD 1-3 bn

“Protection only”
• Investment pays back through reduced damage
• But city still has net losses

“Full Grid Resilience”
• Protection PLUS system resilience, reliability and efficiency
• Net benefits

- No Action
- Partial Investment
- Full Implementation

US$Billions

Years

0 5 10 15 20

$6 $4 $2 $0 ($2) ($4)

6/10/2013
Creating Resilient Systems
Focus on Energy, Transport, Water

Information & Telecommunication Networks

Transport
- Passengers
- Emergency services
- Logistics, incl. food, waste, materials.

Energy
- Generation
- Transmission
- Distribution

Water
- Potable supply & distribution
- Waste water

Buildings
- Residential
- Commercial
- Public / Institutional

Security & Physical Protection

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Energy System Resilience

- Demand response prioritises critical users
- Submersible equipment resists inundation
- Automated monitoring & adjustment
- Micro grids protect from wider failure
Virtual Power Plant
Munich, Germany

- Initiative of Munich City Utilities & Siemens
- Small-scale, distributed energy sources pooled & operated as single installation
- Improves reliability of planning & forecasting decentralized sources
- Promotes efficient use of decentralized energy, & greater diversity of sources
- Enables decentralized sources to operate flexibly either as a single unit, or in island-mode to serve a more localized network
- Includes cogeneration modules (8MW), hydropower & wind farm (12MW)
- Distributed Energy Management System
Resilience
Revealed by Hurricane Sandy

Co-Op City, Bronx, NYC

- 14,000 apartments
- 35 high-rise buildings
- 40MW steam turbine generator, plus CHP
- Operates on a micro grid
- Retained power for 60,000 residents
Grid Automation
Hawaiian Electric Company, East Oahu, USA

- Automation of 46kV sub-transmission system
- To address overload & reliability issues in East Oahu
- New transformers installed to shift load from north to south corridor
- Automated high-load distribution circuits to feed sections of East Oahu
- Creates intelligent hierarchical control systems
- Substations & devices become intelligent agents supervised by the control center, providing robust contingency situations, maintenance switching, fault isolation & restoration
Transport System Resilience

- Prioritised signalling for emergency vehicles
- Multi-modal systems provide options
- Real-time data enables coordination of evacuation
- Modern rail controls create capacity
Vehicle-to-Infrastructure Communications
Houston, Texas, USA

- Pilot project in Harris County, Texas, in response to Hurricane Ike
- Traffic lights & vehicles communicate in real time
- Data from smart phones in vehicles are aggregated to produce real-time estimates of numbers of vehicles on the road, & their speeds
- Data mapped in a database accessible to drivers via smartphone
- During evacuation, allows drivers to choose route with shortest travel time
- Traffic lights can detect emergency vehicles & turn green to facilitate rapid response
Communications-Based Train Control
Metro lines - São Paulo, New York, Paris, Beijing

- Railway signaling system using telecommunications between train & track equipment for traffic management
- Position of train known more accurately
- Safer & more efficient way to manage railway traffic
- Enables improved time intervals between trains, & therefore increased passenger capacity on the line
- Technology allows ‘driverless trains’
- More energy-efficient than traditional signaling equipment, reducing draw on the grid
Transport Coordination Centre

London 2012 Olympics, UK

- Transport Coordination Centre for the London Olympics 2012
- Active sharing of information & coordinated responses to incidents
- Multi-modal transport providers & other key stakeholders
- Supported the 2012 Games additional spectator movement, whilst enabling London & the UK to maintain free flow of people
- Estimated passenger time savings due to TCC intervention on a single event at Bank Station, were quantified at £85,538
Water System Resilience

- Leak detection enables rapid response
- Automated distribution re-directs supply
- Quality sensors monitor & control pollution
- Automated monitoring forecasting dam failures
Real-time Levée Monitoring System
Livedijk, Netherlands

- EU Urban Flood project
- Internet-based early warning system issues warnings if there is threat of flood or breaks in dikes
- Sensors buried in dike measure water height/pressure, moisture, temperature
- Data transferred to via internet to connected server
- System evaluates data & issues early warning
- Seasonal & daily weather phenomena are integrated within the evaluation
- Livedijk at Eemshaven is first coastal levée that can be monitored online
6 major earthquakes in California the last 100 years

San Francisco undertaking a $4.6 billion comprehensive program to upgrade the water system by 2016

Broad range of projects covering all aspects of the water system – from dams, reservoirs, pipelines, & tunnels to treatment facilities & pump stations

The aim is to ensure that should a large seismic event occur, the system can remain relatively intact & continue to deliver water to 2.4 million people

The project includes projects that harden the infrastructure, add redundancy to the system & increase monitoring & automation
Action points

- Resilience is a must to become and remain competitive
- Resilience should be an integral part of planning and can be achieved through normal operational investment cycles
- Resilience provides additional benefits, e.g. energy efficiency, safety & security etc.
- Intelligent, automated, infrastructure is a major lever for resilience