GLOBAL CLIMATE CHANGE IMPACTS ON COASTAL INFRASTRUCTURE SERVICES

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GLOBAL WARMING CONDITIONS IMPACTING INFRASTRUCTURE

- **Increasing Temperature Affecting Condition of Building Materials**

- **Sea Level Rise Inundating and Disabling Coastal Infrastructures**

TABLE 9-7

Transportation Facilities Potentially with More Modest Vulnerability of Inundation from Global Climate Change (at NGVD 10 ft < NGVD <= 12 ft)

Facility and Owner/Operator	Elevation (NGVD)
MTA	
AMTRAK/LIRR East River Tunnel, Top of ramp	12
AMTRAK/LIRR West Side Storage Yard	10
LIRR Far Rockaway Branch Line, Valley Stream Station	11.4
Metro-North Grand Central Terminal, Steinway Tube, Queens Vent (#7 line)	11.0
53rd St. Tunnel at Nott Ave. Vent	10
Rutgers St. Tunnel at South St. Vent (F line)	10.6
Metro-North/TA Steinway Tunnel at 50th Ave. Vent (7 line)	11
Brooklyn-Battery Tunnel, Brooklyn Entrance	11.6
Queens Midtown Tunnel, Queens Entrance	10.6
Bronx-Whitestone Bridge	12
Throgs Neck Bridge	10
PANYNJ	
Holland Tunnel, New Jersey River Vent Shaft	10.6
Holland Tunnel, New Jersey Vent Shaft	10.6
Lincoln Tunnel, New York River Vent Shaft	11.6
Lincoln Tunnel, New York Third Tube Vent Shaft	10.6
JFK International Airport	11.7
Newark International Airport	10.3
NJDOT	
U.S. Highway 1 at Linden, Union County	11

Source: USACE, FEMA, NWS (1995) and reported in (Jacob, Edelblum, and Arnold, April 2000)

R. Zimmerman and M. Cusker, "Institutional Decision-making," Chapter 9 and Appendix 10 in *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change. Metro East Coast,* edited by C. Rosenzweig and W.D. Solecki, New York, NY: Columbia Earth Institute 2001. Pp. 9-1 to 9-25 and A11-A17.

TABLE 9-6

Transportation Facilities Potentially Most Vulnerable to Inundation from Global Climate Change (at NGVD < or = to 10 ft.)

Facility and Owner/Operator	Elevation (NGVD)
Metropolitan Transportation Authority (MTA)	
AMTRAK/LIRR East River Tunnel, Long Island Shaft	9
LIRR Long Beach Branch Line, Oceanside Tunnel	6.2
LIRR Port Washington Branch Line, Flushing Tunnel	9.2
LIRR Far Rockaway Station	9.2
LIRR Oyster Bay Station	9.5
Metro-North Hudson Line tracks, South of Croton River	6.3-6.5
Metro-North Hudson Line tracks, Croton River Bridge	7.0-7.5
Metro-North Hudson Line, Spuyten Duyvil Station	7.7
Metro-North New Haven Line at Sherwood Millpond	9.8
Metro-North New Haven Line at Grasmere Brook	9.6
14th St. Tunnel at Avenue D vent (L line)	7.2
Canal Street Grate (1, 2, 3, 9 lines)	9.8
Canal Street Station (A, C, E lines)	8.7
Clark Street Tunnel at Front Street Vent (2, 3 lines)	9.1
Cranberry Street Tunnel at Front Street Vent (A, C lines)	7
Greenpoint-Jackson Ave. (Newtown Center) Vent (G line)	8.1
Joralemon Tunnel at State St. Grate (4 and 5 lines)	9.8
Lexington Ave. Tunnel at 135th St. Bronx Vent (4, 5, 6 lines)	9.9
Montague St. Tunnel at Broad St. Vent (M, N, R lines)	7.5
South Ferry Station (1, 9 lines)	9.1
Whitehall St. Station (M, N, R lines)	9.1
Christopher St. Station	-14.6
9th St. Station	-15
12th St. Station	0
Brooklyn-Battery Tunnel, Morris St. Entrance	8.6
Brooklyn-Battery, West St. Entrance	8.6
Cross Bay Parkway (Bridge), Queens	8
Marine Parkway/Gil Hodges Memorial Bridge	8
Verrazano-Narrows Bridge	8
Port Authority of New York and New Jersey (PANYNJ)	
PATH Stations at Exchange Place, Grove St., Hoboken, Pavonia	7, 9.8, 7.4, 10
PATH shafts at Morton St., Railroad Ave., Washington St.	7.3, 9.7, 7.6
***Port Authority of New York and New Jersey (PANYNJ)* CONTINUED**	
PATH/TA Station (Ramp D) at World Trade Center	8.1
Holland Tunnel, New Jersey Entrance	7.6
Holland Tunnel, New Jersey Land Vent Shaft	7.6
Holland Tunnel, New York Entrance	9.5
Holland Tunnel, New York River Vent Shaft	8.6
Holland Tunnel, New York Land Vent Shaft	8.6
Autoport Marine Terminal in Essex County, NJ	9.5
Howland Hook Marine Terminal in Staten Island	9.9
Port Newark & Elizabeth	9.6
Red Hook Marine Terminal in Brooklyn	9.8
Passenger Ship Terminal	8.9
Pier 40	8.9
LaGuardia Airport	6.8
Teterboro Airport	5
NYC DOT	
Battery Park Tunnel	9
West Street	9
FDR Drive, above 59th St. and vicinity of Williamsburg Bridge	6
NJ DOT	
U.S. Highway 1 at Rahway and Elizabeth in Union County	9.4 and 9.6
U.S. Highways 1 and 9 at Jersey City and Newark in Hudson County, and North Bergen Township in Bergen County	2, 6.8, 8
I-95 in Bergen County	5.8
N.J. Route 17 in Bergen County	3.9
U.S. Highway 46 at Little Ferry in Bergen County	5.6
N.J. Route 3 at Secaucus in Hudson County	8
NYS Department of Parks and Recreation	
Meadowbrook Parkway	7.3
Wantaugh Parkway	6.3

Source: USACE, FEMA, NWS (1995) and reported in Chapter 4 *Infrastructure.*

R. Zimmerman and M. Cusker, "Institutional Decision-making," Chapter 9 and Appendix 10 in *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change. Metro East Coast,* edited by C. Rosenzweig and W.D. Solecki, New York, NY: Columbia Earth Institute 2001. Table 9-6.

BASELINE FOR INFRASTRUCTURE

Physical Condition of Infrastructure

Aviation	D+	Rail	C-
Bridges	C	Roads	D
Dams	D	Schools	D
Drinking Water	D-	Security	I
Energy	D	Solid Waste	C+
Hazardous Waste	D	Transit	D+
Navigable Waterways	D-	Wastewater	D-
Public Parks & Recreation	C-		

America's Infrastructure GPA D

Total investment needs $1.6 trillion

(estimated 5 year need)

Source: ASCE (2005) "2005 Report Card for America's Infrastructure," Online. Available at: <http://www.asce.org/reportcard/2005/index.cfm> (accessed November 7, 2005).

Social Conditions of Infrastructure

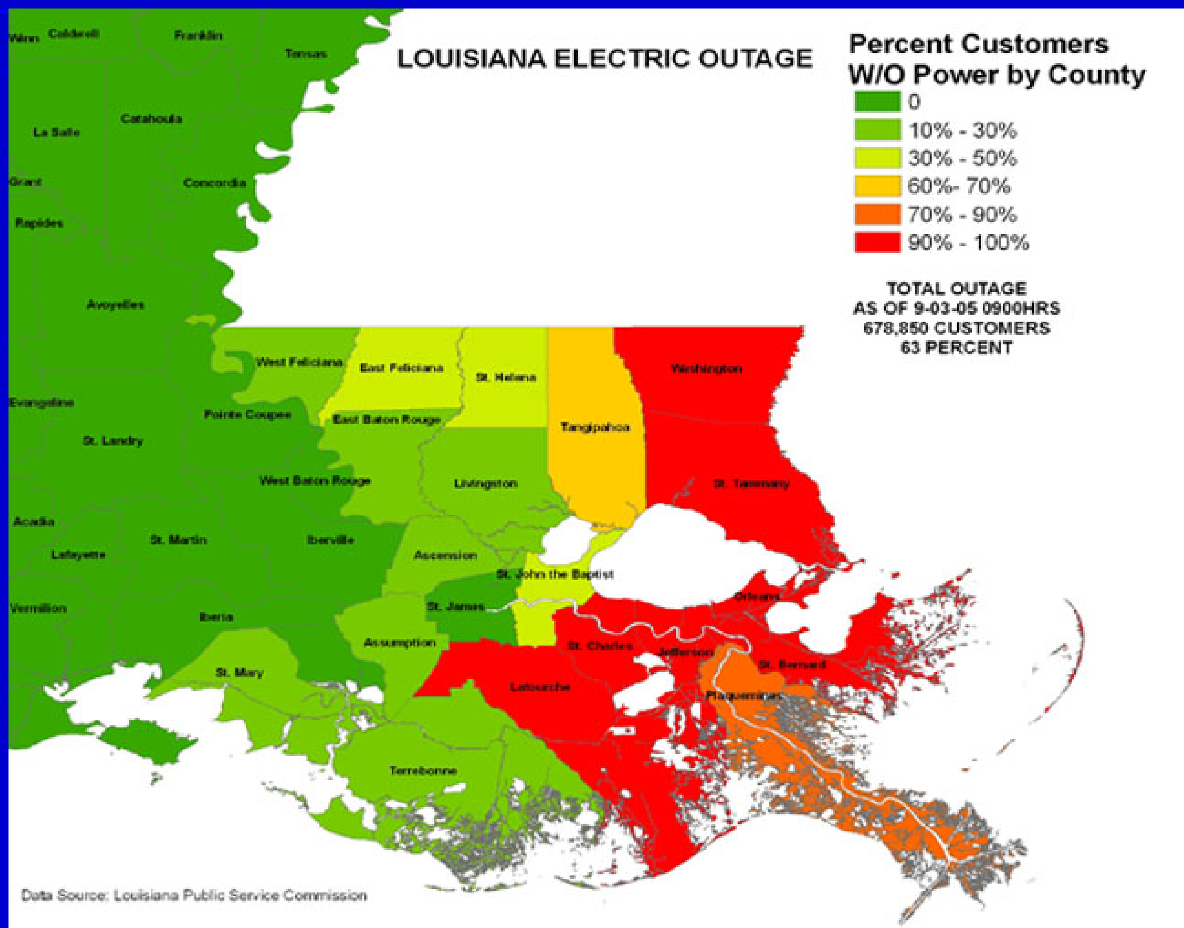
- **Accessibility**
- **Affordability**

POTENTIAL IMPACTS OF GLOBAL WARMING ON INFRASTRUCTURE

- **Electricity outages due to submerged electric power facilities**
- **Outages of Infrastructure Dependent on Electric Power**
- **Flooding of conduits and facilities located near coasts and riverine areas**
- **Potential perpetuation of the global warming phenomenon due to overuse of energy**

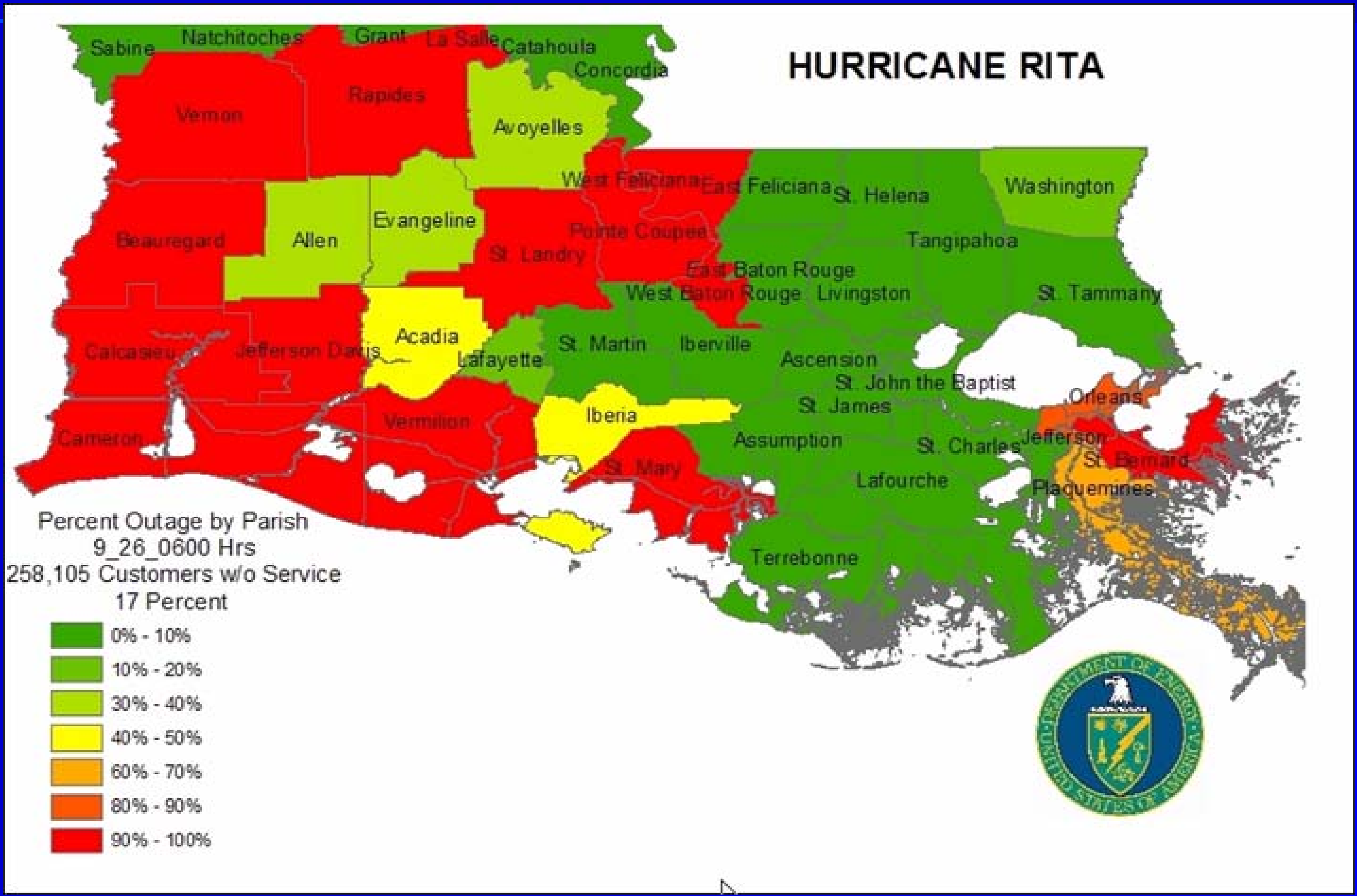
Electricity Outages – Analogies to Hurricane Katrina (LA), 9/03/2005

US DOE, Office of Electricity Delivery and Energy Reliability



Source: http://www.electricity.doe.gov/images/la_outage_9_3_0900.jpg

Electricity Outages – Analogies to Hurricane Rita (LA by Parish)



Source:http://www.electricity.doe.gov/about/../images/rita_outage_092605_0600.jpg

Water Supply/Wastewater Outages -Hurricane Katrina, 2005

LOUISIANA, MISSISSIPPI, ALABAMA:

- **About 1000 water supply systems were destroyed, disabled or contaminated, with 90% still affected after two weeks**
- **Extensive contamination of drinking water and standing water occurred**
- **About 172 wastewater treatment plants were disabled**

(Sources: U.S. EPA, http://www.epa.gov/katrina; NRDC 2005: 4):

Debris Accumulation – Analogy to Major Disasters

Location	Event	Date	Volume of Debris
Metro-Dade County, FL	Hurricane Andrew	August 1992	43 million cubic yards
Los Angeles, CA	Northridge	January 1994	7 million cubic yards
Kauai, HI	Hurricane Iniki	September 1992	5 million cubic yards
Mecklenburg County, NC	Hurricane Hugo	September 1989	2 million cubic yards
Gulf States	Hurricane Katrina	August 2005	22 million tons
New York, NY	WTC attack	September 2001	1.6 million tons
Midwest: 75 towns, 9 states	Floods	Summer 1993	Not available

Source: The first four entries are summarized from U.S. EPA, (1995) *Planning for Disaster Debris*. Washington, DC: U.S. EPA. Gulf State estimates for Hurricane Katrina and NYC 9/11 estimates are government estimates.

Communication Failures - Hurricane Katrina

Process

- Those requiring evacuation and health care institutions are unable to communicate with responders
- People in shelters cannot communicate with service/supply providers
- Criminal threats cannot be communicated
- Overall effects are differentially felt by different populations

Technology

- Bridge collapse destroys most of fiber optic cable lines
- Electric power disruptions disable cell towers and cell phones and radio and television broadcasting
- Innovative technologies are used: satellite radio, ham radios

Infrastructure Recovery: Electricity Outage Durations T(e) and Affected Infrastructure Outage Duration T(i)

Outage Durations for the August 2003 Blackout
(Total Duration = 42-72 hours)

	T(i)/T(e)
Transit-electrified rail (NYC)	**1.3**
Traffic Signals (NYC)	**2.6**
Water Supply (Cleveland, OH)	**2.0**
Water Supply (Detroit, MI)	**3.0**

Source: R. Zimmerman and C. Restrepo, "The Next Step: Quantifying Infrastructure Interdependencies to Improve Security," ***International Journal of Critical Infrastructures*****, 2005 forthcoming. UK: Inderscience Enterprises, Ltd. www.inderscience.com Summarized from Table 3.**

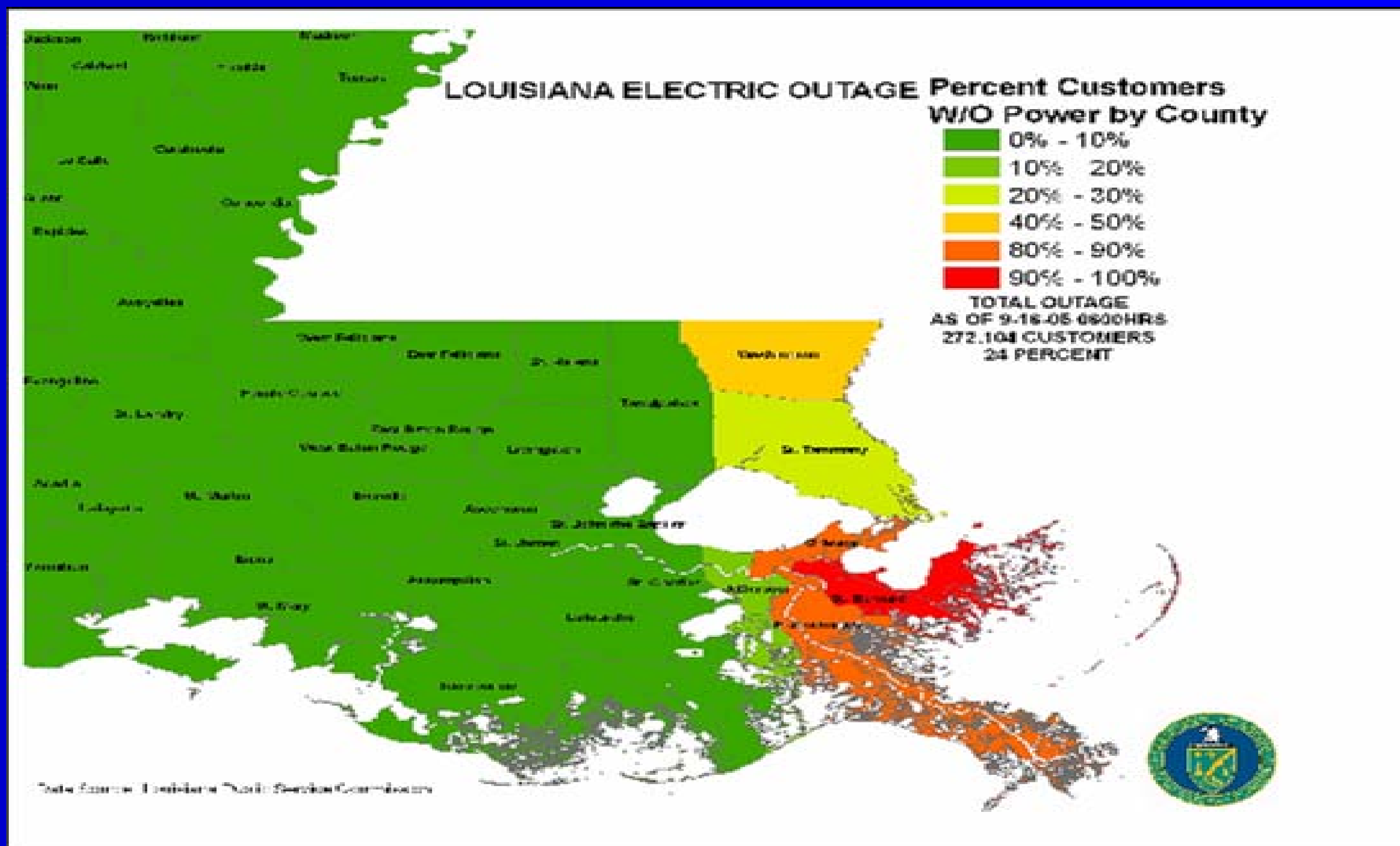
INFRASTRUCTURE RECOVERY: Oil Pipelines

- Colonial Pipeline linking Gulf Coast to northeast recovers in about six days
- Recovery after Hurricane Katrina occurs more rapidly and is more evenly distributed than after Hurricane Rita

Source: NYU-Wagner I3P SCADA project funded through the Dartmouth I3P Consortium (see acknowledgements)

Infrastructure Recovery: Electric Power Outages (LA) - Hurricane Katrina, 9/16/2005

US DOE, Office of Electricity Delivery and Energy Reliability



Source:http://www.electricity.doe.gov/program/../images/la_outage9_16_0600.jpg

Infrastructure Recovery: Debris Removal after the World Trade Center attacks, 9/11/01, NYC

- Debris removal at the WTC site occurs at a steady pace
- Removal is completed earlier and at a lower cost than initially estimated
- Fast-track procedures for debris disposal were used, including reopening Fresh Kills and use of storage at JFK airport

Source: R. Zimmerman, “Public Infrastructure Service Flexibility for Response and Recovery in the September 11th, 2001 Attacks at the World Trade Center,” in Natural Hazards Research & Applications Information Center, Public Entity Risk Institute, and Institute for Civil Infrastructure Systems, Beyond September 11th: An Account of Post-Disaster Research. Special Publication #39. Boulder, CO: University of Colorado, 2003.

INFRASTRUCTURE INNOVATIONS - Recovery

Post-Katrina

- Communications: Innovative use of technologies - satellite radios, ham radios
- Oil and gas pipeline recovery methods

Post-September 11, 2001 WTC Attacks

- Electric Power: Immediate Recovery - Cables Installed Over Streets
- Electric Power: Longterm Recovery – Rapid installation of replacement substations in Lower Manhattan

INFRASTRUCTURE INNOVATIONS – Prevention Scenarios: Alternative Vehicle GHG Emissions & Fuel Economy

CAR MODEL	GREENHOUSE GAS (GHG) EMISSIONS/ FUEL ECONOMY
Hybrid Cars	3.5-6.0 ave. annual tons CO_2 29-56 combined mpg
Electric Vehicles	3.5-7.8 ave. annual tons CO_2 55-123 combined mpg
Regular or Typical Car	8.4 ave. annual tons CO_2 23 combined mpg

Source: Based on data from www.fueleconomy.gov; from R. Zimmerman, "Robust Transportation and Future Threats: from Terrorism to Climate Change," Presentation for the U.S. DOT, FHWA Advanced Research Forum, Boston, MA, July 13, 2005.

INFRASTRUCTURE INNOVATIONS – Prevention Scenarios for Transportation

Source: R. Zimmerman, "Robust Transportation and Future Threats: from Terrorism to Climate Change," Presentation for the U.S. DOT, FHWA Advanced Research Forum, Boston, MA, July 13, 2005.

	GCC Criteria			
Security Criteria	Reduce Fossil Fuel Usage in Transpor-tation	Reduce Land Consumption to Reduce Travel	Reduce Traffic Congestion	Use Alternative Transport Technology
Decentrali-zation / decoupling	X	(X)	X	(X)
Sustained capacity	X	X	X	X
Compati-bility	X	X	X	X

CONCLUSIONS

- Infrastructure is both a cause of global climate change, and is highly vulnerable to the effects or consequences of global climate change
- Innovations exist to reduce infrastructure contributions to global warming and to reduce consequences to infrastructure of effects of global warming
- Global climate change and security needs for infrastructure can be met simultaneously

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Author's Related Earlier Work:

Zimmerman, R. "Global Climate Change and Transportation Infrastructure: Lessons from the New York Area," in *The Potential Impacts of Climate Change on Transportation: Workshop Summary and Proceedings*, Washington, DC: U.S. DOT, 2003, pp. 91-101. http://climate.volpe.dot.gov/workshop1002/index.html;

Zimmerman, R. and M. Cusker, "Institutional Decision-making," Chapter 9, 10 in *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change*. Metro East Coast, C. Rosenzweig and W. D. Solecki, eds. NY, NY: Columbia Earth Institute and Goddard Institute of Space Studies, 2001, pp. 9-1 to 9-25; A11-A17.

Zimmerman, R. "Global Warming, Infrastructure, and Land Use in the Metropolitan New York Area: Prevention and Response," in *The Baked Apple? Metropolitan New York in the Greenhouse*, Douglas Hill, ed. NY, NY: NY Academy of Sciences, 1996. Pp. 57-83.