Congressional Research Service

Vulnerability of Concentrated Critical Infrastructure: Background and Policy Options

name redacted
Specialist in Energy and Infrastructure Policy

September 12, 2008

Congressional Research Service
7-....
www.crs.gov
RL33206

CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

"Critical infrastructure" consists of systems and assets so vital to the United States that their incapacity would harm the nation's physical security, economic security, or public health. Critical infrastructure is often geographically concentrated, so it may be distinctly vulnerable to events like natural disasters, epidemics, and certain kinds of terrorist attacks. Disruption of concentrated infrastructure could have greatly disproportionate effects, with costs potentially running into billions of dollars and spreading far beyond the immediate area of disturbance. Hurricane Katrina in 2005, and Hurricane Ivan in 2008, have demonstrated this kind of geographic vulnerability by disrupting much of the U.S. energy and chemical sectors.

Congress has been examining federal policies related to the geographic concentration and vulnerability of critical infrastructure. In the 109th Congress, the Energy Policy Act of 2005 (P.L. 109-58) facilitated the construction of new liquefied natural gas import terminals in diverse ports. Provisions in the Pipeline Safety Improvement Act of 2006 (P.L. 109-468) require studies to identify geographic areas in the United States where unplanned loss of oil pipeline facilities may cause oil shortages or price disruptions. The 110th Congress is considering additional policies which may affect critical infrastructure concentration. Prominent among these are legislative proposals such as H.R. 6566, H.R. 6709, S. 3202, and S. 3126, which would lift federal moratoriums on, or otherwise encourage, offshore oil and natural gas development outside the western Gulf of Mexico.

Geographic concentrations of U.S. critical infrastructure typically have developed through some combination of market influences, including resource location, agglomeration economies, scale economies, community preferences, and capital efficiency. Congress and federal agencies also have adopted policies affecting the capacity and location of critical infrastructure, including prescriptive siting, economic incentives, environmental regulation, and economic regulation. Some federal policies have been developed specifically to address perceived threats to critical infrastructure. These influences often have been in place for decades, gradually driving critical infrastructure to its geographic configuration today.

Some analysts may argue that little government intervention is necessary to alleviate geographic vulnerabilities of critical infrastructure because the private sector will adjust its practices out of its own financial interest. However, if Congress concludes that federal intervention is needed, it may employ a number of policy options to encourage geographic dispersion (including eliminating policies that encourage concentration), ensure survivability, or ensure that effective infrastructure recovery capabilities are in place to mitigate impacts of concentrated infrastructure disruption. Addressing geographic vulnerabilities may call for a combination of options. Congress may also consider whether other legislative proposals with the potential to affect critical infrastructure development—directly or indirectly—are likely to relieve or exacerbate geographic vulnerability. The economic efficiency of public critical infrastructure and the efficient use of federal funds for infrastructure development may also be important considerations.

Contents

Introduction 1
Scope and Limitations 2
Geographic Infrastructure Concentration 2
What is Critical Infrastructure? 2
What is Geographic Concentration? 3
Geographic Hazards 5
Meteorological Events 5
Earthquakes and Tsunamis 5
Infectious Disease 6
Terrorism 7
Frequency of Major Geographic Events 7
Market Influences on Geographic Concentration 8
Resource Location 8
Agglomeration Economies 9
Scale Economies 10
Community Preferences 10
Capital Efficiency 11
Federal Policies and Infrastructure Concentration 11
Prescriptive Siting 12
Economic Incentives 12
Environmental Regulation 13
Economic Regulation 14
Policy Options to Reduce Infrastructure Vulnerability 15
Eliminating Policies Encouraging Concentration 15
Encouraging Geographic Dispersion 16
Ensuring Infrastructure Survivability 17
Ensuring Infrastructure Recovery Capabilities 18
Conclusions 18

Figures

Figure 1. Oil and Gas Pipelines in the Continental United States 9

Tables

Table 1. Selected U.S. Disasters Since 1990 with Costs Exceeding $1 Billion 7

Contacts

Author Contact Information 19

Introduction

Critical infrastructure is so vital to the United States that its incapacity would harm the nation's physical security, economic security, or public health. The federal government has a key role in helping protect the nation's critical infrastructure from all types of hazards through programs of mitigation, preparedness, response, and recovery. Accordingly, Congress has a strong interest in the vulnerability of critical infrastructure to natural hazards, accidents, or terrorism. Since September 11, 2001, legislators, government agencies, and industry increasingly have been focused on the sources of infrastructure vulnerability and potential measures to address those vulnerabilities through operational changes and capital investment.

When infrastructure is physically concentrated in a limited geographic area it may be particularly vulnerable to geographic hazards such as natural disasters, epidemics, and certain kinds of terrorist attacks. Whereas a typical geographic disruption is often expected to affect infrastructure in proportion to the size of an affected region, a disruption of concentrated infrastructure could have greatly disproportionate—and national—effects. A catastrophic ice storm in metropolitan Chicago, for example, would undoubtedly create local emergencies, but could also temporarily disrupt rail transportation and associated commerce throughout the country because Chicago is a major railway hub. Extended closure of the port of Long Beach, the largest port in the nation, would greatly harm California's economy, but could also disrupt vital supply chains for a number of national industries.[1] The social and economic impacts of geographic disasters are often difficult to quantify, but their costs can quickly run into the billions and can spread far beyond the area of the event itself. In 2005, Hurricanes Katrina and Rita demonstrated this kind of geographic impact by disrupting a substantial part of the national U.S. energy and chemical sectors, both heavily concentrated in the Gulf of Mexico. In 2008, Hurricanes Gustav and Ike have caused similar disruptions, renewing concerns about geographic vulnerability.

As the nation's responses to recent natural disasters continue, and as its homeland security activities evolve, Congress has been examining federal policies related to the geographic concentration and vulnerability of critical infrastructure. For example, in the 109th Congress, the Energy Policy Act of 2005 (P.L. 109-58) facilitated the construction of new liquefied natural gas import terminals in diverse ports by granting the Federal Energy Regulatory Commission exclusive siting approval authority (Section 311). Provisions in the Pipeline Safety Improvement Act of 2006 (P.L. 109-468) require periodic studies to identify geographic areas in the United States where unplanned loss of oil pipeline facilities may cause oil shortages or price disruptions (Sec. 8(a)). The 110th Congress is overseeing implementation of these measures and considering additional policies which may affect critical infrastructure concentration. Prominent among these are legislative proposals such as H.R. 6566, H.R. 6709, S. 3202, and S. 3126, which would lift federal moratoriums on, or otherwise encourage, offshore oil and natural gas development outside the western Gulf of Mexico.[2]

This report provides an overview of geographic concentration and related vulnerability among critical infrastructures in the United States. The report illustrates the nature of such geographic

---

[1] Hall, P.V. "'We'd Have to Sink the Ships': Impact Studies and the 2002 West Coast Port Lockout." *Economic Development Quarterly*, vol. 18, no. 4. November 2004, pp. 354-367.

[2] For further discussions, see CRS Report RL33404, *Offshore Oil and Gas Development: Legal Framework*, by (name redacted), and CRS Report RL33493, *Outer Continental Shelf: Debate Over Oil and Gas Leasing and Revenue Sharing*, by (name redacted).

concentration and how it may expose infrastructures to catastrophic failure due to geographic hazards. It identifies several long-term forces which have contributed to infrastructure concentration. These forces include resource location, agglomeration economies, scale economies, community preferences, and capital efficiency. It reviews several ways in which the federal government has also influenced critical infrastructure, such as prescriptive siting, economic incentives, environmental regulation, and economic regulation. The report concludes with options to address geographic vulnerability in the context of current federal infrastructure policy.

Scope and Limitations

This report focuses on "nationally" critical infrastructure and related federal policies. While many of the infrastructure and policy issues addressed in this report may also apply at the state and local levels, the report discusses them only in the context of federal activities. This report also discusses a number of specific geographic hazards to critical infrastructure in the context of a broader federal policy discussion. The report does not attempt to quantify the likelihood of any particular hazard occurring in any particular location, or the degree of vulnerability of any particular infrastructure concentration to geographic hazards. Such projections are available elsewhere[3] and are beyond the scope of this analysis.

Geographic Infrastructure Concentration

What is Critical Infrastructure?

Twenty years ago, "infrastructure" was defined primarily with respect to the adequacy of the nation's public works.In the mid-1990's, however, the growing threat of international terrorism led policy makers to reconsider the definition of "infrastructure" in the context of homeland security. Successive federal government reports, laws, and executive orders have refined, and generally expanded, the number of infrastructure sectors and the types of assets considered to be "critical" for purposes of homeland security. The USA PATRIOT Act of 2001 (P.L. 107-56 Section 1016e) contains the federal government's most recent definition of "critical infrastructure." According to the act, "critical infrastructure" is

> systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (Section 1016e).

This definition was adopted, by reference, in the Homeland Security Act of 2002 (P.L. 107-296, Section 2.4) establishing the Department of Homeland Security (DHS). The Bush Administration's 2006 *National Infrastructure Protection Plan* (NIPP) contains a detailed list of critical infrastructures and assets of national importance, as follows:

[3] See, for example: Risk Management Solutions, Inc., "Catastrophic Risk in the United States," cited in U.S. Government Accountability Office, *Natural Disasters: Public Policy Options for Changing the Federal Role in Natural Catastrophe Insurance*, GAO-08-7, November 2007, p. 9.

- Agriculture and food
- Banking and finance
- Chemicals
- Commercial facilities
- Commercial nuclear
- Critical manufacturing[4]
- Dams
- Defense industrial base
- Drinking water/water treatment
- Emergency services
- Energy (except nuclear)
- Government facilities
- Information technology
- National monuments/icons
- Postal and shipping
- Public health and healthcare
- Telecommunications
- Transportation

As the list suggests and the NIPP acknowledges explicitly, "The majority of the [critical infrastructure/key resource]-related assets, systems, and networks are owned and operated by the private sector."[5] The list may continue to evolve as economic changes or geopolitical developments influence homeland security policy.

What is Geographic Concentration?

This report defines "geographic concentration" of critical infrastructure as the physical location of critical assets in sufficient proximity to each other that they are vulnerable to disruption by the same, or successive, regional events. To be of national significance, the collection of concentrated assets may account for a significant fraction of the nation's total infrastructure capacity in a given sector or subsector. Alternatively, the collection of regional assets could make up an infrastructure hub, accounting for a nationally significant fraction of commodity or service flows through that infrastructure sector or subsector. The threshold above which such assets could be considered "nationally" concentrated would depend upon the type of impact resulting from a prolonged disruption. From strictly a market perspective, for example, some policy makers have suggested that a change in energy infrastructure capacity of as little as 10% to 15% could have an exaggerated effect on related market prices.[6] The corporate merger guidelines used by the United States, Canada, and the European Union variously assume that a company must have a 25% to 35% market share to exercise market power, and so uncompetitively influence market prices or supplies.[7] Although the loss of critical infrastructure would have effects beyond market price, other possible metrics of concentration (e.g., environmental) offer little additional clarity on concentration thresholds.

---

[4] "Critical manufacturing" was subsequently added to this list by the DHS. See Department of Homeland Security, "Designation of the National Infrastructure Protection Plan Critical Manufacturing Sector," Docket No. DHS-2008-0038, *Federal Register*, April 30, 2008 (Volume 73, Number 84), pp. 23476-23478.

[5] NIPP. p. 10.

[6] Hon. Joe Barton, Remarks at the House Energy and Commerce Committee Hearing on Recovering from Katrina, September 7, 2005.

[7] Facey, B.A. and H. Huser, "A Comparison of Horizontal Merger Guidelines in Canada, the European Union, and the United States," *Antitrust*, fall 2004, pp. 43-50.

Many of the critical infrastructure sectors identified in the NIPP exhibit some degree of geographic concentration, as illustrated by the following examples.

- Chemicals (chlorine)—Over 38% of U.S. chlorine production is located in coastal Louisiana.[8]
- Transportation (marine cargo)—Over 33% of U.S. waterborne container shipments pass through the ports of Long Beach and Los Angeles in southern California.[9]
- Transportation (rail)—Over 37% of U.S. freight railcars pass through Illinois, primarily around Chicago. Over 27% of freight railcars pass through Missouri, primarily around St. Louis.[10]
- Agriculture and food (livestock)—Approximately 28% of U.S. hog inventories are located in Iowa. Another 15% of hog inventories are located in the eastern counties of North Carolina.[11]
- Public health and health care (pharmaceuticals)—Approximately 25% of U.S. pharmaceuticals are manufactured in Puerto Rico, primarily in the San Juan metropolitan area.[12]
- Energy (refining)—Approximately 43% of total U.S. oil refining capacity is clustered along the Texas and Louisiana coasts.[13]
- Banking and finance (securities market)—Approximately 39% of U.S. securities and options (by market value) are traded on the floors of the New York and American Stock Exchanges in lower Manhattan.[14] Approximately 21% of U.S. securities industry employees are located in New York City.[15]
- Defense industrial base (shipyards)—Over 31% of U.S. naval shipbuilding and repair capacity is in and around Norfolk, VA.[16]

---

[8] U.S. Census Bureau, *Alkalies and Chlorine Manufacturing: 2002*, Economic Census, Manufacturing Industry Series, EC02-31I-325181 (RV), December 2004, Table 2, Table 6b.

[9] Army Corps of Engineers, Waterborne Commerce Statistics Center (WCSC). "U.S. Waterborne Container Traffic by Port/Waterway in 2006." Last revised January 29, 2008. http://www.iwr.usace.army.mil/ndc/wcsc/by_portname06.htm.

[10] Assoc. of American Railroads. "Rail Carloads Carried by State: 2006." 2008. http://www.aar.org/PubCommon/Documents/AboutTheIndustry/RRState_Rankings.pdf.

[11] U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), *Quarterly Hogs and Pigs*, June 27, 2008. p. 5.

[12] U.S. Census Bureau, *Pharmaceutical Preparation Manufacturing: 2002*, Economic Census, Manufacturing Industry Series. EC02-31I-325412 (RV), December 2004. Table 2; *Puerto Rico Manufacturing.* 2002 Economic Census of Island Areas. IA02-00I-PRM (RV). October 2005. Table 1.

[13] Energy Information Administration. *Refinery Capacity 2008*. June 20, 2008. Table 1. http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcapacity.html.

[14] U.S. Securities and Exchange Commission. "Select SEC and Market Data Fiscal 2006." 2007. Table 12. http://www.sec.gov/about/secstats2007.pdf.

[15] Securities Industry Association (SIA). "Securities Industry Employment." August 2008. p. 7. See http://www.sifma.org/research/statistics/other/employment-NY-quarterly.pdf.

[16] Colton Company. "Employment in the Major Shipbuilders." August 14, 2006. http://www.shipbuildinghistory.com/today/statistics/jobsbyyard.htm Capacity estimate based on 2004 major shipyard relative employment data.

In addition to single infrastructure concentrations, some regions of the United States contain concentrations of multiple critical infrastructures. As indicated in the examples above, coastal Louisiana has concentrations of both refining and chemical production capacity. In addition to a concentration of financial services, the metropolitan New York and New Jersey area contains a concentration of U.S. port capacity (12% of container shipping) and airport capacity (8% of airline passengers), among other critical infrastructure.[17]

Geographic Hazards

Where critical infrastructure is geographically concentrated, it may be distinctly vulnerable to a range of geographic hazards, including natural or unnatural events. These events could have varying potential for infrastructure disruption depending upon the type of event, its location, and the infrastructure sectors present in that location. What such events have in common is their geographic scale. Among the geographic events posing the greatest hazard to U.S. critical infrastructure concentrations are the following.

Meteorological Events

Major meteorological events, such as hurricanes, tropical storms, floods, and ice storms, have the potential to physically disrupt critical infrastructures or displace related critical workers in large geographic areas. For example, the damaging effects of hurricanes Katrina and Rita (and associated flooding) on energy and chemicals infrastructure in the Gulf of Mexico have been widely reported. In 1998, a major ice storm in Quebec, Canada, and the northeastern United States caused widespread, persistent power and communications blackouts, disrupted other power-dependent services, and prevented critical workers from traveling to their jobs.[18]

Earthquakes and Tsunamis

Earthquakes have the potential to damage concentrations of critical infrastructure in seismically active regions of the United States, including the west coast, Alaska, and the central Mississippi Valley. The 1994 earthquake in Northridge, CA, is an example of such seismic activity in a region with concentrated critical infrastructure. The Northridge earthquake had limited impact on the region's major ports, airports, and energy infrastructure, but it did cause significant damage to bridges and highways vital for commercial trucking and public transportation.[19] A 1995 earthquake in Kobe, Japan was far more destructive to Japanese critical infrastructure. In addition to highway damage, the earthquake heavily damaged the port of Kobe, Japan's largest container shipping port, as well as chemical manufacturers, steel manufacturers, railroads, and utilities in the area. Repairs to the port took almost a year to complete.[20]

---

[17] WCSC. 2008; U.S. Department of Transportation, Bureau of Transportation Statistics (BTS). *Airport Activity Statistics (AAS) 2000*. BTS01-05. 2002. Table 3.

[18] Environmental Index. "The Storm of the Century in Canada, January 1998." 2000. Some 700,000 Canadians were without power for over two weeks; U.S. Army Cold Regions Research and Engineering Laboratory. "An Evaluation of the Severity of the January 1998 Ice Storm in Northern New England: Report for FEMA Region 1." April 1998.

[19] M.G. Boarnet, "Business Losses, Transportation Damage, and the Northridge Earthquake." *Journal of Transportation and Statistics*, vol. 1, no. 2, May 1998.

[20] Risk Management Solutions, Inc. *1995 Kobe Earthquake 10-year Retrospective*. Newark, CA. January 2005. p. 5.

Coastal infrastructure concentrations are also potentially vulnerable to disruption by tsunamis. The infrastructure damage to Sri Lanka, India, Indonesia, and other Asian nations from the 2004 tsunami in the Indian Ocean was extensive. Experts have testified before Congress that the United States is also potentially vulnerable to a major tsunami.[21] Depending upon its magnitude, such an event could disrupt ports and other critical transportation infrastructure.[22] According to California's Seismic Safety Commission, for example, a major tsunami in southern California could close the ports of Long Beach and Los Angeles for two months and cause $60 billion in economic losses.[23]

Infectious Disease

Epidemics and pandemics of infectious diseases such as Severe Acute Respiratory Syndrome (SARS) and avian influenza (bird flu) have the potential to disrupt critical infrastructure by infecting critical workers or restricting their movement. The Bush Administration's *National Strategy for Pandemic Influenza* states that "while a pandemic will not damage power lines, banks or computer networks, it will ultimately threaten all critical infrastructure by removing essential personnel from the workplace for weeks or months."[24] An outbreak of infectious disease may sicken critical workers or force them into quarantine. It may also restrict their access to critical facilities where the disease may be present. As one federal government report states, during such an event "operations become disrupted, exposed people and facilities undergo extensive testing ... and buildings and equipment require decontamination."[25]

The 2003 SARS outbreak in Toronto demonstrated the vulnerability of critical health and transportation infrastructure in Canada to such an infectious disease. The World Health Organization, the U.S. Department of Health and Human Services, and other health organizations have since expressed concern about the likelihood of a bird flu pandemic with more serious potential consequences than SARS.[26] In the event of a bird flu or similar outbreak in a particular geography, some analysts have predicted up to 40% absenteeism among workers during the peak weeks of a regional outbreak.[27]

Concentrations of livestock may be similarly vulnerable to infectious disease, with the potential to catastrophically affect the nation's food supply. As one expert has testified before Congress, "animal diseases can be quickly spread to affect large numbers of herds over wide geographic areas. This reflects the intensive and concentrated nature of modern farming practices in the

---

[21] C. Groat, Director, United States Geological Survey (USGS). Testimony before the House Science Committee hearing, *Tsunamis: Is the United States Prepared?*, January 26, 2005.

[22] J. Borrero, S. Cho, J.E. Moore II, H.W. Richardson, and C. Synolakis, "Could it Happen Here?," *Civil Engineering*. April 2005. pp. 54-65.

[23] California Seismic Safety Commission. *The Tsunami Threat to California*. CSSC 05-03. December 2005. p. 6.

[24] Office of the President, Homeland Security Council. *National Strategy for Pandemic Influenza*. November 1, 2005. p. 2.

[25] A. Brecher, U.S. Department of Transportation (DOT), Volpe National Transportation Systems Center. "Cleanup and Recovery of Passenger Transportation Facilities after a Bio-attack." Workshop resource paper. March 30, 2004.

[26] For further background see CRS Report RL34190, *Pandemic Influenza: An Analysis of State Preparedness and Response Plans*, by (name redacted) and (name redacted); World Health Organization (WHO)*Avian Influenza: Assessing the Pandemic Threat*. WHO/CDS/2005.29. January 2005.

[27] U.S. Department of Health and Human Services. "Pandemic Influenza Planning." Internet page. December 5. 2005. See http://pandemicflu.gov/plan/pandplan.html.

US."[28] Foot and mouth disease (FMD), in particular, has the potential to infect regionally concentrated stocks of hogs, cattle, and sheep should they be exposed. A 2002 General Accounting Office report found that an FMD outbreak could cost the U.S. economy up to $24 billion dollars and could have "significant social impacts, such as enormous psychological damage, especially on families and localities directly affected by the outbreak."[29]

Terrorism

Certain types of terrorist attacks could be of sufficient scale to pose a geographic threat to critical infrastructure. Nuclear bombs, radiological weapons ("dirty" bombs), or electromagnetic pulse (EMP) devices could damage or render inaccessible concentrated critical assets. Cyber-attacks on regional computer systems also have the potential to damage or disrupt computer networks' ability to control critical infrastructure.[30] Biological attacks could have impacts similar to those of epidemics, although they could be more specifically targeted at particular regions.[31]

Frequency of Major Geographic Events

Taken individually, the types of disasters discussed above occur only rarely in a specific location. Taken collectively, however, such events occur often enough to warrant dedicated policy attention. As **Table 1** shows, reviewing only the past 15 years, major disasters have occurred in North America almost annually. Not all of these events have impacted regions of concentrated critical infrastructure, nor have they all significantly affected such infrastructure where it has been present. Nonetheless, the cost estimates for these events indicate their disruptive power.

Table 1. Selected U.S. Disasters Since 1990 with Costs Exceeding $1 Billion

Year	Event	Location	Costs ($ billions)
2006	Tornadoes	Midwest/Ohio Valley	1.1
2005	Hurricanes (Category 4, 3, 1)	Central Gulf of Mexico, Florida	113.8
2004	Hurricanes (Category 2, 3, 4)	Florida, Alabama	45.0
2003	Hurricane (Category 3)	Mid-Atlantic	3.4
2003	Epidemic (SARS)	Ontario	0.8[a]
2001	Terror attacks	New York, Virginia, Pennsylvania	38.0
2001	Tropical storm	Texas, Southeast U.S.	5.0
1998	Ice storm	Quebec, Northeast U.S.	1.4[b]
1997	Flood/Tornados	Ohio/Mississippi Valley	1.0

[28] P. Chalk, RAND Corp. "The Bio-Terrorist Threat to Agricultural Livestock and Produce." Testimony before the Senate Government Affairs Committee. November 19, 2003.

[29] General Accounting Office. *Foot and Mouth Disease*. GAO-02-808. July 2002. pp. 20-21.

[30] Weiss, J. "CyberWar." *Frontline*. Public Broadcasting System. Television interview. April 24, 2003.

[31] For further discussion see Senate Judiciary Committee, Subcommittee on Terrorism, Technology and Homeland Security hearing, *Lessons Learned from Hurricane Katrina in Regard to Emergency Preparedness for a Terrorist Attack*, October 26, 2005.

Year	Event	Location	Costs ($ billions)
1996	Hurricane (Category 3)	North Carolina	3.2
1995	Flood / Tornados / Hail	South Central U.S.	5.5
1994	Ice storm	Southeast U.S.	3.0
1994	Earthquake	California	40.0
1993	Flood	Midwest	21.0
1992	Hurricane (Category 5)	Florida, Louisiana	26.5

Sources: National Hurricane Center. "The Thirty Costliest Mainland United States Tropical Cyclones 1900-2005." Dec. 2007. http://www.aoml.noaa.gov/hrd/tcfaq/costliesttable.html; National Climatic Data Center. "1980-2007 Billion Dollar U.S. Weather Disasters." 2007. http://lwf.ncdc.noaa.gov/img/reports/billion/disasters2007.pdf; Dixon, L. and Stern, R.K., RAND Corp. "Compensation for Losses from the 9/11 Attacks." Nov. 8, 2004; Eyesenbach, G. "SARS and Population Health Technology." *Journal of Medical Internet Research*, vol. 5, no. 2, 2005;R.T. Eguchi, J.D. Goltz, C.E. Taylor, S.E. Chang, P. J. Flores, L. A. Johnson, H. A. Seligson, and N. C. Blais, "Direct Economic Losses in the Northridge Earthquake: A Three-Year Post-Event Perspective," *Earthquake Spectra*, vol. 14, no. 2, May 1998, pp. 245-264.

a. Includes only direct costs for extra protective gear, clinics, isolation rooms, and lost wages for quarantined health-care workers. Cost likely exceeds $1 billion with business losses included.

b. Excludes Canadian costs.

Market Influences on Geographic Concentration

Although attention to the geographic concentration of U.S. critical infrastructure has increased in the wake of recent terrorist attacks and natural disasters, such geographic concentrations are not new. They have developed for multiple reasons—typically some combination of market influences, including resource location, agglomeration economies, scale economies, community preferences, and capital efficiency. These influences often have been in place for decades, gradually driving critical infrastructure development to its geographic configuration today.

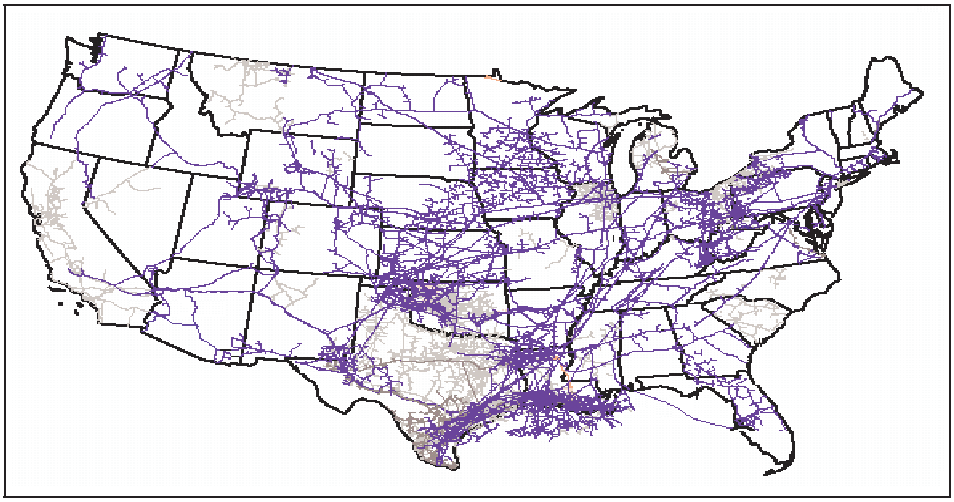
Resource Location

The location of certain critical infrastructures is driven by the location of related natural resources or, in some cases, natural terrain. Such influences are particularly apparent in energy, agriculture, and transportation. United States oil and natural gas basins, for example, are located in particular regions of the country, including the Gulf of Mexico, the Rockies, and Appalachia. These locations are generally far from Northeastern urban centers which are the primary locations of oil and gas demand. Consequently, large oil and gas pipelines tend to be concentrated between these widely separated resource regions and the Northeast, as shown in **Figure 1**. Likewise, production of phosphoric acid, a key component of agricultural fertilizer, is concentrated in Florida, which has the nation's largest deposits of phosphoric rock.[32] Agricultural production is also driven by geography, since particular crops require particular climates, weather conditions, and types of soil. Terrain may also be a driver of infrastructure concentration. There are relatively few natural harbors suitable as deepwater ports in the western United States compared to the eastern part of

[32] Environmental Protection Agency (EPA). "About Phosphogypsum." July 31, 2008. http://www.epa.gov/rpdweb00/neshaps/subpartr/about.html.

the country. Consequently, the ports that exist, such as Long Beach, have become very heavily utilized. In these cases, and others, the concentration of a natural resource drives the concentration of infrastructure exploiting that resource.

Figure 1. Oil and Gas Pipelines in the Continental United States



Source: Energy Information Administration.

Agglomeration Economies

Where resource location and terrain are not constraints, concentrations of critical infrastructure may emerge due to economic factors collectively referred to as "agglomeration economies."

> Broadly speaking, it is clear that [industry] concentrations form and survive because of some form of agglomeration economies, in which spatial concentration itself creates the favorable economic environment that supports further or continued concentration.[33]

For critical infrastructure, such agglomeration economies may include the availability of specialized knowledge, the availability of skilled workers, access to production inputs, and access to large markets for the goods and services produced.[34] The concentration of semiconductor manufacturing in Silicon Valley illustrates such economies. Silicon Valley emerged near major research institutions (e.g., Lawrence Livermore National Laboratory), with the ready availability of highly skilled graduates from leading research universities (e.g., U.C. Berkeley, Stanford University), and with access to both product suppliers, computer manufacturers (e.g., Apple Computer), and software companies. Agglomeration economies have also been demonstrated in food manufacturing, and may similarly influence other critical infrastructure sectors such as financial services, chemicals manufacturing, and telecommunications.[35]

---

[33] M. Fujita, P. Krugman, and A. Venables, *The Spatial Economy*. MIT Press. 1999. p. 3. (Hereafter cited as Fajita, et al., *The Spatial Economy*.)

[34] Fujita, et al., *The Spatial Economy*, p. 5.

[35] J.P. Cohen, and C.J.M. Paul, "Agglomeration Economies and Industry Location Decisions: The Impacts of Vertical and Horizontal Spillovers." Working Paper 01-010. University of California, Davis, U.S. Department of Agricultural and Resource Economics. October 2001.

Scale Economies

Critical infrastructure may become geographically concentrated in pursuit of "scale economies."

> Scale economies are found in industries where unit costs fall as the scale of operations increases. This phenomenon was first studied in pipeline industries ... when it was observed that the amount of material required to make a pipe of a given diameter increased only two-thirds as quickly as the carrying capacity of the pipe. This observation led to larger pipes having lower unit costs.[36]

In addition to pipelines, researchers have identified scale economies across many critical infrastructure sectors.[37] The size of new chemical plants, for example, increased by a factor of five between the late 1950s and early 1980s, in part due to scale economies.[38] Some analysts likewise suggest that the concentration of shipping container traffic among several U.S. "megaports" is partly due to economies of scale in warehousing and terminal operations.[39] Because scale economies tend to drive an increase in size of individual facilities, they may also geographically concentrate regional infrastructure capacity where multiple facilities are located in the same region.

Community Preferences

Community preferences have sometimes led to concentrations of critical infrastructure by preventing or inviting the development of new facilities in particular new locations. Such preferences have affected, for example, ongoing efforts by energy developers to site new liquefied natural gas (LNG) import terminals. Since 2000, developers have proposed the construction of over 70 new LNG terminals in U.S. ports or U.S. waters, many near major natural gas markets in California and the Northeast. But most near-to-market terminal proposals have struggled for approval due to community concerns about LNG safety, effects on local commerce, and other potential negative impacts. Due primarily to local community opposition, LNG developers have withdrawn terminal proposals in Alabama, California, Maine, Massachusetts, North Carolina, and Florida. Other terminal proposals in Rhode Island, New York, and New Jersey are facing stiff community opposition. In some cases state and local agencies also have been at odds with federal agencies over LNG terminal siting jurisdiction. Communities in only a few states, notably Louisiana and Texas, have encouraged the siting of new LNG facilities. As a result, most new LNG terminals approved by federal agencies are located in the Gulf of Mexico, where natural gas infrastructure is already heavily concentrated.[40] Similar siting preferences have

---

[36] P.W. Bauer, "Are We in a Productivity Boom? Evidence from Multifactor Productivity Growth." *Economic Commentary*. Federal Reserve Bank of Cleveland. October 15, 1999.

[37] L.R. Christensen, and W.H. Greene, "Economies of Scale in U.S. Electric Power Generation." Journal of Political Economy, vol. 84, no. 4, 1976, p. 655.

[38] M.B. Lieberman, "Market Growth, Economies of Scale, and Plant Size in the Chemical Processing Industries," *Journal of Industrial Economics*, vol. 36, no. 2, 1987, pp. 175-191.

[39] National Research Council. *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism.* National Academies Press. 2002. p. 216.

[40] For further discussion of LNG siting see CRS Report RL32205, *Liquefied Natural Gas (LNG) Import Terminals: Siting, Safety, and Regulation.*

faced other types of critical infrastructure and industries, including electric power, telecommunications, and transportation.[41]

Capital Efficiency

Capital efficiency seeks to maximize financial returns on capital investment. Since most U.S. critical infrastructure is in the private sector, capital efficiency has long influenced how and where private companies have invested in infrastructure capacity.[42] Attention to capital efficiency sharply increased in the 1990s, however, as financial markets grew dissatisfied with other measures of company performance such as simple revenue growth.[43] This attention, in turn, led a range of capital-intensive infrastructure companies, such as electric utilities, telecommunications providers, pipelines, and other industrial companies, to sharply reduce annual capital requirements from historical levels.[44] Economic deregulation of the energy, telecommunications, and transportation industries, among others, accelerated this trend.

In some cases companies reduced capital requirements by cutting "excess" infrastructure capacity—reducing reserve capacity in capital equipment or reducing inventories of production supplies ("just-in-time" inventory). For example, power generation capacity margins for the U.S. electric utility industry as a whole fell by almost 40% between 1992 and 2000.[45] There has been a similar reduction in excess capacity among other critical infrastructures, many of which now operate near or at capacity. Oil refineries, for example, have seen capacity utilization rise from below 77% in 1985 to 89% in 2005.[46] While such a reduction in reserve capacity has not, itself, led to geographic infrastructure concentration, it has greatly increased the sensitivity of infrastructures to the disruption of concentrated capacity.

Federal Policies and Infrastructure Concentration

Although market forces have been the primary influence on critical infrastructure development, especially in the private sector, Congress and federal agencies historically have, from time to time, adopted policies intended to affect the capacity and location of critical infrastructure in the national interest. Although these policies often have been motivated by the desire to promote specific social objectives (e.g., economic development, environmental protection, infrastructure reliability) they have sometimes also encouraged or discouraged the geographic concentration of critical infrastructures. Examples of these policies follow.

---

41 D. Laws, and L. Susskind, "Changing Perspectives on the Facility Siting Processes." *Maine Policy Review*. December 1991. pp. 29-44.

42 General Accounting Office (GAO). *Challenges for Critical Infrastructure Protection*. GAO-03-233. February 28, 2003. p. 1. This report states that over 80% of critical infrastructure is private.

43 See, for example, S.R. Rajan, "Turning Capital to Wealth: A Ranking of U.S. Utilities." *Public Utilities Fortnightly*. December 1999.

44 M. Singer, and K. Turnipseed, "Curing Capital Addiction." *McKinsey Quarterly*. 1993. no. 4. pp. 69-77.

45 T. Karier, "Keeping the Lights On: A Banking Industry Model to Avoid Shortages." *Public Utilities Fortnightly*. July 1, 2002.

46 Energy Information Administration. "Refinery Utilization and Capacity." July 28, 2008. Internet database. http://tonto.eia.doe.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm.

Prescriptive Siting

The federal government has prescriptively sited, constructed, and operated federally owned or operated critical infrastructure. Such infrastructure includes transportation facilities, military bases, postal facilities, federal energy facilities, and national laboratories. In some cases, such prescriptive siting has led to geographic concentration of critical infrastructure. For example, the federal government sited and constructed the Panama Canal in the early 1900s, encouraging a concentration of military and commercial shipping through the new waterway which persists today. (The canal carried over a third of U.S. grain exports in 2006.)[47] In the Pacific Northwest, dams constructed or operated by federal agencies on the Columbia River system account for 28% of U.S. hydroelectric generation capacity.[48] In other cases, prescriptive federal siting has dispersed critical infrastructure. In the early 1940s, for example, the federal government financed and sited a major steel plant in Utah, far from existing U.S. steel plants and steel markets. A key reason for siting the plant (viewed as critical for shipbuilding during World War II) in Utah was "as a precaution against steel shortages in the West in case of a Pacific coast invasion or closure of the Panama Canal."[49] A more current example is the U.S. Postal Service, which routes no more than 1.3% of all mail through any single processing and distribution center.[50]

Although the federal government prescriptively sites its own infrastructure, it is difficult to find examples of federal prescriptive siting of private sector infrastructure. One way the government has done so, however, is through its control of federal lands and other federal assets necessary for infrastructure development. For example, the Trans-Alaska Pipeline Authorization Act of 1973 (P.L. 93-153) directed the Secretary of the Interior to authorize a right-of-way for construction of the Trans-Alaska Pipelines System (TAPS) through federal lands in Alaska. The construction of TAPS physically diversified U.S. oil supplies, although it initiated a new geographic concentration of critical infrastructure in Alaska. TAPS transports nearly 17% of United States domestic oil production.[51] More recently, the Energy Policy Act of 2005 (P.L. 109-58) directs federal agencies to designate "energy corridors" on federal lands in 11 western states for the siting of new oil, gas, and hydrogen pipelines and electricity transmission facilities (Section 368). While both the TAPS and energy corridor projects involve privately owned facilities, the location of those facilities is established prescriptively by the federal government.

Economic Incentives

Economic incentives are another policy mechanism employed by the federal government to direct private sector infrastructure siting. Such incentives are intended to encourage private developers to build infrastructure that might otherwise not be built or to build infrastructure in a location favored by government. While most federal incentive programs are not geographically targeted, some are intended to affect infrastructure development in particular geographic areas. The

[47] U.S. Army Corps of Engineers. *Waterborne Commerce of the United States: Calendar Year 2006*. Part 5—National Summaries. July 2008. Table 2-1; Panama Canal Authority. "Commodity Movement through the Panama Canal over Principal Trade Routes." 2008. Available at http://www.pancanal.com/eng/maritime/statisti.html.

[48] Energy Information Administration . Energy Information Administration. *Electric Power Annual 2006*. DOE/EIA-0348(2006). October 22, 2007. Table 2.1; Federal Columbia River Power System. *Federal Columbia River Power System.* August 2003. p. 9. http://www.bpa.gov/power/pg/fcrps_brochure_17x11.pdf.

[49] A.K. Powell. "Geneva Steel Plant." *Utah History Encyclopedia*. University of Utah Press. 1994.

[50] U.S. Postal Service. Personal communication and non-public data. December 7, 2005.

[51] Alyeska Pipeline Service Co. Internet page. Anchorage, AK. May 2008. http://www.alyeska-pipe.com/about.html.

construction of the transcontinental railroad and telegraph is an historic example of such a policy. Under the Pacific Railway Act of 1862, the Congress provided private companies with 30-year bonds, federal land grants, and other incentives to construct a rail and telegraph line along a specified route from Nebraska to the Pacific coast. The federal government continues to offer such financial incentives for critical infrastructure projects today. For example, in 2004 Congress passed the Alaska Natural Gas Pipeline Act (P.L. 108-324, Div. C) offering an $18 billion loan guarantee, accelerated depreciation, and investment tax credits to private developers for the construction of a new natural gas pipeline similar to the existing Trans-Alaska oil pipeline. In both the railroad and the Alaska gas pipeline cases, Congress has viewed the new infrastructure as critical for expanding and diversifying (geographically) the nation's critical assets.

Environmental Regulation

Federal environmental laws, such as the Coastal Zone Management Act and the Clean Air Act, also have influenced the geographic development of critical infrastructure. The Coastal Zone Management Act of 1972 (CZMA, P.L. 92-583) was enacted to enable states to establish coordinated coastal zone management programs balancing environmental protection with coastal development. State coastal management plans implemented under the CZMA may affect the geographic concentration of infrastructure by encouraging or discouraging the siting of coastal infrastructure. Research has shown, for example, that one third of states with coastal management plans under CZMA appear to have adopted policies seeking to confine the physical expansion of ports to areas already committed to port and industrial uses.[52] Energy industry representatives have argued that state plans under CZMA have also been used to block the development of new energy infrastructure in many parts of the country.[53]

The Clean Air Act of 1970 (CAA, P.L. 91-604) created a national program to mitigate the harmful effects of air pollution by regulating pollution sources. Among other provisions, the CAA requires that new facilities emitting certain air pollutants install best available control technology as determined by the Environmental Protection Agency. New facilities being sited in counties not in attainment of federal air quality standards may have more stringent—and potentially more costly—emissions control requirements than facilities sited in counties that are in attainment of those standards, depending upon a state determination of the lowest emission rate available and the need to acquire emissions offsets. By affecting facility costs in this way, some analysts argue that the CAA encourages the concentration of infrastructure in geographic "pollution havens," or, alternatively, encourages the dispersion of facilities away from existing infrastructure in polluted regions. One empirical study in New York, for example, suggests that air quality regulations have significantly affected the destination choices of relocating manufacturing plants.[54] Because facility siting decisions are complex, however, other empirical studies of CAA effects on siting concentration, specifically, have been less conclusive.[55]

[52] M.J. Hershman, "Seaport Development and Coastal Management Programs: A National Overview." Coastal Management, vol. 27, 1999, pp. 271-290.

[53] Argonne National Laboratory. *Environmental Policy and Regulatory Constraints to Natural Gas Production*. ANL/EAD/04-1. December 2004. p. 25.

[54] J.A. List, et al. "Effects of Air Quality Regulation on the Destination Choice of Relocating Plants." *Oxford Economic Papers*, vol. 55, no. 4, 2003, pp. 657-678.

[55] T. Jeppesen, et al. "Environmental Regulations and New Plant Location Decisions: Evidence from a Meta-Analysis." Journal of Regional Science, vol. 42, no. 1, 2002, pp. 19-49.

While the environmental regulations under the CZMA and CAA apply generally to many regions in the United States, some federal environmental policies have been directed at more specific geographic areas. Congressional moratoria on oil and natural gas development in specific parts of the outer continental shelf (due to concerns about local economic and environmental impacts) are one example of such federal policy.[56] Energy industry analysts have argued that the moratoria have resulted in oil and gas infrastructure concentration in the central and western Gulf of Mexico, where such development is permitted. This example notwithstanding, the federal government does not appear to impose regional-level (as opposed to facility-level) environmental restrictions frequently.[57]

Economic Regulation

Economic regulation of critical infrastructure, or the lack thereof, by the federal government may also influence infrastructure concentration. Under federal price regulation, the U.S. airlines industry offered primarily direct, point-to-point service. After economic deregulation in 1978, the airlines began offering far more indirect flights, routing air traffic through concentrated "hub" airports—a largely unanticipated consequence of inter-carrier competition.[58] Federal deregulation of banking led to a consolidation of the banking sector, with ever-larger banks concentrating critical operations in centralized administration facilities to capture economies of scale.[59]

Limited federal regulation does not necessarily lead to infrastructure concentration, however, especially if state or local agencies have regulatory authority. Under the Federal Power Act of 1935 (FPA), for example, retail electricity sales and generation investments of investor-owned electric utilities are regulated by the states. State regulators have historically required utilities to meet state electric generation needs by constructing in-state plants, or by jointly constructing plants with neighboring utilities. Consequently, privately-owned electric power plants have been geographically dispersed among the 50 states. The largest shares of U.S. generating capacity in individual states are 10% in Texas and 6% in California.[60] By contrast, the federally owned Tennessee Valley Authority (TVA) had plans in the 1960s to construct 17 nuclear power reactors at seven sites.[61] Although TVA only completed six reactors due to changes in the energy market and nuclear safety regulation, its original plans would have created a nationally significant concentration of nuclear generating capacity within TVA's territory. It is interesting to note that the recent restructuring of the electric utility industry, which exempts new generation plants from state economic regulation, appears to be encouraging the geographic concentration of new generating plants near certain transmission corridors because plant developers are no longer constrained by state regulators in their site selection.

---

[56] For further discussion see CRS Report RL33493, *Outer Continental Shelf: Debate Over Oil and Gas Leasing and Revenue Sharing*, by (name redacted).

[57] Environmental Law Institute, *Institutional Controls in Use*. Washington, D.C. September 1995. p. 14.

[58] G. Gowrisankaran, "Competition and Regulation in the Airline Industry." *FRBSF Economic Letter*. No 2002-01. Federal Reserve Bank of San Francisco. January 18, 2002.

[59] S.J. Pilloff, *Bank Merger Activity in the United States, 1994-2003*. Board of Governors of the Federal Reserve System. Staff Study 176. May 2004.

[60] Energy Information Administration. *Electric Power Annual 2006*. DOE/EIA-0348(2006). October 22, 2007. Figure 2.1. p. 23.

[61] McCullough, Jr, G.L., Chairman, Tennessee Valley Authority. Testimony before the Senate Energy and Natural Resources Committee, Energy Subcommittee. March 4, 2004.

Policy Options to Reduce Infrastructure Vulnerability

Since helping to reduce the overall vulnerability of critical infrastructure is an objective of the federal government, it is useful to outline what options, if any, may be considered to reduce vulnerabilities and potential national consequences arising specifically from the geographic concentration of such infrastructure.

Some analysts may argue that little government intervention in infrastructure concentration is necessary because the private sector will appropriately adjust its infrastructure practices out of its own financial interest. Catastrophic insurance premiums, for example, or internal corporate risk management programs, may influence corporate practices in a way that reduces vulnerabilities and associated risk to future profits by reducing the geographic vulnerability of private infrastructure. As the *National Strategy for the Physical Protection of Critical Infrastructures and Key Assets* states,

> Customarily, private sector firms prudently engage in risk management planning and invest in security as a necessary function of business operations and customer confidence.... Consequently, private sector owners and operators should reassess and adjust their planning, assurance, and investment programs to better accommodate the increased risk....[62]

Holders of such a view would assert that the socially optimal geographic distribution of critical infrastructure, balancing economic efficiency with geographic risk, is best left to the market forces outlined earlier in this report.

Other analysts have argued that the private sector does not properly account for the full social costs of critical infrastructure failure, or that individual companies cannot independently and significantly influence geographic concentration in a critical sector.[63] Holders of this view would see a definite and active role for the federal government in alleviating geographic vulnerability of critical infrastructure in addition to the market-driven measures taken by the private sector on its own. If Congress concludes that federal intervention is appropriate, it has several broad policy options for doing so.

Eliminating Policies Encouraging Concentration

One way Congress may alleviate geographic concentration and associated vulnerability is to eliminate existing policies that encourage such concentration. As the previous discussion has shown, some federal policies may increase concentration prescriptively. Others, especially certain economic and environmental policies, may implicitly or unintentionally encourage geographic concentration. Without such government influence, market forces may drive developers to less geographically concentrated locations for future infrastructure projects. The challenge to this approach of alleviating geographic concentration is that it may conflict with other objectives of

---

[62] Office of the President. *The National Strategy for the Physical Protection of Critical Infrastructure and Key Assets*, February 2003. p. X.

[63] See, for example, P.R. Orszag, The Brookings Institution, "Homeland Security and the Private Sector." Testimony before the National Commission on Terrorist Attacks Upon the United States. November 19, 2003.

federal legislation. In the case of the economic deregulation, for example, geographic concentration often provides the consumer cost reductions and service improvements that deregulation was intended to achieve. In the case of environmental laws, concentration is often viewed as a desirable means of preserving undisturbed natural areas from destructive development. Would the CZMA be able to fulfill its fundamental balance of environmental protection and economic development if states were not free to concentrate infrastructure where they choose to? The resolution of such policy questions would require a careful and complex reconsideration of long-standing policy objectives in light of evolving concerns about critical infrastructure risk.

Encouraging Geographic Dispersion

Another remedy for geographic vulnerability is to encourage the geographic dispersion of concentrated assets where such dispersion is possible. As discussed in this report, the federal government may implement a range of targeted policies, including prescriptive siting, economic incentives, and regulation, to help bring about infrastructure dispersion. Such dispersion could involve the development of new infrastructure capacity or the shifting of critical goods and services among existing infrastructure. Some transportation analysts, for example, have proposed shipping containers through Mexican ports and then on to the United States by rail as a means of reducing cargo traffic in Southern California's ports.[64] Shifting concentrations of critical supplies and services to alternative infrastructure already in place (and not itself concentrated) may be one way to alleviate geographical vulnerabilities relatively quickly. If the alternative infrastructure lies outside the United States, however, such a strategy may create new vulnerabilities since it might no longer be under U.S. protection or administration.

While encouraging infrastructure dispersion through federal policy may be helpful, doing so may be challenging. It may be difficult, for example, to identify and prioritize geographic infrastructure concentrations amenable to such dispersion. Predicting the long-term effects of such polices on market economics, especially the effects on market competition, may also be uncertain. If incentives are involved, dispersion policies may also be costly to the federal government, potentially drawing resources away from other federal programs. Furthermore, since infrastructure development is mostly in private and regional government (state and local) hands, ensuring that regional infrastructure projects are consistent with federal objectives may also be a problem. As the Congressional Budget Office has stated,

> The federal government's most important role in infrastructure provision is as a source of finance.... Thus, for infrastructure to be managed in a way that furthers national objectives, federal agencies must offer incentives for local managers to align their choices with the welfare and equity goals of federal programs. Choices for infrastructure systems that aim at such broad objectives must similarly be based on wide searches among new investments, rehabilitation efforts, or operational changes. They must also be derived from consistent evaluations of the long-term effects of these possible choices on the efficiency of activities using the infrastructure.[65]

Infrastructure owners and regional governments are also likely to have vested interests in existing concentrations of critical infrastructure and may oppose dispersion on competitive or other

[64] R.C. Mireles, "A Cure for West Coast Congestion." *Logistics Today*. January 2005.

[65] Congressional Budget Office (CBO). *Federal Policies for Infrastructure Management*. June 1986. p xi.

economic grounds. State and local governments may also have concerns about federalism, particularly where federal policies affecting infrastructure dispersion may supercede local infrastructure priorities.

Notwithstanding the challenges of promoting infrastructure dispersion, Congress appears to be pursuing such policies with respect to the siting of new energy infrastructure, including LNG import terminals, oil refineries, electric transmission lines, and an Alaska gas pipeline. Even where such federal policies may be implemented successfully, however, it may still take years or decades to achieve dispersion objectives because critical infrastructure often develops slowly. For example, industry experts project that it would take five to seven years, absent community opposition, to construct a new U.S. oil refinery.[66] It would take at least nine years to build the Alaska natural gas pipeline.[67]

Ensuring Infrastructure Survivability

For geographic concentrations of critical infrastructure that are difficult to diversify, or that may take a long time to diversify, Congress may wish to ensure their near-term ability to function, or "survivability," during and after a major geographic disaster. Particularly where resource location provides few geographic alternatives (as in the case of ports) reducing vulnerability through infrastructure protection may be effective. Such an approach would broadly align with the President's existing strategy for protecting critical infrastructure from terrorist attack as stated in the NIPP, although it would incorporate explicitly geographic vulnerabilities. In the context of the NIPP or other emergency management programs, geographic vulnerability could be viewed as a distinctive type of infrastructure vulnerability and therefore considered in federally mandated risk assessments.

Increasing standards for design, construction, and operation, and retrofitting existing infrastructure to higher standards may also enhance infrastructure survivability. While there are numerous industry and government building standards for protection from earthquakes, hurricanes, and floods in regions where such hazards exist, such standards may not account for the critical nature of certain types of assets. In particular, the degree of general survivability these standards impose on critical assets may not appropriately reflect the economic and social costs that might arise should such an asset fail. Federal authority to change such standards may be limited, however, if they fall primarily under state or local jurisdiction.

A principal challenge to alleviating geographic infrastructure vulnerabilities is incorporating the geographic dimension appropriately into the broader infrastructure risk management and decision-making process. One key question is whether survivability measures in place to protect against a facility-specific event would be effective against a regional event. Backup supply networks, redundant control centers, and other systems intended to "harden" infrastructure may themselves be subject to disruption from a geographic hazard. Although history does provide some guidance as to the likelihood of disruptive natural events and their potential effects, quantifying such geographic vulnerabilities in a way that allows comparison to a broader set of vulnerabilities may be analytically complex. Predicting the likelihood of future terrorist attacks,

---

[66] O'Conner, T., ICF Consulting. Testimony before the House Government Reform Committee, Subcommittee on Energy and Resources. "Petroleum Refineries: Will Record Profits Spur Investment in New Capacity?" October 19, 2005.

[67] Energy Information Administration. *Annual Energy Outlook 2008*. DOE/EIA-0383(2008). June 2008. p. 39.

for which history provides little guidance, adds considerable uncertainty. Attempting to allocate limited public resources for critical infrastructure survivability based on geographic considerations may also be challenging. In particular, it could complicate the use of quantitative, risk-based formulas to distribute federal support for critical infrastructure protection.[68] Increasing the private costs of infrastructure through new construction standards to improve survivability could also be controversial.

Ensuring Infrastructure Recovery Capabilities

In addition to policies promoting geographic dispersion and survivability, Congress may consider infrastructure recovery as a means of mitigating the impacts of geographic hazards on concentrated critical infrastructure. The federal government, through the Federal Emergency Management Agency (FEMA) and other agencies, provides a range of emergency aid programs for communities affected by disasters such as hurricanes, earthquakes, or terrorist attacks. Among other assistance, these federal programs can provide grants, loans, loan guarantees, food, and shelter to disaster victims. They may also provide long-term infrastructure assistance, such as repair of public utilities, to affected communities.[69]

While the evolving objectives of federal emergency assistance programs are a topic of ongoing debate in Congress, the programs traditionally have been intended to assist primarily in the recovery of an immediate disaster area.[70] However, if a natural disaster, terrorist attack, or other regional incident disrupts critical infrastructure, it may have serious social or economic consequences far beyond the area where the disaster occurs. The loss of concentrated natural gas supplies in the Gulf of Mexico after hurricanes Katrina and Rita, for example, sharply increased U.S. energy prices and threatened to create significant shortages of fuel for home heating and electric power generation in New England.[71] These natural gas shortages prompted congressional calls to increase federal aid for low income households nationwide facing high natural gas bills.[72] In light of the far-reaching impacts like these, Congress may wish to incorporate into existing federal infrastructure recovery plans and aid programs measures that account for the distinctive vulnerabilities of concentrated critical infrastructure. Measures related to the restoration or alternative provision of critical infrastructure services away from the immediate area of a geographic incident may warrant particular attention.

Conclusions

Geographic concentrations of critical infrastructure exist across a number infrastructure sectors. Although such concentrations often provide substantial economic and social benefits, they may

---

[68] For further discussion see CRS Report RL32348, *Selected Federal Homeland Security Assistance Programs: A Summary*, by (name redacted).

[69] See CRS Report RL31734, *Federal Disaster Recovery Programs: Brief Summaries*, by (name redacted).

[70] Federal Emergency Management Agency, "Federal Aid Programs for Louisiana Disaster Recovery," Fact sheet HQ-08-182, September 2, 2008; P.M. Prah, "Is the U.S. Ready for Another Major Disaster?," *CQ Researcher*, vol. 15, no. 41, November 18, 2005.

[71] R. Adams, "A Hard Winter, A Thin Natural Gas Pipeline," *CQ Weekly*, October 7, 2005.

[72] See, for example: Senator Edward M. Kennedy. "Sen. Kennedy, Colleagues Urge Bush Administration to Include Low Income Home Heating Funds in Budget." Press release. November 21, 2006.

also be distinctly vulnerable to catastrophic geographic disruption. Any public policy addressing critical infrastructure concentration must try to balance these benefits and potential costs. Both government and industry have taken steps to try to protect critical infrastructure from natural disasters, epidemics, and terrorist attacks. Nonetheless, questions remain as to whether these steps appropriately address such geographic vulnerabilities. If Congress concludes that more federal intervention is needed to alleviate vulnerabilities due to geographic concentration, it may employ a number of policy options to encourage geographic dispersion (including eliminating policies that encourage concentration), ensure survivability, or ensure that effective infrastructure recovery capabilities are in place to mitigate impacts of concentrated infrastructure disruption. Because geographic hazards exist today, and geographic dispersion would likely take decades to achieve, addressing geographic vulnerabilities may call for a combination of options.

In addition to these issues, Congress may assess how geographic infrastructure vulnerability and survivability fit together in the nation's overall infrastructure policies. As Congress evaluates diverse proposals with the potential to affect critical infrastructure development—directly or indirectly—Congress may consider whether such proposals are likely to relieve or exacerbate geographic vulnerability. The economic or social benefits of adding capacity (e.g. refinery, airport, shipping) to an existing concentration of critical infrastructure, or developing additional infrastructure in a new location, may be outweighed by the increased geographic risk implicit in such an expansion. Fiscal implications, especially related to the economic efficiency of public critical infrastructure and the efficient use of federal funds for infrastructure projects, may also be an important consideration. Reviewing how such infrastructure priorities fit together could be an oversight challenge for Congress.

Author Contact Information

(name redacted)
Specialist in Energy and Infrastructure Policy
[redacted]@crs.loc.gov, 7-....