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Nuclear Power Plant Sites: Maps of Seismic Hazards and Population Centers

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Currently, 104 commercial nuclear power plants operate on 64 sites in the 48 contiguous United States. [1] Sixty-nine of the 104 are pressurized water reactors (PWR) and the 35 remaining are boiling water reactors (BWR). The PWR plants are based on Babcock & Wilcox, Combustion Engineering, and Westinghouse designs. The BWR plants are based on a series of General Electric designs. The Nuclear Regulatory Commission (NRC) has received 28 Combined License (COL) applications for new reactors based on advanced reactor designs (**Table 2**). Three COL applications will involve new sites.

CRS determined the coordinates of plant sites using web-based applications and overlaid the sites on base maps of:

1. Quaternary faults,
2. Seismic hazards in terms of percent gravitational acceleration,
3. Levels of horizontal ground shaking (gravitational acceleration) that have a 2-in-100 (2%) probability of being exceeded in a 50-year period, and
4. Metropolitan populations

To map the proximity of plant sites to faults (**Figure 1**), CRS referred to the USGS Quaternary Fault and Fold Database of the United States.[2] This database contains information on faults and associated folds in the United States that are believed to be sources of greater than magnitude 6 (M>6) earthquakes during the Quaternary (the past 1,600,000 years). It is important to note that this map is not a prediction of an earthquake event.

To map the proximity of plant sites to seismic hazards (**Figure 2**), CRS referred to the USGS Seismic Hazard Map for the United States.[3] This map displays quantitative information about seismic ground motion hazards as horizontal ground acceleration (in terms of gravitational acceleration) of a particle at ground level moving horizontally during an earthquake. It is important to note that this map is not a prediction of an earthquake event.

To map the proximity of plant sites to geographic areas with levels of horizontal shaking having a 2% probability of being exceeded in a 50-year period (**Figure 3**), CRS referred to the 2008 United States National Seismic Hazard Maps.[4] The U.S. Geological Survey (USGS) National Seismic Hazard Maps incorporate the latest findings on earthquake ground shaking, faults, seismicity, and geodesy to display earthquake ground motions for various probability levels across the United States. The resulting maps are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the frequency of exceeding a set of ground motions. The Seismic Hazard maps are the basis for seismic design provisions of building codes to allow buildings, highways, and critical infrastructure to withstand earthquake shaking without collapse.[5] The NRC requires that every nuclear plant be designed for site-specific ground motions

[1] There are no nuclear power plants operating in Alaska or Hawaii.

[2] USGS Earthquake Hazards Program, Quaternary Fault and Fold Database of the United States http://earthquake.usgs.gov/hazards/qfaults/.

[3] USGS http://www.nationalatlas.gov/mld/quksigx.html

[4] USGS, 2008 United States National Seismic Hazard Maps, http://pubs.usgs/fs/2008/3018/pdf/FS08-3018_508.pdf

[5] For complete discussion of the USGS methodology see Mark D. Petersen, Arthur D. Frankel, Stephen C. Harmsen et al.; *Documentation for the 2008 Update of the United State National Seismic Hazard Maps.* Open-File Report 2008–1128; USGS.

that are appropriate for their site locations. In addition, the NRC has specified a minimum ground motion level to which nuclear plants must be designed. For further information about nuclear power plant siting criteria, refer to 10 Code of Federal Regulation, Appendix A to Part 100—Seismic and Geologic Sitting Criteria for Nuclear Power Plants. It is important to note that this map is not a prediction of an earthquake event.

For further information about earthquake hazards, refer to CRS Report RL33861, *Earthquakes: Risk, Detection, Warning, and Research*, by Peter Folger.

In mapping the population near nuclear power sites (**Figure 4**), CRS referred to the U.S. Census Bureau FactFinder website for 2009 population estimates on urban area nearest to each of the plant site.[6] The latest census figures do not include all smaller geographic locations, so we used Census Bureau estimator for the last known projected estimates before the 2010 census was taken. It is important to note that the circular map symbol denotes population size, not the areal extent of population.

Table 1. Operating Nuclear Power Plants

Unit	Type	MW	Vendor	St.	Unit	Type	MW	Vendor	St.
Arkansas Nuclear One 1	PWR	843	B&W	AR	Monticello	BWR	579	GET3	MN
Arkansas Nuclear One 2	PWR	995	CE	AR	Nine Mile Pt .1	BWR	621	GET2	NY
Beaver Valley 1	PWR	892	W3L	PA	Nine Mile Pt. 2	BWR	1,140	GET5	NY
Beaver Valley 2	PWR	846	W3L	PA	North Anna 1	PWR	981	W3L	VA
Braidwood 1	PWR	1,178	W4L	IL	North Anna 2	PWR	973	W3L	VA
Braidwood 2	PWR	1,152	W4L	IL	Oconee 1	PWR	846	B&WLL	SC
Browns Ferry 1	BWR	1,065	GET4	AL	Oconee 2	PWR	846	B&WLL	SC
Browns Ferry 2	BWR	1,104	GET4	AL	Oconee 3	PWR	846	B&WLL	SC
Browns Ferry 3	BWR	1,115	GET4	AL	Oyster Creek	BWR	619	GET2	NJ
Brunswick 1	BWR	938	GET4	NC	Palisades	PWR	778	CE	MI
Brunswick 2	BWR	937	GET4	NC	Palo Verde 1	PWR	1,335	CES80	AZ
Byron 1	PWR	1,164	W4L	IL	Palo Verde 2	PWR	1,335	CES80	AZ
Byron 2	PWR	1,136	W4L	IL	Palo Verde 3	PWR	1,335	CES80	AZ
Callaway 1	PWR	1,236	WFL	MO	Peach Bottom 2	BWR	1,112	GET4	PA
Calvert Cliffs 1	PWR	873	CE	MD	Peach Bottom 3	BWR	1,112	GET4	PA
Calvert Cliffs 2	PWR	862	CE	MD	Perry 1	BWR	1,261	GET6	OH
Catawba 1	PWR	1,129	W4L	SC	Pilgrim 1	BWR	685	GET3	MA
Catawba 2	PWR	1,129	W4L	SC	Point Beach 1	PWR	512	W2L	WI
Clinton 1	BWR	1,065	GET6	IL	Point Beach 2	PWR	514	W2L	WI
Columbia Gen. St.	BWR	1,190	GET5	WA	Prairie Island 1	PWR	551	W2L	MN

[6] U.S. Census Bureau, American fact Finder, http://factfinder.census.gov/home/saff/main.html?_lang=en.

Unit	Type	MW	Vendor	St.	Unit	Type	MW	Vendor	St.
Comanche Peak 1	PWR	1,200	W4L	TX	Prairie Island 2	PWR	545	W2L	MN
Comanche Peak 2	PWR	1,150	W4L	TX	Quad Cities 1	BWR	867	GET3	IL
Cooper Station	BWR	830	GET4	NE	Quad Cities 2	BWR	869	GET3	IL
Crystal River 3	PWR	838	B&WLL	FL	R. E. Ginna	PWR	498	W2L	NY
Davis-Besse	PWR	893	B&WLL	OH	River Bend 1	BWR	989	GET6	LA
Diablo Canyon 1	PWR	1,151	W4L	CA	Salem 1	PWR	1,174	W4L	NJ
Diablo Canyon 2	PWR	1149	W4L	CA	Salem 2	PWR	1,130	W4l	NJ
Donald C. Cook 1	PWR	1,009	W4L	MI	San Onofre 2	PWR	1,070	CE	CA
Donald C. Cook 2	PWR	1,060	W4L	MI	San Onofre 3	PWR	1,080	CE	CA
Dresden 2	BWR	867	GET3	IL	Seabrook 1	PWR	1,295	W4L	NH
Dresden 3	BWR	867	GET3	IL	Sequoyah 1	PWR	1,148	W4L	TN
Duane Arnold	BWR	640	GET4	IA	Sequoyah 2	PWR	1,126	W4L	TN
Fermi 2	BWR	1,122	GET4	MI	Shearon Harris 1	PWR	900	W3L	NC
Fitzpatrick	BWR	852	GET4	NY	South Texas 1	PWR	1,410	W4L	TX
Fort Calhoun	PWR	500	CE	NE	South Texas 2	PWR	1,410	W4L	TX
Grand Gulf 1	BWR	1,297	GET6	MS	St. Lucie 1	PWR	839	CE	FL
Hatch 1	BWR	876	GET4	GA	St. Lucie 2	PWR	839	CE	FL
Hatch 2	BWR	883	GET4	GA	Surry 1	PWR	799	W3L	VA
Robinson 2	PWR	710	W3L	SC	Surry 2	PWR	799	W3l	VA
Hope Creek 1	BWR	1,061	GET4	NJ	Susquehanna 1	BWR	1,149	GET4	PA
Indian Point 2	PWR	1,023	W4L	NY	Susquehanna 2	BWR	1,140	GET4	PA
Indian Point 3	PWR	1,025	W4L	NY	Three Mile Island 1	PWR	786	B&WLL	PA
Joseph M. Farley 1	PWR	851	W3L	AL	Turkey Point 3	PWR	720	W3L	FL
Joseph M. Farley 2	PWR	860	W3L	AL	Turkey Point 4	PWR	720	W3l	FL
Kewaunee	PWR	556	W2L	WI	VC Summer	PWR	966	W3l	SC
LaSalle County 1	BWR	1,118	GET5	IL	Vermont Yankee	BWR	510	GET4	VT
LaSalle County 2	BWR	1,120	GET5	IL	Vogtle 1	PWR	1,109	W4L	GA
Limerick 1	BWR	1,134	GET4	PA	Vogtle 2	PWR	1,127	W4L	GA
Limerick 2	BWR	1,134	GET4	PA	Waterford 3	PWR	1,250	CE	LA
McGuire 1	PWR	1,100	W4L	NC	Watts Bar 1	PWR	1,123	W4l	TN
McGuire 2	PWR	1,100	W4L	NC	Wolf Creek 1	PWR	1,166	W4L	KS
Millstone 2	PWR	884	CE	CT					
Millstone 3	PWR	1,227	W4L	CT					

Source: NRC *Operating Nuclear Power Reactors by Location or Name.*http://www.nrc.gov/info-finder/reactor/index.html#AlphabeticalList

Notes: W2L - Westinghouse Two-Loop, W3L -Westinghouse Three-Loop, W4L -Westinghouse Four-Loop, GET2 -General Electric Type 2, GET3 - General Electric Type 3, GET4 - General Electric Type 4, B&WLL - Babcock & Wilcox Lowered Loop, CES80 -Combustion Engineering System 80

Table 2. Combined License Applications for New Reactors

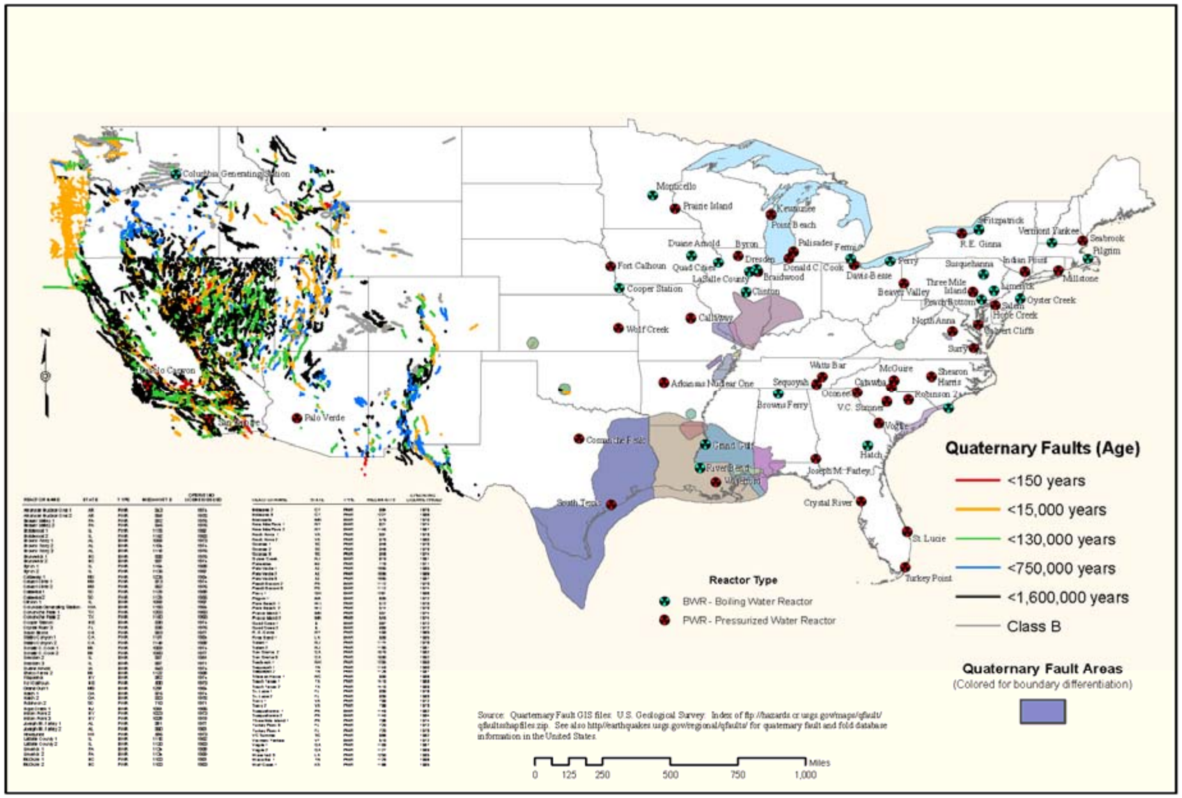
Received by the Nuclear Regulatory Commission

Proposed New Reactors	Design	
Bell Bend Nuclear Power Plant	U.S. EPR	New Site, Luzerne, PA
Bellefonte Nuclear Station, Unit 3 & 4	AP1000	
Callaway Plant, Unit 2	U.S. EPR	
Calvert Cliffs, Unit 3	U.S. EPR	
Comanche Peak, Units 3 & 4	US-APWR	
Fermi, Unit 3	ESBWR	
Grand Gulf, Unit 3	ESBWR	
Levy County, Units 1 & 2	AP1000	New Site, Levy County, FL
Nine Mile Point, Unit 3	U.S. EPR	
North Anna, Unit 3	U.S. EPR	
River Bend Station, Unit 3	ESBWR	
Shearon Harris, Units 2 & 3	AP1000	
South Texas Project, Units 3 & 4	ABWR	
Turkey Point, Units 6 & 7	AP1000	
Victoria County Station, Units 1 & 2	ESBWR	New Site, Victoria County, TX
Virgil C. Summer, Units 2 & 3	AP1000	
Vogtle, Units 3 & 4	AP1000	
William State Lee III, Units 1 & 2	AP1000	

Source: NRC.

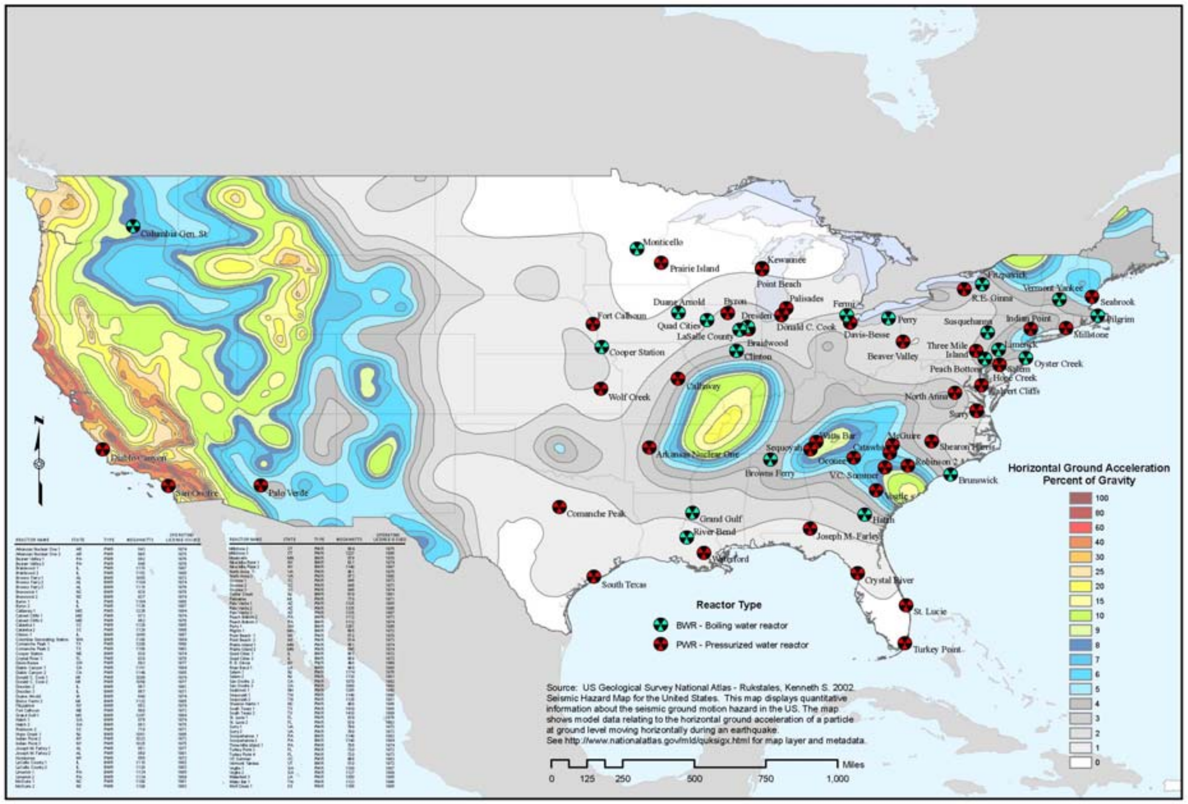
Notes: AP1000—3,400 Megawatt Advanced Passive Reactor, ESBR—4,500 Megawatt Economic Simplified Boiler, U.S. APWR—4, 451 Megawatt Advanced Pressurized Reactor, U.S. EPR—4,500 Megawatt Evolutionary Power Reactor.

Figure 1. Operating Nuclear Power Plants vs. Quaternary Faults Associated with Greater Than Magnitude 6 Earthquakes



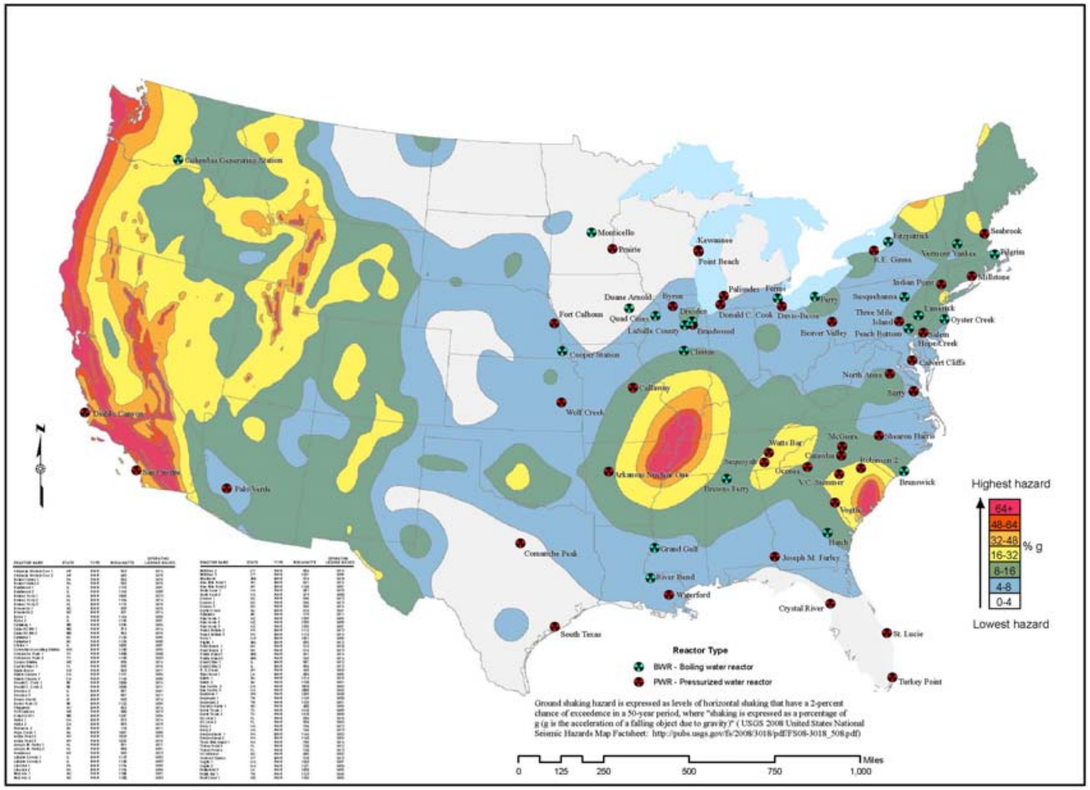
Source: Prepared by CRS and the Library of Congress Geography and Maps Division based on USGS *Quaternary Fault and Fold Database of the United States.*

Figure 2. Operating Nuclear Power Plants vs. Seismic Hazards in Terms of Percent Gravitational Acceleration



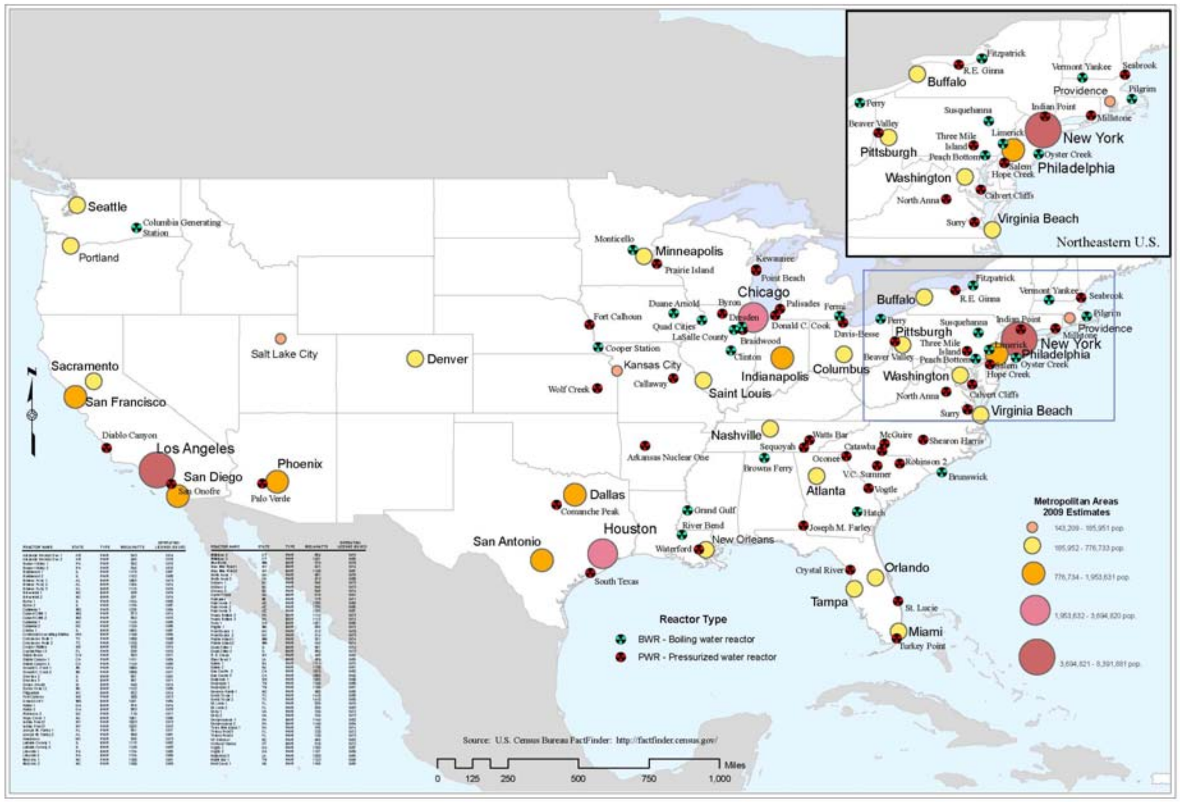
Source: Prepared by CRS and the Library of Congress Geography & Maps Division based on USGS *Earthquake Hazards Program, Hazard Mapping Images and Data.*.

Figure 3. Operating Nuclear Power Plants vs. Hazard Levels of Horizontal Shaking That Have a 2% Probability of Being Exceeded in a 50-Year Period



Source: Prepared by CRS an the Library of Congress Geography and Maps Division based on USGS *Earthquake Hazards Program, Hazard Mapping Images and Data.*

Figure 4. Operating Nuclear Power Plants vs. Major Metropolitan Areas



Source: Prepared by CRS and the Library of Congress Geography and Maps Division based on U.S. Census Bureau data.

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