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Pandemic Influenza, Electricity, and the Coal Supply Chain

Addressing Crucial Preparedness Gaps in the United States

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CIDRAP

Center for Infectious Disease Research & Policy

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NOVEMBER 2008

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■ The Center for Infectious Disease Research & Policy (CIDRAP)

CIDRAP, founded in 2001, is a global leader in addressing public health preparedness and emerging infectious disease response. Part of the Academic Health Center at the University of Minnesota, the center reduces illness and death from infectious diseases by effecting change through public policy refinement, fostering the adoption of science-based best practices in public health among professionals and the public, and conducting original interdisciplinary research.

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■ Acknowledgments

The following individuals graciously volunteered their time, knowledge, and review: Laura Hussey, Edison Electric Institute; Dan Keen, Association of American Railroads; Paul Lang, Arch Coal; Dr. Kenneth Friedman, US Department of Energy, Daniel Flood, Xcel Energy; and Stan Johnson, North American Electric Reliability Corporation. This report does not necessarily represent their viewpoints or those of their employers.

CIDRAP staff members Amy Becker LaFrance, Kathleen Kimball-Baker, Aaron Desmond, Marty Swain, and Jim Wappes also provided assistance.

A copy of this report is available at http://www.cidrapsource.com/reports/coal

Table of Contents

Executive Summary

What's the link between pandemic influenza, electricity, and the coal supply chain? And why should anyone care?

Influenza pandemics are a recurring cause of widespread morbidity and mortality in humans. They occur when a predictable set of factors coincides: A new influenza A virus that is highly pathogenic and antigenically unique is readily transmitted to and by humans. The next pandemic will occur in an unprecedented societal and economic context—a global just-in-time economy—that will seriously compromise the public health response. The global economy will likely suffer serious supply-chain delays and failures, owing to a lack of surge capacity and the likelihood of international and domestic travel/trade restrictions.

During the next pandemic, the demand for critical products and services that we depend on for immediate health and safety will likely outstrip supply, prompting shortages that could exacerbate morbidity and mortality. One example of such a critical product is electricity. Coal, a major source of energy for generating electricity in many areas of the world, is the primary fuel for power generation in the United States. Usage varies by region; the Midwest, for example, generates approximately 75% of its electricity from coal, whereas the west coast generates about 5% from coal. Despite regional differences in coal usage, a pandemic is likely to break links in the coal supply chain, thus disrupting electrical generation. This has the potential to severely endanger the bulk electrical power system in most of the United States.

An effective overall and public health response depends largely on the availability of electricity. Preventing disruptions in the coal supply chain is paramount, and such an effort will certainly require a financial investment. But the consequence of failing to prepare may be catastrophic.

We believe the nation must reduce the risk that a pandemic poses to the generation of electricity and the collateral damage to society that will occur without electricity. The following steps urgently need to be taken:

1. ***Build coal stocks.*** The buildup of coal stocks in preparation for peak electrical demand (the summer in the United Sates) results in the highest coal stock level for the year. We believe that this peak coal stock level should now be maintained as the new minimum at every coal power plant around the nation year-round.

2. ***Place coal miners and supporting infrastructure personnel in the highest priority levels for pandemic response.*** The United States government should assume primary responsibility for ensuring that coal miners and their supporting infrastructure personnel have priority access to antiviral drugs, pandemic vaccines, and other critical products and services (eg, critical pharmaceutical drugs and food). Currently, they are not identified as a priority in the federal or state plans to support critical infrastructure during a pandemic.
3. ***Plan for disruptions in the coal supply chain.*** Fully expect to see unprecedented disruptions of global, national, and regional supply chains and employee absenteeism that could require responses beyond what is typically found in business continuity plans—and not currently addressed in national and state disaster management plans.
4. ***Anticipate and develop strategies for responding to disruptions in electrical service.*** Adverse weather and equipment failures are the most common causes of electrical disruptions. Both will occur during a pandemic—in addition to probable fuel shortages.

Introduction

A coal shortage during an influenza pandemic portends grim outcomes. With this report, we attempt to conceptualize what happens when a pandemic disrupts the supply chain for coal, the fuel nearly half of the United States relies upon for electricity—the cornerstone of public health and organizational continuity.

Historical overview

Influenza pandemics are naturally occurring events that have been recorded since antiquity. They occur when the following factors coincide: (1) a new influenza A virus that is (2) highly pathogenic and (3) antigenically unique is (4) readily transmitted to and by humans.

Although the influenza virus was not identified until 1933, historical records describe influenza pandemics dating back to the days of Hippocrates. The first severe influenza pandemic for which substantial historical records exist occurred in 1580 (Potter 2001), and it reportedly depopulated some Spanish cities (Beveridge 1991). In the last 300 years, 10 influenza pandemics have been documented (Potter 1998, Osterholm 2005a).

The influenza pandemic of 1918-19 has been studied extensively as one of the most dramatic infectious disease outbreaks ever recorded (Potter 1998, Barry 2005, Taubenberger 2006). From 50 million to 100 million people died in this pandemic (Johnson 2002). The two that followed, in 1957-58 and 1968-69, were relatively mild in comparison (Potter 1998).

Based on precedent, another influenza pandemic is inevitable. Experience with influenza pandemics of the recent past is largely guiding our response for the next one. We know that "pandemics have always spread in patterns consistent with the speed and pathways of human travel" (Patterson 1986). Further, seriously ill individuals are only part of the impact a community experiences as a result of a pandemic. A large number of less severely ill individuals may become a "threat to the community" by reducing community resources lost to absenteeism (Kilbourne 1987).

The past three pandemics, which occurred in the 20th century, have provided the background from which we have derived most of the assumptions about the next pandemic. These assumptions include (1) a clinical attack rate of 30% or higher, (2) 50% of the ill requiring outpatient care, (3) communities affected for 6 to 8 weeks, (4) the entire world experiencing the pandemic at approximately the same time, and (5) each wave of the pandemic lasting between 2 to 3 months (HHS-a). While there is value in using past pandemic experiences to project what will happen in the future, history as a guide for pandemic preparedness is limited.

A candidate for the next pandemic is the **novel** influenza A/H5N1 virus, which is currently causing an international epidemic in wild birds and poultry. We know the following (WHO working group 2006):

- The virus has caused a limited number of **human infections**.
- A **high case-fatality rate** has been documented.
- The current Influenza A/H5N1 epidemic in birds is **antigenically unique**.
- Influenza A/H5N1 has not yet acquired the ability to spread *easily* between humans, but it could do so at any time.

Influenza A/H5N1 is not the only virus with pandemic potential; epidemiologists are concerned about the influenza A/H7 family, among other influenza A strains (Belser 2008). While it is unclear which infuenza strain will cause the next pandemc, there will be another influenza pandemic.

Pandemic planning in the 21st century

The "flattening of the world" (a term coined by *New York Times* columnist Thomas Friedman) has changed society dramatically since 1968, the year of the last human influenza pandemic (Friedman 2006). In a flat world, Friedman says, supply chains (all the inputs for a product, from its origin to end use) depend on rapid and reliable communication, and previous demand determines projections of products needed. Stocks of products can be kept to a minimum, thereby reducing costs up and down the supply chain.

The world has never experienced a pandemic during the just-in-time global economy (Osterholm 2005a, Osterholm 2007). Today's supply chains lack surge capacity—the ability to quickly scale up to meet demands (Sheffi 2005, Friedman 2006). During an influenza pandemic, the number of illnesses and deaths worldwide will inevitably cause problems throughout supply chains. Worker absenteeism (whether from illness, fear, need to care for dependents or loved ones, or lack of ability to travel) and disruptions in international and domestic travel will affect every facet of supply chains that deliver the critical products we depend on for immediate health and safety, such as electricity and, in turn, water supplies and sewage systems, food, prescription drugs, and community safety (Osterholm 2005b). So interwoven are these products and services in our lives today, their availability is simply taken for granted. Most of the critical lifesaving drugs found in every hospital, for example, are produced outside of the United States, particularly in China and India. A pandemic will likely seriously disrupt the international supply chain of these pharmaceutical products, from the synthesis of an active ingredient in a facility in Asia to delivery of the finished drug to a hospital pharmacy in the United States.

We can also expect to run short of supplies of products used to prevent and control the spread of infectious agents (Neil 2006, Rhea 2007). During the 2003 outbreak of severe acute respiratory syndrome (SARS), for example, there were shortages of medical products such as N-95 respirators (Lim 2004). The problems with medical supply shortages during the SARS epidemic, which did not spread beyond a few countries or continue for a long period, will pale in comparison to what can be expected during an influenza pandemic, as regions will not be able to resupply one another during waves of outbreaks in which no area will be spared. Clearly, the just-in-time supply-chain dynamics have made pandemic preparedness a complicated issue in the 21st century.

Even with this economic backdrop, pandemic planning has focused primarily on public health prevention strategies. But public health planning has not historically included business continuity or critical infrastructure planning. Nor has public health had a statutory authority to require planning and preparedness of the critical infrastructure (GAO 2008). Most of the guidance does not factor in the dynamics of a pandemic in the 21st century, aside from pointing out that supply-chain disruptions are likely. Considerable work has been devoted to vaccine/antiviral drug distribution plans, preventing infections, and healthcare surge capacity. An extensive body of literature can be found on these core public health strategies, including those of every state and the national pandemic preparedness plan.

Federal-level guidance. US Department of Health and Human Services (HHS) guidance focuses on *preventing illness and death* related to pandemic influenza infections. The underlying assumption is that the primary impact of a pandemic will be the morbidity and mortality associated with the disease itself. Department of Homeland Security (DHS) guidance, on the other hand, is concerned with *maintaining critical infrastructures and key resources* during a pandemic. Its underlying assumption is that the impact to the critical infrastructure and key resources in the United States could be as significant as the disease itself. These two views are harmonized in the National Strategy for Pandemic Influenza (NSPI) published in 2005 (HSC 2005). But both views are not reflected in the separate planning guidance from the two executive branch agencies. This lack of coordination on priorities and assumptions has hampered comprehensive and consequential pandemic planning efforts in the United States.

State-level guidance. To date every state has developed a pandemic influenza plan, most of which are available on government Web sites. Three reviews have addressed state pandemic influenza plans since planning began in earnest in 2005. The first review, by Holmberg et al, focused exclusively on such public health measures as vaccine allocation and containment strategies. The authors found that state plans (many were in draft form) were quite varied, and they concluded that the variability stemmed from a lack of strong federal leadership and poor answers to critical epidemiologic questions, such as what a typical intrahousehold attack rate is during a pandemic (Holmberg 2006). The next review, by Thomas et al, focused on the ethics underlying state plans. The authors found that most states did not adequately address such issues as providing an ethical justification for allocation of scarce resources during a pandemic (Thomas 2007). The most recent review, which was requested by Congress and conducted by Lister et al, considered multiple aspects of pandemic planning at the state level. While the authors highlighted many areas that need improvement, of most concern was the lack of planning for service continuation outside of public health and healthcare. They found that only 7 out of 51 (their analysis included the District of Columbia) state documents mentioned plans for continuation of such essential services as utilities (Lister 2007). Essential services, similar to critical products, are ones we depend on for health and safety. Such services are mostly taken for granted until a disruption occurs. Utilities, including power companies that provide electricity, are prime examples of essential services.

The importance of electricity

Electricity is the underpinning of society in developed countries. But our dependence is rarely recognized, except during occasional electrical blackouts when production lines at manufacturing plants shut down, computer systems go offline, and cities grow dark. Fortunately these events are very rare and short-lived in most developed countries. While the consequences of any power outages can be broad, this paper focuses on the public health effects.

We recognize that approximately 2 billion people in the world do not have access to a stable supply of electricity. However, these people still use products or services that come from parts of the world that do have electricity. For example, many regions of the world in which electricity is intermittent or unavailable depend on vaccines produced in factories that use electricity.

When one considers public health preparedness, the availability of electricity generally is not considered a factor of concern for public health planners. Electricity is typically regarded as reliable and is, in most instances, available for all public health needs. Whether planning for influenza vaccination clinics, investigating outbreaks of a foodborne disease, or responding to a bioterrorism event, public health workers almost always assume that the lights will be on and power available. For disaster scenarios that would compromise electricity, such as after a hurricane, planning activities take into account the loss of power. Most pandemic planning activities, however, do not consider the potential for the loss of electricity.

Most Americans rarely experience power outages for more than a short time (Apt 2004, Hines 2008). Between 1984 and 2006, organizations reported to the US Department of Energy (DOE) and National Electricity Reliability Corporation (NERC) that 861 disturbances affected power delivery (Hines 2008). Of these disturbances, some 44% were related to weather (eg, ice storms, wind), nearly 30% involved equipment failure, and 5% were caused by supply shortages (Hines 2008). More than one cause can be reported for a failure (eg, high winds *and* ice storms could be listed for an outage), so these numbers are approximate.

The United States has had several major electrical blackouts in the last half century, yet very little has been written about the public health impact of *long-term* electrical power loss. Much, however, has been published about short-term electrical blackouts and their impact on acute care, the risks of carbon monoxide poisoning from generators, and the surge in medical needs in the community after a blackout. Literature can be found on such topics as heat waves and the health impact of associated blackouts, though these articles focus on specific situations and do not expand analysis to broader public health implications related to long-term electrical blackouts.

Hurricane Katrina was a vivid reminder that key components of public health, such as safe water and refrigeration of food and medications, can be rendered ineffective if critical infrastructures break down. Power outages were common after Katrina, because parts of the electrical infrastructure were destroyed. Many healthcare facilities lost power for weeks (Currier 2006, LSU 2006). Hospitals and clinics were not the only facilities impaired by the loss of power. Three major pipelines in the Gulf Coast that transport oil and fuel to the Midwest and east coast of the United States were either totally shut down or partially out of service for a few days (Slaughter 2005). The biggest problem facing crews restoring power after Katrina was the "lack of food, water and shelter for its repair crews who are literally sleeping in their trucks" (Office of Electricity Delivery and Energy Reliability 2005). Conditions like these lead to such public health problems as increasing risks of infectious disease and occupational injury.

Public health preparedness today, whether for a chronic disease or a pandemic, depends on infrastructure advances of the past century and, in particular, on the availability of electricity. The 20th century saw great improvements in public health (CDC 1999c), one of the most significant of which concerned the control of infectious diseases (CDC 1999a). The availability of clean drinking water, sanitary sewage systems, and refrigeration—all of which require electricity—accounted for some of the largest drops in infectious disease mortality (CDC 1999a, CDC 1999b). The ability to provide safe drinking water in the 1900s had a significant impact on reducing infectious disease mortality. For example, the leading cause of mortality of children in Minneapolis in 1900 was typhoid fever, the result of consuming water from contaminated individual water supplies (Osterholm MT, unpublished data). Today, standard environmental health practices like ensuring the safety and maintenance of our water systems is considered the foundation of public health. Such practices typically operate in the background—unless a breakdown in the infrastructure occurs.

But electricity truly undergirds the public health infrastructure. It is so vital today that one of us has noted: "Thomas Edison, not John Snow, is really the father of modern public health" (Osterholm MT, Jun 16, 2008). Without electricity or the availability or use of backup power sources, safe water treatment and distribution systems, sanitary waste treatment systems, food refrigeration processes, and vaccine manufacturing plants cannot operate. In addition, traffic lights go dark, telecommuting isn't possible, public health surveillance activities are crippled, elevators stop working, and the heating and cooling of buildings cease. While it might seem obvious that electricity is critical for public health, the literature on this topic is sparse. In contrast, ample literature exists regarding (1) air, water, and food, and ensuring that such basic needs are protected for the sake of the public's health and (2) the dangers that electrical power generation, primarily coal-based, pose to the public's health. This body of literature, however, does not reflect an understanding of how much society depends on the infrastructure that provides our nation's power or an understanding of what this infrastructure comprises (Leavitt 2006).

This paper is the first attempt to conceptualize the potential impact of an influenza pandemic on electricity in the United States, specifically on the supply of coal, and the subsequent danger to public health. It provides a detailed analysis of the coal supply chain that originates in the Powder River Basin (PRB) of Wyoming and Montana, which is the largest single source of fuel for power generation in the United States (Freme 2008). While coal is mined in multiple locations around the country, the quality and type of coal varies at different mines. Modern coal boilers are not typically designed to use more than one type of coal, such as low-sulfur coal from the PRB. Without modifications, coal mined on the east coast cannot be used in plants designed to burn low-sulfur coal from the PRB. Non-PRB coal is typically used for power generation in the same geographic region from which it is mined. In times of coal shortages, as might be anticipated with a pandemic, the mere availability of coal in one location does not mean that it can be used in other locations. We will discuss later in this report the example of a coal supply-chain disruption that nearly interrupted service to a major coal-fueled power plant near Atlanta. Even though coal mines are geographically close to this plant, the facility had to import from Indonesia the type of coal that could be burned in its boilers. (See page 26 for further discussion.)

Our analysis examines pandemic preparedness in the three main components of this supply chain (production, transport, and consumption) and the planning guidance given to these components by nongovernmental organizations (NGOs) and by state and federal governments. This analysis will provide insight into the dynamics of pandemic preparedness in the 21st century and the impact that pandemics can have in our flat world.

In short, if an influenza pandemic disrupts our nation's coal supply chain, then what impact can we expect on our public health system and what can we do now? A coal shortage during a pandemic portends grim outcomes. Society can take steps to ensure that coal is mined and transported where and when needed, which means decision-makers at all levels must clearly understand the inextricable tie between public health and electricity—and act accordingly well before the pandemic onset.

Pandemic planning in the energy sector

The energy sector comprises multiple assets that provide energy in its raw or refined forms and are typically associated with electricity, natural gas, or petroleum. **Electrical assets** range from transmission and distribution infrastructures to facilities that generate electricity from a wide range of sources, like coal, nuclear, natural gas, and renewables. **Natural gas and petroleum assets** range from wells to transmission and distribution infrastructures and refineries. Such assets can be found throughout the nation, from oil wells in Alaska to refineries in Louisiana, and from water that spins turbines in a dam in the Tennessee Valley to coal seams in Wyoming. While diverse, the assets actually are interdependent. Both the movement of oil from wells to refineries and its refinement to diesel requires electricity. The movement of coal out of the ground and to power plants, where electricity is produced, also requires diesel fuel. And while the electrical sector cannot function without natural gas and oil assets, this paper focuses specifically on coal-fueled power plants.

Base-load power. Coal, hydroelectric, and nuclear power provide most base-load power on which the nation's power grid system relies. Base-load power, the backbone of the electrical grid system, is continuously supplied at a relatively constant level to accommodate a relatively constant demand for electricity. Coal provides the largest percentage of base-load power in the United States. If coal-based power fails due to a widespread pandemic-related supply chain disruption, the country's power system will be crippled. While this situation is theoretically possible, regional disruptions are more likely to occur, because certain regions depend so heavily on coal. (See Figure 2.) However, given that any one area of the country depends upon products and services from other areas, regional disruptions in electricity will have national impact. Even losing individual power plants could result in unforeseen problems (Mili 2004). The effects of the power grid's collapsing would be catastrophic. Simply put, without electricity the critical industries in our nation and around the world shut down.

Generators. Most contingency plans for power outages rely on generators. Generally, these generators use diesel fuel. Some generators use natural gas or another fuel that is delivered via pipeline. Onsite supplies of diesel fuel are typically in use for hours, not days. These fuel supplies are then maintained by emergency fuel contracts. Fuel contracts are typically filled at the refinery or fuel transport medium (pipeline or barge) used in the region. Power disruptions are the most common form of emergency shutdowns that refineries experience (EIA 2007d). Most refineries, sans the larger ones, do not have the capacity to continue work if their power supply is disrupted. When power is disrupted, emergency generators kick in and provide enough power to safely shut down the facility, which can take up to 48 hours. The larger refineries might have on-site co-generation plants that generate electricity for the refineries, but these are still vulnerable to power outages, as they depend on fuel (mostly natural gas) being delivered via pipelines, which are powered by electricity. After the experience with Hurricane Katrina, many key points on the main pipelines now have generator backup. Electricity is critical for natural gas production and transport. If a power disruption results in refineries shutting down, there will likely be limited fuel supplies to meet these emergency fuel contracts, unless fuel can be obtained from sources that are not affected. Given the geographic concentration of refineries, such a scenario is unlikely (Parfomak 2007).

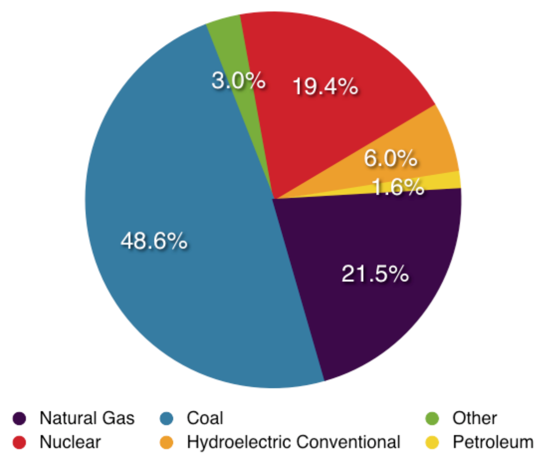
The electrical sector has a long history of dealing with natural disasters and disruptions, which has created a robust culture of preparedness in the industry. Part of this culture comes from an understanding that the multiple energy sources provide power for our nation, thus making electrical generation more redundant. Using guidance from the DHS and HHS, however, the electrical generation industry has developed pandemic plans that primarily focus on employee health and safety (EEI 2007, NERC 2005).

The industry has projected that during a pandemic electricity usage would drop 1% to 9%, owing to community mitigation measures and worker absenteeism (Ontario Emergency Preparedness Task Force 2007). There is existing concern about energy supplies, specifically coal, being disrupted during a pandemic; the Electricity Sector Coordinating Council and the Edison Electric Institute (EEI) have noted that coal stocks may need to be increased to ensure adequate fuel levels during a pandemic (GAO 2007). Presumably, disruptions in mining and transportation will cause a shortage of coal by the end of the first wave. While the energy sector has done significant work to ensure the health of its workforce during a pandemic, little progress has been made to ensure the preparedness of the coal supply chain upon which the industry depends.

An overview of power generation in the United States and the role of coal

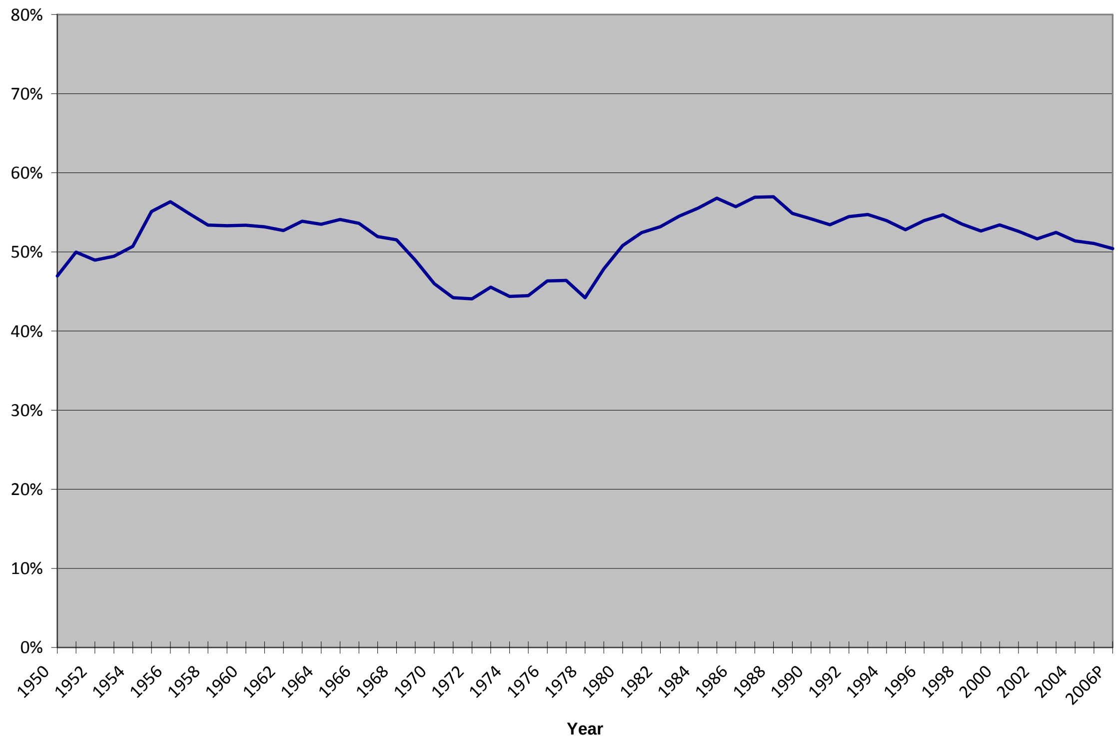
Coal currently is the predominant energy source for the generation of electricity in the United States. In 2007, coal was the source of 48.6% of the electricity generated (EIA 2008d). Figure 1 shows the primary energy sources used to generate the nation's electricity.

Figure 1: Percentage of net electricity generation by energy source, United States, 2007 (EIA 2008d)



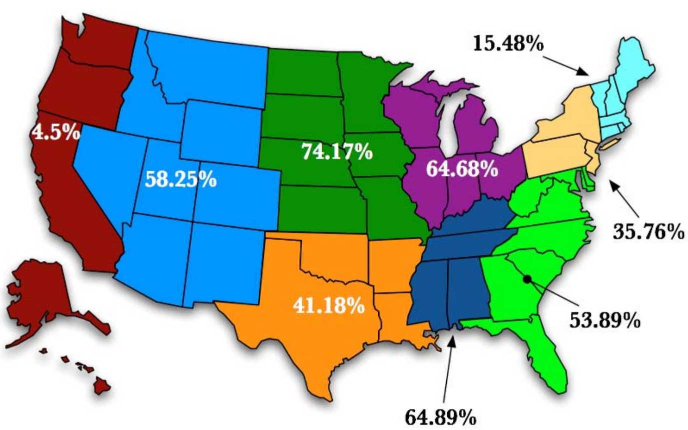
In 2007, the electrical power sector generated 4,006,482 megawatt hours of power in the United States (EIA 2008d). More than 71% of this power was derived from a fossil fuel, including coal or natural gas. As of January 1, 2007, the United States had 620 coal-powered plants (EIA 2008d). Clearly, coal is the cornerstone of electrical power generation in the United States—and has been since the 1950s, as Graph 1 indicates.

Graph 1: Percentage of electrical generation based on coal, 1950 to 2006 (EIA 2007b)



Coal is likely to continue to provide most electrical power in the United States, though regional differences exist, as seen in Figure 2.

Figure 2: Percentage of net electrical generation in the electrical power sector based on coal, in 2007 (Freme 2008)

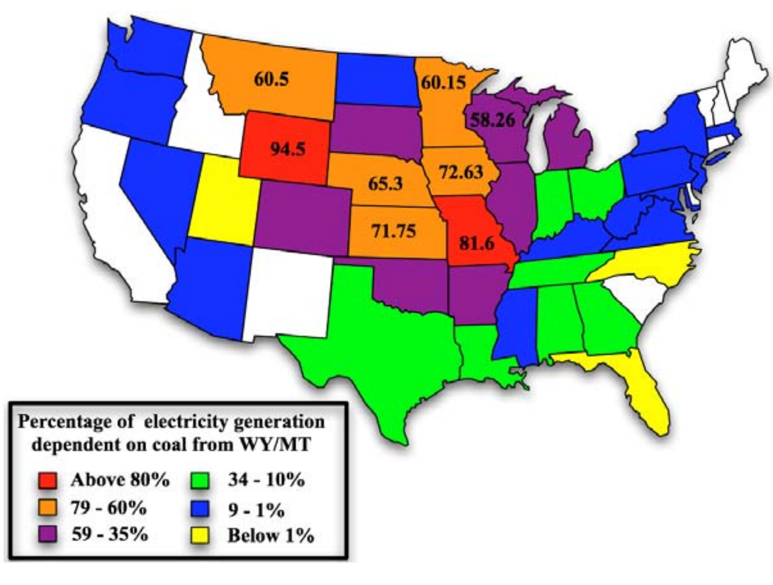


Coal is projected to supply 54% of the nation's electricity by 2030 (EIA 2008b). In accordance with this projection, currently 28 new coal-powered plants are being built in the United States (NETL 2008). A trend worth noting is the growing attention to environmental concerns around coal usage and the impact this will have on investments in the security of the coal supply chain. It is unclear what the concerns about carbon emission caps will do to discourage the construction of new coal-fired plants.

One of the primary reasons the United States relies so heavily on coal for the generation of electricity is that it has the largest known reserves of the fuel in the world (EIA 2007c). At current usage rates, known coal reserves in the United States could provide well over 200 years' worth of fuel, though a more detailed analysis is needed to ensure these estimates are accurate (Committee on Coal Research, Techonology, and Resource Assessments to Inform Energy Policy 2007).

For years the main source of coal in the United States was the underground mines in such states as West Virginia, Pennsylvania, and Kentucky. Underground coal mines consistently produced more coal per year than surface mines until 1974 (EIA 2007b). Passage of the Clean Air Act, intended to reduce sulfur dioxide emissions, ramped up surface mining in the 1970s in the quest to access low-sulfur coal. The United States happens to have a large reserve in the PRB in Wyoming and Montana. Both states saw a boom in coal production in the 1970s, and Wyoming has become the largest source of coal in the United States. In 2007, Wyoming produced 453.6 million short tons of coal or almost 40% of the United States' coal production (Freme 2008). Figure 3 shows the 39 states currently using coal from Wyoming and Montana (EIA 2008c).

Figure 3: Percentage of electrical power generated from Wyoming/Montana coal by state, 2006 (EIA 2008c, EIA 2007b)



Combined, Wyoming, and Montana have 26 coal mines, and the PRB mines account for 17 of them (EIA 2008a). All of the PRB mines are surface mines—and they are highly productive. In 2007, for example, the largest coal mine in the United States was North Antelope Rochelle in the PRB, which produced 91.5 million tons of fuel (Freme 2008). That one mine produced more coal than 22 of the other 24 coal-producing states (Freme 2008). The coal in the PRB lies in thick seams very close to the surface, which makes it conducive to rapid and extremely productive extraction.

In 2007, 6,399 miners worked the 17 mines in the PRB and produced 479.5 million short tons of coal, making them some of the most productive miners in the world (EIA 2008a). In addition, many third-party vendors assisted miners by maintaining equipment and loading the trains, among other activities. The high levels of productivity per person at PRB mines, while impressive, could make any disruption in the availability of miners risky, because productivity could drop dramatically if widespread illness were to occur. Fortunately, PRB mines have never experienced a situation that would disrupt the availability of miners. And, like most people alive today, these highly productive miners have yet to experience a severe influenza pandemic.

What could happen to the coal supply chain during a pandemic?

The coal mining industry will not escape the effects of a pandemic, and the areas of production and transportation will bear the brunt, because demand for coal will not drop during a pandemic. Coal mining is an energy- and human-intense activity. Equipment used in the PRB is massive, requiring enormous amounts of fuel and electricity and highly experienced and skilled workers. Each worker has an essential role, including the limited number of people who can safely and effectively drive one of the 400-ton trucks used to transport coal from the mine to the processing facility, which can be miles away. If, for example, a driver makes 10 trips a shift, delivering 4,000 tons of coal a shift, the impact of this driver missing 10 work shifts would be 40,000 fewer tons of coal being processed at the mines—the equivalent of three full coal trains.

With more than 6,000 miners working in the PRB, losing even 5% of the workforce would severely reduce mining productivity. A 30% workforce absenteeism rate would result in 1,800 miners missing work for days to weeks. The result would be significantly less coal being mined, as each miner plays such an integral role in mining productivity. A reduction in mine productivity will result in less coal being shipped, and, ultimately, coal stocks being drawn down.

Almost all coal coming out of the PRB is moved on railroads, often great distances. As the international coal market continues to expand, the demand for PRB coal on the east coast of the United States is increasing (Carey 2008). The more that utilities on the east coast turn to coal from the PRB, the more stressed the supply chain will become. PRB coal travels as far away as Georgia, a 1,400-mile one-way trip (Sharp 2008). On long-distance trips, a single coal train might have 11 different train crews (a conductor and an engineer) who work locally on tracks they have memorized due to the variability required in train speed per local railroad conditions (McPhee 2005a). Crews are guided by 12 different dispatchers. Each dispatcher (located in a remote facility with other dispatchers) orchestrates the movement of trains and authorizes crews to travel the stretch of track the dispatcher controls (McPhee 2005b). Federal law allows these highly trained train crews to be on the job for a maximum of 12 hours at a time, though this rule will likely be suspended during a pandemic (Establishment of Emergency Relief Dockets 2007). Even with this suspension, the rail system is going to have difficulty operating near current capacity during a pandemic.

The Department of Transportation (DOT) suggests that railroads prioritize their services to ensure essential products like coal are transported during the periods of high absenteeism expected during a pandemic (DOT 2008). While it is likely that coal and other critical products (eg, chlorine for water treatment) will be prioritized by the rail industry, other cargo will necessarily fall by the wayside, a cause for concern because the railroad industry is essential for keeping most of the critical industries in the nation in business. Even short disruptions can be catastrophic for them (Critical Infrastructure Assurance Office 1997).

Every region in the United States is expected to experience the pandemic in a similar time frame, though each region's first case and peak number of cases are not likely to occur on the same day, rather within days to weeks of each other. The railroad system currently operates many vital coal routes at or near capacity (AAR 2007). Any disruption along the supply chain, be it delayed unloading at power plants or reduced loading at the mines, damages the efficiency of the entire system. Given the tightness of the system, any delay can result in multiple delays. Because the rail system does not have the capacity to appreciably increase coal shipments, coal stocks could remain at suboptimal levels for long periods.

Methods

Analysis for this report was based an comprehensive review of power industry reports; government hearings, plans, reports, and guidance; accounts of the 1918-19 pandemic; review of a derailment that affected shipments from the Power River Basin in 2005; and scientific literature. This section summarizes steps taken.

Review of electrical reliability in the United States

NERC is a nonprofit organization responsible for ensuring reliable bulk power in North America. NERC publishes two seasonal reliability assessments per year, summer and winter, as well as one long-term (10-year) reliability assessment. The most recent winter, summer, and long-term reliability assessments were reviewed (NERC 2007a, NERC 2007c, NERC 2008). Special attention was paid to the history of coal stocks and current projections.

Review of the 2005 coal disruption in the Powder River Basin

The circumstances of a 2005 coal shipment disruption in the PRB resemble the potential impact of a pandemic and thus provided a case study to review. The PRB is the single largest source of energy for electrical generation in the United States. A disruption caused by physical damage to rail lines severely reduced rail capacity out of the PRB. While physical damage is not expected during a pandemic, workforce absenteeism will likely cause a reduction in mining and transport, thus limiting the shipment of coal out of the PRB.

Reports on the disruption from (1) NERC, (2) the DOE Office of Electricity Delivery and Energy Reliability, and (3) the Congressional Research Service (CRS) were reviewed in detail. Testimony and comments from three hearings were also reviewed:

- ***Federal Energy Regulatory Commission*** discussion with utility and railroad representatives on reliability matters, June 15, 2006
- ***Surface Transportation Board*** public hearing on rail transportation of energy resources critical to the nation's energy supply, July 18, 2007

- ***Senate Committee on Energy and Natural Resource*** hearing on coal-based generation reliability, May 25, 2006.

Current information on coal and electricity from the DOE Energy Information Administration (EIA) was also reviewed to provide a perspective of the current situation. Documents reviewed are listed in Appendix A.

Literature review on the impact of power outages on public health

A literature review on the impact of electrical power outages on public health was performed via a search of PubMed, IEEE Xplore, Google Scholar, and the Compendex and Engineering Index, using the following keywords: blackout, power outage, electricity, lack of power, natural disaster, generator, public health, critical infrastructure, and power failure. The keywords were used in a variety of combinations. Abstracts were reviewed to determine if a paper addressed the impact of power outages on public health. Papers that focused on a single impact, such as how a hospital emergency room handled a power outage, were excluded, as they did not address broad public health issues.

Review of federal and selected guidance on pandemic planning

Twelve key guidance documents focused on business or critical infrastructure preparedness for a pandemic and/or recognized as significant in pandemic planning were identified. (See Appendix B for a list of the guidance documents and reasons for choosing them.) A detailed review and a keyword search were performed. A list of keywords was compiled, representing common terms associated with electrical generation. Keywords included: critical infrastructure, electricity, power, coal, fuel, utilities, and energy. The documents were searched using the search feature in Adobe Acrobat 8 Professional (Adobe Systems Inc., San Jose, Calif.) for instances in which these keywords appeared. The context for each keyword was examined to ensure it referred to planning for the electrical sector.

Review of coal-producing states' pandemic plans

Pandemic plans were reviewed from 25 states that provide almost all the coal for the generation of electricity in the United States. Coal-producing states were derived from Table 1 of the EIA's 2007 *Annual Coal Report*, which is provided in Appendix C (EIA 2008a). The pandemic influenza plans for these states were then accessed via the state plan listing on www.pandemicflu.gov (HHS-c). To ensure the most current plan was analyzed, each was compared to the state pandemic plan list maintained by the

Center for Infectious Disease Research and Policy at the University of Minnesota (CIDRAP 2008). State pandemic influenza Web sites were also searched for additional material related to business or critical infrastructure pandemic planning. All plans were accessed between April 14, 2008, and May 10, 2008. All plans were downloaded as portable document files (PDFs) or received as Microsoft Word documents and converted to PDFs. West Virginia provided its draft plan via e-mail.

Excluded from the analysis were the following states for the following reasons:

- ***Arkansas.*** The pandemic plan was not made available.
- ***North Dakota.*** The plan was only a summary of activities.
- ***Mississippi.*** The plan addresses only how the state will receive and distribute assets from the Strategic National Stockpile (SNS).

A list was compiled of keywords that are common terms associated with electrical generation. Keywords included: critical infrastructure, electricity, power, coal, fuel, natural gas, utilities, trains, and railroads. The state pandemic plans were searched using the search feature in Adobe Acrobat 8 Professional (Adobe Systems Inc, San Jose, Calif.) for instances in which these keywords appeared. The context for each keyword was examined to ensure it referred to planning for the electrical sector.

Review of the impact of the 1918-19 pandemic on coal production

Archives of *The Chicago Daily Tribune* and *New York Times* were searched via the ProQuest database for references between March 1, 1918, and December 31, 1919, to coal shortages due to an influenza pandemic (dates were chosen so that the pandemic was fully included). A similar search was performed on PubMed and Google Scholar for articles that referenced coal shortages in 1918-19 caused by the influenza pandemic. The US government's pandemic flu portal (pandemicflu.gov) was searched for references to coal. Testimonies from Congressional hearings on coal shortages in 1918-19 were also reviewed for references to the influenza pandemic.

Results

A comprehensive review of government and industry reports and guidance, scientific literature, historical accounts of the 1918-19 pandemic's impact on coal, and hearings about a 2005 train derailment that disrupted coal supply yielded troubling findings. Despite the nation's massive reliance on the coal industry for electricity generation, little has been done to secure this critical infrastructure and the people who run it during a pandemic.

Review of electrical reliability in the United States

The basis for pandemic planning in the electricity generation and delivery industry depends on the reliability of the current system. In October 2007, NERC released its long-term reliability assessment of the bulk electrical power system in North America for 2007 through 2016. This assessment highlighted five key findings that need to be addressed in the next 10 years:

1. Insufficient capacity margins ("extra" energy that can be used for emergencies)
2. The special considerations required for the integration of wind, solar, and nuclear power to the bulk power system
3. A high dependence of some regions on natural gas
4. Insufficient transmission resources (high-voltage power lines that traverse regions)
5. An aging workforce.

Capacity margins, the power produced beyond what is projected to be needed, have been reduced by such factors as regulatory actions, deregulation, political obstacles, environmental constraints, and investor preferences. Long-term investments in capacity in a deregulated industry are more uncertain and risky. Short-term investments work as long as there is sufficient uncommitted capacity (projects that are in the planning stage, but not far enough to be firmly committed to provide power in the future), but they are not sufficient for long-term planning for meeting electrical demand. Current political and environmental trends have reduced the amount of uncommitted capacity, making the long-term capacity margins uncertain. **Integration of wind, solar, and nuclear energy** requires extensive long-term planning and more investments in transmission resources to bring the power generated to large population centers. The **dependence of some regions on natural gas** is of great concern, because supply constraints are expected to increase in the next 10 years as regions increasingly turn to natural gas and refuse to use other energy sources, such as coal or oil. **Transmission resources** are improving, but the industry still ranks aging infrastructure and limited construction as its No.1 challenge for reliability. The industry, like others, is working on challenges posed by an **aging workforce**. All these issues must be addressed to ensure a reliable supply of power in North America.

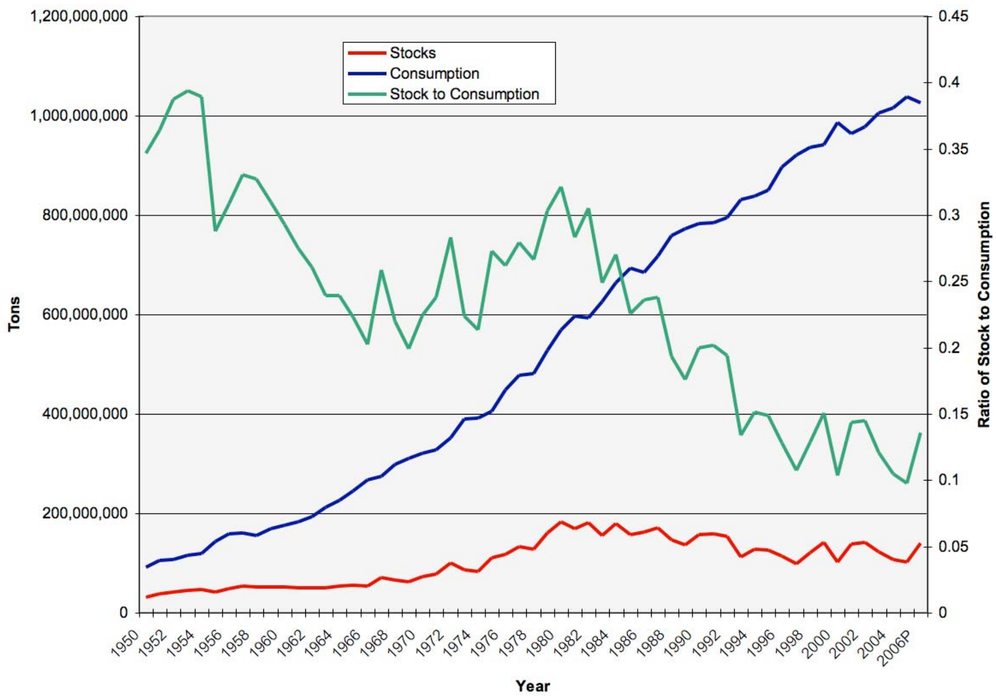
NERC's 2007 long-term assessment was the first to catalog emerging issues with which the industry is dealing. Of the 14 issues identified, two are of importance to this paper:

1. ***Supply of fossil fuels.*** Concern is increasing about the ability of North America to import the volume of natural gas projected to be needed, owing to supply constraints in the domestic and foreign infrastructure. The concern about fossil fuel supply also extends to coal, as the global market is rapidly changing and rail capacity continues to tighten.
2. ***Demand for power system equipment worldwide.*** Driven by developing nations, the growing demand has noticeably lengthened the time from when a product is ordered to when it is delivered: Most manufacturers are running at or near capacity and cannot provide a quick turnaround on orders. In some cases the time from order to delivery has increased by a year.

As of January 1, 2007, the 620 coal-powered plants in the United States (EIA 2008d) all maintain their coal stocks differently. Each coal plant has a unique set of conditions that dictates the size of its coal stocks, but in general 30 days of coal is the industry average. Some plants will keep more than 30 days of coal on hand and some will keep less. A few plants receive their coal via barges on waterways that freeze in the winter, so they must maintain a sufficient amount of coal to last through the winter. Some other plants operate at the mouth of coal mines and have lower coal stocks, as they are at the source. Municipal utility companies tend to maintain larger coal stocks than independent power companies, which have a greater financial incentive to run as "lean" as they can.

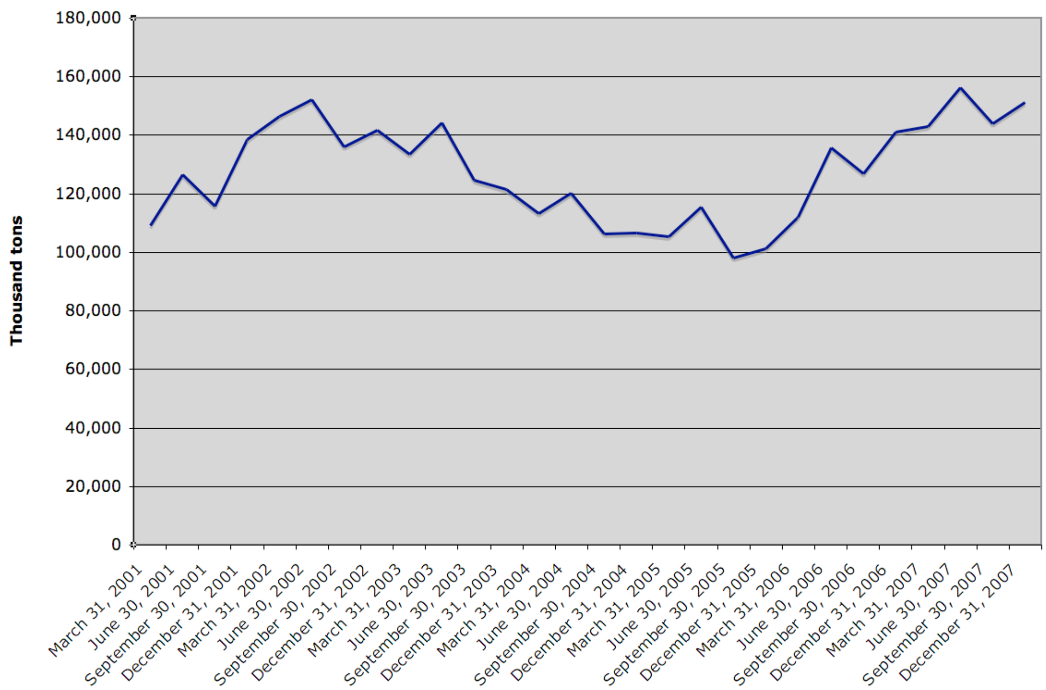
Coal-fueled power plants maintain coal stocks so that power generation can continue in the event of expected and unexpected short-term disruptions in the supply chain. However, as Graph 2 shows, coal stocks in the 1950s were substantially higher than those found today; they were at approximately 90 days of burn, the number of days a plant could operate if its coal supply was cut off. (Days of burn are how coal stocks are frequently reported.)

Graph 2: Historical electrical sector coal stock, consumption, and ratio of stock to consumption (EIA 2007b)



Over time, coal stocks have gradually become smaller. In the 1990s, a concerted effort to cut costs in the competitive electrical sector resulted in coal stocks being decreased from approximately 60 to 30 days of burn. Coal became a commodity that power companies assumed would be reliably transported with minor disruptions. Power companies became increasingly dependent on the coal transport system, as coal became treated as a just-in-time deliverable commodity. Before 2005, most power companies had never experienced prolonged delays in the shipments of coal and thus routinely operated with lower stocks. A severe disruption in 2005 (described on page 26) changed this notion, demonstrating that rail capacity could not expand to allow the industry to recover from large delays in coal transport. While it appears the cost of coal conservation (for an explanation of this process, see page 26) following the disruptions in 2005 has caused the electrical sector to reevaluate its coals stocks, the increases in stock would be largely insufficient for a sustained and substantial decrease in the mining and transport of coal (Graph 3).

Graph 3: Electrical sector coal stock by quarter (EIA 2008e)



While coal stocks have increased, NERC, in its 2008 Summer Reliability Assessment, notes the increase in stock is not uniform (NERC 2008). Coal stocks from the PRB have reached an "unusually high" 64 days of burn at the beginning of 2008, while stocks of northern Appalachian coal have fallen to a low level of 36.8 days of burn (NERC 2008). This is due mostly to notable changes to the international coal market in the last few months. Safety-related mine closures in China, weather-related production delays in China and Australia, and decreased output by some European mines have all produced a shortage of coal in the international market. The result is a significant increase in the export of coal mined in the eastern part of the United States.

The reasons coal stocks can fluctuate include:

- ***Economic pressures.*** The electrical sector, while part of the critical infrastructure, is still a business that must manage its finances in a responsible way. Coal stocks will fluctuate based on forecasted use and price. If coal is cheap, stocks will likely increase.
- ***Seasonal changes.*** Coal stocks are the highest when plants prepare for peak electrical usage days in the summer and lowest in spring and fall, when demand is the lowest.
- ***Mine and transportation issues.*** Extreme weather is a common cause of stocks fluctuating. Stocks also fluctuate based on repair on the mines or on the transportation infrastructure.

Until recently, severe interruptions due to global events such as a pandemic had not been considered.

Review of the 2005 coal disruption in the Powder River Basin

The PRB, which provides the United States with almost 40% of its coal, is the single largest energy source for power generation in the country, and its coal is primarily delivered by railroad. A disruption in 2005 serves as an example of the impact a pandemic might have on the coal supply chain. In late 2004, coal deliveries at some utilities became inconsistent, owing to rail capacity issues (see Appendix E for an overview of the coal supply chain and page 16 for an overview of PRB coal, in the context of electricity generation in the United States). Some power plants reported a 10% drop in coal shipments during this time, which resulted in decreased coal stocks at the plants. Demand for coal was greater than the system could handle. In recent years, railroads, utilities, and mines have all made improvements that have mitigated these earlier capacity issues.

On May 14, 2005 a Burlington Northern Santa Fe (BNSF) train derailed on the South PRB Joint Line. The South PRB Joint Line is a 103-mile rail line that is jointly owned and maintained by BNSF and Union Pacific (UP). BNSF handles the dispatching of trains on the line from its dispatch center in Fort Worth, Tex. The line connects Caballo Junction (near Gillette, Wyo.) and Shawnee Junction (near Douglas, Wyo.), allowing both UP and BNSF to connect to their larger rail infrastructure in Wyoming, from the mines in the PRB. On May 15, a UP train derailed on the same line. These two derailments damaged all three rail lines on the South PRB Joint Line. The derailments were caused by unstable tracks, which was the result of a combination of accumulated coal dust, above-average rainfall, and old tracks. All rail movement of coal in the southern PRB was temporarily halted until tracks could be repaired. All three tracks were returned to service in 3 weeks. During this period, power plants were forced to draw down their coal stocks.

Once the three tracks were repaired, BNSF and UP embarked on a massive maintenance and upgrade program on the South PRB Joint Line. (Now, most of the line is quadruple track. More than 130 trains travel these tracks daily. Measured in tons per mile, the South PRB Joint Line is the busiest and most dense freight railroad system in the world.) During the upgrade effort, some utility companies reported a 15% to 20% reduction in coal shipments for multiple months; a few did not report reductions of this magnitude. The reduction in service made power plants continue to rely on their coal stocks to make up for reduced coal shipments, and it prevented coal stocks from being replenished. PRB-fueled power plants saw coal stock levels fall to worrisome levels. By September 2005, many power plants were down to less than 10 days of coal in their stockpile, with some reporting only 2 days of coal on hand. Plant Schere, in Juliette, Georgia, for example, the second largest coal power plant in the western hemisphere, was reduced to 2 days of coal and chose to import coal from Indonesia in an effort to rebuild its coal stockpile. Most modern coal boilers are designed to use specific kinds of coal, such as low-sulfur coal from the PRB. These boilers require coal with similar characteristics to the coal it was designed to use; in this case Indonesian coal is similar to PRB coal.

According to a CRS analysis of 27 entities in the electrical sector that rely on PRB coal, 25 instituted coal conservation programs. Coal conservation can entail replacing coal-based electricity generation with electricity generated from another fuel source (typically, natural gas), purchasing electricity on the grid, reducing electricity generating time, and purchasing additional coal from other domestic or international sources. According to the EIA, as a result of the 2005 disruption, coal stocks in the electrical sector were still being rebuilt throughout 2007.

Literature review on the impact of power outages on public health

Two published papers that address the impact of power outages on public health were identified in the literature review. The first is based on the experience of the New York City Health Department during an unprecedented electrical blackout 5 years ago. On Thursday, August 14, 2003, at 4:15 pm, an electrical blackout struck the northeastern part of the United States (Beatty 2006). The department undertook efforts to ensure vaccine cold storage was safely maintained, checked the quality of the city's water supply, initiated syndromic surveillance to ensure the blackout was not part of a more sinister plot, increased inspections of restaurants to ensure safe disposal of spoiled food, and had the laboratory continue to process samples, among other actions (Beatty 2006). The emergency operations center functioned without power until 2 am Friday morning, as it did not have emergency backup power on site (Beatty 2006). Subsequently, Beatty et al worked closely with the US Centers for Disease Control and Prevention (CDC) to publish guidelines for the appropriate public health response during a power outage (Beatty 2006, CDC-a).

The second paper, from Australian researchers, focused on efforts to mitigate the public health effects of a natural disaster that destroyed a large portion of the critical infrastructure in New South Wales. During the week of June 7, 2007, a series of storms caused widespread flooding and damage to homes, businesses, hospitals, and critical infrastructure in the Hunter region of New South Wales (Cretikos 2007). One of the biggest public health issues in the region was the loss of electricity to water and wastewater treatment facilities. Some regions experienced sewage backups and had to implement water conservation efforts (Cretikos 2007). The public health response was similar to that in New York City, with an increase in environmental sampling and syndromic surveillance. Damages to the infrastructure made getting out public health prevention message difficult, and this led to building a close working relationship with the local radio station. Cretikos et al concluded that all states and territories should make formal arrangements to provide emergency messages over the local radio network, if ones are not already in place (Cretikos 2007).

While both of these papers addressed broad public health issues associated with electrical blackouts, neither of the events reviewed lasted for a sustained period as would happen during an influenza pandemic. There does not appear to be any peer-reviewed literature about the impact of long-term power outages on the health of the public. Nor does there appear to be any peer-reviewed literature on the impact of geographically widespread outages.

Review of federal and selected guidance on pandemic planning

The 12 guidance documents on pandemic planning that were reviewed each used the same basic assumptions about pandemic planning, namely that it differs from normal business continuity planning. The following statement from the EEI summarizes these assumptions:

> Planning for a pandemic is unique from other business continuity planning because it requires businesses to prepare to operate with a significantly smaller work force, a threatened supply system, and limited support services for an extended period of time at an unknown date in the future.

The White House Homeland Security Council further elaborated upon this point, requiring specific planning for supply shortages in the US pandemic influenza implementation plan in:

- **Action 5.1.2.5:**

  > DHS and DOT, in coordination with DOD and States, shall develop a range of options to cope with potential shortages of commodities and demand for essential services, such as building reserves of essential goods, within 20 months. Measure of performance: options developed and available for State, local, and tribal governments to refine and incorporate in contingency plans.

- **Action 5.1.3.2:**

  > DHS, in coordination with DOT, HHS, DOC, Treasury, and [US Department of Agriculture], shall work with the private sector to identify strategies to minimize the economic consequences and potential shortages of essential goods (eg, food, fuel, medical supplies) and services during a pandemic, within 12 months. Measure of performance: the private sector has strategies that can be incorporated into contingency plans to mitigate consequences of potential shortages of essential goods and services.

The last update on completed actions in the implementation plan was released October 17, 2008, and action 5.1.2.5 is listed in progress, while action 5.1.3.2 is listed as completed (HSC 2008). Action 5.1.3.2 was identified as being complete based on checklists developed for private-sector preparedness. It is unclear how these checklists provide "strategies to minimize the economic consequences and potential shortages of essential good and services." One of the checklists highlighted in the progress report was the *business pandemic influenza planning checklist*, which was one of the 12 documents reviewed. While most documents reviewed specifically noted the likelihood of supply shortages during a pandemic, there was a general lack of conceptual understanding of what such shortages would look like during a pandemic or what must be done now to reduce the likelihood that they will occur. The documents also noted that critical infrastructure planning was essential.

The energy supply chain is only specifically mentioned in the National Infrastructure Advisory Council (NIAC) prioritization of the critical infrastructure document. However, this reference addresses *components* in the power delivery system, such as transformers or utility poles. While the NIAC guidance points out the importance of the transportation sector in moving coal via railroads and barges, none of the 12 documents prioritizes the *mining* of coal. This absence is likely due to coal production not being listed officially as a critical infrastructure or key resource (White House 2003b). Coal supply is not covered in the public version of the DOE Critical Infrastructure and Key Resources Sector-Specific Plan (DHS/DOE 2007). Coal is also not typically thought of as an energy security risk; thus, it is largely ignored (Farrell 2004).

Workers in occupations associated with coal mining (including supporting infrastructure, like vehicle maintenance) are currently prioritized in federal vaccine allocation plans to receive an influenza pandemic vaccine as part of the general population, depending on their health status and age. This is the lowest of the federal priority categories. Some critical transportation workers, such as train engineers, will receive a pandemic vaccine in the 3rd priority tier if the pandemic is severe. However, during a moderate pandemic these workers will also receive the vaccine as part of the general population, depending on their health status and age. In short, the current federal pandemic preparedness plans have failed to (1) conceptualize the magnitude of supply chain disruptions that will occur in a global just-in-time economy, (2) address how to prevent pandemic-related electrical power disruptions, and (3) offer guidance on how to respond if electrical power is disrupted during a pandemic.

Review of coal producing states' pandemic plans

In the United States, 25 states produce coal. The pandemic influenza plans for 22 of those states were analyzed to determine the status for the continuation of the energy sector during a pandemic; results are shown in Table 1. (More information about the pandemic plans analyzed is in Appendix D.)

Table 1: Guidance provided by coal-producing states for continuity of the electrical sector

	Uses federal guidance on vaccine prioritization	Uses federal guidance on antiviral drug prioritization	Specifies what state agency is responsible for the continuation of CI/KR*	Mentions legal authority to direct critical supplies	Prioritizes coal production	Has a plan for fuel (gas & diesel) shortages
Alabama	X		X			X
Alaska						
Arizona						
Colorado						
Illinois	X	X	X	X		
Indiana	X	X				
Kansas		X				
Kentucky	X	X				
Louisiana	X					
Maryland	X	X	X			
Missouri	X	X				
Montana	X					
New Mexico						
Ohio						
Oklahoma	X	X				
Pennsylvania						
Tennessee	X					
Texas						
Utah						
Virginia		X				
West Virginia						
Wyoming	X	X				

** CI/KR = Critical infrastructure/key resource*

In addressing critical infrastructure planning in the state, many of the state plans had text similar to Kentucky's:

> Only limited information was available from which to assess potential impacts on critical infrastructure sectors such as transportation and utility services. Because of changes in business practices and the complexity of networks, information from prior pandemics was not considered applicable.

Eleven of 22 states explicitly adhere to federal guidance on vaccine prioritization within the energy sector. The most current guidance places the sector in tier 2 and is based on the work of the National Infrastructure Advisory Council (NIAC 2007). Coal mining is not considered part of the energy sector in the NIAC guidance and thus not prioritized for a pandemic vaccine. Ironically, while workers in the coal-mining industry will be vaccinated as part of the general population, critical workers in the oil and natural gas industries will be vaccinated at the same time as critical workers in the energy sector. If a pandemic is severe, some critical transportation workers, such as train conductors, will receive pandemic vaccine in the third tier.

Only three states—Alabama, Illinois, and Maryland—specified what agency had responsibility for ensuring the continuity of the critical infrastructure in their states. This is critical information that the energy sector needs in determining which agency or person it should be working with to plan for its pandemic response in each state. Illinois was the only state to specifically describe the governor's legal authority to direct critical products during an emergency such as a pandemic. Such authority might be critical for ensuring coal transport during a pandemic.

Review of the impact of the 1918-19 pandemic on coal production

Coal in 1918-19 was used primarily for industrial purposes like making steel. The railroads also used coal-powered trains, and homes were heated with coal. The influenza pandemic of 1918-19 caused serious disruptions in coal supply. One of the first mentions of the pandemic's impact on coal mining was in an August 5, 1918, article in the *New York Times*. It reported that coal had not been shipped from Germany to Switzerland during the previous 4 days and that many miners had stopped work due to the "epidemic of Spanish grip" (*New York Times* 1918e). Copper mines in Peru were also hit hard. A report in the *New York Times* on August 4, 1918, stated that large copper mining plants "have been virtually paralyzed for the last ten days" (*New York Times* 1918d). The situation in Toronto was similar. In October 1918, one report noted that "coal became difficult to obtain and fuel supplies for the sick and for industry diminished" (Macdougall 2006). Fuel supply issues also kept the schools from reopening in early November (Macdougall 2006).

The coal mining industry itself was also severely affected by the pandemic. On October 16, 1918, the *New York Times* reported, "The epidemic, which is raging the eastern coal regions, is costing the consuming public at that rate of 1,000,000 to 1,200,000 tons of anthracite monthly" (*New York Times* 1918c). Anthracite is a hard coal found in Pennsylvania and known for its high heat value. In October 1917, a record of 7,110,950 tons of anthracite was shipped. A typical shipment was around 6.4 million tons in 1918 (*New York Times* 1917, *New York Times* 1918a). The pandemic resulted in monthly coal shipments being about one-sixth below normal levels. News reports also noted that numerous collieries (coal mines and the associated buildings) were closed and that open ones were struggling to produce with "depleted forces" (*New York Times* 1918c).

The coal shortages also forced the New York City Health Department to monitor the heating situation in the city to ensure that all residents, especially those who were sick, had heat (*New York Times* 1918c). The coal shortage created an additional burden on an already-stressed health department. On November 4, 1918, the *New York Times* quoted Delos W. Cooke, state fuel administrator, saying, "The supply of prepared or domestic sizes of anthracite is not plentiful. On the contrary, it is short and greatly reduced just now by the scourge of influenza in the anthracite mining region" (*New York Times* 1918f). On November 10, 1918, the *New York Times* reported that the state's fuel administration again urged conservation of coal as "production of both bituminous and anthracite coal continues to decrease as the result of the influenza epidemic" (*New York Times* 1918b). The Northeast was not the only region to suffer coal problems due to the pandemic. Mines in Tennessee reported a "50 percent decrease in production," and many mines in the region "were on the verge of closing down" (Garret 2008). Illinois reported that coal-mining districts were hit hard, and Kentucky had mines that did not operate for 6 weeks (HHS-b).

Worth noting is that coal was in short supply during World War I for various reasons, mostly related to a shortage of workers who went off to war and a large increase in manufacturing, leading to an extraordinary increase in the need for coal. The shortage caused problems for the manufacturing sector, which depended heavily on coal. Congress held two hearings specifically on this topic, in 1918 and 1919. On December 2, 1918, Joseph B. Dickson, an anthracite coal distributor, testified to this point when Senator William Kennyon (R - Iowa) asked for suggestions "as to how this coal situation can be relieved." Mr. Dickson's reply is telling:

> My own feeling is that the gradual shutting down of war industries and the return to natural conditions will relieve the pressure in a very, very short time. I believe it would have been relieved by this time if we had not had this epidemic, which very materially interfered with the production of anthracite coal (Dickson 1918).

Eventually the industry recovered, but the severe impact of the influenza pandemic of 1918-19 is well documented. While the process of coal mining has changed in many ways since 1918, it still depends on men and women who drive the dump trucks, operate the machinery to remove the coal, and drive the trains.

Thus, the events of 1918-19 could be seen as a foreshadowing of the next pandemic. At the very least it is worth keeping these experiences in mind as one thinks about the impact a pandemic may cause.

Discussion

Pandemic planning needs to meet the realities of the world in which a pandemic will occur. The coal supply chain, as we have shown, is crucial for an effective pandemic response. We conclude that steps can—and must—be taken to prevent the coal supply chain from being compromised during a pandemic.

There will be another influenza pandemic in the future, though the timing and characteristics are unknown. Preparing for the next pandemic is crucial in this just-in-time delivery world, yet there is a limited emphasis on pandemic preparedness outside of the healthcare sector (UN System Influenza Coordinator & World Bank 2008). This is of great concern, as the lack of preparedness of non-healthcare sectors will dictate the world's response during the next pandemic (Osterholm 2005a, Osterholm 2007a). The United States bulk power system has numerous challenges to overcome in the next 10 years to ensure reliable power, even without an external crisis. A pandemic will undoubtedly make addressing such challenges more difficult. The data here have demonstrated that:

1. National and state pandemic planning guidance plans and state plans fail to address coal production and transportation.
2. The disruption of coal delivery from the PRB in 2005 caused critical drops in coal stocks at electrical generation plants in a large area of the United States and forced the industry to conserve coal. Disruptions of even greater magnitude can be expected during a pandemic, while the programs used to conserve coal may be compromised.

Given the criticality of continuous coal supply to electric-generating plants and the role the generating plants play in maintaining our society, the public health implications of a loss of coal supply must be carefully evaluated.

The data documented here support two main conclusions:

1. **Current levels of pandemic preparedness are likely insufficient to sustain the coal supply chain during a pandemic; the link between the public health response and reliable access to coal-fueled electricity is neither understood nor addressed in current pandemic plans in the United States.**

2. **The public health sector depends on a stable supply of electricity and, in the absence of electricity, will have great difficulty carrying out its key functions during a pandemic.**

Clearly, not enough pandemic or emergency-preparedness planning in general has been devoted to ensure the continuity of the coal supply chain. Among the major reasons for this dilemma are:

- Pandemic planning is ***assumed to be largely a public health issue***.
- ***Meaningful models do not exist*** that depict pandemic-related supply chain disruptions in a global just-in-time economy.
- ***Leadership in pandemic planning*** is lacking for the critical infrastructure sector, specifically for maintaining the coal supply chain.

Although pandemic planning has been regarded primarily as a public health issue, this report demonstrates it is a much bigger concern. Unfortunately, very few state or national plans include elements outside of healthcare/public health. Although this problem is beginning to be addressed, most planning is still primarily based on public health guidance. This situation represents a critical planning shortcoming. Public health guidance is not meant to address the complexities of the modern business world, in which much of the critical infrastructure exists. The critical infrastructure is not required to adhere to public health guidance, as public health has no statutory authority over this industry. However, with pandemic planning, public health needs to be involved in critical infrastructure planning, the results of which directly affect public health's ability to carry out its tasks during the emergency.

The roots of this disconnect go back several decades. The foundations of pandemic planning in the United States date back to 1988 when President Ronald Reagan issued Executive Order 12656, which assigned federal agencies specific responsibilities for emergency preparedness (White House 1988). This executive order was later amended by President George W. Bush in late 2001 to establish the DHS (White House 2001). Homeland Security Presidential Directive 5 established the National Incident Management System (NIMS) (White House 2003b). DHS developed the National Response Plan (NRP) and NIMS, which is the framework from which all events of national significance (incidents that require a coordinated federal response) are managed. It was within this framework that pandemic planning in the United States began as President Bush unveiled the National Strategy for Pandemic Influenza (NSPI) on November 1, 2005 (HSC 2005).

Since the launch of the NSPI, the response plan has been revised and is now known as the National Response Framework (NRF) (DHS 2008f). The NRF more clearly defines the roles and responsibilities of government (state and federal), NGOs, and the private sector during an "all hazards" event. ("All hazards" is a term that refers to a planning framework that is scalable for all known hazards. For example, the same basic principles in the NRF would apply to a tornado as they would to a nuclear incident.) HHS, the lead federal agency responsible for the public health and medical response during a pandemic, has produced the bulk of the federal guidance on pandemic planning and hosts the federal government's pandemic planning portal (www.pandemicflu.gov). As the lead federal agency, HHS provides technical assistance to other federal agencies in fulfillment of their emergency support functions, as outlined in the NRF. In short, selected federal agencies and their responsibilities are as follows:

- ***HHS:*** ensuring the continuation of public health during a pandemic
- ***DHS:*** pandemic planning for critical infrastructure
- ***DOE:*** pandemic planning for the energy sector
- ***DOT:*** pandemic planning in the transportation sector
- ***Department of the Interior (DOI):*** pandemic planning regarding natural resources on federal land

Pandemic threat ties public health to infrastructure

Though HHS is charged with the continuation of public health during a pandemic, ambiguity exists about how it can fulfill its tasks within the scope of its current authority, which doesn't include authorization to protect the critical infrastructure upon which its response depends. We know that a pandemic will cause problems beyond the morbidity and mortality issues with which public health is accustomed to dealing. For example, the supply chains for critical products will be disrupted by a pandemic, increasing morbidity and mortality on multiple levels. As the primary agency responsible for the nation's health, HHS is expected to provide guidance on such issues as infection control when standard barrier precautions cannot be followed because masks, gloves and gowns are unavailable. Because the impact of a pandemic will be felt by all organizations and institutions, it is critical that HHS be prepared to provide leadership when needed.

The scope of HHS authorization. As part of the executive branch, HHS is required by Homeland Security Presidential Directive 20 (HSPD-20) to have a plan for continuity of operations (COOP) in place so that it can help ensure the eight National Essential Functions (NEFs) are maintained during times of crises (Government Organization and Employees 2007, White House 2007). HSPD-20 defines NEFs as "subsets of government functions that are necessary to lead and sustain the Nation during a catastrophic emergency" (White House 2007). HHS will be responsible for ensuring the eighth NEF:

> Providing for critical Federal Government services that address the national health, safety, and welfare needs of the United States. This NEF includes Federal executive department and agency functions that ensure that the critical Federal-level health, safety, and welfare services of the Nation are provided during an emergency (DHS 2008e).

Federal Continuity Directive 1 (FCD 1) requires that primary mission-essential functions (PMEFs), those that support the NEFs, must be continued during an emergency until "normal operations can be resumed," which could be months during a pandemic (DHS 2008e). FCD 1 notes that planning for COOP for the NEFs will require "the robust involvement of NFGs [non-federal governments] and the private sector" (DHS 2008e). It also states that agencies should "identify interdependencies and ensure resiliency with critical infrastructure and services at all levels" (DHS 2008e). Given the issues that could arise with the reliability of electricity during a pandemic and the dependence of the public health infrastructure on electricity, HHS will have problems continuing its NEFs and PMEFs during a pandemic. While this responsibility does not give HHS the authority to require certain levels of planning from the energy sector, it does require HHS to actively determine its interdependencies and mitigation strategies.

One of these interdependencies is electricity. Without electricity, HHS will be unable to maintain the NEFs and the PMEFs as required. One of the largest coal-fueled power plants in the United States is near Atlanta, where the CDC is based. Due to disruption in the PRB and other issues previously discussed, this power plant had only 2 days of coal by September 2005 (FERC 2006). Such disruptions can be expected during a pandemic and have the potential to compromise the generation of electricity. The requirements of FCD 1 suggest that HHS will work or will have already worked with:

- Its federal partners and state and local public health agencies in areas where critical infrastructure/key resources are concentrated
- Critical infrastructure/key resource sectors to ensure that critical supply chains like coal are resilient at all levels

The PRB is an area with a concentration of critical infrastructure/key resources and is responsible for providing a key energy resource to the country. In addition to providing a critical proportion of the coal for the nation, it also produces oil, natural gas, and uranium, among other key resources. The PRB coal fields are found in 17 counties in Wyoming and Montana, but active mining occurs in only a few counties (Kaplan 2007). One of these 17 counties is Campbell County, Wyoming, which produces most of the coal mined in the PRB (BLM 2008). Campbell County has one hospital, Campbell County Memorial Hospital (BLM 2005). During a pandemic, the hospital's 90+ beds are going to be in short supply, and alternative care sites will be overwhelmed (Hargrove 2007). It simply is not possible for the eight Wyoming counties where the PRB is located, which combined have some 225 hospital beds, to handle the surge of cases expected in a pandemic in a region with more than 95,000 residents (BLM 2005). While prevention of illness among the coal-mining infrastructure employees and their families must be the primary goal to maintain coal production, the availability of critical medical services for the ill to facilitate their rapid return to work will be seriously compromised in the PRB area.

Rethinking pandemic vaccine and antiviral drug allocation strategies

One of the cornerstones of the federal pandemic preparedness approach is the deployment of a pandemic vaccine; however, the timing of delivery and the production quantity of an effective vaccine are unknowns. The development and production of a pandemic vaccine, under the best of conditions, will take a few months from the point a pandemic strain is identified. The United States currently maintains a stockpile of a pre-pandemic vaccine for H5N1, for which there are a limited number of doses.

A pre-pandemic vaccine can help bridge the gap between when a pandemic begins and when a pandemic strain-specific vaccine is available. The development of a pre-pandemic vaccine for stockpiling requires surveillance to identify influenza strains that may be emerging as the cause of the next pandemic. The current supply of pre-pandemic vaccine is based on a strain of the influenza A/H5N1 virus now circulating. The efficacy of this vaccine will not be known until a pandemic emerges, and if the pandemic is not caused by H5N1, it will provide little to no protection.

Because scarcity of the pandemic vaccine is assumed in the first 4 to 6 months of the pandemic in the United States, a federal plan has been developed to allocate it (HHS 2008a). The federal allocation plan assigns tiers of priority for vaccination. People in tier 1 will receive a pandemic vaccine first. It is generally assumed that the vaccine will not become available until a pandemic is widespread and supply chains, such as coals, are already stressed.

Coal miners and their supporting industries (eg, operations that maintain the miners' equipment) are not listed in any priority tier and thus will not be prioritized for a vaccine (NIAC 2007, HHS 2008a). Instead, these critical workers will be vaccinated as part of the general population unless their age or health condition places them in a higher tier. Critical workers in the natural gas and oil industries, along with critical workers in the electrical utility industry, are listed in priority tier 2 (NIAC 2007, HHS 2008a). A limited number of critical transportation workers, such as train engineers, will receive vaccines in priority tier 3 in the event of a severe pandemic; otherwise, they will be vaccinated with the general population (NIAC 2007, HHS 2008a). The train engineers and conductors that transport coal are highly proficient at moving some of the heaviest cargo transported by railroads on routes they have memorized.

The entire coal supply chain, from mine to transport, and critical electrical-sector employees, should be placed in tier 1 of the federal vaccine allocation plan. The flow of electricity during a pandemic is as critical as the products and services currently listed in tier 1, all of which depend on electricity. Protecting the supply chain for electricity will likely have a high public health benefit, as it will help to minimize the secondary public health consequences of a pandemic, which may surpass the direct impact of a pandemic (Osterholm 2007b, Kass 2008).

The current allocation strategy also does not take into account the *proportion* of critical infrastructure/key resource staff to the general population. The second largest employer in the PRB is mining (BLM 2005). The largest employer is in the category of "trade, service and other sector," in which a large number are industries that support mining (BLM 2005). As such, a significant proportion of the population employed in critical infrastructure–related jobs is not prioritized in the current allocation strategy and will not receive a vaccine until the general public throughout the United States does. In short, current federal public health guidance as followed will not provide adequate support to the coal mining industry and its supporting industries.

There is a stockpile of antiviral drugs for influenza in the SNS and in many states for use during a pandemic. The vast majority of the antiviral drugs will be used for treatment, with a limited number available for both pre-and post-exposure prophylaxis (HHS 2008b). Prophylaxis (use of antivirals to prevent illness) is recommended only for healthcare workers and front-line emergency service personnel. The reason given in the guidance is that these workers will be exposed frequently and thus should be given pre-exposure prophylaxis. Unless coal companies maintain and distribute stockpiles of antiviral drugs to their employees for preventing influenza, it is highly unlikely that they will receive these drugs unless they become sick. The current allocation plan does not provide for a mechanism for essential workers like coal miners to receive either pre- or post-exposure prophylaxis.

The need is clear, but leadership is lacking

What agency will be responsible for ensuring that coal mining continues during a pandemic remains unclear. What *is* certain is that modern public health depends on electricity. For example, almost every measurement of public health preparedness in the CDC inaugural report on public health preparedness hinges on electricity (CDC 2008). Water treatment is energy intensive. Some 80% of the cost of producing and distributing fresh clean water is due to electricity (EPRI 2002). In the United States, 5% of electricity generated annually is used for transporting this water via an elaborate infrastructure of pipelines and storage tanks (EPRI 2002). Without electricity, water and sewer systems would not function beyond a few days. Refrigeration is critical for preventing foodborne disease (CDC 1999b). It is also key to maintaining the effectiveness of vaccines that prevent infectious diseases. Almost all refrigeration depends on electricity. Public health also depends on a modern laboratory system to detect and identify diseases in the communities. Such systems—from PulseNet, the system for fingerprinting bacteria causing foodborne diseases, to other laboratory tests to determine water contamination—require electricity. A lack of electricity will also reduce the availability of products and services on which public health depends, while at the same time increasing the demand for public health services (as seen during power outages or heat waves). It is hard to imagine the public health system providing assistance during a pandemic without electricity, as it relies on or requires electricity to function.

The maze of agencies that relate to coal mining but are not assigned to ensure the continuity of its supply chain during a pandemic includes:

Department of Energy. The National Infrastructure Protection Plan (NIPP), the NRF, and ESF-12 identify the DOE as the lead agency for the protection of the energy sector (DHS/DOE 2007, DHS 2008f, DHS 2008c). According to the DOE, its "overarching mission is to advance the national, economic, and energy security of the United States" (DOE). Thus, it is of concern that a December 2007 report by the DOE's inspector general concluded that, due to lack of planning for increased worker absenteeism, the DOE "may not be able to ensure continuity of its mission-critical functions" during a pandemic (DOE 2007). Fuel supplies, specifically coal, are not addressed in the DOE Critical Infrastructure and Key Resources Protection Plan (DHS/DOE 2007). It should be noted that the DOE is not responsible for ensuring the continuation of coal mining.

Department of Homeland Security. The term "critical infrastructure" typically includes those entities considered so critical that their destruction or serious loss of function would dramatically hurt the nation (Moteff 2003). As previously noted, coal mining is not explicitly listed as part of the critical infrastructure or key resources as defined by HSPD-7, and coal is typically not regarded as a fuel for which energy security is an issue; thus, the industry typically is overlooked during planning for fuel-supply issues (White House 2003a, Farrell 2004). The critical infrastructure should include coal mining. If it did, the industry would likely fall under the responsibility of DHS to ensure it continues to operate during a pandemic, as DHS is the lead agency for critical infrastructure and key resources (DHS 2008a).

Department of Interior. It is also possible that the DOI would assume responsibility, because a large percentage of coal is mined on leased federal land, and the DOI is the agency responsible for pandemic planning for natural resources on such land (DOE/DOI/USDA 2007).

Department of Labor. Another possibility is that the Mine Safety and Health Administration (MSHA), a part of the DOL, would be responsible for ensuring the continuation of mining, if the primary reason for disruptions was related to the health of the miners. Congress declared that the "first priority and concern of all in the coal or other mining industry must be the health and safety of its most precious resource—the miner" and gave authority to the MSHA to regulate the industry (Federal Mine Safety and Health Act of 1977).

For effective mitigation strategies to be employed in the coal mining industry, a lead federal agency needs to be clearly defined.

Lack of conceptual framework does not preclude understanding the impact

Academia, the private sector, and government agencies have not provided a meaningful model or conceptual framework for pandemic planning in a global just-in-time economy, though numerous ones have depicted how a pandemic might spread, how mitigation techniques might work, and the potential financial impact. A few studies have looked at supply-chain interruptions due to a pandemic, but little research exists on the impact that worker absenteeism will have during a pandemic. As states have noted, the absence of this kind of data and analysis on supply-chain disruptions or examples of how work absenteeism can affect the critical infrastructure in situations like a pandemic make planning difficult. As a result, planners tend to rely on memory of more recent workplace disruptions (eg, strikes) and localized episodes of supply-chain disruptions for planning. But such events do not portray the global nature of a pandemic, as workers from unaffected areas won't be brought in to help (because all areas will be affected) and products likely will not be available globally.

To date, it appears that this type of research has not been specifically requested. Nor is it the kind of research tied to more prestigious and financially rewarding work, such as pandemic vaccine development or supply-chain optimization. So it is understandable why little research has occurred on this important topic.

We are aware of only one paper, which was presented at a conference in early 2008, that addresses the issue of worker absenteeism in one critical infrastructure—transport of freight (Jones 2008). Jones et al have published the only simulation of the nation's freight system (maritime and rail) during a pandemic. The authors looked at the capacity of eight port terminals on the west coast and 18 rail yards throughout the United States and tried to determine the impact on the freight system if a percentage of the workforce was absent due to a pandemic. Their model assumed that shipment volumes did not decrease (although it is likely that they will). Their results are concerning, specifically for the rail industry.

They found that a 5.8% absenteeism rate peaking in the third month of a pandemic would result in an estimated 2-day delay in rail shipments. They found that a 28.2% absenteeism rate, peaking in the third month of a pandemic, would reduce rail capacity by 45%. They concluded that there "is likely to be an enormous disruption in the rail system over a period of two months or more" (Jones 2008). This finding was derived primarily from examining the result of reduced staffing at rail yards, which diminished efficiency and capacity. This sort of a disruption in the freight rail system is unprecedented.

While unit trains (eg, coal trains) will likely be less affected than the freight system overall (unit trains do not require modifications in rail yards as most freight trains do), they will still be affected. Freight trains typically transport multiple commodities going to multiple locations. When they arrive at rail yards, the rail cars may be redeployed to other freight trains for transportation to another rail yard or to the cars' final destination. Unit trains contain the same commodity and are going to the same location; thus, they do not need to be modified in rail yards. Rail yards have limited capacity to hold trains, which can result in trains being "parked" on the lines coming into the rail yards, waiting to enter. These logjams will cause significant disruptions for all train traffic, regardless of yard usage.

The last time there was a considerable (15% to 20%) reduction in coal shipments via rail, the energy sector was significantly affected within 12 weeks of the disruption—after the derailment that damaged tracks on the Joint Line in the PRB. It also resulted in numerous effective coal conservation methods, which allowed the power system in the United States to stay functional. Without these alternatives, the impact to the country's power system could have been catastrophic. The nation's power system is resilient and has multiple fuel sources; thus, the potential for a catastrophic impact is not expected to materialize until weeks into a pandemic and only if there is a significant impact to the coal supply chain. The methods used to prevent this significant impact—primarily purchasing power on the grid, increased natural gas usage, and purchases of additional coal—will likely be impaired during a pandemic.

Coal will likely not be shipped to the United States during a pandemic, as the maritime freight industry is going be severely taxed (Luke 2008). Further, as the developing world draws more and more on coal for power, the supply situation becomes increasingly chaotic. Supply available now is tied up in contracts for future use by countries developing their economies. There will likely be less electricity to buy on the grid, as staffing/supply issues cause power levels to fluctuate.

Domestic production of natural gas will likely be reduced when absenteeism increases. Imports of natural gas will likely fall if maritime freight is hindered. Another possibility is that countries that export natural gas and coal could use their resources as tools to demand aid, specifically pandemic vaccine. The United States is considered one of the better prepared nations in the world for a pandemic and thus will be perceived to have resources that are globally in scarce supply. Such action is not unprecedented. Russia currently uses its control of natural gas pipelines into Europe, and Indonesia refuses to share its avian influenza isolates with the world for geopolitical reasons (Belkin 2008, Fidler 2008). Finally, if rail traffic is disrupted during a pandemic for months, as it was in 2005, then the reliability of coal-based power will be compromised. The scenario worsens if alternative sources of fuel are not as readily available as they were during the last major disruption in coal transport.

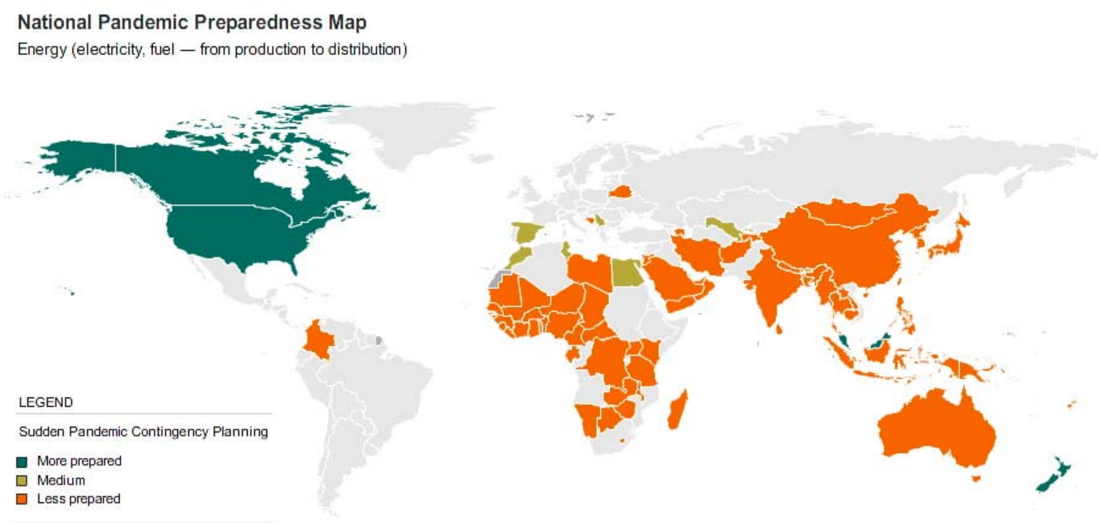
Industry experts are aware of this situation, yet little has been done to remedy it—not for lack of trying, but primarily because of the costs of increasing coal stocks at power plants in current market conditions. The amount of coal kept on the ground by coal-powered plants has decreased significantly from the 1970s, when keeping 60 to 90 days of coal stock was the norm. The reduction to 30 days of coal was encouraged by public utility commissions as a way to cut costs (NERC 2007a). Most public utility commissions will not allow power companies to raise their electricity rates solely for the purpose of increasing their coal stocks. Similarly, most power companies will not spend the extra capital to increase coal stocks in the competitive US energy market.

Gaps in pandemic preparedness globally

The gaps in pandemic planning for the energy sector are not unique to the United States and have been reported around the world (Uscher-Pines 2006, Coker 2006, Ortu 2008, Mounier-Jack 2007, ECDC 2007, UN System Influenza Coordinator & World Bank 2008). The United Nations System Influenza Coordinator (UNSIC), who overseas pandemic preparedness at the UN, started a program in early 2007 aimed at improving the preparedness in non-health sectors in the UN and in member nations. The UNSIC Pandemic Influenza Contingency (PIC) team has performed additional analyses of national pandemic plans and found that preparedness outside of the healthcare sector is lacking. The UNSIC PIC Web site offers analyses of pandemic planning at the UN and member nations (OCHA 2008).

Figure 4: Energy sector pandemic preparedness map

(OCHA 2008)



As Figure 4 shows, the United States is one of four nations believed to be "more prepared" in the energy sector, while most of the world is considered "less prepared" for ensuring the flow of energy during a pandemic. This is of great concern, not only for the impact it will have on human life if electricity fails, but also in the loss of production and trade of critical products from around the world.

In today's global economy, the impact of a pandemic on power generation in other nations can directly affect the response of countries that depend on products from other nations. Recent coal shortages and rising fuel costs have driven up electricity rates sharply in China, which has resulted in the world's largest aluminum smelter reducing production (Yu 2008). Problems with power and rising fuel costs were some of the reasons cited for Hong Ray Enterprises (based in China), the world's largest manufacturer of vinyl exam gloves, to invoke a *force majeure* clause (Medline 2008). A continued shortage of coal in South Africa has required that mining companies reduce their demand for electricity yet again. South African mining production has dropped (Burgis 2008); globally, metal prices have risen sharply, and suppliers are scrambling to find alternative manufacturing capacity.

Such problems are occurring without a pandemic stressing the global just-in-time economy. Many critical products are produced overseas and shipped to the United States, including more than 10% of the medical supply imports that are from China (Langton 2008). More important, 50% of clinical thermometers, 13% of syringes, and 13% of respirators imported by the United States come from China (Langton 2008). The vast majority of pharmaceuticals used in the United States are also manufactured abroad. These products will likely be in high demand during a pandemic. Among other factors, a lack of reliable power overseas will likely cause fragile supply chains to crumble during a pandemic. The United States can expect an increase in morbidity and mortality during a pandemic when standards of care are modified because of supply shortages and a rise in patient numbers. In essence, as we run out of critical supplies, the care provided during a pandemic will be similar to the care provided during the 1918-19 pandemic.

Future research

The impact of a pandemic on the coal supply chain is not entirely clear. All indications are that it could be significant. More research is urgently needed to further understand the likelihood of this scenario occurring and to estimate the potential impact of pandemics of various severities on the coal supply chain. The National Energy Technology Laboratory at the DOE in partnership with Carnegie Mellon University has designed a system to assess vulnerabilities in the nation's power system caused by a supply disruption (Shih 2007). The system was designed to look at vulnerabilities in the coal supply chain from the point of view of geographic disruptions (eg, a key rail bridge being destroyed). In theory, this system could be used to project the impact of pandemics of various severities. We will submit a proposal to use this system this year.

The lack of leadership at the federal level for pandemic planning in the coal industry is another serious concern. Further research is suggested to determine what agency is ultimately responsible for this planning. The United States currently stockpiles such critical products as oil, because to not have them over a period of time could compromise national interests. Given the heavy dependence on coal and the possibilities of disruptions, the availability of regional or state-owned coal stockpiles should be examined.

The easiest way to prevent a coal supply-chain disruption from reducing electricity production during a pandemic is to ramp up coal stocks at power plants. Such a strategy assumes that space for additional coal is available and that other issues, such as environmental concerns, are addressed.

Though some in the industry might consider building up coal stocks too risky financially, a sound argument can be made that maintaining the peak coal stock levels, associated with the preparation for peak electrical demand, as a required minimum coal stock level year round can be compared to investing wisely in insurance, a necessary cost of doing business. A comparison of the costs to the industry of running out of coal during a pandemic versus the expense of maintaining a much larger stockpile should be performed at the national level. It is likely more financially viable to maintain a larger stockpile to mitigate many of the problems this paper highlights.

Public health needs to better understand the infrastructure on which it depends. Having more research on the interdependencies of the public health infrastructure would also be valuable. Public health must understand the implications of its policies on critical infrastructure. For instance, community mitigation measures such as closing schools could disrupt delivery of coal if workers in the small towns along the supply chain have few options but to stay home with their children or other family members. Many states already have multidisciplinary groups that address issues related to emergency preparedness. It would be beneficial if these groups devoted more effort to understanding each agency's interdependencies and expectations during an emergency.

At the national level, much more work is needed to understand the dependence of public health on electrical power. A good starting place for this research would be the work done at the Carnegie Mellon Electricity Industry Center for the state of Pennsylvania (Apt 2005). The authors conducted an extensive study looking at the impact of an electrical grid failure on the continuation of critical services. It would also be valuable for the prioritization of critical infrastructure to be based on the essential nature of that infrastructure. For example, electricity is needed to produce vaccines; thus, generating electricity is equally critical to vaccine manufacturing itself (Osterholm 2007b).

While public health should continue to be involved in efforts to address global climate change, it should do so with responsible foresight. The same passion that public health puts behind opposition to new power plants should be used to advocate for alternative power plants and the associated transmission resources. This will likely come naturally as public health becomes more aware of its dependence on electricity and the challenges facing electrical generation in the future. It is crucial for the electrical sector to become more environmentally responsible, but it must not become less reliable at the same time.

Much work is needed to prepare the electrical sector around the world for a pandemic. Two main issues must be addressed related to pandemic planning and the electrical sector.

- ***Conceptualize fuel-supply disruptions.*** Almost every nation imports fuel, yet pandemic planning is primarily focused on issues within national borders. The narrow focus could be devastating for nations, such as Japan, that depend heavily on imported fuel like natural gas for electrical generation (EIA 2006). Pandemic planning must move beyond national borders, because our global just-in-time economy knows virtually no borders.
- ***Address failing power systems in the world.*** Nations such as South Africa and China have recently or are currently experiencing blackouts due to coal supply deficiencies. The coal supply chains supporting their energy sectors are unable to maintain enough coal at power plants, and blackouts are not unusual. These blackouts have already affected global commerce (Koh 2008, Shelley 2008). The world must figure out a way to deal with global manufacturing hubs that experience blackouts during a pandemic due to the incredibly fragile fuel supply chains.

Recommendations

Based on an understanding of the inextricable link between public health and electricity (and the supply of coal, in particular), decision-makers should consider the following recommendations to reduce the risks posed by an inevitable pandemic:

Recommendation 1: Build coal stocks. First and foremost, every effort must be made to ensure the reliability of electricity supply during a pandemic. With coal plants, the most practical way to ensure a steady supply of fuel during a pandemic is to keep larger stocks at power plants or storage facilities.

When the industry prepares for peak electrical demand (the summer in the United States), coal stocks reach their highest for the year. ***This peak coal stock level should now be maintained as the new minimum level at every coal power plant around the nation.*** The normal fluctuation in coal stocks due to price, season, and other issues should occur *above* this peak coal stock level. Given the unknown timing of a pandemic and the long lead time needed to significantly increase coal stocks, this level will provide a larger buffer against supply-chain disruptions expected during a pandemic. Coal stocks can be increased in the United States in at least three ways:

1. ***A representative group of the electrical* sector** could be convened to make this new minimum coal stock level an *industry guideline*. Such groups already exist in organizations like the EEI, which currently helps develop industry guidelines.

2. ***The National Association of Regulatory Utilities Commissioners*** could promulgate the new minimum coal stock level in the form of a resolution. Such action would bring the issue to the attention of the public utility commissioners in each state, who could add the new minimum coal stock level as a *requirement*. Such an approach could be effective for utility facilities that are regulated by state public utility commissions (PUCs) but would not necessarily affect facilities such as competitive generation plants that are not subject to PUC regulation.
3. ***The Federal Energy Regulatory Commission*** could require the North American Electrical Reliability Corporation to promulgate this new minimum coal stock level as a *reliability standard*.

Representatives of the coal and transportation industries need to be involved in these decisions, because a national increase in coal stocks will have an impact on their operations. There will be a significant cost associated with increasing coal stocks to and maintaining them at this new minimum level. This cost should be passed on to the consumers responsibly.

Recommendation 2: Place coal miners and their supporting infrastructure personnel in the highest priority levels for pandemic response. The United States government should assume primary responsibility for ensuring coal miners and their supporting infrastructure have priority access to antiviral drugs, pandemic vaccine, and other critical products and services (eg, critical pharmaceutical drugs, food), because they are not currently indentified as a priority in the federal or state plans for supporting the critical infrastructure during a pandemic. As such, coal miners and their supporting infrastructure are not incorporated into allocation plans.

Given the nation's dependence on miners and their supporting infrastructure, the United States government should ensure they are prioritized for allocation of pandemic vaccine, antiviral drugs, and critical products in a pandemic, until such time as these critical workers can be incorporated into current state and local plans. Without federal intervention and prioritization of coal miners and their associated infrastructure, elevation of their priority is unlikely to happen for some time, as states and localities did not include these critical workers in the planning process or procure an allotment of supplies (eg, antiviral drugs) for them. The following reviews how coal miners may have been overlooked and how to properly include them.

- ***Vaccines.*** The allocation of pandemic vaccine is primarily based on the work of the National Infrastructure Advisory Council's work on prioritization. Like other national guidance documents, this work does not recognize the need to prioritize coal mining and its supporting infrastructure. Stockpiles of coal at power plants are rarely fully depleted, though during a pandemic, as we have shown, supply-chain disruptions will likely fully deplete them or draw them down to dangerously low levels. Depleting the coal stocks could take some time and may not have been seen as an acute problem or even recognized. Manufacturing pandemic vaccine will take several months, the same time frame in which coal stocks are projected to be at dangerous levels. A limited number of doses of a pre-pandemic vaccine for H5N1 are currently stockpiled. However, the efficacy of this vaccine will be unknown until a pandemic begins, and it may not prove useful if the pandemic is a different strain. To date, coal miners have not been considered among the first to receive pandemic influenza vaccine the tiered vaccine-allocation plan. But the rationale for including them is sound. While it is obvious that employee categories currently listed in tier 1 (eg, first responders) should be at this priority level for occupational exposure purposes, they also require the availability of electricity to perform their critical job-associated duties. The rest of the coal supply chain, transportation, and electrical sector should be included as part of tier 1 of the federal vaccine allocation strategy. In tier 1 of the federal allocation plan, 24 million people are eligible to receive a pandemic vaccine. The coal industry in 2007 employed approximately 81,000 people in the United States (EIA 2007a). Furthermore, additional workers are employed in numerous supporting industries, such as those who build and maintain engines for mine equipment. While not *all* these employees are critical for the continuation of operations, the number of truly essential employees needs to be determined. There are 244,600 critical employees in railroad and inland-waterway transportation industries, as defined by the NIAC; however, only a portion of them are involved in the movement of coal (NIAC 2007). While the current number of critical employees in the coal supply chain is unknown, based on available data, it is likely under 300,000. These workers should all be included in tier 1 of the federal vaccine allocation plan.

- ***Influenza antiviral drugs.*** The allocation guidance for influenza antiviral drugs is based primarily on using these drugs for *treatment*. There is some limited guidance on prophylaxis (administration of antivirals to prevent an individual from falling ill). According to the guidance, people who receive prophylaxis must fall into a specific category, for example, healthcare workers or front-line emergency services personnel. Prophylaxis is unlikely to occur with state and federal stockpiles, owing to restraints related to the number of drug courses available. Most prophylaxis, if any, will go to those exposed to a sick individual. In the absence of privately held stockpiles of antiviral drugs by coal-mining companies, there will likely be very limited supplies of antiviral drugs available for treatment or prophylaxis of employees in the coal-mining industry. Coal miners and their supporting infrastructure should be considered essential and given highest priority for antiviral drug treatment and prophylaxis.

- ***Other critical supplies.*** Like most industries, the coal mining industry undoubtedly employs critical individuals who have chronic medical conditions, such as diabetes, or whose family members do. Pharmaceutical products used to address these conditions likely will be in short supply during a pandemic. We also know that other critical drugs will be scarce. Shortages of critical products like food are expected during a pandemic. Ethical allocation plans need to be developed to address these shortages, and they should take into account occupations, including coal miners and supporting infrastructure personnel, among many other variables.

Recommendation 3: Plan for disruptions in the coal supply chain. There will be disruptions in the coal supply chain during a pandemic. In the absence of prior planning, these disruptions will be more severe. It is anticipated that these disruptions will be similar in impact to the disruptions of PRB coal in 2005. Coal shipments are likely to be reduced by at least 15% to 20% for periods up to 60 days. This disruption could also occur more than once if, as in other pandemics, illness comes in waves.

These disruptions will occur up and down the supply chain; therefore, it is critical that the whole supply chain be involved in pandemic planning. The company that supplies the tires for the dump trucks at the surface mines in the PRB, for example, might have supply or staffing shortages that prevent it from maintaining the trucks' tires, thus reducing the number in operation. Maintaining a larger inventory of critical supplies and cross-training will help these companies continue to function when supply chains are disrupted. At mines, high absenteeism could lead to a drop in productivity, exacerbating supply disruption with lowered output. To counter this dilemma, larger mine operations might want to consolidate operations temporarily; smaller mine operations might want to consider short-term pooling of resources (staff or equipment) to maintain the higher levels of productivity. A pandemic will cause problems beyond those typically considered in business continuity planning, such as multiple suppliers being unable to fulfill orders, or simultaneous high levels of absenteeism between workers and their back-ups. This situation will require planning beyond what is normally anticipated.

Recommendation 4: Anticipate and develop strategies for responding to disruptions in electrical service. Given multiple waves of illness, a pandemic could last up to 18 months. During this time, storms will continue to strike, human accidents will still occur, acts of terrorism are a real possibility, and electrical components will continue to fail. Some of these disturbances could happen during times of high absenteeism, making restoration of service even more challenging. Every power company currently has procedures for such crises as blackouts caused by ice storms, but the procedures typically assume that resources (people, equipment and/or parts) can be rapidly obtained from utilities in unaffected areas. This will not be the case during a pandemic, as no area will be spared. Further, procedures are not typically developed for dealing with fuel shortages, because they are rare and localized. Planners should plan on dealing with and responding to power disruptions during periods when fuel (for power generation and response vehicles) may be scarce. As these plans are developed or modified, care should be taken to ensure that people who receive power when it is scarce are providing the most critical services to the community. These plans should also be integrated with community mitigation strategies, such as closing schools and malls that do not need power.

Protecting the coal supply chain

Another influenza pandemic is anticipated; however, the timing and characteristics will not be known until the pandemic has begun. This pandemic will be the first to occur in a just-in-time global economy. While there has been substantial planning for pandemic preparedness in the healthcare sector, it has largely been outside the realities implicit in a just-in-time world. As this report has shown, a pandemic has the potential to cause unprecedented disruptions throughout the coal supply chain, endangering the reliability of electricity in the United States. Pandemic planning needs to meet the realities of the world in which a pandemic will occur. The coal supply chain, as we have shown, is crucial for an effective pandemic response. We have concluded that steps can be taken to prevent the coal supply chain from being compromised during a pandemic. We must do everything to protect the coal supply chain, and in turn electrical generation, as our pandemic response hinges on electricity not being compromised.

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Appendix B: References for the review of federal and selected guidance on pandemic planning

Title	Authoring Agency	Date of Publication	URL	Reason for including
Guidance on Allocating and Targeting Pandemic Influenza Vaccine	HHS	7/23/2008	http://www.pandemicflu.gov/vaccine/allocationguidance.pdf	This guidance document prioritizes the critical infrastructure (energy and transportation assets) for receiving a pandemic vaccine. A similar prioritization scheme is used for antivirals.
Final Report and Recommendations of the Prioritization of Critical Infrastructure for a Pandemic Outbreak in the United States Working Group	National Infrastructure Advisory Council (NIAC)	1/16/2007	http://www.dhs.gov/xlibrary/assets/niac/niac-pandemic-wg_v8-011707.pdf	This document served as the cornerstone for the HHS prioritization of critical infrastructure. The recommendations of this working group were carried over into national prioritization guidance. This working group document also defined these critical infrastructures and tiers within them for receiving vaccines.
Third Global Progress Report: Response to Avian Influenza and State of Pandemic Readiness	UN System Influenza Coordinator & World Bank	12/18/2007	http://un-influenza.org/files/12-18-07UN-WBAHIProgressReportfinal.pdf	This document provides a high level overview of pandemic planning around the world and at the UN. It points out weaknesses and provides suggestions for improvement. It specifically addressed planning in non-health related sectors.
Pandemic Influenza Preparedness, Response, and Recovery Guide for Critical Infrastructure and Key Resources	DHS	12/2006	http://pandemicflu.gov/plan/pdf/cikrpandemicinfluenzaguide.pdf	This guidance document is widely referenced in the critical infrastructure for pandemic planning.
National Strategy for Pandemic Influenza	Whitehouse: Homeland Security Council	11/1/2005	http://www.whitehouse.gov/homeland/nspi.pdf	This guidance document lays out the strategy for responding to a pandemic in the US.
National Strategy for Pandemic Influenza: Implementation Plan	Whitehouse: Homeland Security Council	5/2006	http://www.whitehouse.gov/homeland/nspi_implementation.pdf	This guidance document specifics tasks and responsibilities for implementation of the US pandemic influenza plan.

Checklist for Influenza Pandemic Preparedness Planning	WHO	10/2005	http://www.who.int/entity/csr/resources/publications/influenza/FluCheck6web.pdf	This document is considered the cornerstone of many pandemic-planning checklists around the world and is a widely citied guidance document.
39 Steps Governments Should Take to Prepare for a Pandemic	Pandemic Influenza Contingency (PIC) – UN	12/2007	http://un-influenza.org/files/39-steps.pdf	This revised guidance was developed to ensure government continues to function during a pandemic.
Business Pandemic Influenza Planning Checklist	HHS & CDC	09/2006	http://pandemicflu.gov/plan/pdf/businesschecklist.pdf	A widely cited business preparedness checklist on pandemic preparedness.
North American Plan for Avian and Pandemic Influenza	Security and Prosperity Partnership of North America	8/17/2007	http://www.state.gov/documents/organization/91311.pdf	This guidance document outlines the North American plan for critical infrastructure during a pandemic.
Electricity Sector Influenza Pandemic Planning, Preparation, and Response Reference Guide	North American Electric Reliability Council (NERC)	2/1/2006	ftp://www.nerc.com/pub/sys/all_updl/cip/Influenza%20Pandemic%20Reference%20Guide.pdf	This guidance document was developed specifically for the electrical sector.
Straight Talk About Electrical Utilities and Pandemic Planning	Edison Electric Institute (EEI)	5/2007	http://www.eei.org/industry_issues/reliability/business_continuity/pandemic_planning/Straight_Talk.pdf	This guidance document was developed specifically for the electrical sector.

Note: The authors were not able to obtain pandemic planning guidance from the National Mining Association and the Association of American Railroads, which does not mean guidance does not exist.

Appendix C: The number of mines, their type, and production by state

This table shows the 25 coal producing states in the United States. It also provides information about the number of mines, types of mines, and production in each state. This information is useful in setting the context of the paper, as some states, notably Wyoming, dominate the coal industry.

Table 1. Coal Production and Number of Mines by State and Mine Type, 2007-2006
(Thousand Short Tons)

Coal-Producing State and Region[1]	2007		2006		Percent Change	
	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production
Alabama	**49**	**19,327**	**57**	**18,830**	**-14.0**	**2.6**
Underground	8	11,462	9	10,737	-11.1	6.7
Surface	41	7,865	48	8,092	-14.6	-2.8
Alaska	**1**	**1,324**	**1**	**1,425**	**-**	**-7.1**
Surface	1	1,324	1	1,425	-	-7.1
Arizona	**1**	**7,983**	**1**	**8,216**	**-**	**-2.8**
Surface	1	7,983	1	8,216	-	-2.8
Arkansas	**2**	**83**	**2**	**23**	**-**	**263.4**
Underground	1	80	1	18	-	357.0
Surface	1	2	1	5	-	-53.8
Colorado	**12**	**36,384**	**12**	**36,322**	**-**	**0.2**
Underground	8	27,610	7	26,659	14.3	3.6
Surface	4	8,774	5	9,663	-20.0	-9.2
Illinois	**21**	**32,445**	**22**	**32,729**	**-4.5**	**-0.9**
Underground	14	26,807	15	27,120	-6.7	-1.2
Surface	7	5,638	7	5,609	-	0.5
Indiana	**27**	**35,003**	**28**	**35,119**	**-3.6**	**-0.3**
Underground	7	10,604	7	10,736	-	-1.2
Surface	20	24,399	21	24,383	-4.8	0.1
Kansas	**2**	**420**	**2**	**426**	**-**	**-1.3**
Surface	2	420	2	426	-	-1.3
Kentucky Total	**417**	**115,280**	**442**	**120,848**	**-5.7**	**-4.6**
Underground	201	69,217	227	73,182	-11.5	-5.4
Surface	216	46,064	215	47,666	0.5	-3.4
Eastern	**394**	**87,068**	**416**	**93,607**	**-5.3**	**-7.0**
Underground	191	44,703	214	49,312	-10.7	-9.3
Surface	203	42,365	202	44,295	0.5	-4.4
Western	**23**	**28,212**	**26**	**27,241**	**-11.5**	**3.6**
Underground	10	24,513	13	23,870	-23.1	2.7
Surface	13	3,699	13	3,370	-	9.7
Louisiana	**2**	**3,127**	**2**	**4,114**	**-**	**-24.0**
Surface	2	3,127	2	4,114	-	-24.0
Maryland	**19**	**2,301**	**19**	**5,054**	**-**	**-54.5**
Underground	2	611	3	2,826	-33.3	-78.4
Surface	17	1,690	16	2,228	6.3	-24.1
Mississippi	**1**	**3,545**	**1**	**3,797**	**-**	**-6.6**
Surface	1	3,545	1	3,797	-	-6.6
Missouri	**2**	**236**	**2**	**394**	**-**	**-40.1**
Surface	2	236	2	394	-	-40.1
Montana	**6**	**43,390**	**6**	**41,823**	**-**	**3.7**
Underground	1	47	1	321	-	-85.3
Surface	5	43,343	5	41,502	-	4.4
New Mexico	**4**	**24,451**	**4**	**25,913**	**-**	**-5.6**
Underground	1	6,898	1	6,993	-	-1.4
Surface	3	17,553	3	18,919	-	-7.2
North Dakota	**4**	**29,606**	**4**	**30,411**	**-**	**-2.6**
Surface	4	29,606	4	30,411	-	-2.6
Ohio	**57**	**22,575**	**52**	**22,722**	**9.6**	**-0.6**
Underground	13	15,793	11	15,126	18.2	4.4
Surface	44	6,783	41	7,596	7.3	-10.7
Oklahoma	**9**	**1,648**	**10**	**1,998**	**-10.0**	**-17.5**
Underground	2	514	2	464	-	10.8
Surface	7	1,134	8	1,534	-12.5	-26.1
Pennsylvania Total	**264**	**65,048**	**270**	**66,029**	**-2.2**	**-1.5**
Underground	50	53,544	54	53,801	-7.4	-0.5
Surface	214	11,504	216	12,228	-0.9	-5.9
Anthracite	**72**	**1,564**	**74**	**1,529**	**-2.7**	**2.3**
Underground	15	224	17	272	-11.8	-17.8
Surface	57	1,340	57	1,256	-	6.7
Bituminous	**192**	**63,484**	**196**	**64,500**	**-2.0**	**-1.6**
Underground	35	53,320	37	53,529	-5.4	-0.4
Surface	157	10,164	159	10,972	-1.3	-7.4
Tennessee	**17**	**2,654**	**23**	**2,804**	**-26.1**	**-5.3**
Underground	5	892	10	1,191	-50.0	-25.1
Surface	12	1,763	13	1,613	-7.7	9.3
Texas	**11**	**41,948**	**12**	**45,548**	**-8.3**	**-7.9**
Surface	11	41,948	12	45,548	-8.3	-7.9
Utah	**10**	**24,307**	**13**	**26,018**	**-23.1**	**-6.6**
Underground	10	24,307	13	26,018	-23.1	-6.6

See footnotes at end of table.

continued

Table 1. Coal Production and Number of Mines by State and Mine Type, 2007-2006 (Continued)
(Thousand Short Tons)

Coal-Producing State and Region [1]	2007		2006		Percent Change	
	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production
Virginia	**118**	**25,346**	**127**	**29,740**	**-7.1**	**-14.8**
Underground	71	15,731	76	18,681	-6.6	-15.8
Surface	47	9,615	51	11,059	-7.8	-13.0
Washington	**-**	**-**	**1**	**2,580**	**-100.0**	**-100.0**
Surface	-	-	1	2,580	-100.0	-100.0
West Virginia Total	**282**	**153,480**	**290**	**152,374**	**-2.8**	**0.7**
Underground	168	84,853	174	84,628	-3.4	0.3
Surface	114	68,627	116	67,746	-1.7	1.3
Northern	**43**	**42,219**	**49**	**42,398**	**-12.2**	**-0.4**
Underground	23	36,076	29	36,074	-20.7	*
Surface	20	6,144	20	6,324	-	-2.9
Southern	**239**	**111,260**	**241**	**109,976**	**-0.8**	**1.2**
Underground	145	48,777	145	48,554	-	0.5
Surface	94	62,483	96	61,421	-2.1	1.7
Wyoming	**20**	**453,568**	**21**	**446,742**	**-4.8**	**1.5**
Underground	1	2,822	1	519	-	443.5
Surface	19	450,746	20	446,223	-5.0	1.0
Appalachian Total	**1,200**	**377,800**	**1,254**	**391,159**	**-4.3**	**-3.4**
Underground	508	227,588	551	236,303	-7.8	-3.7
Surface	692	150,213	703	154,856	-1.6	-3.0
Northern	**383**	**132,144**	**390**	**136,203**	**-1.8**	**-3.0**
Underground	88	106,023	97	107,827	-9.3	-1.7
Surface	295	26,121	293	28,376	0.7	-7.9
Central	**768**	**226,329**	**807**	**236,127**	**-4.8**	**-4.1**
Underground	412	110,103	445	117,739	-7.4	-6.5
Surface	356	116,227	362	118,388	-1.7	-1.8
Southern	**49**	**19,327**	**57**	**18,830**	**-14.0**	**2.6**
Underground	8	11,462	9	10,737	-11.1	6.7
Surface	41	7,865	48	8,092	-14.6	-2.8
Interior Total	**100**	**146,668**	**107**	**151,389**	**-6.5**	**-3.1**
Underground	34	62,519	38	62,209	-10.5	0.5
Surface	66	84,149	69	89,180	-4.3	-5.6
Illinois Basin Total	**71**	**95,660**	**76**	**95,089**	**-6.6**	**0.6**
Underground	31	61,924	35	61,727	-11.4	0.3
Surface	40	33,736	41	33,362	-2.4	1.1
Western Total	**58**	**621,012**	**63**	**619,449**	**-7.9**	**0.3**
Underground	21	61,683	23	60,510	-8.7	1.9
Surface	37	559,329	40	558,939	-7.5	0.1
Powder River Basin	**17**	**479,496**	**18**	**472,202**	**-5.6**	**1.5**
Underground	-	-	-	-	-	-
Surface	17	479,496	18	472,202	-5.6	1.5
Uinta Region	**19**	**59,815**	**23**	**61,446**	**-17.4**	**-2.7**
Underground	16	51,446	19	52,189	-15.8	-1.4
Surface	3	8,368	4	9,257	-25.0	-9.6
East of Miss. River	**1,272**	**477,006**	**1,331**	**490,046**	**-4.4**	**-2.7**
West of Miss. River	**86**	**668,474**	**93**	**671,952**	**-7.5**	**-0.5**
U.S. Subtotal	**1,358**	**1,145,480**	**1,424**	**1,161,997**	**-4.6**	**-1.4**
Refuse Recovery	**16**	**1,156**	**14**	**752**	**14.3**	**53.6**
U.S. Total	**1,374**	**1,146,635**	**1,438**	**1,162,750**	**-4.5**	**-1.4**

Source: EIA 2008b

Appendix D: Details of coal-producing states' pandemic plans reviewed

State	Date on pandemic plan	Plan in draft form	URL of plan
Alabama	04/2007	No	http://adph.org/pandemicflu/assets/Alabama%20PI%20Operational%20Plan%20041607.pdf
Alaska	02/2008	No	http://www.pandemicflu.alaska.gov/panfluplan.pdf
Arizona	06/2006	No	http://www.azdhs.gov/pandemicflu/pdf/az_influenza_pandemic_response_plan.pdf
Colorado	12/2006	No	http://www.cdphe.state.co.us/epr/Public/InternalResponsePlan/CDPHEPanfluVer2.pdf
Illinois	10/2006	No	http://www.idph.state.il.us/pandemic_flu/Illinois%20Pandemic%20Flu%20Plan%20101006%20Final.pdf
Indiana	10/2006	No	http://www.in.gov/isdh/bioterrorism/PandemicFlu/pdfs/PandemicInfluenzaPlan.pdf
Kansas	10/2005	No	http://www.kdheks.gov/flu/download/KS_Pan_flu_10_05.pdf
Kentucky	04/2007	No	http://chfs.ky.gov/NR/rdonlyres/6CD366D2-6726-4AD0-85BB-E83CF769560E/0/KyPandemicInfluenzaPreparednessPlan.pdf
Louisiana	09/2006	Yes	http://www.dhh.louisiana.gov/offices/publications/pubs-276/Pandemic%20Influenza%20Plan_100906.pdf
Maryland	04/2008	No	http://bioterrorism.dhmh.state.md.us/docs_and_pdfs/Pan%20Flu%202008_MD%20Revised%20Pan%20Flu%20Annex%20--%20%2004-23-08.pdf
Missouri	01/2008	No	http://www.dhss.mo.gov/PandemicPlan/PanFluPlan.pdf
Montana	05/2006	No	http://www.dphhs.mt.gov/PHSD/Communicable-disease/pandemic-flu-plan/3flu-2006-RevisedFluPlan-5-17-06.pdf

New Mexico	04/2007	Yes	http://www.health.state.nm.us/ohem/.documents/New%20Mexico%20PanFLU%20Ops%20Doc%2016Apr07%20draft%20for%20distribution.pdf
Ohio	03/2006	Yes	http://www.ohiopandemicflu.gov/docs/ODHPanFluPlan.pdf
Oklahoma	09/2007	No	http://www.ok.gov/health/documents/TPRS_2007%20OK%20State%20Pandemic%20Plan%20.pdf
Pennsylvania	2005	Yes	http://www.dsf.health.state.pa.us/health/lib/health/pandemic/PAPandemicFluPlan.pdf
Tennessee	07/2006	No	https://health.state.tn.us/Ceds/PDFs/2006_PanFlu_Plan.pdf
Texas	10/2005	Yes	http://www.dshs.state.tx.us/idcu/disease/influenza/pandemic/Draft_PIPP_10_24_web.pdf
Utah	08/2007	Yes	http://www.pandemicflu.utah.gov/plan/CorePanFlu-08302007.pdf
Virginia	03/2006	Yes	http://www.vdh.virginia.gov/PandemicFlu/pdf/DRAFT_Virginia_Pandemic_Influenza_Plan.pdf
West Virginia	05/2008	Yes	Received via email
Wyoming	01/2008	No	http://wdh.state.wy.us/Media.aspx?mediaId=3736

Appendix E: An overview of the coal supply chain

The 17 mines in the Powder River Basin (PRB) operate in a similar way. The overburden (the earth above the coal) is removed and a drag line removes the coal. This coal is dumped into the bed of a truck or onto a conveyer. Dump trucks carry between 250 to 400 tons of coal to a processing facility that breaks the coal into smaller chunks. From the processing facility the coal is loaded into hoppers for storage until it is transferred onto a train.

Most of the coal mined in the PRB is transported by train to its final destination. Trains are loaded via an automated system, which typically drops between 110 to 120 tons of coal in each gondola (a specialized piece of equipment) while the train is moving. Each train typically has more than 120 cars. Trains proceed out of the PRB on the Joint Line, the busiest rail line in the world. Daily, more than 60 of loaded trains leave the PRB and more than 60 empty trains return. The process happens 24 hours a day, 365 days a year.

Trains leaving the PRB are heading for a specific power plant in the United States. These trains are considered units, meaning that the cars and the engines are not separated in a train yard. They are dedicated trains moving back and forth between the mine and the power plant.

Most power companies own their own fleet of gondolas, which are used solely for transporting coal to their facilities. A general overview of how pulverized coal combustion system works follows. When trains arrive, coal is placed in the plant's bunker if space is available. From the bunker, coal moves to a pulverizer before being blown into the boiler, which generates the steam to turn the turbine that generates electricity. Electricity is then sent out via transmission lines to the grid, where it goes through different transformers before being used by a power consumer.

If bunkers are full when the train arrives, the coal is placed on top of the stockpile that sits in the power plant yard. Between train shipments the coal is reclaimed from the coal stockpile and used to fill the bunker. Stockpiles typically hold an average of 30 days worth of coal at the summer peak burn rate. Most power plants build up coal stocks in the spring, in preparation for peak summer usage. The coal stockpile rarely drops to less than 15 days. The closer that coal is to the bottom of the stockpile, the poorer its quality. This is a result of the pressure exerted on the coal at the bottom of the pile, chemical degradation, and the likelihood of dirt and rocks being scooped up with the coal, as these stockpiles are kept on bare ground.

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