# The Costs of Failing Infrastructure

TALLYING UP DISASTERS

BY BENJAMIN K. SOVACOOL

Benjamin Sovacool with the Singapore skyline behind him.

**VIRTUALLY NO ONE — WITH PERHAPS** the exception of the occasional Amish person or a Luddite – would contest that energy systems such as electricity networks, refineries, and pipelines have brought society innumerable benefits. But, as one new study shows, society's burgeoning reliance on fossil-fueled, hydroelectric, and nuclear systems has also come with significant costs.

One recent study published in the May issue of *Energy Policy* looked at major energy accidents from 1907 to 2007. The major accidents were defined as incidents that resulted in either death or more than $50,000 of property damage. The study identified 279 incidents totaling $41 billion in damages and 182,156 fatalities, with the number of accidents peaking in the decade between 1978 and 1987, which had more than 90 accidents.

While responsible for less than 1 percent of total energy accidents, hydroelectric facilities claimed 94 percent of reported fatalities. Looking at the gathered data, the total results on fatalities are highly dominated by one accident in which the Shimantan Dam failed in 1975 and 171,000 people perished.

In terms of cost, nuclear plants ranked first with regard to their economic damage, accounting for damages equivalent to $16.6 billion, or 41 percent of all damages during the past century. Contrary to the industry's claim that nuclear facilities are safe, 63 major accidents have occurred at nuclear power plants. Twenty-nine accidents have occurred since the Chernobyl disaster in 1986, and 71 percent of all nuclear accidents, that is, 45 out of 63, occurred in the United States, refuting the notion that severe accidents cannot happen within the country or that they have not happened since Chernobyl.

Using extremely conservative estimates, nuclear power accidents have also killed 4,100 people. The nuclear power accidents have involved meltdowns, explosions, fires, and loss of coolant, and have occurred during both normal operation and extreme, emergency conditions such as droughts and earthquakes.

In terms of frequency, natural gas infrastructure is the most likely to fail, accounting for 33 percent of all major energy accidents worldwide. Faulty joints, malfunctioning valves, operator error, and corrosion induce frequent leaks and ruptures in natural gas pipelines. The U.S. Department of Transportation has even noted that oil and gas pipelines fail so often here that they expect 2,241 smaller accidents and an additional 16,000 spills every 10 years.

A database of major industrial accidents from 1969 to 1996 compiled by the Paul Scherrer Institute found that 31 percent, or 4,290 out of 13,914, were related to the fossil fuel sector. Another assessment concluded that about 25 percent of the fatalities caused by severe accidents worldwide in the period 1970 to 1985 occurred in the fossil fuel energy sector.

So why is it that these energy systems fail? Generally, those analyzing technology and risk have argued that the more complicated and interdependent technological systems and subsystems become, the more vulnerability they exhibit. This vulnerability arises from their complexity, tight coupling, speed of interaction, and fallibility of their human designers and operators.

Large, centralized energy technologies are often so complex that no human designer can know or comprehend all of the factors needed for flawless system operation. This means that the failure of a single component such as a fuse can affect the entire system, and that multiple components can fail in the same manner by a single initiating event such as a lightning strike or fire.

Complexity alone would not be deleterious if not for the tendency for large systems to be tightly coupled.

Even though energy technologies can be incredibly complicated, their overarching goal is simple: A nuclear power plant is merely a complicated machine for producing electricity, and a natural gas pipeline is an engineering feat designed to distribute fuel. This makes energy systems highly precise and efficient, but it also means that such systems have little flexibility and room for error.

Complexity and tight coupling are compounded by a third problem: speed of interaction. To achieve their efficiency, large-scale technologies have more time-dependent processes, and in many cases operate automatically. Given the speed at which system components interact, however, malfunctions usually occur faster than any combination of problem solvers can anticipate or overcome them.

A fourth factor, human fallibility, exacerbates each of these tendencies. Proponents of large-scale energy technologies are often encouraged to think that they can control the best in nature and the worst in themselves, and they continue to think so until carried beyond the limits of their own intelligence or stamina.

Regulators and businesspeople can ultimately glean at least two lessons.

First, there is no such thing as safe conventional energy technologies, much in the same way there is no such thing as an energy system that is completely benign to the natural environment. Energy accidents have become a more common theme as cultures embrace electrification, industrialization, economic growth, and higher standards of living, and to a certain degree will remain an inevitable feature of our modernized environment.

Second, we need to do better. Energy accidents exact a significant toll on human health and welfare, the natural environment, and society. Such accidents are now part of our daily routines, a somewhat intractable feature of our energy-intensive lifestyles. They are an often-ignored negative externality associated with energy conversion and use. This conclusion may seem quite banal to some, given how fully energy technologies are integrated into modern society. Yet energy systems continue to fail despite drastic improvements in design, construction, operation, and maintenance, as well as the best of intentions among policy makers and operators.

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