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Nuclear Power: Cost, Benefits & Black Swans

By Chuck Dinerstein, MD, MBA — March 10, 2020

At one point, nuclear power provided 25% of Germany's electricity. But the fallout from Chernobyl, both political and real, led to a moratorium on construction and an initial planned phaseout of all nuclear reactors by 2022. That deadline subsequently was extended to 2032, but after the events at Fukushima in Japan, the phaseout policy deadline reverted back to two years from now. Today, Germany gets 11% of its electricity from nuclear sources. A study from the National Bureau of Economic Research measures the fallout.

Fukushima Nuclear Reactors Courtesy of IAEA on Flickr [1]

The study considers the period from 2011 to 2017, after the "Chernobyl-induced" moratorium, when 10 of the seventeen operational nuclear reactors in Germany were shut down. It considers changes in energy sources, and the costs to consumers and society in terms of both climate damage from CO_2 as well as health injuries from SO_2, NO_x, and PMs. It makes use of a machine learning model with variables including electrical demand, weather, local plant marginal costs, fuel types, efficiencies, locations, and production. The algorithm was shown to be 98% accurate in validity testing. Apply as many grains of salt as you feel necessary.

- During this period, generating capacity increased from 172.2 to 217.6 gigawatts (GW)

primarily due to a doubling of capacity by renewables.
- Production also increased by roughly 40 Terrawatt hours (TWh), and wholesale prices decline by 40%.
- Germany remained a net exporter of electricity rising from 3.5TWh to 33.5 TWh in 2017

But within those numbers, there were significant shifts in sources of energy and their impacts. These results include factual data as well as values from the model (in italics)

- Electricity from nuclear power declined precipitously, by 5GWh (Gigawatt hours) or 38%, replaced mainly by increased production from coal (32%) and gas-fired (26%) plants. There was an additional 37% increase in net imports and *an increase in wholesale prices by $1.80 MWh or 3.9%* if no phaseout had occurred. Emphasis added [1]
- The average revenue from nuclear plants decreased by $2.2 billion/year, with those funds transferred to fossil fuel facilities. Because fossil fuel plants have higher operating costs than nuclear the transfer resulted in revenue increases of only 63% for coal plants

It is difficult to ascribe all of these changes to the reduction in nuclear power plants. The energy market remained dynamic with decreasing costs of coal as well as increasing costs for gas. These aggregate costs were fairly uniform across the country. But as we turn to consider the environmental costs, we note that they were unevenly distributed centering around the fossil fuel plants, which came online or increased production. This is especially true for adverse health outcomes that are dependent upon exposure and time, with exposure tied directly to the location. [2]

The researcher used two methods to determine environmental costs. In the first method, they used plant production of pollutants, specifically CO_2, SO_2, NO_x, and PMs, and the currently in vogue costs of air pollution. In the second method, they used atmospheric monitoring at the impacted plants and the population within a radius of 20 miles.

- CO2 admissions increased by 36.3 Metric tons/year, a *13% increase* relative to no phaseout. It was primarily attributable to coal plants and produced *$1.8 billion in "climate change damage."* Production of SO_2, NO_x, and PM increased by 12%, again primarily due to coal. The phaseout of nuclear increased premature mortality by 1,100 lives or 15%, 80% of that impact from coal.
- When using atmospheric measurements, all pollutants increased, but the significant health effects were attributed to $PM_{2.5}$ and PM_{10}. They calculated a slightly smaller increase in premature mortality of about 10%.

"Nuclear power plants emit virtually no global or local air pollution. However, nuclear energy does come with catastrophic accident risk and requires storing the waste that results from nuclear production, which has important costs as well."

While storage costs can be reasonably estimated, the cost of nuclear accidents, like the cost of premature deaths, is an exercise in guesstimation. Literature estimates put the cost of storage and accidents at between $1.12 - $4.50 MWh roughly $200 million annually. Even if increasing the price to $30 a MWh, far above any literature estimates, the annual cost is $2 billion far less than the costs of excess mortality from coal.

- Cost to individuals, in terms of higher energy prices, was $1.6 billion
- Societal costs include CO_2 damage of $1.8 billion and losses from premature mortality of $8.7 billion. Savings from switching away from nuclear and reducing storage costs as well as costs of accidents range from $0.2 billion to $2 billion
- Net, there are both individual and societal savings from nuclear power.

Given the cost-benefit analysis, why would the Germans choose to shut down the nuclear option?

"This is due in large part to concerns about long-term solutions for storing nuclear waste and public fears of catastrophic nuclear accidents."

The Black Swan

81% of Germans are in favor of nuclear phaseouts. And they are equally committed to reducing air pollution and forestalling climate change with over 25% of their energy coming from alternative sources. The US uses renewables for only 11% of our electrical needs. But the risk of nuclear is uncertain. And that is where Black Swans come in. Black Swan events, popularized by Nissam Taleb, are infrequent, surprising, unpredictable events with enormous consequences. The events at the Fukushima and Chernobyl reactors are classic examples of Black Swan events.

Using the $12 billion in savings over the potential 21 years of shutdowns, the researchers estimate savings of roughly $250 billion. With the estimated cost of cleaning up Fukushima totaling $750 billion, they conclude that for nuclear energy to be a net detriment, the risk of another Fukushima type accident would have to be one out of three. [3]

Of course, a nuclear disaster is far more dramatic than the day-to-day societal costs of air pollution. As a result, a cost-benefit analysis is insufficient to make determinations about our energy sources. We'll give the authors the almost last word.

"Policymakers around the world thus face a difficult trade-off. On the one hand, many climate change experts have argued that nuclear power is a necessary part of the shift away from carbon-intensive fossil fuels. Moreover, many voters are willing to incur substantial costs to reduce the risk of climate change. However, many of these same voters are also unwilling to support nuclear power due to fears surrounding nuclear accidents and nuclear waste disposal. Facing this political pressure, countries around the world are shifting away from nuclear production despite the substantial increases in operating costs and air pollution costs associated with this policy."

I used the author's measures of premature mortality without criticism; they reflect the numbers offered by proponents of regulating air "pollutants." But the same numbers indicate that nuclear power is net beneficial, so why are so many of these same proponents against the use of nuclear energy. It is fear, not numbers driving that decision.

[1] Wholesale prices are reported because of variations in consumer costs related to "network charges, renewable subsidy fees, and taxes." Wholesale price is typically 25% of what the consumer pays. It seems demand may be "insensitive" to price.

[2] This inability to account accurately for time-dependent disease is an Achille's heel for many air pollution studies.

[3] Using the actual time frame, the calculation is about 1 in 5.

Source: The Private And External Costs Of Germany's Nuclear Phase-Out National Bureau of Economic Research Working Paper 26598 [2]